

**THE DESIGN AND EVALUATION OF  
NON-VISUAL INFORMATION SYSTEMS FOR BLIND USERS**

**SARAH MORLEY**

A thesis submitted in partial fulfilment of the  
requirements of the University of Hertfordshire  
for the degree of Doctor of Philosophy

The programme of research was carried out in the  
Sensory Disabilities Research Unit, Department of Psychology,  
University of Hertfordshire

June 1999

This research was motivated by the sudden increase of hypermedia information (such as that found on CD-ROMs and on the World Wide Web), which was not initially accessible to blind people, although offered significant advantages over traditional braille and audio-tape information. Existing non-visual information systems for blind people had very different designs and functionality, but none of them provided what was required according to user requirements studies: an easy-to-use non-visual interface to hypermedia material with a range of input devices for blind students. Furthermore, there was no single suitable design and evaluation methodology which could be used for the development of non-visual information systems. The aims of this research were therefore: (1) to develop a generic, iterative design and evaluation methodology consisting of a number of techniques suitable for formative evaluation of non-visual interfaces; (2) to explore non-visual interaction possibilities for a multimodal hypermedia browser for blind students based on user requirements; and (3) to apply the evaluation methodology to non-visual information systems at different stages of their development.

The methodology developed and recommended consists of a range of complementary design and evaluation techniques, and successfully allowed the systematic development of prototype non-visual interfaces for blind users by identifying usability problems and developing solutions. Three prototype interfaces are described: the design and evaluation of two versions of a hypermedia browser; and an evaluation of a digital talking book. Recommendations made from the evaluations for an effective non-visual interface include the provision of a consistent multimodal interface, non-speech sounds for information and feedback, a range of simple and consistent commands for reading, navigation, orientation and output control, and support features. This research will inform developers of similar systems for blind users, and in addition, the methodology and design ideas are considered sufficiently generic, but also sufficiently detailed, that the findings could be applied successfully to the development of non-visual interfaces of any type.

*For my parents*

Ancoro Imparo

# Table of Contents

ABSTRACT.....	I
DEDICATION .....	II
PREFACE.....	1
ACKNOWLEDGEMENTS.....	2
THE ACCESS PROJECT AND THE RESEARCHER'S INVOLVEMENT .....	2
PUBLICATIONS AND PRESENTATIONS .....	3
<b>1 INTRODUCTION .....</b>	<b>5</b>
1.1 CHAPTER OVERVIEW .....	6
1.2 CONTEXT OF THE RESEARCH.....	6
1.2.1 <i>How It All Started</i> .....	6
1.2.2 <i>A User-Centered Approach</i> .....	6
1.2.3 <i>Custom Technology</i> .....	7
1.2.4 <i>Design and Evaluation</i> .....	9
1.3 THE RESEARCH AIMS .....	11
1.4 ORGANISATION OF THE THESIS .....	11
1.5 THE SCOPE OF THIS RESEARCH.....	15
1.6 COMING NEXT.....	15
<b>2 REVIEW OF RELATED RESEARCH AND DEVELOPMENT.....</b>	<b>16</b>
2.1 CHAPTER OVERVIEW .....	17
2.2 PART I: BLINDNESS AND NON-VISUAL INFORMATION ACCESS .....	18
2.2.1 <i>The Target Group</i> .....	18
2.2.1.1 Definitions of Blindness, Partial Sight and Visual Impairment .....	18
2.2.1.2 Estimates of the Incidence of Blindness.....	19
2.2.1.3 Computer and World Wide Web (WWW) Use by Visually Impaired People.....	20
2.2.1.4 Talking Book Use .....	20
2.2.1.5 Causes of Vision Loss and Additional Impairments.....	20
2.2.2 <i>Limitations of Traditional Braille and Audio-Tape Information Access</i> .....	21
2.2.2.1 Problems with Production.....	22
2.2.2.2 Problems with Use.....	22
2.2.3 <i>Technology and Accessibility</i> .....	24
2.2.4 <i>Assistive Technology</i> .....	26
2.2.4.1 The Graphical User Interface (GUI) Problem.....	26
2.2.5 <i>Custom Technology</i> .....	27
2.2.5.1 Multimedia and Multimodal Input and Output .....	28
2.2.5.2 Diagrams and Verbal Descriptions .....	29
2.2.5.3 Non-Speech Sounds .....	30
2.2.5.4 Access to Scientific and Mathematical Material.....	31
2.2.6 <i>An Electronic Environment for Learning</i> .....	32
2.2.7 <i>Non-Visual Information Systems for Blind People</i> .....	33
2.2.7.1 Electronic Newspapers and Magazines .....	34
2.2.7.2 Electronic Books .....	35
2.2.7.3 Hybrid Books.....	37
2.2.7.4 Digital Talking Books.....	39
2.2.8 <i>World Wide Web (WWW) Access</i> .....	40
2.2.8.1 V-Lynx, WAB and Emacspeak.....	40

2.2.8.2	Mainstream Windows Browsers used with Screenreaders.....	41
2.2.8.3	pwWebSpeak .....	42
2.3	<b>PART II: NON-VISUAL INFORMATION SYSTEMS FOR SIGHTED USERS .....</b>	<b>44</b>
2.3.1	<i>Introduction</i> .....	44
2.3.2	<i>Examples of Non-Visual Systems for Sighted Users</i> .....	45
2.3.2.1	A Hyperspeech Application .....	45
2.3.2.2	NewsComm .....	46
2.3.2.3	SpeechSkimmer .....	46
2.3.2.4	VoiceNotes.....	48
2.3.2.5	SpeechActs.....	48
2.3.3	<i>Special Design Required for Auditory Systems</i> .....	49
2.4	<b>PART III: DESIGNING FOR USABILITY: USER-CENTERED DESIGN AND EVALUATION.....</b>	<b>50</b>
2.4.1	<i>User-Centered Design</i> .....	50
2.4.2	<i>The ‘Design for All’ Principle</i> .....	51
2.4.3	<i>Usability Engineering</i> .....	52
2.4.4	<i>The Goals of Evaluation</i> .....	53
2.4.5	<i>Rapid Prototyping</i> .....	54
2.4.6	<i>Usability Inspection Methods - Testing Without Users</i> .....	55
2.4.6.1	Design Guidelines .....	56
2.4.6.2	Heuristic Evaluation.....	56
2.4.6.3	Scenarios and Walkthroughs .....	57
2.4.7	<i>Usability Testing - Testing with Users</i> .....	58
2.4.7.1	Cooperative Evaluation .....	59
2.4.7.2	Subjective Assessment Questionnaires.....	61
2.4.7.3	Questionnaire and Interview Design .....	61
2.4.8	<i>Participants</i> .....	63
2.4.8.1	Range of Users or Designers.....	63
2.4.8.2	Number of Users or Designers.....	64
2.4.9	<i>Multi-Faceted Iterative Testing</i> .....	65
2.4.10	<i>Methodology - A Discussion and Definition of the Term</i> .....	66
2.5	<b>PART IV: LESSONS FROM HYPERMEDIA DESIGN AND EVALUATION .....</b>	<b>67</b>
2.5.1	<i>Brief Overview of Hypertext/Hypermedia</i> .....	67
2.5.2	<i>Types of Hypermedia Evaluations</i> .....	68
2.5.2.1	Interface Versus Contents .....	69
2.5.2.2	Multi-Faceted, Iterative Design and Evaluation.....	70
2.5.2.3	Guidelines for Evaluation .....	71
2.5.3	<i>What Tasks Are Supported by Hypermedia?</i> .....	72
2.5.4	<i>Navigation and Orientation</i> .....	73
2.5.4.1	Headings: Navigational Aids and Measures of Incidental Learning.....	74
2.6	<b>PART V: CONTRIBUTION TO THE FIELD MADE BY THIS RESEARCH.....</b>	<b>75</b>
2.6.1	<i>Design Issues</i> .....	75
2.6.2	<i>Evaluation Issues</i> .....	76
2.7	<b>COMING NEXT.....</b>	<b>77</b>
<b>3</b>	<b>DESIGN OF A GENERIC ITERATIVE DESIGN AND EVALUATION</b>	
	<b>METHODOLOGY FOR NON-VISUAL INTERFACES.....</b>	<b>79</b>
3.1	CHAPTER OVERVIEW .....	79
3.2	INTRODUCTION.....	79
3.3	GOALS OF ITERATIVE DESIGN AND EVALUATION .....	80
3.4	TESTING WITHOUT USERS.....	81
3.5	PARTICIPANT (USER) SELECTION .....	82
3.6	PERSONAL DATA COLLECTION.....	82
3.7	BRIEFING.....	83
3.8	TRAINING.....	83

3.8.1	<i>Rationale</i> .....	83
3.8.2	<i>Content and Training Style</i> .....	84
3.8.3	<i>Tactile Diagrams</i> .....	85
3.8.4	<i>Piloting and Training Time Allocated</i> .....	85
3.9	EVALUATION TASKS.....	85
3.9.1	<i>Rationale</i> .....	85
3.9.2	<i>Types of Evaluation Task</i> .....	86
3.9.2.1	Directive and Explicit Tasks.....	86
3.9.2.2	Guided Tasks (Directive, Non-Explicit).....	86
3.9.2.3	Completely Free Tasks.....	87
3.9.2.4	Generic Tasks.....	87
3.9.2.5	Content Questions.....	88
3.9.2.6	Separate Investigations.....	88
3.9.3	<i>Protocol Elicitation (Informal Think-Aloud)</i> .....	88
3.9.4	<i>Piloting and Task Time Allocated</i> .....	90
3.9.5	<i>Measures Taken</i> .....	90
3.10	EVALUATION QUESTIONNAIRE.....	91
3.10.1	<i>Rationale</i> .....	91
3.10.2	<i>Topics Covered and Measures Used</i> .....	91
3.10.3	<i>Piloting and Evaluation Time Allocated</i> .....	92
3.11	RECORDING METHODS.....	93
3.12	DEBRIEFING.....	93
3.13	PERSONNEL.....	93
3.14	DATA COLLATION AND ANALYSIS.....	94
3.15	SUMMARY OF THE GENERIC DESIGN AND EVALUATION METHODOLOGY.....	94
3.16	COMING NEXT.....	95
<b>4</b>	<b>DESIGN OF DAHNI-1: THE FIRST ACCESS HYPERMEDIA NON-VISUAL INTERFACE</b> .....	<b>96</b>
4.1	CHAPTER OVERVIEW.....	97
4.2	THE DEVELOPMENT OF MOCK-UPS.....	97
4.2.1	<i>Design of Initial Mock-Ups</i> .....	97
4.2.1.1	Commands and Links.....	98
4.2.1.2	Hypermedia Material and Links.....	99
4.2.2	<i>Evaluation of Mock-Ups</i> .....	100
4.3	RESULTS AND RECOMMENDATIONS FROM EVALUATIONS OF MOCK-UPS.....	101
4.3.1	<i>Presentation of Commands and Command Functionality</i> .....	101
4.3.1.1	Spatial Presentation of Commands.....	101
4.3.1.2	Use of Digitised Speech for Commands.....	102
4.3.1.3	Length of Interactions.....	102
4.3.1.4	Reading Hypermedia Content.....	102
4.3.1.5	Selecting Links.....	102
4.3.1.6	The 'Back' Command.....	103
4.3.2	<i>Presentation of Hypermedia Content</i> .....	104
4.3.2.1	Synthetic Speech.....	104
4.3.2.2	Digitised Audio.....	104
4.3.2.3	Non-Speech Sounds to Indicate Structure.....	104
4.3.3	<i>Presentation of Links</i> .....	105
4.3.3.1	Non-Speech Sounds to Indicate Links and Link Type.....	105
4.3.3.2	'Current Link' Concept.....	105
4.3.4	<i>Conclusions from Mock-Up Evaluations</i> .....	106
4.4	DEVELOPMENT OF DAHNI-1.....	106
4.4.1	<i>User Requirements Identified for the Design of DAHNI-1</i> .....	107
4.4.2	<i>Design Principles and Usability Inspection</i> .....	108

4.4.3	<i>Interface Design and Hypermedia Content</i> .....	108
4.5	INTERFACE DESIGN OF DAHNI-1 .....	109
4.5.1	<i>Basic Reading, Navigation and Output Control</i> .....	109
4.5.1.1	The 'Unit' Concept .....	109
4.5.1.2	Reading Commands .....	110
4.5.1.3	Finding and Selecting Links .....	110
4.5.1.4	Navigation Commands .....	110
4.5.1.5	Output Control Commands .....	111
4.5.2	<i>Potential Commands For Later Versions</i> .....	112
4.5.3	<i>Interface Layout: The Workspace</i> .....	113
4.5.4	<i>Using the Workspace with the Three Input Devices</i> .....	114
4.5.5	<i>Input Device Specifications</i> .....	117
4.6	HYPERMEDIA CONTENT .....	117
4.6.1	<i>Presentation Methods</i> .....	118
4.6.2	<i>Structure of Hypermedia Content</i> .....	118
4.6.3	<i>Sample Output</i> .....	121
4.7	LIMITATIONS AND JUSTIFICATIONS .....	122
4.8	COMING NEXT .....	122
<b>5</b>	<b>EVALUATION OF DAHNI-1</b> .....	<b>123</b>
5.1	CHAPTER OVERVIEW .....	124
5.2	INTRODUCTION .....	124
5.2.1	<i>Features to be Evaluated</i> .....	124
5.3	METHOD .....	125
5.3.1	<i>Design</i> .....	125
5.3.2	<i>Participants</i> .....	126
5.3.2.1	Age, Gender, Level of Vision, and Braille Experience .....	126
5.3.2.2	Computer Experience .....	126
5.3.3	<i>Hardware</i> .....	128
5.3.4	<i>Materials</i> .....	128
5.3.4.1	Tactile Diagrams and Pictures .....	128
5.3.4.2	Training Schedule .....	128
5.3.4.3	Evaluation Tasks .....	129
5.3.4.4	Evaluation Questionnaire .....	130
5.3.5	<i>Measures Taken</i> .....	131
5.3.6	<i>Procedure</i> .....	131
5.3.6.1	Introduction and Training Session .....	131
5.3.6.2	Evaluation Session .....	132
5.3.6.3	Personnel .....	132
5.4	RESULTS AND DISCUSSION .....	132
5.4.1	<i>Ratings of Blind and Partially Sighted Participants</i> .....	133
5.4.2	<i>Overall Usability</i> .....	133
5.4.2.1	Effective Command Use .....	134
5.4.2.2	Command Confusion .....	135
5.4.3	<i>Usability of the Workspace</i> .....	136
5.4.3.1	Usefulness of the Workspace .....	136
5.4.3.2	Effectiveness of Workspace with Different Input Devices .....	137
5.4.3.3	The Dead-End Sound .....	137
5.4.3.4	Digitised Speech for Commands .....	138
5.4.4	<i>Usability of the Three Input Devices</i> .....	139
5.4.4.1	Keyboard .....	140
5.4.4.2	Joystick .....	140
5.4.4.3	Touchtablet .....	141
5.4.5	<i>Presentation of Links and Hypermedia Material</i> .....	142
5.4.5.1	Methods of Presenting Links .....	142

5.4.5.2	Methods of Selecting the Current Link.....	143
5.4.5.3	Link Types.....	144
5.4.5.4	The 'Current Unit' Concept.....	145
5.4.5.5	The Use of Synthetic Speech Nodes.....	145
5.4.5.6	Digitised Audio Nodes.....	146
5.4.5.7	Sound Effects.....	147
5.4.5.8	Picture Nodes, Verbal Descriptions and Tactile Pictures.....	147
5.5	CONCLUSIONS.....	148
5.5.1	<i>General Findings</i> .....	148
5.5.1.1	Overview and Locational Information.....	149
5.5.1.2	Finding and Selecting Links.....	149
5.5.2	<i>Methodology</i> .....	149
5.5.3	<i>Future Development</i> .....	151
5.6	COMING NEXT.....	153
<b>6</b>	<b>DESIGN OF DAHNI-2: THE SECOND ACCESS HYPERMEDIA NON-VISUAL INTERFACE.....</b>	<b>154</b>
6.1	CHAPTER OVERVIEW.....	155
6.2	INTRODUCTION.....	155
6.3	DESIGN METHODOLOGY.....	156
6.4	INTERFACE DESIGN OF DAHNI-2.....	157
6.4.1	<i>Command Re-Naming</i> .....	157
6.4.2	<i>Non-Speech Sounds For Information and Feedback</i> .....	159
6.4.2.1	Structural Information: Presentation of Links.....	160
6.4.2.2	Structural Information: Dead-Ends.....	160
6.4.2.3	Structural Information: Headings.....	161
6.4.2.4	Command Feedback: 'Heading'.....	161
6.4.2.5	Command Feedback: 'Home'.....	162
6.4.2.6	Command Feedback: Reading and Navigational Commands.....	162
6.4.2.7	Command Feedback: Centrepoint.....	163
6.4.3	<i>Orientation and Navigation Commands</i> .....	163
6.4.3.1	Initial Welcome Message.....	164
6.4.3.2	'Where Am I?' Command.....	164
6.4.3.3	'Overview' Command.....	164
6.4.4	<i>Finding and Selecting Links</i> .....	165
6.4.4.1	'Read Current Link' Command.....	165
6.4.4.2	Link-To-Link Navigation.....	165
6.4.5	<i>Control of Auditory Presentation</i> .....	166
6.4.5.1	'Change Voice' Command.....	166
6.4.5.2	'Change Rate' Command.....	166
6.4.5.3	'Change Unit' Command.....	167
6.4.6	<i>Improvements to the Input and Output Devices</i> .....	167
6.4.6.1	Text-To-Speech Conversion.....	167
6.4.6.2	Keyboard.....	167
6.4.6.3	Joystick.....	169
6.4.6.4	Touchtablet.....	170
6.4.7	<i>Re-Design of the Workspace</i> .....	170
6.4.8	<i>Support Features</i> .....	172
6.4.8.1	Background Literature.....	172
6.4.8.2	On-Line Tutorial Module.....	173
6.4.8.3	Context-Specific Help.....	174
6.4.8.4	On-Line General Help Module.....	174
6.4.9	<i>User Configuration</i> .....	175
6.5	HYPERMEDIA CONTENT: A TOUR AROUND LONDON - PAST AND PRESENT.....	176
6.5.1	<i>Structure of Nodes</i> .....	178

6.6	LIMITATIONS AND JUSTIFICATIONS.....	178
6.7	COMING NEXT.....	178
<b>7</b>	<b>EVALUATION OF DAHNI-2.....</b>	<b>179</b>
7.1	CHAPTER OVERVIEW.....	180
7.2	INTRODUCTION.....	180
7.2.1	<i>Summary of DAHNI-2 Features.....</i>	<i>180</i>
7.2.2	<i>Refined Methodology.....</i>	<i>181</i>
7.2.2.1	More Efficient Training Procedure.....	181
7.2.2.2	Practice Period.....	181
7.2.2.3	More Realistic Set Tasks.....	182
7.2.2.4	Separate Investigations.....	183
7.2.3	<i>Features to be Evaluated.....</i>	<i>183</i>
7.3	METHOD.....	184
7.3.1	<i>Design.....</i>	<i>184</i>
7.3.2	<i>Participants.....</i>	<i>185</i>
7.3.2.1	Age, Gender, and Level of Vision.....	185
7.3.2.2	Computer Experience.....	185
7.3.3	<i>Hardware and Software.....</i>	<i>187</i>
7.3.4	<i>Materials.....</i>	<i>187</i>
7.3.4.1	Tactile Diagrams and Pictures.....	187
7.3.4.2	Training Schedule and On-Line Tutorial.....	187
7.3.4.3	Questions for the Practice Period.....	188
7.3.4.4	Evaluation Tasks.....	188
7.3.4.5	Evaluation Questionnaire.....	189
7.3.4.6	Separate Investigations.....	190
7.3.5	<i>Measures Taken.....</i>	<i>191</i>
7.3.6	<i>Procedure.....</i>	<i>192</i>
7.3.6.1	Group and Individual Training.....	192
7.3.6.2	Practice Period.....	192
7.3.6.3	Evaluation Session.....	192
7.4	EVALUATION RESULTS AND DISCUSSION.....	194
7.4.1	<i>Overall Usability.....</i>	<i>195</i>
7.4.1.1	Overall Usability Score.....	195
7.4.2	<i>Ratings of Blind and Partially Sighted Participants.....</i>	<i>197</i>
7.4.3	<i>Overall Task Performance.....</i>	<i>197</i>
7.4.3.1	Times and Methods.....	197
7.4.3.2	Efficient Strategies.....	199
7.4.3.3	Cautious Strategies.....	199
7.4.3.4	Types of Mistakes.....	200
7.4.4	<i>Input Devices.....</i>	<i>201</i>
7.4.4.1	Keyboard.....	201
7.4.4.2	Joystick.....	202
7.4.4.3	Touchtablet.....	202
7.4.5	<i>The Workspace.....</i>	<i>203</i>
7.4.6	<i>Hypermedia Presentation Methods.....</i>	<i>204</i>
7.4.6.1	Synthetic Speech and Output Control Commands.....	204
7.4.6.2	Picture Nodes with Descriptions.....	205
7.4.6.3	Digitised Audio Nodes.....	206
7.4.6.4	Memorability of Information from Audio and Picture Nodes.....	206
7.4.7	<i>Navigation and Orientation.....</i>	<i>207</i>
7.4.7.1	Navigation Strategies.....	207
7.4.7.2	Feelings of Orientation.....	208
7.4.7.3	Level of Concern if Disoriented.....	209
7.4.7.4	Orientation Strategies.....	209

7.4.7.5	Headings as Navigational Aids.....	210
7.4.8	<i>Non-Speech Sounds</i> .....	211
7.4.8.1	Usefulness.....	211
7.4.8.2	Inconsistent Sound Implementation.....	212
7.4.8.3	User Preferences.....	213
7.4.8.4	Dead-Ends and Links in a Node.....	213
7.4.8.5	Memorability of Non-Speech Sounds.....	214
7.4.9	<i>Preferences for Media for Learning</i> .....	215
7.4.10	<i>Support Features: On-Line Tutorial and Help Features</i> .....	216
7.5	LIMITATIONS.....	217
7.6	CONCLUSIONS AND DESIGN RECOMMENDATIONS.....	218
7.6.1	<i>The Workspace</i> .....	219
7.6.2	<i>Input devices</i> .....	219
7.6.2.1	Keyboard.....	219
7.6.2.2	Joystick.....	219
7.6.2.3	Touchtablet.....	219
7.6.3	<i>Hypermedia Presentation Methods</i> .....	220
7.6.3.1	Synthetic Speech and Refreshable Braille Output.....	220
7.6.3.2	Content Material.....	220
7.6.4	<i>Links</i> .....	221
7.6.4.1	Presentation of Links.....	221
7.6.4.2	Finding and Selecting Links.....	221
7.6.5	<i>Non-Speech Sounds</i> .....	222
7.6.5.1	General Sound Guidelines.....	222
7.6.5.2	Sounds for Structural Information and Command Feedback.....	223
7.6.6	<i>Commands: Improvements and Additions</i> .....	223
7.6.6.1	Output Control Commands.....	223
7.6.6.2	Reading Commands.....	224
7.6.6.3	Orientation and Navigational Commands.....	224
7.6.6.4	Support Systems.....	225
7.6.6.5	Potential Advanced Commands with Simple Implementations.....	225
7.6.7	<i>Additional Further Research</i> .....	226
7.7	COMING NEXT.....	226
<b>8</b>	<b>EVALUATION OF THE DAISY PLAYBACK SOFTWARE.....</b>	<b>227</b>
8.1	CHAPTER OVERVIEW.....	228
8.2	INTRODUCTION.....	228
8.3	DESIGN OF THE DAISY PLAYBACK SOFTWARE.....	229
8.3.1	<i>Reading and Navigation Commands</i> .....	233
8.3.2	<i>Orientation Commands</i> .....	234
8.3.3	<i>Bookmarks and Search Facilities</i> .....	234
8.3.4	<i>Voice Control Commands</i> .....	235
8.3.5	<i>Help Commands</i> .....	235
8.3.6	<i>Potential Usability Problems Identified Before Evaluations</i> .....	236
8.4	METHOD.....	237
8.4.1	<i>Design</i> .....	237
8.4.2	<i>Participants</i> .....	237
8.4.3	<i>Hardware and Software</i> .....	239
8.4.4	<i>Materials</i> .....	239
8.4.4.1	DAISY Books.....	239
8.4.4.2	Training Schedule.....	239
8.4.4.3	Evaluation Tasks (Free with Generic Tasks).....	240
8.4.4.4	Evaluation Questionnaire.....	241
8.4.5	<i>Measures Taken</i> .....	242
8.4.6	<i>Procedure</i> .....	243

8.4.6.1	Briefing and Training Session.....	243
8.4.6.2	Evaluation Session.....	243
8.5	RESULTS AND DISCUSSION.....	244
8.5.1	<i>General Usability</i> .....	244
8.5.1.1	General Mean Usability Ratings.....	245
8.5.1.2	Features Most Liked.....	246
8.5.1.3	Use of Shortcut Keys and Numpad for Commands.....	246
8.5.1.4	Use of Supporting Braille or Electronic Text.....	247
8.5.1.5	Interest in Continued Use of the Software.....	248
8.5.2	<i>Usability of Reading Commands</i> .....	248
8.5.2.1	Open Book Command.....	249
8.5.2.2	Play/Stop Command.....	249
8.5.2.3	Next/Previous Phrase Commands.....	250
8.5.2.4	New Commands Proposed: Word and Character Reading.....	251
8.5.2.5	First/Last Phrase Commands.....	252
8.5.2.6	Next/Previous Group Commands.....	253
8.5.2.7	New Command Proposed: Repeat.....	254
8.5.3	<i>Usability of Heading Navigation Commands</i> .....	254
8.5.3.1	Next/Previous Section and Level Up/Down.....	255
8.5.3.2	First/Last Section Commands.....	255
8.5.3.3	Jump Forwards/Backwards 15 Sections Command.....	256
8.5.4	<i>Heading Navigation Problems</i> .....	257
8.5.4.1	Navigation Problem 1: Heading Navigation Not Hypertext.....	257
8.5.4.2	Navigational Problem 2: Lack of Structural Information.....	258
8.5.4.3	Navigational Problem 3: Overlapping and 'Jumping' Commands.....	258
8.5.5	<i>Navigation Solutions</i> .....	259
8.5.5.1	Solution 1: Improve Understanding of DAISY Headings.....	259
8.5.5.2	Solution 2: Provide Structural Cues.....	259
8.5.5.3	Solution 3: Provide New Structural Overview Commands.....	264
8.5.5.4	Solution 4: Restrict Commands.....	265
8.5.6	<i>Usability of Orientation Commands</i> .....	266
8.5.6.1	Remembers Last Reading Position when Insert Disk.....	267
8.5.6.2	Section Information Command.....	259
8.5.6.3	Current Position Command.....	268
8.5.6.4	Page Information Command.....	269
8.5.6.5	Goto Page Command.....	270
8.5.6.6	Next/Previous Page Commands.....	271
8.5.6.7	New Command Proposed: Time Information.....	271
8.5.6.8	New Commands Proposed: Goto Start/End of Book.....	272
8.5.6.9	New Command Proposed: Access to Information on Status Bar.....	273
8.5.7	<i>Usability of Bookmark Commands</i> .....	273
8.5.7.1	Set Bookmark Command.....	273
8.5.7.2	New Command Proposed: Highest Bookmark Set Confirmation.....	275
8.5.7.3	Goto Bookmark Command.....	276
8.5.8	<i>Usability of Search Commands</i> .....	276
8.5.8.1	Search Command.....	277
8.5.8.2	Search Next/Previous Commands.....	278
8.5.9	<i>Usability of Voice Control Commands</i> .....	279
8.5.9.1	Mute Command.....	279
8.5.9.2	Output Speed.....	280
8.5.9.3	New Command Proposed: Volume.....	281
8.5.9.4	New Command Proposed: Pitch.....	282
8.5.10	<i>Usability of System Messages</i> .....	282
8.5.11	<i>Usability of Audio Help System</i> .....	283
8.5.12	<i>New Feature Proposed: User Customisation</i> .....	283
8.6	SCOPE AND LIMITATIONS.....	284

8.7	CONCLUSIONS AND FUTURE DIRECTIONS.....	285
8.7.1	<i>General Issues</i> .....	286
8.7.2	<i>Reading</i> .....	286
8.7.3	<i>Heading Navigation</i> .....	287
8.7.4	<i>Orientation</i> .....	288
8.7.5	<i>Bookmarking</i> .....	288
8.7.6	<i>Searching</i> .....	289
8.7.7	<i>Voice Control</i> .....	289
8.7.8	<i>System Messages</i> .....	289
8.7.9	<i>Help</i> .....	290
8.7.10	<i>User Customisation</i> .....	290
8.7.11	<i>Book Recording</i> .....	290
8.7.12	<i>Book Structural Information</i> .....	290
8.8	COMING NEXT.....	291
<b>9</b>	<b>RECOMMENDATIONS FOR THE DESIGN AND EVALUATION OF NON-VISUAL INTERFACES FOR BLIND USERS.....</b>	<b>292</b>
9.1	CHAPTER OVERVIEW.....	293
9.2	INTRODUCTION.....	293
9.3	ITERATIVE DESIGN AND EVALUATION RECOMMENDATIONS.....	294
9.4	NON-VISUAL INTERFACE DESIGN RECOMMENDATIONS.....	297
9.4.1	<i>General Interface Design</i> .....	297
9.4.2	<i>Input Devices</i> .....	297
9.4.3	<i>Output Methods</i> .....	298
9.4.4	<i>Reading</i> .....	301
9.4.5	<i>Output Control</i> .....	302
9.4.6	<i>Orientation and Navigation</i> .....	302
9.4.7	<i>Finding and Selecting Links</i> .....	304
9.4.8	<i>Support and Personalisation Features</i> .....	305
9.5	COMING NEXT.....	306
<b>10</b>	<b>CONCLUSIONS.....</b>	<b>307</b>
10.1	CHAPTER OVERVIEW.....	308
10.2	INTRODUCTION.....	308
10.3	SUMMARY OF THIS RESEARCH.....	309
10.3.1	<i>Generic Design and Evaluation Methodology</i> .....	310
10.3.1.1	<i>Basis of the Methodology</i> .....	310
10.3.1.2	<i>Assessment of the Methodology</i> .....	310
10.3.2	<i>Non-Visual Interface Design</i> .....	312
10.3.2.1	<i>DAHNI-1</i> .....	312
10.3.2.2	<i>DAHNI-2</i> .....	313
10.3.2.3	<i>The DAISY Playback Software</i> .....	316
10.4	FINAL REMARKS.....	318
	<b>GLOSSARY.....</b>	<b>319</b>
	<b>REFERENCES .....</b>	<b>323</b>
	<b>APPENDICES.....</b>	<b>348</b>
1.1	DAHNI-1: PARTICIPANT CHARACTERISTICS QUESTIONNAIRE.....	349
1.2	DAHNI-1: EVALUATION TASKS.....	350
1.3	DAHNI-1: EVALUATION QUESTIONNAIRE.....	352
1.4	DAHNI-2: CONTENT OF THE LONDON HYPERMEDIA MODULE .....	355

1.5	DAHNI-2: PARTICIPANT CHARACTERISTICS QUESTIONNAIRE.....	363
1.6	DAHNI-2: EVALUATION TASKS & SEPARATE INVESTIGATIONS.....	364
1.7	DAHNI-2: EVALUATION QUESTIONNAIRE.....	365
1.7.1	<i>Memorability of Headings Investigation.....</i>	<i>367</i>
1.7.2	<i>Non-Speech Sounds Questions.....</i>	<i>367</i>
1.7.3	<i>Sound Memorability Investigation.....</i>	<i>368</i>
1.7.4	<i>Memorability of Information from Different Media Investigation.....</i>	<i>369</i>
1.7.5	<i>Evaluation of Hypermedia Questionnaire.....</i>	<i>370</i>
1.8	DAHNI-2: SEPARATE INVESTIGATIONS - RAW DATA.....	371
1.8.1	<i>Memorability Of Information From Picture and Audio Nodes: Raw Data.....</i>	<i>371</i>
1.8.2	<i>Memorability of Headings: Raw Data.....</i>	<i>372</i>
1.8.3	<i>Identification and Memorability of Non-Speech Sounds: Raw Data.....</i>	<i>373</i>
1.9	DAISY PLAYBACK SOFTWARE: VISUAL HELP SYSTEM V1.0.....	374
1.10	DAISY PLAYBACK SOFTWARE: PARTICIPANT CHARACTERISTICS QUESTIONNAIRE.....	379
1.11	DAISY PLAYBACK SOFTWARE: GENERIC EVALUATION TASKS.....	381
1.12	DAISY PLAYBACK SOFTWARE: EVALUATION QUESTIONNAIRE.....	383

## Tables

TABLE 2.1: OPTIMUM PARTICIPANT NUMBERS FOR DIFFERENT EVALUATION METHODS FOR BEST COST/BENEFIT RATIO.....	64
TABLE 2.2: EXAMPLES OF MEASURES AND DATA CAPTURE METHODS USED IN HYPERMEDIA EVALUATIONS.....	71
TABLE 3.1: A 5-POINT LIKERT RATING SCALE.....	92
TABLE 4.1: MOCK-UP IMPLEMENTATIONS OF KEYBOARD, JOYSTICK AND TOUCHTABLET TO FIND AND EXECUTE COMMANDS AND LINKS.....	98
TABLE 4.2: THE NINE FUNCTIONAL COMMANDS IN DAHNI-1.....	116
TABLE 4.3: COMPARISON OF INTERACTIONS WITH THE THREE INPUT DEVICES.....	116
TABLE 5.1: PARTICIPANTS' CHARACTERISTICS IN DAHNI-1 EVALUATIONS.....	127
TABLE 5.2: EXAMPLE OF EVALUATION TASK FOR DAHNI-1 (TASK 3).....	130
TABLE 5.3: MEAN EASE OF USE, EASE OF LEARNING AND ENJOYMENT RATINGS.....	133
TABLE 5.4: RATINGS FOR USEFULNESS OF WORKSPACE.....	136
TABLE 5.5: RATINGS FOR USEFULNESS OF DEAD-END SOUND.....	137
TABLE 5.6: RATINGS FOR IMPORTANCE OF DIGITISED SPEECH FOR COMMANDS.....	138
TABLE 5.7: RATINGS FOR THREE INPUT DEVICES ON FIVE USABILITY ISSUES.....	139
TABLE 5.8: RATINGS FOR IDENTIFYING LINKS (CURRENT AND POTENTIAL METHODS).....	142
TABLE 5.9: RATINGS FOR EASE OF SELECTING LINKS WITH THE THREE INPUT DEVICES.....	143
TABLE 5.10: RATINGS FOR LINK TYPE INFORMATION.....	144
TABLE 5.11: RATINGS FOR SYNTHETIC SPEECH.....	145
TABLE 5.12: RATINGS FOR DIGITISED AUDIO NODES.....	146
TABLE 5.13: RATINGS FOR SOUND EFFECTS.....	147
TABLE 5.14: RATINGS FOR THE PICTURE NODE.....	147
TABLE 6.1: COMPARISON OF COMMANDS AND FEEDBACK IN DAHNI-1 AND DAHNI-2.....	158
TABLE 6.2: ACCELERATOR KEYS FOR DAHNI-2 COMMANDS.....	169
TABLE 7.1: FUNCTIONAL COMMANDS IN DAHNI-2.....	181
TABLE 7.2: PARTICIPANTS' CHARACTERISTICS IN DAHNI-2 EVALUATIONS.....	186
TABLE 7.3: THE GUIDED EVALUATION TASK FOR DAHNI-2.....	189
TABLE 7.4: AUDIO AND PICTURE NODES FOR INFORMATION RECALL.....	190
TABLE 7.5: TRUE AND FALSE HEADINGS PRESENTED.....	190
TABLE 7.6: NON-SPEECH SOUNDS TESTED.....	191
TABLE 7.7: THE NINE COMPONENTS OF THE OVERALL USABILITY SCORE FOR DAHNI-2.....	196

---

TABLE 7.8: EASE OF USE RATINGS FOR INPUT DEVICES.....	201
TABLE 7.9: LIKEABILITY RATINGS FOR INPUT DEVICES.....	201
TABLE 7.10: RATINGS FOR USEFULNESS OF WORKSPACE.....	203
TABLE 7.11: RATINGS FOR HYPERMEDIA PRESENTATION METHODS.....	204
TABLE 7.12: RATINGS FOR CHANGE VOICE AND CHANGE RATE COMMANDS.....	205
TABLE 7.13: DETAIL RECALLED FROM PICTURE AND AUDIO NODES.....	206
TABLE 7.14: RATINGS FOR EASE OF FINDING INFORMATION.....	208
TABLE 7.15: RATINGS FOR ORIENTATION.....	208
TABLE 7.16: RATINGS FOR CONCERN IF DISORIENTED.....	209
TABLE 7.17: IDENTIFICATION OF TRUE AND FALSE HEADINGS.....	210
TABLE 7.18: RATINGS FOR USEFULNESS OF NON-SPEECH SOUNDS.....	211
TABLE 7.19: INCONSISTENT SOUND IMPLEMENTATION.....	213
TABLE 7.20: IDENTIFICATION AND MEMORABILITY OF NON-SPEECH SOUNDS.....	215
TABLE 7.21: RATINGS FOR USEFULNESS OF SUPPORT FEATURES.....	216
TABLE 8.1: COMMANDS IN THE DAISY PLAYBACK SOFTWARE.....	231
TABLE 8.2: PARTICIPANTS' CHARACTERISTICS - DAISY PLAYBACK SOFTWARE EVALUATION.....	238
TABLE 8.3: GENERIC EVALUATION TASKS FOR THE DAISY PLAYBACK SOFTWARE.....	240
TABLE 8.4: GENERAL MEAN USABILITY RATINGS.....	245
TABLE 8.5: RATINGS FOR COMMAND METHODS.....	247
TABLE 8.6: RATINGS FOR READING COMMANDS.....	248
TABLE 8.7: RATINGS FOR OPEN BOOK COMMAND.....	249
TABLE 8.8: RATINGS FOR PLAY/STOP COMMAND.....	249
TABLE 8.9: RATINGS FOR NEXT/PREVIOUS PHRASE COMMAND.....	251
TABLE 8.10: RATINGS FOR FIRST/LAST PHRASE COMMANDS.....	252
TABLE 8.11: RATINGS FOR GROUP-TO-GROUP COMMANDS.....	253
TABLE 8.12: RATINGS FOR ALL NAVIGATION COMMANDS.....	255
TABLE 8.13: RATINGS FOR HEADING NAVIGATION COMMANDS.....	255
TABLE 8.14: RATINGS FOR FIRST/LAST SECTION COMMANDS.....	256
TABLE 8.15: RATINGS FOR JUMP FORWARDS/BACKWARDS 15 SECTIONS.....	256
TABLE 8.16: RATINGS FOR PROPOSALS OF INDICATING HEADING LEVELS AND SUB-SECTIONS.....	260
TABLE 8.17: RATINGS FOR PROPOSED OVERVIEW COMMANDS.....	265
TABLE 8.18: RATINGS FOR PROPOSED COMMAND RESTRICTION.....	265
TABLE 8.19: RATINGS FOR ORIENTATION COMMANDS.....	266
TABLE 8.20: RATINGS FOR REMEMBERING LAST READING POSITION.....	267
TABLE 8.21: RATINGS FOR SECTION INFORMATION COMMAND.....	267
TABLE 8.22: RATINGS FOR CURRENT POSITION COMMAND.....	268
TABLE 8.23: RATINGS FOR PAGE INFORMATION COMMAND.....	269
TABLE 8.24: RATINGS FOR GOTO PAGE COMMAND.....	270
TABLE 8.25: RATINGS FOR NEXT/PREVIOUS PAGE COMMANDS.....	271
TABLE 8.26: RATINGS FOR PROPOSED TIME INFORMATION COMMAND.....	272
TABLE 8.27: RATINGS FOR PROPOSED GOTO START/END OF BOOK COMMANDS.....	272
TABLE 8.28: RATINGS FOR SET BOOKMARK COMMAND.....	273
TABLE 8.29: RATINGS FOR PROPOSED HIGHEST BOOKMARK SET CONFIRMATION.....	275
TABLE 8.30: RATINGS FOR GOTO BOOKMARK COMMAND.....	276
TABLE 8.31: RATINGS FOR THE SEARCH COMMAND.....	277
TABLE 8.32: RATINGS FOR THE SEARCH NEXT/PREVIOUS COMMANDS.....	278
TABLE 8.33: RATINGS FOR THE MUTE COMMAND.....	279
TABLE 8.34: RATINGS FOR SPEED COMMANDS.....	280
TABLE 8.35: RATINGS FOR AUDIO HELP SYSTEM.....	283

<b>Figures</b>
----------------

FIGURE 1.1: THE DESIGN AND EVALUATION LIFECYCLE DEVELOPED IN THIS RESEARCH.....	12
FIGURE 2.1: AN ELECTRONIC ENVIRONMENT FOR LEARNING (FROM VINCENT 1994, P.163).....	33
FIGURE 2.2: THE NEWSREADER EASY INPUT PAD.....	35
FIGURE 4.1: MOCK-UP LAYOUT OF COMMANDS AND LINKS.....	98
FIGURE 4.2: MOCK-UP FOR READING HYPERMEDIA MATERIAL WITH THE JOYSTICK.....	100
FIGURE 4.3: THE REPEAT, SPEAK LEFT AND SPEAK RIGHT COMMANDS.....	111
FIGURE 4.4: PROPOSED SHAPE AND ORGANISATION OF THE DAHNI-1 WORKSPACE.....	114
FIGURE 4.5: THE DAHNI-1 WORKSPACE.....	115
FIGURE 4.6: THE KEYBOARD, JOYSTICK AND TOUCHTABLET USED WITH DAHNI-1.....	117
FIGURE 4.7: STRUCTURE AND CONTENT OVERVIEW OF THE HYPERMEDIA MODULE "A LONDON DOUBLE DECKER BUS TOUR" USED WITH DAHNI-1.....	120
FIGURE 4.8: TACTILE PICTURE AND VERBAL DESCRIPTION OF A PHOTOGRAPH OF BEEFEATER.....	120
FIGURE 4.9: OUTPUT OF THE HOME NODE FROM "A LONDON DOUBLE DECKER BUS TOUR" HYPERMEDIA MODULE.....	121
FIGURE 6.1: NUMPAD KEYS REQUIRED FOR DAHNI-2 COMMANDS.....	168
FIGURE 6.2: THE DAHNI-2 WORKSPACE.....	171
FIGURE 6.3: STRUCTURE AND CONTENT OVERVIEW OF THE HYPERMEDIA MODULE "A TOUR AROUND LONDON - PAST AND PRESENT" USED WITH DAHNI-2.....	177
FIGURE 7.1: TIMES TAKEN TO COMPLETE THE GUIDED TASKS WITH THE THREE INPUT DEVICES.....	198
FIGURE 8.1: THE VISUAL INTERFACE OF THE PROTOTYPE DAISY PLAYBACK SOFTWARE, VERSION 1.0.....	230
FIGURE 8.2: NUMPAD COMMANDS AND SHORTCUT EQUIVALENTS.....	232



## ***Acknowledgements***

I would like to thank my supervisor, Dr Helen Petrie, for her guidance and support, and for bringing me into this stimulating and rewarding field. I am also grateful to my wider supervisory and monitoring teams, reviewers and conference attendees who have encouraged me to view my work from many different viewpoints. Without the ACCESS Project, the DAISY Consortium, and collaboration with some excellent researchers and developers this work would not have been possible; and my particular thanks go to Anne-Marie O'Neill for her help in the evaluations of DAHNI-1 and DAHNI-2, and to Peter McNally for programming the design ideas - I enjoyed many challenging design discussions with them both. For financial support I am grateful to the Economic and Social Research Council, to MA Systems and Control Ltd, and to the Department of Psychology which has been very generous, enabling me to attend conferences and seminars to develop my knowledge and experience in many areas. The research in this thesis was made possible by the enthusiastic cooperation of many blind and partially sighted students and adults - from Linden Lodge School, Dorton House College of Further Education, the British Computer Association of the Blind, and members of the public - and I thank you all for your patience and wisdom. I am glad to have worked in the Sensory Disabilities Research Unit and thanks to my friends there and in the Psychology Department for helping to keep me sane. Finally, special thanks to Mum, Dad, Chris, and Tam for your constant love, support and encouragement.

## ***The ACCESS Project and the Researcher's Involvement***

Chapters 4, 5, 6 and 7 describe work carried out alongside the EU-funded ACCESS Project. The primary aim of the Project was to develop user interface development and implementation tools which would enable an interface designer to specify an interface at an abstract level, and then automatically generate different versions of this interface suitable for the specific needs, requirements and preferences of different user groups - such as people with a visual, motor-speech, or language-cognitive impairment.

The ACCESS partners included programmers, interface designers and disability experts from around Europe. The Sensory Disabilities Research Unit (SDRU) at the University of Hertfordshire (UH) was primarily responsible for the development and evaluation of the

---

non-visual demonstrator of the ACCESS tools by creating an interface for blind students, which involved the following activities:

- Gathering initial user requirements from blind students, their teachers, and blind computer experts
- Evaluating the mock-ups which had been designed by other ACCESS partners (UH had no part in the design of the mock-ups)
- Developing the design specification for DAHNI-1 (Demonstrator of the ACCESS Hypermedia Non-Visual Interface version 1)
- Designing and conducting the evaluations of DAHNI-1
- Developing the design specification for DAHNI-2 (Demonstrator of the ACCESS Hypermedia Non-Visual Interface version 2)
- Designing and conducting the evaluations of DAHNI-2

The UH team consisted of: the Director of the SDRU (Dr. Helen Petrie); the lead researcher (Sarah Morley) who already had several years experience in non-visual interaction design and evaluation; a supporting researcher (Anne-Marie O'Neill) new to the field; and a programmer (Peter McNally). Following the Technical Annex of the ACCESS Project, and under the general direction of Dr. Petrie, Sarah Morley was responsible for the overall management of the UH activities. She led the design and evaluation work, supported by Anne-Marie and Peter, and the actual programming of DAHNI-1 and DAHNI-2 was undertaken by Peter and other ACCESS partners.

### ***Publications and Presentations***

I have reported and/or presented the majority of the work in this thesis in the following publications, conference proceedings and presentations, and copies of the publications are available from the Sensory Disabilities Research Unit, University of Hertfordshire:

Morley, S., Petrie, H., O'Neill, A-M. and McNally, P. (1998). The Use of Non-Speech Sounds in a Hypermedia Interface for Blind Users. In A.D.N. Edwards, A. Arató, W.L. Zagler (Eds.) Computers and Assistive Technology, Proceedings of ICCHP'98, (pp. 205-214). Vienna: Austrian Computer Society.

Morley, S., Petrie, H., O'Neill, A-M. and McNally, P. (1998). Auditory Navigation in Hyperspace: Design and Evaluation of a Non-Visual Hypermedia System for Blind Users. Behaviour and Information Technology, 18 (1), 18-26. First published in:

- Proceedings of The Third International ACM Conference on Assistive Technologies, ASSETS '98, 100-107. Presented.
- Morley, S. (1998). Digital Talking Books on a PC: A Usability Evaluation of the Prototype DAISY Playback Software. Proceedings of The Third International ACM Conference on Assistive Technologies, ASSETS '98, 157-164. Presented.
- Morley, S. (1997). Usability Evaluation of the DAISY Playback Software. Report from the Sensory Disabilities Research Unit, University of Hertfordshire, submitted to the DAISY Consortium.
- Morley, S. (1997). Design and Evaluation of Hypermedia Access for Blind Users. Doctoral Consortium Paper. In P. Thomas and D. Withers (Eds.) Conference Companion to Proceedings of Conference on Human Computer Interaction, HCI'97, 78-80. Presented.
- Morley, S. (1997). Design and Evaluation of Computer Systems for Blind Users. Abstract in Proceedings of the British Psychological Society, 7 (1) p.4. Presented.
- Petrie, H., Morley, S., McNally, P., Graziani, P., and Emiliani, P.L. (1996). Access to Hypermedia Systems for Blind Students. In D. Burger (Ed.) New Technologies in the Education of the Visually Handicapped Vol 237, (pp. 233-227). Montrouge, France: Colloque INSERM/John Libbey Eurotext Ltd. Presented.
- Petrie, H. Morley, S., McNally, P., O'Neill, A-M., and Majoe, D. (1997). Initial Design and Evaluation of an Interface to Hypermedia Systems for Blind Users. Proceedings of The Eighth ACM Conference on Hypertext, Hypertext'97, 48-56.
- Petrie, H., Johnson, V., McNally, P., Morley, S., O'Neill, A-M., and Majoe, D. (1997). Inexpensive Tactile Displays for Blind Computer Users: Two Application Domains. Developments in Tactile Displays. IEE Colloquium, Jan 1997, digest number: 96/012.
- November 1997: *Invited Speaker* for the Lighthouse Inc, New York, Brown Bag Lunch. Advances in Accessing Windows 95 and Digital Talking Books.
- November 1997: *Invited Speaker* for the Lighthouse Inc, New York, Vision Research Group. Design and Evaluation of Hypermedia Access for Blind Users.
- June 1997: *Invited Speaker* for Computer Science Departmental Seminar, University of Reading. Design and Evaluation of Computer Systems for Blind Users.
- April 1997: *Invited Speaker* for IEE Evening Lecture, for PG M4 (Management Education and Training Group), London. Access to Computers by Blind Users: Windows and Hypermedia.
- April 1997: 2 days of demonstration at Hypertext'97 Conference, Southampton.
- March 1997: Demonstrations to European Commission at final ACCESS Project Review, Brussels.
- January 1997: Demonstration at IEE Symposium on Tactile Displays, London.
- November 1996: Psychology Department Seminar, University of Hertfordshire. The Role of Psychologists in the Design of Computer Systems for Blind Users.
- December 1995: *Invited Speaker*: Information Technology and Visual Impairment Round Table. Research and Training: Windows and Hypermedia.

## **1 Introduction**

## **1.1 Chapter Overview**

This chapter describes the background to the research reported in this thesis, and identifies the need for such research to be conducted. A guide to the contents of the remainder of the thesis is presented outlining the progression of the research ideas. A glossary is presented at the end of the thesis listing terms and acronyms.

## **1.2 Context of the Research**

### **1.2.1 How It All Started**

The researcher first began work in this field in 1993 as a research assistant on the European GUIB Project developing one particular type of non-visual information system: a screenreader to provide non-visual access to graphical user interfaces (GUIs) for blind persons. She joined mid-way through the project and was responsible for conducting evaluations of the developing prototype with blind users, and recommending design improvements to partners to improve the usability of the interactions. During the researcher's involvement with this prototype, it became clear to her that it was not sufficient to simply *present* graphical information in an auditory form - this did not make sense to users who were listening to, rather than looking at, the interface. In addition, the amount of information displayed by a GUI was presented in parallel so that sighted users could absorb a vast array of information very quickly. This was clearly not possible using linear speech output without overwhelming users with long strings of information (or a very expensive 3D auditory display). What was needed was a different approach altogether - to identify the *meaning* and *importance* of the information on the screen and to present it in auditory form as a logical, informative, but serial string. In other words, the aim is to create an *auditory display*, rather than provide access to a visual display (as found by Arons 1991, Edwards, Mynatt & Stockton 1995, Yankelovich, Levow & Marx 1995).

### **1.2.2 A User-Centered Approach**

Once the GUIB Project had ended, the accessibility of hypermedia information by blind users - such as that found on CD-ROMs and on the World Wide Web (WWW) - became a

priority issue. These media were becoming increasingly prevalent in education, employment and leisure, but the available screenreaders for GUIs were not sufficiently advanced to provide access to blind users (see Hudson 1996b). With the knowledge that it was difficult (but not impossible) to convert a complex graphical environment into an auditory environment, it seemed more sensible to work with a user-centered approach, based on what blind people would want from a system providing access to hypermedia applications. This is how the European-funded ACCESS Project began their work, and the current research was conducted alongside the ACCESS Project, to develop and evaluate a stand-alone non-visual hypermedia browser specifically for blind students (see the Preface for specific details of the researcher's involvement in the ACCESS Project).

The user requirements findings from the ACCESS project are published in Petrie, Morley, McNally, Graziani & Emiliani (1996), and reported in detail in Free, Graziani, Lauder, Majoe, Morley, & Petrie (1995). Based on these user requirements, initial mock-ups of sample interactions were designed, and evaluated by the researcher, followed by two successive prototypes: Demonstrators of the Access Hypermedia Non-Visual Interface; DAHNI-1 and DAHNI-2 (pronounced 'Danny'). When the ACCESS Project ended in 1997 after the evaluation of DAHNI-2, the researcher was invited by the DAISY Consortium to conduct an evaluation of their existing prototype software for playing digital talking books on a PC (DAISY stands for Digital Access to Structured Information Systems). This prototype had also been designed based on an extensive user requirements survey (European Blind Union 1996), but the researcher had not been involved with the design of the software.

### **1.2.3 Custom Technology**

A review of existing non-visual information systems for blind users revealed that they could be classified into two types: (1) assistive technology, such as a Windows screenreader, which helps users to work with existing mainstream products; and (2) custom technology, which is designed specifically for a particular user-group, and usually results in a stand-alone non-visual information system. Other researchers use slightly different terms to describe these two types of system (for example, Petrie 1997). By developing a stand-alone non-visual system based on user requirements, it would be possible to explore methods of auditory interaction with hypermedia, in isolation from the

problems inherent with assistive technology, which for example, rely on accessible programming of the mainstream product - known to be almost non-existent at the time.

There are a range of custom non-visual information systems for blind users relevant to the current research which include: electronic newspapers and magazines (Kochanek 1992, Kelway 1993, Resele & Resele 1994); electronic books (Barker 1991, Taylor 1991, Hawley, Jeffries, Ross, Spencer & Tobin 1987, Barker & Sutherland 1996, Söderberg 1996); hybrid books (Vincent & Taylor 1994, DigiBook 1995, Arató, Barkaszi, Buday & Vaspöri 1996); digital talking books (Hansson, Sönneno & Lindholm 1994, European Blind Union 1996); and web browsers (Bowler, Okamoto & Pothier 1996, Hudson 1996a 1996b). There are also several custom non-visual systems for sighted users, such as a speech-only hypertext browser for recordings of interviews (Arons 1991); and systems for working with structured digital audio such as lectures (Arons 1993, 1997); news stories (Roy & Schmandt 1996); notes and lists (Stifelman, Arons, Schmandt & Hulteen 1993); and e-mail and calendar information (Yankelovich, Levow & Marx 1995).

Many of these systems were designed to overcome the problems which people experience working with audio and braille material - the number of volumes required, and the difficulty in locating information and skimming through the material because of its serial nature with little structuring information (found amongst blind people by Aldrich & Parkin 1988, Bruce, McKennell & Walker 1991, Taylor 1991, Vincent & Taylor 1995, Petrie, Morley, McNally, Graziani & Emiliani 1996, and amongst sighted people using audio by Degen, Mander & Salomon 1992, Whittaker, Hyland & Wiley 1994).

Published reports on the design of these non-visual information systems indicated that they provided a variety of commands for reading, navigation, orientation, and for output control, as well as application-specific commands, but there was a tremendous diversity in the implementation of these commands - indicating that there may not be one single method most suitable for interaction in a non-visual information system. In addition, many systems were limited to a particular form of electronic information, or did not provide the type of functionality which the ACCESS Project was aiming to provide. In addition, these systems (particularly those designed for blind students in education) made use of a variety of input and output devices (but rarely in combination), such as a keyboard, joystick, touchtablet, synthetic and digitised speech, non-speech sounds, and descriptions of pictures and tactile pictures. The ACCESS Project user requirements studies had indicated

that a combination of these different input and output methods would be welcomed in a hypermedia browser.

#### 1.2.4 Design and Evaluation

In addition to identifying user requirements and developing a prototype non-visual hypermedia system, issues surrounding the design and evaluation of such a prototype had to be resolved. In the first instance, there was no commonly-used design and evaluation methodology<sup>1</sup> for non-visual information systems. Although usability engineering has three guiding principles: (1) early and continual focus on users and tasks, (2) empirical measurement, and (3) iterative design (Gould & Lewis 1985), there was very little evidence in published work of non-visual information systems that these guidelines were followed in practice, with much development work seeming to be conducted without consultation with users at any stage, without careful user-testing or even without any testing by designers during development. Where evaluations *were* reported, they frequently seemed to be very generic, vague and without any real focus or aim, other than to find out 'if users liked it'. In addition, these brief evaluations often occurred too near the end of the development cycle for any improvements to be made (as Arons 1997 recently noted about his own work on an auditory browser), making many evaluations appear to be no more than a validation of the design.

Nevertheless, there are several examples of good research and development of non-visual information systems, notably from the GUIB Project (1995), Stevens & Edwards (1996), Stifelman, Arons, Schmandt & Hulteen (1993), and Yankelovich, Levow & Marx (1995). The usability evaluation methodology developed in the GUIB Project had many similarities to the Cooperative Evaluation approach of Monk, Wright, Haber & Davenport (1993), involving participants completing set tasks using an informal think-aloud method with user-researcher interaction, and a semi-structured interview concerning the usability of the system features.

---

<sup>1</sup> The term 'methodology' is taken from experimental psychology, used to refer to an empirical approach consisting of a variety of specific methods or techniques - discussed in Chapter 2, section 2.4.10.

Evaluation goals could also be borrowed from the hypermedia field, where investigations often focus on the effectiveness of the presentation of information in hypermedia format, rather than on the design of the interface, such as for example, navigational issues and the memorability of information.

An iterative evaluation process as recommended by the usability engineering field firstly involves users throughout several design stages of a prototype; and secondly gives scope for designers to conduct testing without users - usability inspection methods (Karat 1988, Nielsen & Mack 1994) - at each design stage, using methods such as guidelines (Norman 1988), heuristics (Nielsen 1993), jogthroughs (Rowley & Rhoades 1992), and so on, to ensure that design decisions are suitable before testing by real users.

Working with a small user-group in a novel application domain such as auditory hypermedia is particularly challenging and interesting, because the requirements for working in such an application are very different from those of visual interfaces. Whereas sighted users can fairly easily imagine how other sighted people might respond to a visual interface, it is very difficult to anticipate how a user with special needs, such as a blind user might respond (Petrie 1997), and it is this which makes the design and evaluation of these types of interfaces highly stimulating - and demands the involvement of blind users throughout the design cycle. As Newell & Cairns (1993) remark:

“... a disabled user can present with very difficult problems [sic.] which demand very detailed consideration of the real needs and wants of the user, how they differ from the expectations of the designer, and whether and how these vary between the potential users of the proposed equipment. These requirements can stimulate the designer to develop new and more effective interfaces.” (p. 5)

An important issue relating to the assessment of usability of parts of a prototype is that it is not sufficient simply to *measure* usability problems, and nor is it always relevant to look for statistically significant measurements - usability problems must be *highlighted and explained* in order to develop solutions for the purpose of re-design.

### **1.3 The Research Aims**

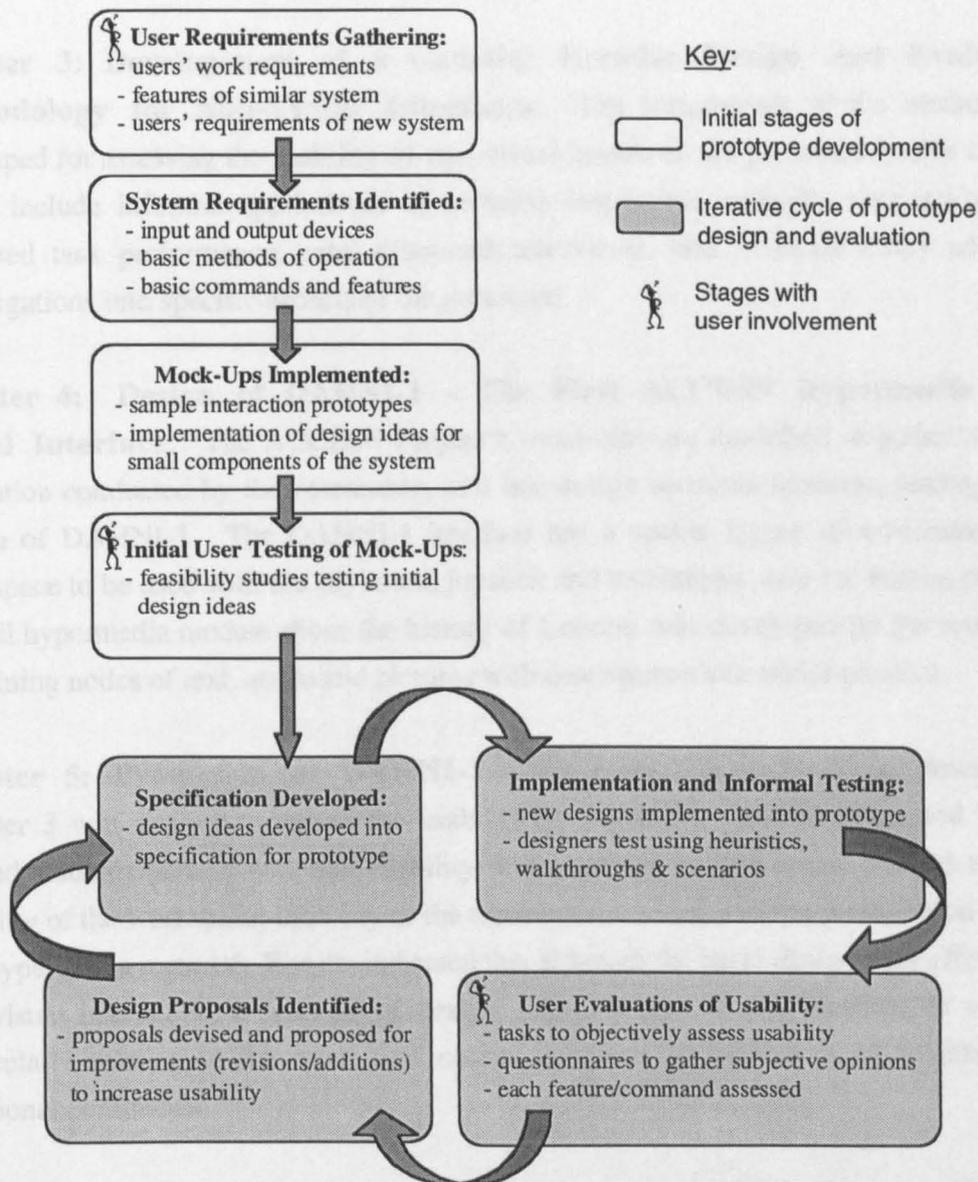
For the reasons described in the previous sections, the research presented in this thesis set out to achieve the following three aims:

- 1) To develop a generic, iterative design and evaluation methodology suitable for formative evaluation of prototype non-visual interfaces at different stages of their development, to include both informal evaluation by designers themselves, and user-testing involving observed task performance and subjective measures. The goal of the evaluations is to identify and explain usability problems and to develop design improvements, in an iterative cycle where possible.
- 2) To explore non-visual interaction possibilities for a multimodal hypermedia browser for blind students. These would be based on existing user requirements, provide a range of input and output devices, and support users with a range of computer experience.
- 3) To apply the evaluation methodology to prototype non-visual interfaces at different stages of development.

The design and evaluation lifecycle developed in this research to achieve these aims is illustrated in Figure 1.1. Initial user requirements were gathered first and mock-ups then designed and evaluated. A cycle of prototype design and evaluation then began (the lower four boxes shown in grey). The researcher was involved in all stages for the development of DAHNI-1 and DAHNI-2, and in one iteration of evaluation of the DAISY Playback Software since the prototype already existed.

### **1.4 Organisation of the Thesis**

To help the reader to navigate through this thesis, the following section describes the progression of research ideas through the remaining chapters. The chapters presenting the design and evaluation of these non-visual interfaces contain detailed descriptions of the process of the design and discussion of the evaluation findings. This is intended to provide a full account of the design process - how it was shaped by the findings from evaluations and how it relates to other research and development - to enable other designers to benefit from this in-depth analysis of the relevant issues.



**Figure 1.1: The Design and Evaluation Lifecycle Developed in this Research**

**Chapter 2: Review of Related Research and Development.** This chapter presents a review of related research and development in a range of fields in order to (1) identify the size, scope and requirements of the target group; (2) gather ideas for the development of non-visual interfaces to hypermedia material and digital talking books; (3) establish what kinds of evaluation methodologies exist and which methods can be used to achieve the aims outlined above, and (4) identify how this research attempts to fill gaps in the existing knowledge.

**Chapter 3: Development of a Generic, Iterative Design and Evaluation Methodology for Non-Visual Interfaces.** The components of the methodology developed for assessing the usability of non-visual interfaces are presented in this chapter. These include informal applications of usability inspection methods, user-testing with observed task performance, semi-structured interviews, and in some cases additional investigations into specific aspects of the prototype.

**Chapter 4: Design of DAHNI-1 - The First ACCESS Hypermedia Non-Visual Interface.** The ACCESS Project's mock-ups are described, together with the evaluation conducted by the researcher, and her design recommendations, leading to the design of DAHNI-1. The DAHNI-1 interface has a spatial layout of commands on a workspace to be used with the keyboard, joystick and touchtablet, and for testing purposes a small hypermedia module about the history of London was developed by the researcher, containing nodes of text, audio and pictures with descriptions and tactile pictures.

**Chapter 5: Evaluation of DAHNI-1.** The evaluation methodology described in Chapter 3 was applied to assess the usability of DAHNI-1. Seven blind and partially sighted students participated, and usability was explored in four areas: general usability; usability of the workspace; usability of the three input devices; and the presentation of links and hypermedia material. Results indicated that although the basic design was effective for non-visual interaction, a number of design improvements would increase its usability, particularly relating to the input and output devices, the provision of feedback, and additional commands.

**Chapter 6: Design of DAHNI-2 - The Second ACCESS Hypermedia Non-Visual Interface.** The results from the evaluation of DAHNI-1 led to the design of a second version of the interface, DAHNI-2, described in this chapter. Improvements included: the re-naming and re-location of commands on the workspace; the addition of non-speech sounds to provide structural information and feedback; the addition of new commands to improve orientation, navigation, for finding and selecting links, and for controlling the output; re-implementations of the input and output devices; the addition of an on-line tutorial, help systems and user configuration; and the development of a larger and more varied hypermedia module.

**Chapter 7: Evaluation of DAHNI-2.** The evaluations involved nine blind and partially sighted students, and included a practice period of 2 weeks between training and evaluation sessions to allow participants to become familiar with DAHNI-2. The evaluations covered: overall usability; the usability of the input and output methods, the non-speech sounds, the on-line help and tutorial modules; and preferences for media for learning. Separate investigations assessed the memorability of the non-speech sounds, of headings, and of information presented in different media. Although the results indicate that DAHNI-2 now provided more effective non-visual interaction with hypermedia material, a number of design proposals are suggested which would improve its longer-term use by a range of users, and which can be used to inform the designers of other similar systems.

**Chapter 8: Evaluation of the DAISY Playback Software.** A brief description is given of the functionality of the software for the benefit of readers unfamiliar with its design. The evaluation methodology developed by the researcher was again applied, and thirteen blind students and adults worked freely with several DAISY books, being asked to complete generic tasks if they had not already used a specific feature. While the software was found to be generally easy to use, several major usability problems were identified, particularly relating to navigation through headings because of a lack of structural information and feedback, and many minor usability issues were also highlighted. Design recommendations are proposed to increase the usability of the software, including the addition of non-speech sounds for structural information and command feedback, the re-implementation of certain commands, and the addition of new commands.

**Chapter 9: Recommendations for the Design and Evaluation of Non-Visual Interfaces for Blind Users.** This chapter draws together the findings and recommendations from the design and evaluation of these three non-visual interfaces, indicating areas requiring further investigation. The recommendations cover firstly, the design and evaluation methodology, and secondly, issues of non-visual interface design, covering: general interface design; input and output methods; reading; output control; orientation and navigation; finding and selecting links; and support and personalisation features.

**Chapter 10: Conclusions.** The final chapter presents a summary of the research and the main conclusions and recommendations from: the development of a generic iterative design and evaluation methodology; the design and evaluation of two prototype non-visual hypermedia interfaces; and the evaluation of an existing prototype non-visual digital talking book system. The overall main recommendations are firstly, to develop new interfaces adopting a user-centered approach, following the generic iterative design and evaluation methodology developed in this research, in order to identify usability problems and develop design solutions; and secondly, to design multimodal interfaces providing a range of input and output devices, with a range of well-implemented commands for reading, navigation and orientation, output control, for finding and selecting links, and to personalise and customise the system. This will support different users working in different materials undertaking different tasks.

### ***1.5 The Scope of this Research***

This research explores fundamental non-visual interaction methods within prototype interfaces to hypermedia and digital talking book material for the purposes of improving the design from one version of a prototype to another. It was not possible to cover high-level issues which would have been possible if the systems had been more advanced, concerning for example, browsing strategies, learning outcomes and so on. Participants were representative of the target end-user group, and sufficient numbers were included for the results to be considered valid and reliable. The design proposals recommended by the researcher are based on her interpretation of the evaluation results, and where several possible design alternatives might be appropriate, the researcher presents them all for consideration.

### ***1.6 Coming Next...***

The following chapter presents a review of related research and development, covering issues relating to: blindness and non-visual information access; non-visual information systems for sighted users; user-centered design and evaluation; and lessons to be learned from hypermedia design and evaluation. The chapter concludes with a description of how the present research attempts to fill gaps in existing knowledge.

## **2 Review of Related Research and Development**

## 2.1 Chapter Overview

This review of relevant research and development covers a wide range of fields in order to determine what kinds of non-visual information systems and evaluation methods exist, and to identify their strong and weak aspects which can contribute to the current research. The review indicates that although a range of systems are available, none specifically address non-visual access to hypermedia material by blind students, and there is no commonly-used evaluation method suitable for assessing the usability of non-visual interfaces. These issues are discussed in the following five sections:

- **Part I** identifies and defines the target group for this research, and outlines the types of problems blind people experience with traditional information access using braille and audio materials. A review is then presented of existing technology designed for blind users which attempt to overcome these problems, and outlines their designs and limitations.
- **Part II** presents a review of non-visual information systems for sighted users, describing their designs and limitations.
- **Part III** discusses the issues surrounding user-centered design and evaluation, in an attempt to identify methods which might be appropriate to the current research.
- **Part IV** highlights some lessons which can be learned from the design and evaluation of hypermedia systems from the hypertext/hypermedia literature.
- **Part V** concludes the chapter by summarising how the present research attempts to fill gaps in the existing knowledge already presented in this chapter.

At various points throughout the review, short summaries are provided in 'Implications' boxes, to help the reader to identify the main points reviewed in the section which have contributed to the current research.

---

## 2.2 Part I: *Blindness and Non-Visual Information Access*

### 2.2.1 The Target Group

This thesis addresses issues which could potentially affect the design of technologies used by millions of users across the world; whether blind, partially sighted, or fully sighted using hands-free and eyes-free systems for study, work or leisure activities. Absolute figures of the number of visually impaired people (blind and partially sighted) and how many use computers are difficult to obtain for two main reasons: firstly the varying definitions in different countries; and secondly the varying methods of data collection, participant selection and data extrapolation (for example using interviews, postal questionnaires, or self-selecting on-line surveys). However, the available figures do offer an indication of the size of the target group - presented below.

#### 2.2.1.1 *Definitions of Blindness, Partial Sight and Visual Impairment*

It is useful to clarify the terms to be used relating to vision loss early in the thesis. According to UK definitions:

- *Blindness* can be described as not having sufficient vision to perform any task for which eyesight is essential - this explains why the majority of 'blind' people can see light and dark, shapes, and/or colour, and only 18% cannot see anything at all (Bruce, McKennell & Walker 1991). In technical terms, this can be measured by a visual acuity of less than 3/60<sup>1</sup> or corresponding visual field loss in the better eye with best possible correction. This corresponds to loss of walk-about vision (WHO 1997), and whose primary information medium is touch and sound.
- *Partial Sight* can be described as being substantially and permanently handicapped by defective vision caused by congenital defect, illness or injury. This can be measured by

---

<sup>1</sup> The Snellen Scale is the standard measure of visual acuity. It is typically measured with an eyechart, placed 6 metres (or 20 feet in the United States) away from the person being tested. The average person with unimpaired vision can just read letters of a certain size at this distance and is said to have 6/6 vision (or 20/20 vision in the USA). A person who cannot read these letters, but is able to make out letters of twice that size, has 6/12 (or 20/40) vision, which is to say that at 6 metres from the chart they can read letters that someone with unimpaired vision could distinguish at 12 metres. The worse a person's acuity, the larger the denominator in the sight rating.

a visual acuity of less than 6/18, but equal to or better than 3/60 in the better eye with the best possible correction (WHO 1997). In simpler terms, this is when a person's best corrected vision falls significantly outside the normal ranges for near or distance visual acuity.

- *Visual Impairment* is the term which will be used throughout this thesis to refer to people with a functional loss of their sight, to include both blindness and partial sight. This term is chosen in preference to 'disability' which is generally used to refer to the restriction or inability to perform an activity due to the impairment (WHO 1980), and 'handicap' which usually refers to the social consequences of the functional loss (Bruce, McKennell & Walker 1991, Martin, Meltzer & Elliot 1988). Where relevant, the distinction between a person who is blind, and a person who has partial sight will be made explicit.

#### ***2.2.1.2 Estimates of the Incidence of Blindness***

There are estimated to be at least 1 million blind and partially sighted adults (over 16 years old) in the UK (Bruce, McKennell & Walker 1991); about 2.3 million in Europe (all age groups in 11 member states, Carruthers, Humphreys & Sandhu 1993); and in the USA an estimated 1.5-1.6 million people (aged 15-64) are known to be blind or have vision problems (Sevigny & Scourfield 1997, US Census Bureau 1997). In the UK, 14% of visually impaired people aged 16-59 read braille, compared with only 1% of over 60's (Bruce, McKennell & Walker 1991). All these figures include a high proportion of mature people losing their sight in later years, however a significant number of young people and adults are at school, college, university and in employment using technology for a range of activities.

Estimates of the numbers of visually impaired children in the UK are between 10,000 and 25,000, with around 5% being able to read and write braille. Of these around 53-59% are educated in mainstream settings with sighted peers rather than in special schools for visually impaired children; and as many as half of visually impaired children have additional special needs (Walker, Tobin & McKennell 1992, Clunies-Ross 1997). In 1992 many visually impaired children were found to be using computers at school (68%) and at home (36%) (Walker, Tobin & McKennell 1992), and these numbers are likely to have increased dramatically in recent years.

### ***2.2.1.3 Computer and World Wide Web (WWW) Use by Visually Impaired People***

It is especially difficult to estimate the number of visually impaired adults using computers; but in 1997 the Royal National Institute for the Blind (RNIB) informally estimated that at least 25,000 visually impaired people are using computers every day in the UK (Tyler 1997, personal communication); and estimates in the USA suggest that around 1.2 million visually impaired people are using computers every day; 900,000 of whom have an internet connection (according to an un-named survey reported in Ability, Issue 21 1997).

The Georgia Institute of Technology WWW 4<sup>th</sup> User Survey in 1996 found that 3.7% of their 11,736 self-selecting respondents reported a vision disability across all age groups (see the GVIU WWW User Surveys home page in the Reference list for details). Interestingly, in their most recent 10<sup>th</sup> User Survey (1998) the number of impaired respondents was found to be similar (3.5% of 5,022 respondents), and there are now high numbers of young and elderly people using computers and the WWW - with 7.7% of people in the 11-20 year age group reporting a visual disability, compared with 3.6% aged 21-25, 2.7% aged 26-50, and 5.0% aged 50+.

### ***2.2.1.4 Talking Book Use***

The RNIB's Talking Book Service (founded in 1935) reaches the largest number of visually impaired people than any other of RNIB's services. This is a membership-based library of a wide range of fiction and non-fiction books, specially recorded and produced for visually impaired readers, to be played on a specialised 2-track Talking Book Player (Friedlander 1987, Griffiths 1994). In 1994 the Talking Book Service had 70,000 members (Griffiths *ibid.*), and this accounts for about 12% of all blind and partially sighted people, 37% of whom are aged 16-59, and 26% are aged 60+ (Bruce, McKennell & Walker 1991).

### ***2.2.1.5 Causes of Vision Loss and Additional Impairments***

Among working age people (aged 16-64 years) the main cause of blindness is diabetic retinopathy, and the most common cause of partial sight is macular degeneration (Evans, Rooney, Ashwood, Dattani, & Wormald 1996). Almost one third of working age adults experienced their sight problems from birth, and 60% reported that their sight problem

occurred later, possibly as a result of illness, disease such as diabetes, or accident (Bruce, McKennell & Walker 1991). Amongst children aged 3-19, almost 80% were reported to have had their sight problems from birth (Walker, Tobin & McKennell 1992). One cause of blindness, retinopathy of prematurity (formerly known as 'retrolental fibroplasia'), may have implications for later life, particularly concerning orientation and spatial skills (Mason 1997).

It is important to remember that as many as 60% of visually impaired adults and 56% of children have additional significant illnesses or disabilities (Bruce, McKennell & Walker 1991, Walker, Tobin & McKennell 1992, Clunies-Ross 1997) which might affect their ability to use standard equipment for blind people.

**Implications:** Many visually impaired people across the world, both young and old, with a range of abilities could benefit from the careful design and evaluation of technology to suit their needs for leisure, study and work activities, particularly concerning auditory information from a computer or talking book.

### **2.2.2 Limitations of Traditional Braille and Audio-Tape Information Access**

Before the arrival of computer-based electronic text, visually impaired people relied on audio and braille materials for information access (large print materials used by partially sighted people will not be discussed since this thesis mainly addresses non-visual systems). Both braille and audio-taped materials are made available through certain charities or organisations (especially in the case of text books, exam papers, newspapers and magazines), and audio-books can be obtained from specialist lending libraries. However, with only a small number of people reading braille the use of audio-materials has been, and remains, quite significant.

The limitations of both braille and audio-taped materials for information access are well-known, and people requiring access to study or reference materials in these media, such as students, have many problems (Aldrich & Parkin 1988, Bruce, McKennell & Walker 1991, Taylor 1991, Vincent & Taylor 1995, Petrie, Morley, McNally, Graziani, & Emiliani 1996, Aitken 1997, and in the USA, Senge & Dote-Kwan 1995). These surveys all highlight the problems blind users face with these media: firstly relating to the

production of materials, and secondly, relating to the actual use of those materials, and the main findings combined from these surveys are presented below.

#### ***2.2.2.1 Problems with Production***

- **Slow Production:** material takes several months to produce which is problematic in classroom or office situations where material is needed quickly.
- **Costly:** small numbers are produced, so cost per unit is high.
- **Low Availability:** because of the expense and time-factor of producing materials, only a relatively small amount of material is available in audio or braille formats.

#### ***2.2.2.2 Problems with Use***

- **Slow to Read:** The reading rates for both braille and audio-tape are very slow, compared to a sighted reader's average speed of around 300 words per minute (wpm) (Hollins 1989, Foulke 1982). Braille reading speeds for children and adults generally range between 57-70 wpm (Warren 1978, McCall 1997) with fluent adults reading up to 150 wpm (Warren *ibid.*). Rates for listening to audio-tape are slightly higher, at around 175 wpm (normal speaking rate), and with high playback speed or using speech compression provided by some audio devices, rates of up to 275 wpm are possible (Warren *ibid.*). Even sighted people can recognise familiar speech speeded up to almost 100% its original speed, and unfamiliar speech is still recognisable up to 75% (Degen, Mander & Salomon 1992). Comprehension of accelerated female speech has been found to be less easy to comprehend than accelerated male speech unless a high quality pitch controller is used (Aldrich and Parkin 1989), so care should be taken in the use of different speakers when recording texts which may require speed listening.
- **'Passive Reading':** This could apply equally to reading braille and print, but listening to an audio-tape in particular can lead to 'passive reading', where listeners do not process the material very deeply, quickly lose concentration and are generally less efficient than active listeners in their ability to retain what they have heard. When reading for education or for information, listeners may have to be taught 'higher listening skills' (as described in Arter 1997b). Similarly, editors may need to include special features in the material such as summaries, explanations, examples, activities and highlights of important points (Deshler & Graham 1980), or self-assessment

questions (Parkin & Aldrich 1989), in order to increase the amount of active listening of material.

- **Limited Search and Skimming:** Because audio-tape is a serial medium, it can be very slow and cumbersome to use text books or other material which requires 'skimming', and to locate specific points in the recording, especially when one text book may be on many cassettes. Although braille material is likely to have a contents page and page numbers, making it easier to locate specific places in the text, a braille text book may require several bulky volumes, which can be as difficult to manage as many cassettes. Sighted readers would be able to simply scan the pages of a book looking for the relevant phrase, but this is almost impossible to do in a braille or audio book.
- **Lack of Overview:** Sighted readers scan through a document looking for major headings and sub-sections, using the print formatting to develop a mental picture of how the material is structured. Unless the publisher or recording editor of a braille or audio book has included a summary of the book and its structure, the non-visual reader may have to search for many minutes until they can locate a table of contents or summary which offers them an overview of the book. It is also hard to gain an overview of the topics in a given section.
- **Problems with Diagrams and Figures:** There are no accepted guidelines for dealing with diagrams and figures when transcribing material into braille or audio. Thus, diagrams may be simply omitted, or an attempt made to describe them, and then the effectiveness of the description depends on the nature and purpose of the figure, the relationship of the figure with the text (see Kurze, Petrie, Morley, Deconninck & Strothotte 1995), and the skill of the narrator in interpreting and describing the figure.
- **Audio is Serial and Transitory:** Once a sound has been played it is no longer 'in view' and auditory readers cannot use the sighted readers' ability to speed-read by looking at several words at once. Any auditory display may require additional features to support the limitations of auditory processing which affect memory, cognitive load and comprehension differently than visual processing (Cress & Goltz 1989a, Moore 1989, Kramer 1994).
- **No Annotation or Bookmarking Capability:** Students working with either braille or audio-taped materials cannot annotate the texts, which may help contribute to passive reading. Although bookmarking is possible in braille material to aid orientation, users of audio tape cannot mark parts of interest, to help them to later re-

locate specific material. Compare this with sighted students' use of bookmarks, underlining and making notes in margins, to aid their comprehension, memory and orientation through the material.

**Implications:** The difficulties blind people face using audio and braille material are caused mainly by the linear and serial nature of these media, making it difficult to browse or locate information easily. Audio material places additional cognitive load on listeners because of its transitory nature, and its tendency to lead to passive listening.

### 2.2.3 Technology and Accessibility

Computers have an enormous potential to empower people with disabilities in all aspects of life, including education. Technology can compensate for lost functioning, and enhance functioning; can enable people to write, to organise their affairs, to speak and to communicate, to express themselves in leisure activities, in education or at work, when doing these things independently may have seemed previously unachievable; and can increase educational and job opportunities (Luxton 1990, Fine 1997, Petrie 1997, Lock 1998, Wolffe 1998). Computers offer benefits such as immediate feedback; flexibility in content, presentation and pace of learning material; independence; and the support for many different input and output devices to support various configurations to suit a range of user for a range of task. However, teachers must be equipped for using this new technology if blind students really are to benefit (Mack, Koenig & Ashcroft 1990, Fetton 1994).

However, these advantages of computer technology are only available if products are 'accessible'. There are many definitions of accessibility, and as an ideal we might refer to the following, proposed by the Texas Education Agency (1997), relating to the use of educational electronic textbooks by disabled students:

*“Accessibility refers to the freedom or ability of an individual to obtain or make full use of a product or environment. A product is accessible to an individual only if he or she is able to use it to carry out all of the same functions and to achieve the same results as individuals with similar skills and training who do not have disabilities.”*  
(p. 3)

They go on to describe that the minimum requirements of an 'accessible' electronic textbook should be that it is:

- *Perceivable*: The information contained in the book must be available in a form which can be perceived by the student.
- *Operable and Navigable*: Students should be able to orient themselves and move within the textbook.
- *Functional*: The textbook should provide the same function or benefit to the individual with a disability as it would to other students.

These three issues are addressed by this research, although rather than having to make adaptations to an existing mainstream visual system, these requirements can be met by designing an interface specifically suited to the needs of blind users. For example, perceivable information for a blind user might include audio transcription, but might also include tactile pictures with verbal descriptions, or audio captioning. Although significant effort and expertise is required to produce these 'accessible' materials, it could be viewed as equivalent to designers expending effort creating visually appealing screens of information. Similarly, rather than requiring a mouse to operate a system, if a keyboard (or other input device) is provided, interactions become 'accessible' to someone who cannot use a mouse.

It is less clear how to enable a blind user to "carry out all of the same functions and to achieve the same results" as non-disabled users. In educational terms, this could be measured by access to certain topic areas and information within the application, for example, allowing a blind student to study for and produce an essay. However, when considering the accessibility of applications such as Microsoft Windows, and comparing the parallel visual presentation of this environment with the relatively slow, serial presentation of the same information in audio or tactile form, it is difficult to see how the experience will ever be exactly equal to that of a sighted user, because our audio and tactile processing abilities are simply less fine than for visual processing (Hollins 1989).

However, the goal of practitioners in this field is to develop interfaces which provide as much equality as possible to blind users, in terms of both functionality and benefit, often providing special features to compensate for the limitations of auditory and tactile processing capabilities. To this end, specially-designed non-visual interfaces such as those

reported in this research can further good interface design, and suggest ideas to mainstream designers working on auditory systems.

The range of technology specially designed for blind computer users is wide-ranging, including output methods such as speech synthesis, and braille displays; magnification systems and optical character recognition (as described in Lazzaro 1993, 1995, Lodge 1994, Gray & McDonald 1993, Baldewijns 1997, Waddell 1998). Various electronic publishing technologies could enable visually impaired learners to have independent control of the search of, and retrieval from, huge amounts of information; provide immediate and low cost provision of resource material in large print or braille; and could reduce the time previously spent searching for and manipulating information (Vincent & Taylor 1995).

Such technologies can be conceptually grouped into two categories:

- (1) technology providing access to mainstream products (assistive technology), and
- (2) purpose-built technologies (custom technologies)

Different researchers use slightly different terms to describe these technologies (for example, Petrie 1997), but the types of technologies available in these categories are described briefly in the following sections with indications of their benefits and drawbacks.

#### **2.2.4 Assistive Technology**

Assistive Technology is software and hardware allowing access to mainstream applications (such as DOS and Windows applications). Examples include screenreaders for DOS and Windows. Assistive technology has the advantage of allowing access to mainstream products, thus providing some level of equality with sighted peers. However, access to mainstream products, particularly the Graphical User Interface (GUI), has proved particularly difficult to address, described below.

##### ***2.2.4.1 The Graphical User Interface (GUI) Problem***

After the arrival of the GUI, blind people could not initially access new software with their existing screenreaders. The pixel-based presentation of the screen images meant that their assistive technology which presented DOS-based systems in synthetic speech or on a

braille display no longer worked. Issues of presenting a graphical display with many objects visible at once and requiring the use of a mouse, in auditory or tactile form were initially very difficult to solve (as discussed by Vanderheiden 1989, Boyd, Boyd & Vanderheiden 1990, Edwards 1991, Petrie & Gill 1993, Thatcher 1993, Edwards, Mynatt & Stockton 1995) and it became clear that the *concepts* of the interaction were more important than the visual presentation on the screen, and a multimodal presentation of information would be most likely to be appropriate.

GUIB and Mercator are two examples of research project screenreaders providing early access to the complex, visual Microsoft Windows and X-Windows respectively, based on the concepts of the information (Mynatt & Weber 1994). They made use of different models of the interface, but used speech, braille, and non-speech sound output; with the GUIB display also supporting a range of input devices - a touchtablet and routing buttons in addition to the keyboard (see the GUIB Project Final Report 1995). An early experimental system for the Macintosh was designed, Soundtrack, to explore these issues, using speech and sound output with a mouse (Edwards 1989), and later full screenreaders for other systems were made available, such as Screenreader/2 for OS/2 (Thatcher 1994) and Outspoken for the Macintosh (Edwards 1995b).

In addition to special software and hardware, blind people required new types of training in order to make use of these graphical environments (Weber, Petrie, Kochanek & Morley 1994, Petrie, Morley, Weber & Kochanek 1995, Morley 1995, 1997b). As more Windows screenreaders became available and were gradually developed to access WWW browsers, blind people were eventually able to access the WWW; however, as reported later in Section 2.2.8, these interactions were initially not reliable or effective, leaving blind people still unable to access hypermedia material.

### 2.2.5 Custom Technology

Custom Technology is software and hardware designed for a particular purpose; a stand-alone application which does not interact with existing mainstream applications. Examples include talking diaries, text editors, and browsers for electronic books, which might use input devices other than the keyboard, such as a joystick, touchtablet or voice recognition (e.g. Blenkhorn 1986, RCEVH Centre Software Catalogue 1996). Custom-built technology offers the advantages of being designed with the needs of blind users in mind,

and can provide features to support users in effective ways, but has the disadvantage that users may find the non-compatibility with mainstream products and concepts to be a barrier to equality.

The systems described in the majority of this review and throughout the thesis fit into the 'Custom' category - most have been designed for a particular user group for a particular purpose. The following sections illustrate various aspects of their design.

#### ***2.2.5.1 Multimedia and Multimodal Input and Output***

Research into the use of devices in schools for visually impaired children show that a wide variety of input and output devices are being used in schools, such as touchscreens, mouse, switches, concept keyboard (a touchtablet used with tactile overlays), joysticks, and speech synthesisers (Hill & Tobin 1992, Douglas & Gamble 1994), used for a variety of educational purposes. Indeed, some teaching centres provide multiple modalities in their programs specifically to enable children to interact with the software in their most preferred manner appropriate to the current task and stage of development (Tobin, Bozic, Douglas & Greaney 1996).

The possible use of multiple input and output devices - such as a keyboard, joystick, touchtablet with overlays, scanning, synthetic and digitised speech, sound effects, and a braille display) has been discussed for graphical user interfaces (Vanderheiden 1989), for a hypermedia system (Perkins 1995), and for electronic books (Barker 1991), with the intention of presenting the interface and content of the system to the user in a flexible, supportive and efficient manner. A multimodal, multimedia approach was successfully used to present Windows 3.1 to blind users in the GUIB project (GUIB Project Final Report 1995), and even Microsoft (1997) are recommending the use of multiple input and output methods to support a range of users.

Apart from providing variety in an interface, one of the strongest arguments for providing a multimodal and multimedia display is the provision of redundancy; such that the system is sufficiently flexible to support different kinds of activities, different users, and can aid orientation and understanding (Edwards 1992, Texas Education Agency 1997). Findings from the ACCESS Project's User Requirements Survey of blind students, their teachers and blind computer experts revealed enthusiasm for a hypermedia system which made use

of a variety of input and output devices (Free, Graziani, Lauder, Majoe, Morley & Petrie 1995).

However, care should be taken when selecting an input device for a given purpose, and in order to maximise usability and reduce cognitive load there should be a good mapping between device and interaction (Arons 1993, 1997), and between user, device and task (Cress & Goltz 1989a, Cress & Tew 1990, Cress & French 1994). For example, a particular arrangement of commands might work well with one device but not with another, and a consistent model of commands might be more appropriate when working with several input devices. Studies with people with motor disabilities using a mouse and the keyboard (Trewin 1996, Trewin & Pain 1998) indicate that careful analysis of how input devices are used could enable more effective interactions to be designed.

#### ***2.2.5.2 Diagrams and Verbal Descriptions***

To increase the level of access to information for visually impaired students, many organisations make special efforts to provide some level of access to diagrams and graphical information. This might take the form of a verbal description of an image, or a tactile image together with a verbal description - despite the lack of guidelines for producing and describing graphics for blind people (but see Edman 1992). Whether educated in a mainstream or special school, it would seem important to provide equal access to educational materials, including images, to provide students with knowledge equivalent to their sighted peers (Best 1992).

Hand-drawn images, thermoformed collage and other methods can all be used successfully, and a computer-based translation of photographs into tactile pictures (for example Ina 1996) has great potential in the classroom. Larsen & Jorgensen (1989) assert that books on tape with 'sound illustrations' (accurate narrative descriptions of graphics and photos), and tactile books stimulate young blind children to better understand their physical world. They also stress (as do Mason & Arter 1997) that learning using several senses, not only the auditory modality, is needed for a child's conceptual, social and educational development.

With careful preparation of the images and training in the use of such diagrams (Bentzen 1982, Kennedy 1993, Tobin 1993), coupled with verbal descriptions, blind students can

find material more interesting, easier to understand and to remember, and increases their level of independence with learning materials (Arter 1997a, Mason & Arter 1997, Wild & Hinton 1996). In addition, the use of diagrams relieves the monotony of reading audio or braille material by retaining some of the variety of the print original (Cobb 1997) and can be very useful to illustrate difficult concepts, for example illustrating graphical user interface screens (Petrie, Morley, Weber & Kochanek 1995), fine art (Othman & Levanto 1996), or maps (Fanstone 1995).

It is important to remember that diagrams may not be suitable for every blind student, nor for every type of diagram. For example, some blind people may find it difficult to create meaning out of spatial diagrams as a result of the cause of their blindness (for example, those who suffered from retinopathy of prematurity, formerly known as retrolental fibroplasia, Mason 1997). In addition, the use of tactile diagrams may improve recall of pictorial information, but this may be at the expense of recall of non-pictorial information (Pring & Rusted 1985).

The use of descriptions of moving images (such as TV, film, and theatre) is normally referred to as audio description, which is reported to significantly improve blind persons' information access and subjective enjoyment to these media (Raffray 1995, Pettitt, Sharpe & Cooper 1996, Peli, Fine & Labianca 1996). Descriptions of both static and moving images could be added to educational systems to further increase interest and accessibility.

### **2.2.5.3 *Non-Speech Sounds***

The purposes of auditory enhancements such as non-speech sounds to computer displays are varied and have many benefits, summarised by Kramer (1994); for example, for eyes-free work, rapid detection, alerting, orienting, backgrounding, parallel listening, acute temporal resolution, affective response, and auditory gestalt formation. When coupled with other interface channels Kramer (ibid.) identifies other benefits including non-intrusive enhancement, increase in perceived quality, superior temporal resolution, high dimensionality and engagement, and intermodal correlations.

Sounds are being used in a variety of interfaces to provide feedback for user actions and about the system state, aiming to improve the quality of the interaction, and the field has been directed by two distinct approaches. Gaver (1989, 1994) developed '*auditory icons*',

everyday sounds mapped to computer events by analogy with everyday sound-producing events. These sounds are intended to be easy to learn and to remember since they are 'naturalistic'. The alternative approach, developed by Blattner, Sumikawa & Greenberg (1989) uses a language built from short sequences of tones using pitch and rhythm, to form 'earcons', which are associated with actions and objects. These tones and patterns of tones form a grammar for the interface which needs to be learned. Brewster, Wright & Edwards (1994) went on to develop musical earcons which they found to be more effective than Blattner et al's simple tones. It is clear that although some of Gaver's natural sounds have an obvious appeal (a printer sound for the printing process, for example), they are unlikely to be adequate for presenting highly complex interface messages (Edwards 1989).

Sounds have been added to experimental interfaces for blind users such as: menus on the Macintosh (Karshmer, Brawner & Reiswig 1994); a haptic pointing device to explore the Windows interface (Ramstein, Martial, Dufresne, Carignan, Chassé & Mabillean (1996); and to the WWW browser Mosaic (Albers 1996) to reinforce user actions and to aid navigation through web material.

A possible alternative to either Gaver or Blattner's approach is a combination of both types of sound, to form a 'hybrid' sound interface, such as used in the GUIB Windows screenreader so that auditory icons are used where an obvious mapping exists, and earcons are used for more complex messages (see GUIB Project Final Report 1995, Petrie & Morley 1998).

Since blind people do not have inherently better hearing than sighted people, but are more experienced at using auditory discrimination in their daily lives (Warren 1978, Hollins 1989), it is likely that the use of non-speech sounds in interfaces will be a successful method of reducing verbosity while maximising information provision from auditory displays.

#### ***2.2.5.4 Access to Scientific and Mathematical Material***

Although tangential to the main focus of this thesis, it is important to note that although advanced scientific documents have historically been inaccessible to blind students (since it is difficult to present in braille or speech output (Cahill, Linehan, McCarthy, Bormans & Engelen 1996), several efforts have been made to provide audio access to scientific and

mathematical material. These include for example, Mathtalk (Stevens, Edwards & Harling 1997) and AsTeR (Raman 1994), using various acoustic cues such as pitch, intonation, non-speech sounds and spatial audio to present overviews of, and navigation through complex mathematics. Mathtalk has been evaluated using a modified cooperative evaluation technique where real users worked with algebraic equations presented in Mathtalk and Latex, and performance and subjective measures allowed comparison of the two systems (Stevens & Edwards 1996). Audio access to graphs of data have been made possible using Sound-Graphs (Mansur, Blattner & Joy 1985), AudioGraf (Kennel 1996) and to shapes using AUDIOGRAPH (Rigas & Alty 1997).

### 2.2.6 An Electronic Environment for Learning

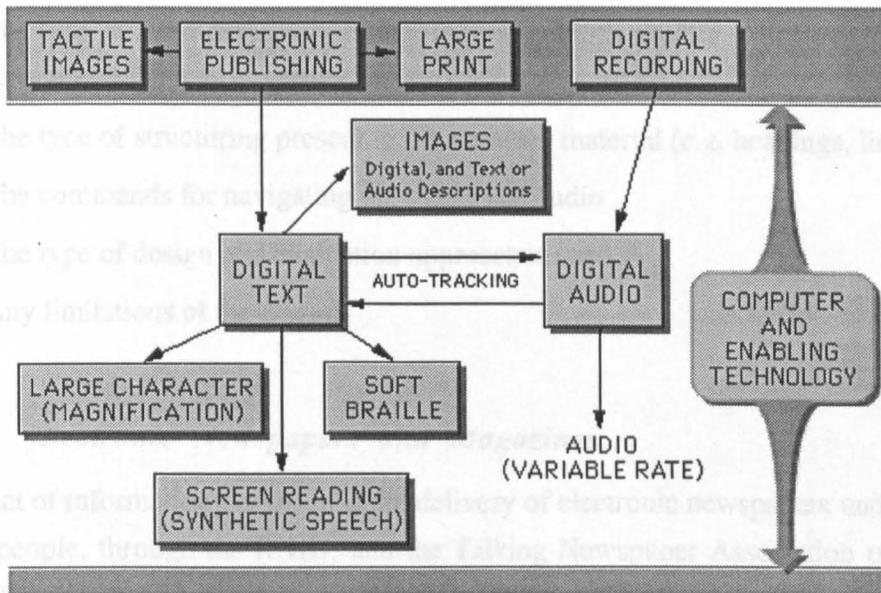
An approach which integrates new computer technology and the traditional methods of information provision for visually impaired students has been pioneered at the Open University (OU). Vincent (1994) identified the ability of computer technology to enhance multimedia information provision which used to be based on audio-tape, printed, and video-tape materials:

“... the future offers the potential of integrating these media in a way that offers the learner the choice of the most appropriate medium when engaging in an educational activity. Fundamental to this development is having teaching materials available in digital media (text, audio, images).” (p. 162)

Vincent goes on to describe their model of “an electronic environment for learning” which integrates the digital output from electronic publishing with digital audio recording (see Figure 2.1), which has been applied to a number of OU courses.

**Implications:** Custom technology for blind students has the potential to include multimodal and multimedia approaches, using a variety of input and output devices to provide redundancy and flexibility to suit different users at different times, although the use of these media in combination should be carefully explored. The use of diagrams and descriptions helps maintain variety in learning material, and the use of non-speech sounds can be used to reduce the verbosity of feedback from computer systems. Integrating computer-based materials with traditional materials can provide a flexible learning environment for blind students.

The following section describes a range of technology offering blind users access to electronic information.



**Figure 2.1: An Electronic Environment For Learning (from Vincent 1994, p.163)**

### 2.2.7 Non-Visual Information Systems for Blind People

The following sections describe several kinds of non-visual information systems designed specifically for blind users to navigate through a range of electronic documents, which attempt to overcome some of the problems of using traditional media described earlier in Section 2.2.2. The descriptions highlight their main design features and their limitations. A variety of products has been developed to allow blind people to access and navigate through electronic documents. These include systems to:

- Read plain text files (such as electronic newspapers or books);
- Read and navigate through structured electronic text (such as hypertext books);
- Read and navigate through hybrid books (structured electronic text with linked digital audio)
- Read and navigate through structured digital audio (digital talking books)

The following sections present a review of the main features of a range of relevant non-visual information systems, and attempt to identify:

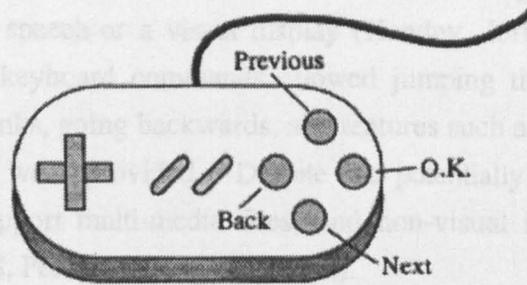
- The type of input devices and presentation methods used (e.g. human audio, synthetic speech, non-speech sounds)
- The type of structuring present in the auditory material (e.g. headings, links)
- The commands for navigating the structured audio
- The type of design and evaluation approaches used
- Any limitations of the design

#### ***2.2.7.1 Electronic Newspapers and Magazines***

One aspect of information provision is the delivery of electronic newspapers and magazines to blind people, through the RNIB, and the Talking Newspaper Association of the Blind (McLachlan 1997). However, the electronic files provided have only basic structuring (such as using '#' to indicate main sections), and can be read in a text editor or browser such as 'ReadIt'.

The main requirements of electronic newspaper are: that they are current, affordable and comprehensive, and they provide the ability to be selective and browse desired sections, and to save material for later reading (Print Access Project 1993). Several electronic newspaper initiatives produced products or prototypes which did attempt to address some of these issues, but most did not survive into maturity, for example: the UK-based ETNA system (Electronic Text Network Association) (Kelway 1993) which used a control pad to browse and navigate through the text and headings and to perform searches; and a similar proposal for a hypertext newspaper system in Germany (Kochanek 1993).

An Austrian system NewsReader (Resele & Resele 1994) provided sophisticated navigation through the structured newspaper using the computer's 10 cursor navigation keys, or using an 'easy input pad' (see Figure 2.2), based on an off-the-shelf video game console, ideal for reading away from the computer or for those unable to use the keyboard. Resele & Resele report that the field trials indicated that that the system was easy to learn and to use.



**Figure 2.2: The NewsReader Easy Input Pad**  
(from Resele & Resele 1994, p.259)

Issues relating to the needs of reading impaired persons using electronic document reading (such as newspapers) have been developed in the CAPS and HARMONY projects (Bauwens, Engelen, Evenepoel, Tobin & Wesley 1994, Katholieke Universiteit Leuven 1997b, Harmony Project Final Report 1997). These recommend using SGML to present the structure of a document or a web page, and a special SGML browser together with synthetic speech and braille output, and the proposals are likely to influence future newspaper systems.

#### 2.2.7.2 *Electronic Books*

An electronic book can be described as an *electronic text file of a book, with little or no structuring*. Electronic books are argued to offer advantages over traditional material (such as braille and audio), including easier access to text-based information, the support of better study habits, more powerful editing capabilities, better overviews and easier access to different kinds of material (Söderberg 1996, Taylor 1991, Barker 1991). However, although browsers do provide access to material, since the material has so little structure they do not support effective navigation through the material.

Several initiatives have taken advantage of the WWW for the dissemination of electronic books (or e-texts). One such example is Project Gutenberg, which has made thousands of books available on-line (see the Project Gutenberg Home Page) - but they are in plain ASCII format with no structuring to allow effective navigation.

An early initiative 'Talking Viewbooks' provided document navigation through hypertext textbooks, via synthetic speech or a visual display (Hawley, Jefferys, Ross, Spencer & Tobin 1987). Simple keyboard commands allowed jumping through pages, sections, paragraphs, following links, going backwards, and features such as Help, search, printing, saving and note-taking were provided. Despite the potentially useful features of this system, it could not support multi-media files, and non-visual interaction is no longer supported (Hawley 1998, Personal Communication).

The 'Talking Hypertext' system at the Open University (OU) provided navigation through a computer science hypertext book using (the mainstream) Hyperbook with the DOS screenreader HAL (Taylor 1991). Hyperbook provided navigation using up to six levels of heading, link selection, and extraction to an editor; but the screenreader had to provide reading functions, and had to be configured to present certain areas of the visual display to be effective. The system was field-tested by two visually impaired students, who reported that the Hyperbook version had enhanced their learning, although neither student relied solely on the electronic version of the book. The limitations of Talking Hypertext (such as the labour-intensive production of materials; no support for multimedia material; and restriction of only 6 levels of heading) fuelled the OU to develop a more effective electronic learning environment (ReadOut, described later in Section 2.2.7.3).

TextView is a Swedish electronic book DOS-based browser, which also relies on a screenreader (Söderberg 1996). Books are encrypted and structured using HTML-type tags, into up to 10 sections (chapters). Navigation to chapter headings is possible, together with note-taking, bookmarks, and search. The system is limited since it provides only high-level structuring, cannot support multimedia files, and is not self-voicing.

Barker & Sutherland (1996) describe a prototype for basic audio reading of a hypertext book. Material consisted of information structured as audio pages, presented one page at a time, as either synthetic speech or digitised speech (the two were not linked). The implementation of commands here is unusual in that the system only requires the use of the left-hand and right-hand mouse button, and relies upon the user pressing a mouse button during the pause after a page is read out, or in the pause between auditory menu items presenting navigation commands - listed in sequence once the whole page has been read, for example:

Outputs whole page. Waits. “Previous Page” wait. “Next Page” wait. “Link 1” wait. “Link 2” wait. “Link 3” wait. Reads next page.

Barker & Sutherland report that four visually impaired users completing evaluation search tasks in a computing textbook found the system easy to learn, the design implementation useful; and the use of the digitised speech pages easier to listen to than synthetic speech. Nevertheless, this system has obvious shortcomings: it is system-controlled, slow, serial, has very little structure or the possibility of providing more sophisticated structure, and most importantly, does not provide user-control over executing commands or reading through auditory material.

### 2.2.7.3 Hybrid Books

Hybrid books can be described as the *combination of structured electronic text linked to unstructured audio material*. Two examples of hybrid books are being developed by the OU (Vincent 1994, Vincent & Taylor 1995), and by the DigiBook Project (DigiBook 1995, Arató, Barkaszi, Buday & Vaspöri 1996, Katholieke Universiteit Leuven 1997a). It is proposed that the benefits of hybrid books are that while students may be able to use magnification or synthetic speech to read their electronic book, prolonged listening to synthetic speech can be tiring, un-motivating and slow, and that switching to listening to a human voice would allow them to study for longer sessions.

‘ReadOut’ is DOS-based browser developed at the OU to overcome the limitations of audio and braille materials which students were experiencing (Vincent & Taylor 1995), and to provide greater functionality in a browser than the ‘Talking Hypertext’ program offered (Taylor 1991). This browser is used with screen access technology, and provides access to structured electronic text and linked digitised audio of the same text, or descriptions of graphics for example (see ReadOut web pages for details); and ReadOut is a key component of the ‘electronic learning environment’ (described earlier in Section 2.2.6) in 13 OU courses (Vincent 1994).

ReadOut navigates through material marked up using HTML-type tags, and can support many levels of heading structuring, and the identification of many elements within text such as graphics, audio files, page numbers, bold, italics, footnotes and so on; it allows the presentation of pictures and corresponding audio description, and the insertion of bookmarks, and annotations; and provide access to scientific material using serial

presentation. Importantly, ReadOut supports paragraph-level links to the human audio recordings previously only available on cassette-tape. Although the reader can listen to all the audio recordings in a serial manner, the audio itself is not structured, and to navigate through the material users must switch back to the text.

Although detailed usability evaluations have not been conducted, the results of field trials with five visually impaired students indicate that ReadOut has made a significant improvement in access to, and easy navigation around such a large amount of material, without the difficulties of searching through 100 or so cassette tapes (see the ReadOut Web pages). However, there are several main limitations of ReadOut. Firstly, the limitations of a DOS-based program made it less flexible than students would like; secondly, the lack of structure in the digital audio was restricting (for example, not being able to skim, or read in smaller chunks); and thirdly, there was some pitch distortion at fast playback rates.

In contrast to ReadOut, DigiBook is a self-voicing hybrid book, also designed to support study reading (DigiBook 1995, Arató, Barkaszi, Buday & Vaspöri 1996, Katholieke Universiteit Leuven 1997a). DigiBook materials consist of SGML structured text linked at each paragraph and heading to an audio file containing the digitally recorded text. DigiBook supports up to six levels of heading structure, and links to cross-references and page numbers. As with ReadOut, DigiBook navigation is also through the structured text, rather than the digital audio, and while navigation through the tree, bookmarks, and page numbers is supported within the text, only standard cassette-player commands are provided for controlling the audio (pause, fast forward, rewind). However, Arató et al (ibid.) argue that this is the key advantage with a hybrid book :

“the hybrid talking book provides all the advantages of both the digital audio (clearer, high quality voice, more suitable to reading poetry and fiction) and the structured electronic text. The hybrid book permits manipulation, fast navigation, serial, random and structured access, by the text mode through synthetic speech, as well as in the audio mode with high quality human speech” (p. 247)

Questionnaire-based evaluations recently reported with a small number of DigiBook users have indicated that users find this approach useful, but design improvements seem necessary given the problems summarised concerning using the structure of the book and particular commands, and the lack of word or sentence reading in the electronic text (Graziani & Vaspöri 1998).

#### 2.2.7.4 *Digital Talking Books*

There are several possible definitions of a digital talking book, but the one used here is that of *structured digital audio* (rather than for example, an entire audio recording simply stored on a CD). Proposals for the use of digital technology for talking books in order to improve access to auditory information were made within RNIB as early as 1987 (Friedlander 1987), and by 1994 user requirements had been established by the DAISY Consortium (see Hansson, Sönnebo & Lindholm 1994, and European Blind Union 1996). Similar investigations are being undertaken by the National Library Service for the Blind and Physically Handicapped, Library of Congress in the USA (Cookson, Rasmussen & Stockton 1997), and the National Information Standards Organisation (NISO).

The main goal of the DAISY project was to create a self-voicing digital talking book system which would provide fast, random access to a book's digital high quality audio material (stored on CD-ROM) using similar structural features as the original print book. The DAISY approach uses automatic pause-detection software to allow structuring of the audio material into phrases (approximately sentences), and groups of phrases (approximately a paragraph). Manual coding then allows marking of headings and sub-headings, creating a talking table of contents of the audio material which can be navigated. The user-interface is designed with the intention of allowing readers to work with the audio book in a similar way to reading a print book. Users can navigate through the book by phrase, groups of phrases, section headings (with no restriction on the number of levels) and by page. Listening to the desired section in continuous playback mode is also possible. The playback rate is under user control, since intelligent time compression is used to increase the output rate without pitch distortion.

Two types of DAISY playback device became available in 1997, designed to suit different types of reader.

1. A portable, stand-alone player, the PlexTalk Player (developed by Plextor, Japan). This has a small number of buttons on the casing to control basic navigation through books (sections, phrases, groups of phrases, page and time information, and a simple bookmark); and more advanced navigational commands using bookmark and page modes are made available on a separate model using additional buttons. The PlexTalk Player is expected to appeal to mobile users, or people who only require basic to moderate access to structured digital talking books.

2. The DAISY Playback Software for use on a PC (developed by Labyrinten Data AB, Sweden). This Windows-based software allows users to read and navigate DAISY books on their PC. The software has its own digitised system messages and can therefore be used without a screenreader. Basic and advanced navigation commands are provided, together with searches in the section headings. This system is expected to appeal to readers who require more sophisticated access to their structured digital talking books.

### **2.2.8 World Wide Web (WWW) Access**

At the start of the ACCESS Project when the initial specifications for the ACCESS non-visual hypermedia browser were drawn up (1995-6), blind people had no access to the WWW at all. In order to determine what functionality was provided in browsers for sighted users, the ACCESS Project reviewed a range of browsers, including Netscape Navigator, Mosaic, Lynx and CD-ROMs (see Free, Graziani, Lauder, Majoe, Morley & Petrie 1995). Common commands included: Home; Select Link; Back; Forward; Bookmarks; History List; Help; and Exit.

During 1996, developments with DOS-based browsers (such as Lynx) and Windows screenreaders did enable blind users to access the WWW (several possibilities are described in Hudson 1996a, 1996b, and Bowler, Okamoto & Pothier 1996), and a selection of these are described below. The importance of access to the WWW for blind people and other people with special needs is substantial, especially for its ability to make vast amounts of electronic information available, and for the anonymity and equality the web provides once users are on-line (Rose 1996, Murnion 1996a, 1996b, Bayha 1998). However, the design of web pages can prove to be a major barrier to information on the WWW for blind users (Vanderheiden, Chisholm & Ewers 1996), and efforts are being made to develop guidelines for creating accessible web pages and browsers (for example, Laux, McNally, Paciello & Vanderheiden 1996, and see the Web Accessibility Initiative Home Page).

#### **2.2.8.1 *V-Lynx, WAB and Emacspeak***

V-Lynx (Krell & Cubranic 1996) provides synthetic speech for Lynx, presenting structural elements of the web page as for example, “begin heading 1”... “end heading 1”, and “begin link”... “end link”. Screenreader-type commands are also included to allow review of

information, and improvements proposed include using different voices and non-speech sounds to reduce verbosity while presenting structure. Another example of a tool to aid blind users accessing web information is WAB, a Proxy-Server for W3-Access (Kennel, Perrochon, & Darvishi 1996). This is not a web browser itself, but it presents a modified form of the HTML to the users' browser providing additional features for auditory navigation. These include, for example, a (linked) list of all the links in the document, and a (linked) nested list of all titles in the document for navigation. Emacspeak (Raman 1996) was designed as a document reader for Emacs, to improve upon existing screenreading access by conveying information about the structure and parts of a document, using cues such as pitch and non-speech sounds. An extension allows access to the WWW, with links spoken in a different voice, and non-speech sounds (auditory icons) to indicate for example, following a link, jumping link-to-link, and opening a new document.

#### ***2.2.8.2 Mainstream Windows Browsers used with Screenreaders***

During 1996 several Windows screenreaders were developed which could be used to access the Mosaic and Netscape browsers (including outSPOKEN, JAWS for Windows, Window-Eyes, Window-Bridge, and ASAW). However, early versions of Mosaic and Netscape did not support keyboard navigation, and many of these early Windows screenreaders could not provide effective access to these browsers or to information on web pages (Bowler, Okamoto & Pothier 1996). Hudson (1996b) identified the problem as being:

“the inability of current Windows screen readers to reliably and consistently identify important items on a web page” (p. 17)

However, gradually the situation improved and browsers became more keyboard-accessible, fuelled by the arrival of Microsoft Internet Explorer in late-1996, containing many features designed to improve access to the browser and web pages by disabled users, and to provide better communication with screenreaders (see Morley 1996).

Following their evaluation with blind users, Bowler, Okamoto & Pothier (1996) concluded that blind users requiring sophisticated access to a range of internet and WWW facilities would be best supported using a mainstream browser with a screenreader, such as Netscape and JAWS for Windows (although refer back to Hudson's remark regarding the effectiveness of this combination). However, blind users requiring an easy to learn, easy

to use program to access only basic WWW facilities would be better supported using a custom-built browser, pwWebSpeak, designed specially for blind users (described below).

### 2.2.8.3 *pwWebSpeak*

A specialist self-voicing browser, pwWebSpeak was designed “from scratch” with the intention of supporting a range of users and devices - in particular visually impaired users - with synthetic speech output and a high contrast display (Hakkinen & De Witt 1996). The goal of pwWebSpeak was to present the structure of a hypertext web page, rather than its visual presentation. This is a Windows application, although does not use a Windows interface, and all commands are executed using Function keys or alphanumeric keys. The web page is broken into ‘elements’ - a unit of the page between HTML tags, so an element might be for example, a heading, a link, or a paragraph. Based on the current researcher’s own experience with pwWebSpeak, three types of command are provided:

- Standard web browser commands: Back, Open, Stop, Reload, Find and Search using AltaVista, Help.
- Non-visual interaction navigation and review commands:
  - Page Summary (presents number of links, headers, images etc in the page)
  - Read/Spell URL
  - Word List (read word-by-word (or Spell Word) in the current element).
  - Where Am I? (identifies the current item in a list, and any related URL)
  - Save Current Element, and append to scrapbook
  - Read Whole Page from current location to end
  - Pause / Resume
  - List of Links (cursor through list of links and their associated line of text)
  - Select Link (<spacebar> while on link in list of links)
  - Page Elements List (cursor through each element on a page)
  - Goto Next Link (Anchor) (jumps link-to-link)
  - Goto Next Heading (jumps to next heading)
  - Goto Next Paragraph (jumps to next paragraph)
  - Goto Next Entry Form (jumps to next entry form)
  - Add Page to Favourites List
- Output control commands: for increasing and decreasing the: Rate; Volume; Print Size; changing display colours.

Despite the potential usefulness of these features, the researcher felt that the usability of pwWebSpeak was reduced by the way the features were implemented which seemed at times clumsy, slow and uninformative (also found by Bowler, Okamoto & Pothier 1996). For example, to navigate around the page, users choose either 'Page Elements' mode or 'Links List' mode; but since in each case large amounts of text are spoken, it is impossible to determine what is a link, a heading, or just a short piece of text, and users often feel disoriented and confused about what mode they are in, what they are hearing, and where they are on the page. A potential disadvantage of the program is that it does not use standard Windows controls, and therefore an entirely new range of keyboard commands must be learned. A new version has recently been released (see De Witt & Hakkinen 1998) which has resolved some of these issues.

**Implications:** The non-visual information systems described here include some useful methods of navigating through electronic material, albeit at different levels of structure. Commands include jumping through headings, pages, paragraphs, and features such as 'where am I?', bookmarks, annotations, save, print and search provide additional support. However, some of these systems are limited because they do not support the use of highly structured text, or multimedia components, and rely on screenreaders for the presentation and control of information (which may only be usable by experienced users). Some systems provide fine levels of control over the output, but others do not allow users to determine how much information they read at one time, and there seems to be no consistent way to present links in electronic material. There is little use of non-speech sounds to provide information and to reduce verbosity, and although most systems use a standard keyboard, some use alternative input devices such as a keypad or a mouse. Finally, if any evaluations have been conducted, they are often not reported in sufficient detail to allow the methods to be used by others.

The following section describes some non-visual information systems designed for sighted users, with a similar aim of identifying their main features, input and output methods, and limitations.

## **2.3 Part II: Non-Visual Information Systems for Sighted Users**

### **2.3.1 Introduction**

User requirements studies of sighted people working with audio material - such as professionals using dictaphones (Degen, Mander & Salomon 1992), and using tapes when note-taking (Whittaker, Hyland & Wiley 1994) - have found that they experience similar difficulties as blind people:

- difficulty finding specific information on the tape
- not being able to make annotations;
- not being able to speed up the playback rate without degradation of the speech quality

A variety of systems has been designed to address these issues, by exploring methods of inserting structure into auditory material and navigating through structured auditory material. This is often human audio, but synthetic speech output is used by one system; and several include non-speech sounds for feedback to reduce the output verbosity. Some rely on speech-input, others on a touchpad, or buttons on a Walkman or Dictaphone; and systems range from personal note-taking devices to browsers for reading news broadcasts or recorded lectures. Although only one of these systems specifically addresses auditory hypertext (Arons 1991), they all attempt to overcome the limitations of the transitory nature of audio media. In addition, many are based on user-requirements studies, iterative design and user testing (although some seem to have been driven by technology rather than by an identified user need). This brief review highlights the main design features of the systems relevant to the current research, and attempts to identify:

- The type of input and output methods used (e.g. human audio, synthetic speech, non-speech sounds)
- The type of structuring present in the auditory material
- The commands for navigating the structured audio
- The type of design and evaluation approaches used
- Any limitations of their design

## 2.3.2 Examples of Non-Visual Systems for Sighted Users

### 2.3.2.1 *A Hyperspeech Application*

Arons (1991) presents a research prototype for a speech-only hypertext application, containing 80 digitised audio nodes of recorded interviews, with speech recognition for input, and synthetic speech using naturalistic language for user feedback. The hypertext system of short audio nodes (mean 10 secs, max 25 secs) was designed for free-browsing of information by following logical connections and related ideas between 'summary nodes' containing the major themes of a topic, and 'detail nodes' containing detailed comments about a topic. Nodes were linked together in a number of ways: speaker; opinion; time-sequence; and overview-sequence.

To allow users to move from node-to-node by following links, in the first version links were listed at the end of each node in synthetic speech, but users found this tedious and repetitive. In the next iteration, the auditory menu was replaced by ensuring that each node contained one of every type of link, so users knew that every command was always available from each node. Despite the consistency of this approach across nodes, it is limited since it makes authoring difficult, and cannot be used when more than one link of the same type is included in a node. Basic additional navigational and control commands were also provided: 'Return' (to previous node), 'Repeat' (play node again), and 'Help' (output description of current location) provided additional navigational support. To provide users with immediate control over the system, output is halted immediately when a speech-input command is recognised, "providing crucial feedback to the user that a command was heard".

Although an interactive design was reported (and two versions of the system described), no user evaluations were presented, but Arons proposes a range of improvements to the system: including bookmarking, adding user links and nodes, and additional browsing commands (for example, to browse nodes containing a particular speaker or topic). Audio effects proposed to improve navigation included the use of non-speech sounds to indicate the length of a node, spatial audio and simultaneous speech streams.

### **2.3.2.2 *NewsComm***

Roy & Schmandt (1996) describe a hand-held playback device called NewsComm (a Walkman-type device) with a primarily non-visual interface for downloading and navigating structured audio broadcasts, such as news or talkshows. Automatic segmentation is achieved using pause detection (long and short pauses) and voice detection (speaker change) to create what they call “semantically meaningful” (but very basic) structural markers.

The final hand-held prototype requires only six buttons for navigation and reading: for ‘Play’ and ‘Stop’; and two types of jump to navigate through short and long distances through the audio material: ‘Fine-Jumps’ back/forwards of about 5 seconds, and ‘Coarse-Jumps’ back/forwards fixed between 30-120 seconds depending on the type of material being read. To aid orientation while jumping, an auditory icon of sped-up speech was played, proportional to the size of the jump, and suggestions were made to use a different sound for jumping backwards and jumping forwards. Skimming and summary features using the break points allowed users to gain overviews of the material, useful when browsing the audio, or when selecting material to download from the server.

User testing over four iterations of the design was considered essential to maximising usability and creating a simple interface with a few user-directed controls:

“Usability tests were essential in guiding the design process. ... [A]lthough the authors had a tendency to design powerful but complex interfaces, in most cases users preferred a less powerful, simpler interface” (p. 179)

Evaluation tasks involved exploratory learning of the interface; performing search tasks in a 20-minute newscast; and discussing the usability of the system and areas for improvement.

### **2.3.2.3 *SpeechSkimmer***

Arons (1993, 1997) reports the iterative design and evaluation of SpeechSkimmer, a hand-held touchpad device for interactively skimming speech recordings at four different levels of structure: (1) Normal Playback; (2) Silence Removed - short pauses removed, long pauses shortened; (3) Pause-Based Skimming - only short segments of the recording (highlights) following long pauses are played; (4) Bookmark-Based Skimming - playback is moved to the location of user-inserted bookmarks. Variable playback at each level of skimming structure was possible, using time compression (from 0.6x up to 2.4x).

When choosing an input device for SpeechSkimmer, Arons states that it was difficult to find one with a good mapping to these commands, and tried a mouse, trackball and a joystick, finally choosing a touchpad<sup>2</sup> (7 x 11 cm) which included a colour-graded overlay with tactile markers to indicate the different skimming speeds and playback rates, and was finally implemented on an electronic Apple Newton MessagePad. Good mappings between input and output methods are known to be crucial for usable systems (Norman 1988).

Non-speech sounds (auditory icons) were added during the development of SpeechSkimmer to provide terse, unobtrusive feedback while navigating: a dead-end sound was used (“boing”); and when changing skimming levels, a tone changed in pitch; and when the normal level was reached, a double-tone was played as an auditory landmark. Sounds were added for ‘Pause/Resume’ “machine stopping/starting”, and for ‘Jump Forward’ “ascending tone”, and for ‘Jump Backwards’ “descending tone”.

Arons (1997) reports that user testing (of only the fourth design) occurred “too late in the design”, and realised that significant design choices could have been improved with much earlier user testing. The 12 evaluation users explored the interface without training, and completed three search tasks through a recorded lecture while thinking aloud, followed by an interview. Results showed that generally SpeechSkimmer was reasonably easy to use, with the use of a combination of skimming methods to find specific information. However, confusion was common over several command names and functions, and about the purposes of the non-speech sounds. In many cases, users reported not knowing specifically what each sound was for, but felt reassured that “something was going on”. Specific training (rather than exploratory learning) of an interface would be likely to reduce these confusions and improve usability.

Despite the potential effectiveness of the penultimate prototype (which was purely auditory) Arons proposes that the future development of SpeechSkimmer should be towards a more graphical interface for displaying more complex visual cues, together with alternative methods for structuring audio recordings.

---

<sup>2</sup> A touchpad is the same type of device as a touchtablet (described earlier used by visually impaired students) but the term ‘touchpad’ is often given to a device which is much smaller than a touchtablet.

#### 2.3.2.4 *VoiceNotes*

VoiceNotes is hand-held portable audio note-taking device to capture, organise and retrieve short spoken notes made by the user (Stifelman, Arons, Schmandt & Hulteen 1993). The prototype (an adapted Dictaphone-type device connected to a PC), offers both voice-input and button-input to allow users to record individual notes, set up categories, and organise lists of notes into these categories, such as 'to do', or 'groceries' using a variety of commands. Items can be presented one at a time, or listed all at once, and orientation commands such as 'where am I?' outputs the current category name.

User testing was conducted with six users, working with VoiceNotes for one hour to complete realistic tasks creating an inventory of an office, followed by an interview. Usability problems were revealed concerning user-control of their location within the information: for example, users were automatically placed back at a higher level when the end of a list was reached (that is, users never found any dead-ends). Users reported that they would prefer to execute another command than have such automatic re-positioning which was disorienting. The synthetic speech feedback confirming commands was found to be overly talkative, and non-speech sounds (auditory icons) were proposed, for example for 'next note' a "page flipping" sound. Users appreciated the flexibility of having both speech and button input.

#### 2.3.2.5 *SpeechActs*

SpeechActs (Yankelovich, Levow & Marx 1995) is a conversational phone-based system to access email, stocks, weather, and calendar (diary) information using naturalistic voice input and synthetic speech output, to avoid the tedious menuing systems commonly found with phone-based interfaces. The system was designed with a user-centered, iterative approach: starting with a field survey to gather user requirements study followed by several rounds of iterative, formative usability testing.

In addition to the challenge of converting a GUI into speech user interface (SUI) discussed earlier, Yankelovich et al also identify the lack of visual feedback as a major design challenge. The final version of SpeechActs therefore provided application-specific features to allow efficient access to information, including features to compensate for the lack of visual scanning, exploration and cueing; and 'tapered presentation' of feedback to minimise the verbosity of the output when reading repetitious lists of items.

Formative evaluation tasks using the system to complete realistic tasks (taking about 20 minutes) over several iterations of the design led to improvements in the dialogue with the system, and a proposal for using non-speech sounds to replace some verbal prompts.

### 2.3.3 Special Design Required for Auditory Systems

A major conclusion from these studies can be drawn relevant to the current research: auditory systems should be designed from scratch, rather than simply trying to convert existing GUI applications into an auditory environment (as was found when converting GUIs into auditory form for blind users, as described earlier). This straight translation was found to lead to designs which were confusing, frustrating and disorienting for users (Arons 1991, Yankelovich, Levow & Marx 1995).

In designing his HyperSpeech application, Arons (1991) identified the main problems with designing interfaces for auditory applications as relating to the temporal and transitory nature of audio:

“Navigation in the audio domain is more difficult than in the spatial domain. Concepts such as highlighting, to-the-right-of, and menu selection, must be accomplished differently in audio than in visual interfaces. For instance, one cannot ‘click here’ in the audio world to get more information - by the time a selection is made, time has passed, and ‘here’ no longer exists.” (p. 134)

and Yankelovich, Levow & Marx (1995) found while designing SpeechActs that a speech user interface (SUI) demands different abilities of the user:

“For users to succeed with a SUI, they must rely on a different set of mental abilities than is necessary for successful GUI interactions. For example, short-term memory, the ability to maintain a mental model of the system’s state and the capacity for visualising the organisation of information are all more important cognitive skills for SUI interactions than for GUI interactions.” (p. 375)

Yankelovich et al also stress that the *concepts* of each interface should be consistent from one modality to the other, especially if both types of interface are to be used concurrently.

**Implications:** These examples of non-visual information systems for sighted users have illustrated the need to design auditory interfaces with a user-centered approach if they are to be effective, and to use iterative design and evaluation with users to improve usability. A variety of control commands have been described for working with audio material which is structured in different ways, and issues of controlling the amount of information presented and indicating the user's location within the material are identified as being important for usability. The use of non-speech sounds is quite common in these systems to reduce verbosity, and hand-held input devices are also frequently used, although the conceptual mappings must be consistent between input and output methods and across different implementations of the same system.

The reviews presented so far have highlighted that there are no commonly-used design and evaluation methods for designing non-visual information systems. For this reason, the following sections present a review of design and evaluation methods - both generic, and for hypermedia systems in particular, with the aim of identifying appropriate methods to use for the current research.

## **2.4 PART III: Designing for Usability: User-Centered Design and Evaluation**

### **2.4.1 User-Centered Design**

From the descriptions of the systems in the previous sections, it should be clear that only a few systems have been designed with a user-centered approach, one that is

“... based on the needs and interests of the user, with an emphasis on making products usable and understandable” (Norman, 1988, p. 188)

For example, in his discussion about electronic books, Barker (1991) stresses the need to design systems specifically tailored to the needs of particular users:

“Fundamental to the whole design process is an understanding of the nature of the various categories of end-user for whom a particular book is intended, and an important part of this understanding relates to the nature of the types of interface, styles of interaction and different communication modes preferred by different categories of user.” (p. 20)

Newell & Cairns (1993) also argue that the design of systems for users with special needs requires the designer to listen to the needs of the intended users, and to design systems to meet these requirements:

“... a disabled user can present with very difficult problems [sic.] which demand very detailed consideration of the real needs and wants of the user, how they differ from the expectations of the designer, and whether and how these vary between the potential users of the proposed equipment. These requirements can stimulate the designer to develop new and more effective interfaces.” (p. 5)

#### 2.4.2 The ‘Design for All’ Principle

A particular aspect of user-centered design among designers involved in special needs fields is a belief that if products are designed with the intention of supporting a range of users (not just the typical stereotyped young, male, able-bodied end-user), the resulting products will be more carefully thought-out, providing more widely useful design solutions for everyone (for example, Vanderheiden 1990, Newell & Cairns 1993, Newell 1995, Stephanidis, Savidis & Akoumianakis 1995, Gates 1997, Petrie 1997).

This ‘Design for All’ (or ‘Interfaces for All’, or ‘Universal Design’) principle can lead to products which offer unexpected benefits to other user groups in new situations (Newell 1995). For example, features designed for disabled people such as closed captioning, video description, large keypad keys, sound feedback when keys are pressed, keyboard shortcut commands, elevator chimes and lights, curb cuts on the pavement, and so on, have all provided benefits to people other than the intended users. As Newell & Cairns (1993) propose, this is because although disabled people have a range of ‘extra-ordinary’ needs, most people have a mix of ordinary and extra-ordinary needs, which are often dependent on the situation in which people find themselves.

We have seen that some researchers in the sighted field have designed non-visual systems which are more complex and sophisticated than users actually wanted when they finally came to evaluate the product (for example, Arons 1993, 1997, Roy & Schmandt 1996). This highlights the need for: (a) user requirements capture using methods such as Contextual Inquiry (Holtzblatt & Jones 1993), or formal methods such as Task Analysis (Kirwan & Ainsworth 1992); and (b) early user testing with real end users, to ensure that designers are aware of real user needs (Lindgaard 1994). This may be especially important

when designing for blind users, since their needs and abilities are not easily imagined by sighted designers (Petrie 1997).

### 2.4.3 Usability Engineering

Usability engineering is concerned with defining and measuring aspects of usability, to guide design choices (Good, Whiteside, Wixon & Jones 1984, Whiteside, Bennett & Holtzblatt 1988, Gould 1988, Nielsen 1993). Both formative evaluation (during design) and summative evaluation (on a finished product) (Hewett 1986) can be assessed using usability engineering methods, by specifying and measuring in *quantitative* terms both objective and subjective aspects of usability. For example, Shackel (1986, 1991) suggested that aspects of usability which might be used for benchmarking include: (1) effectiveness, (2) learnability, (3) flexibility, and (4) attitude; and Shneiderman (1992) suggests (1) time to learn, (2) speed of task performance, (3) rate of errors, (4) subjective satisfaction, and (5) user retention of commands over time; and the draft international standard on usability (ISO DIS 9241-11, 1994) also concerns the measurement of aspects such as effectiveness, efficiency and satisfaction. These measurements allow criteria to be set, such that a system is considered acceptable if, for example, error rates are less than 15%; efficiency is increased by 10%; or user satisfaction is over 95%, and so on.

The usability field has been guided by the principles of Gould & Lewis (1985), who proposed three principles of design which have become the foundation of user-centered, iterative design processes:

- Early and Continual Focus on Users and Tasks
- Empirical Measurement
- Iterative Design

For example, Shackel's (1991) definition of usability (which forms the basis of many current definitions) integrates the user, the task, and the tools provided in the context of the environmental situation. He also describes usability in terms of both subjective assessment ("easily"), and objective measurement ("effectively"):

"the capability in human functional terms to be used easily and effectively by the specified range of users, given specified training and user support, to fulfil the specified range of tasks, within the specified range of environmental scenarios" (p. 24)

Gould (1988) discusses methods of designing usable systems, and Karat (1988) describes methods of evaluating systems, which address the three principles of Gould & Lewis (1985). These include methods such as user observation and formal or informal think-aloud methods, task analysis, surveys and questionnaires, the use of scenarios, mockups, simulations and prototypes, videotaping, formal experimental tests, and field studies in order to include users, measure usability and iteratively design systems. Karat (ibid.) highlights the need to gather evidence for changing designs and for providing rationale for making changes, and the benefits of iterative design and evaluation are summarised by Hewett (1986):

“using iterative evaluation during design does not necessarily guarantee design of a good system but can help avoid designing an unusable one.” (p. 213)

Any design and evaluation methodology which has a user-centered approach posits that the users' requirements (personal, task-related and work-related) are of paramount importance in the design of a technology to maximise the suitability of the product to the needs, skills and experiences of the intended user group. For example, Participative Design (Edwards 1995a) and Participatory Design (Schuler & Namioka 1993) involve users throughout the design and evaluation process, often including users on the actual design team.

#### 2.4.4 The Goals of Evaluation

Although the goals of each evaluation are different, depending on for example, the type of system, the intended users, and the stage of prototype, Dix, Finlay, Abowd & Beale (1993) see the following as the goals of evaluation:

- To assess the extent of the system's functionality
- To assess the effect of the user interface upon the user
- To identify any specific problems with the system

An important issue relating to the assessment of usability of parts of a prototype is that in many cases, for the purpose of re-design it is not sufficient simply to measure usability problems, but to highlight and attempt to explain them, for the purpose of re-design:

“... once the design has begun, the issue is not so much *measurement*, but rather *identification*. The focus of our analysis, design and evaluation activities is to identify potential usability issues and develop appropriate recommendations to

resolve them. If one user has difficulty using a part of an application, we need to understand why. It is not necessary to wait for a *statistically significant* number of users to have a problem in order to obtain valuable design insights.” Myself in Bevan & Curson 1997 (p. 125). His italics.

A wide range of books describes the use of different types of evaluation methods, including for example: Dumas & Redish (1994), Lindgaard (1994), Nielsen & Mack (1994), Hiser Group (1995), Daly-Jones, Bevan & Thomas (1997), and these cover different kinds of experimental methods, observational techniques, interviews and questionnaires, discussed in the remaining sections.

#### 2.4.5 Rapid Prototyping

Rather than build a single prototype which is only tested at the end of development, iterative design often includes the use of rapid prototyping where several prototypes, or components of the full prototype are designed and tested during development (Wilson & Rosenberg 1988, Barker 1991, Preece 1993a). The purpose of a prototype is to demonstrate a set of abstract ideas about a computer system in a concrete form (Lindgaard 1994), to help designers and users consider a design. Prototypes can come in many forms; paper-based story-boards, mock-ups or simulations of the final interaction, or a limited range of functioning parts within the complete system. Where the full functionality is not yet available, a Wizard-of-Oz approach can be used to simulate the missing computer-based interaction (Gould, Conti & Hovanyecz 1983, Kelly 1984, Good, Whiteside, Wixon & Jones 1984), where a human provides the computer's interaction. In this way, some aspects of the design of the interaction can be assessed and improved ready for full implementation. Software prototypes are an integral part of iterative design, which can:

“help designers to make decisions by eliciting information from representative users on all aspects of the system: its structure and functionality, the operation sequences, the required representations and user support needs.” Preece 1993a (p. 105)

The use of low-fidelity prototypes (such as paper-base prototypes, or mock-ups) has been shown to be appropriate for highlighting usability problems early in the design cycle. For example, when comparing the numbers and types of problems found in user testing of low-fidelity prototypes and high-fidelity prototypes (such as computer-based or the final product), almost the same number and type of usability problems are found (Virzi, Sokolov

& Karis 1996), and therefore early evaluations using low-fidelity prototypes should be very useful in reducing usability problems at early design stages.

Many suggest that different types of evaluation methods are appropriate at different stages during prototype development. For example some methods are more appropriate when testing early ideas, such as focus groups and walk-throughs; and as the prototype advances, user-testing and laboratory tests of increasing levels of sophistication can be used, with the addition of in-depth field testing when the prototype is nearly complete (Christie & Gardiner 1990).

**Implications:** User-centered, iterative design should be used, involving several rounds of iteration with different levels of prototypes (both low and high-fidelity prototypes), with the goals of the end-user in mind at all times. The purposes of evaluation should include: the assessment of the functionality of the system; the effect of the interface on the user; and the identification of specific problems and the development of solutions.

#### 2.4.6 Usability Inspection Methods - Testing Without Users

During the development of prototypes, various usability inspection methods can be used by designers to assess their design, without necessarily involving users. This allows designers to brainstorm different design ideas, and to remove usability problems without wasting users' time working with obviously un-usable designs (Nielsen 1993).

The use of inspection methods for the purposes of developing an interface also removes the need to measure performance to justify design decisions (as in the traditional usability engineering style), since at this stage in design any finding that one aspect is better or worse than another allows designs to be improved - "even tests that are not statistically significant are well worth doing since they will improve the quality of decisions substantially" (Nielsen 1994c). It is also beneficial to have designers examine their own interfaces using methods such as following design guidelines, using heuristic evaluation, scenarios, and walkthroughs, since frequently designers are better able to identify and to understand problems they find than non-experts (Mack & Nielsen 1994, Wright & Monk 1991) and can help them to improve their designs before users have to experience such problems.

### 2.4.6.1 *Design Guidelines*

There are many guidelines for good interface design which should be kept in mind by designers throughout their design processes (see Mosier & Smith 1986); but they can also be used to inspect resulting designs. For example, Norman (1988) proposed that in a usable system users should be able to (1) figure out what to do, and (2) tell what's going on.

Norman's (1988) guidelines for designing usable systems include:

- Make it easy to determine what actions are possible at any moment.
- Make things visible, including the conceptual model of the system, the alternative actions and the results of actions.
- Make it easy to evaluate the current state of the system.
- Follow natural mappings between intentions and the required actions; between actions and the resulting effect; and between the information that is visible and the interpretation of the system.

Others have identified that usability defects commonly fall into several categories which can be targetted when considering design alternatives (Lindgaard 1994):

- |                         |                            |
|-------------------------|----------------------------|
| - Navigation            | - Screen design and layout |
| - Terminology           | - Feedback                 |
| - Consistency           | - Modality                 |
| - Redundancies          | - User control             |
| - Match with user tasks |                            |

### 2.4.6.2 *Heuristic Evaluation*

Nielsen's heuristic evaluation approach comes from the usability engineering field (and his own 'discount usability engineering' approach), in which usability criteria are set and measured using a set of derived heuristics for good interface design (Nielsen 1993). He combined a range of design guidelines and conducted factor analyses on published usability studies to find the most powerful guidelines affecting usability of interfaces. The final set of 10 heuristics (Nielsen 1994a) can be used by evaluators (designers or experts) to inspect interfaces, and note where these heuristics are violated:

1. Visibility of system status - provide appropriate feedback
2. Match between system and the real world - speak the users' language using a simple and natural dialogue

3. User control and freedom - provide emergency exits
4. Consistency and standards - ensure words, situations, or actions mean the same thing
5. Error prevention - design to avoid problems occurring
6. Recognition rather than recall - make actions, objects, and options visible
7. Flexibility and efficiency of use - provide accelerators/shortcuts
8. Aesthetic and minimalist design - avoid repetitious, verbose dialogue
9. Help users recognise, diagnose and recover from errors - use plain language, constructive advice
10. Help and documentation - provide help, task-specific, short chunks

Karat, Campbell & Fiegel (1992) integrated Nielsen's heuristics with other design guidelines, and used three additional heuristics:

- Allow user customisation
- Minimise the use and effects of modes
- Support input device continuity

An interface can also be assessed from the users' subjective viewpoint, on five dimensions of usability (Nielsen 1993):

1. Easy to learn
2. Ease to remember
3. Efficient to use
4. Few errors
5. Pleasant to use

#### **2.4.6.3 Scenarios and Walkthroughs**

A range of techniques for assessing the design of prototypes have been developed to help designers to look in detail at their own design, focussed on users and their tasks.

Scenarios are a way of thinking about a design by using concrete descriptions of a particular user attempting to achieve a particular goal, and designers can use scenarios to assess their own design from both a functional and usability viewpoint (Carroll 1995). Scenarios can be used in a number of ways, ranging from informal discussions for brainstorming, to more formal notation methods.

The formal theory-based 'Cognitive Walkthrough' method (Polson, Lewis, Rieman & Wharton 1992) considers user goals, actions, and available options at each step in a task in

a highly theoretical manner. This method is somewhat limited when developing rapid prototypes because its very formal nature requires time-consuming preparation, execution, notation and analysis. However, an alternative is the fast-paced 'Cognitive Jogthrough' (Rowley & Rhoades 1992), in which designers discuss alternative designs for a specific action using a shortened form of the Polson et al schedule. Rowley & Rhoades estimate that about three times as much material can be covered using the jogthrough technique than the walkthrough, and is particularly suited to multi-disciplinary teams. Video-taping the discussions proved more useful than transcribing, and designers preferred the quick results achieved with the jogthrough method, allowing them to identify aspects of the interface that require further attention and to discuss possible alternatives immediately. The use of multi-disciplinary teams (and sometimes end-users) in walkthrough methods is known as the 'Pluralistic Walkthrough' (Bias 1994) which provides many viewpoints on the usability of a system.

**Implications:** Throughout the design of a system, designers from a range of disciplines should examine the interface focussing on the way intended end-users will work with the system. Scenarios can be used together with design guidelines, heuristics, and jogthrough methods (even in an informal way) to guide the design process and to identify usability problems without involving users.

#### 2.4.7 Usability Testing - Testing with Users

The earliest usability engineering guidelines included user-testing in evaluations (for example, Gould & Lewis 1985, Whiteside, Bennett & Holtzblatt 1988), and the benefits of including user-testing during design cannot be overestimated:

“simply because the evaluator will be surprised by what people will do. There are invariably errors or misconceptions which will be discovered in any process of having users test a system that even the most insightful of designers would miss.”  
Karat 1988 (p. 895)

User testing may attempt to gather two types of evidence about usability:

- Performance measures (for example, tasks, observation, computer-logging)
- Subjective opinion (for example, think-aloud, interviews, questionnaires)

Many methods can be employed during user testing to gather these two types of data, including the use of exploratory learning, observed and measured task performance, think-aloud methods, questionnaires and semi-structured interviews, and the combined use of several of these methods is recommended to reveal most data (for example, Dix, Finlay, Abowd & Beale 1993, Preece 1993a, Lindgaard 1994, Henderson, Podd, Smith & Varela-Alvere 1995). Testing with an emphasis on observation using these methods (rather than just measurement of performance) reveals *why* users are doing well or poorly, and offers insights into how to improve the system (Landauer 1996).

#### ***2.4.7.1 Cooperative Evaluation***

One approach which potentially offers a useful and cost-effective method of conducting user evaluations of prototypes during iterative development is 'Cooperative Evaluation', (Wright & Monk 1989, 1991, Monk, Wright, Haber & Davenport 1993). A similar approach was developed by Nielsen (1994c) called 'discount usability engineering', and for testing systems for blind users, such as the evaluation of the GUIB system (Petrie, Strothotte, Weber & Deconinck 1993, GUIB Project Final Report 1995), and the Mathtalk system (Stevens & Edwards 1996).

These cooperative approaches are developed on the belief that purely objective measures of user performance, such as efficiency ratings, are not useful by themselves at identifying or explaining important usability problems, and that observed task performance and qualitative subjective measures are considered to be more important in identifying and explaining usability problems for the purpose of refining and re-designing aspects of a prototype. These approaches can be used at different stages of system development, such as:

- an existing product that is to be improved or extended
- an early partial prototype or simulation
- a full working prototype

There are five key features of cooperative evaluation approaches:

*1. Real Users are Involved in Testing Prototypes.* The users are representative of end-users, and have a mix of abilities and experience, to ensure that a full range of problems are identified. Wright & Monk (1991) have found that about 3-5 users per iteration will reveal the majority of usability problems, of different levels of severity.

2. *Users Complete Set Tasks.* Since the system is only a prototype, it may be incomplete, and have parts which are non-functional or buggy. Therefore rather than distracting users by asking them to work with the whole system (including any areas which do not work), set tasks are designed which direct users to specific areas under assessment and away from troublesome aspects. Testing just these desired aspects also makes the tasks shorter and more manageable. The tasks are designed to be representative of real use of the features, but suitable for the stage of development, and tasks are concrete and work-related (for example: 'change the word *geat* to *great*', rather than 'access the *replace* function'. Set tasks are particularly useful for novices while learning a system, to illustrate typical uses of the system and to allow them to learn the important functionality of the system (Widenbeck, Zila & McConnell 1995).

3. *Informal Think-Aloud During Tasks.* A relaxed, natural and interactive think-aloud method is used while users complete the tasks. This contrasts with the traditional formal (and time-consuming) 'think-aloud' method in which users give a concurrent verbal protocol as they complete a task, without any interaction with the researcher, which is transcribed and later analysed in detail (Ericsson & Simon 1980, van Someren, Barnard & Sandberg 1994). Using the cooperative approach, users are encouraged to talk about what they are doing, and the evaluator probes specific aspects using neutral probes such as "what did you expect to happen?", "what are you trying now?", "what do you want to do?". This more natural and less time-consuming approach allows interpretation of user behaviour, their problems and their opinions in context, and users tend to be more open.

4. *Designers as Evaluators.* The cooperative evaluation method provides a cost-effective method of evaluating prototypes iteratively throughout the design cycle, since designers can easily learn to use the approach, and can easily interpret the findings. Not only that, but designers evaluating their own systems detected more usability problems than similarly experienced evaluators who have not been involved in the design (Wright & Monk 1991).

5. *Subjective Questionnaire.* Users are asked at the end of the tasks asked about their feelings about the prototype. Questions are drawn up by the design team to cover those aspects under consideration, and can range from simple "how easy did you find it to complete the tasks?" and "did you enjoy using the system?" to specific questions concerning the methods of interaction and design of command functionality.

The main advantages of this type of approach over others is that the designers are able to observe and question users working with the system in context of representative tasks, and can use the qualitative feedback obtained from the informal think-aloud method and the questionnaire data to further improve the design of the system.

#### ***2.4.7.2 Subjective Assessment Questionnaires***

A number of tools exist to assess users' subjective opinions of the usability of an interface, including:

- SUMI - The Software Usability Measurement Inventory (see the SUMI web site)
- MUSE - The Method for Usability Engineering (see Lim & Long 1995)
- QUIS - The Questionnaire for User Interface Satisfaction (see Shneiderman 1992)
- IBM Computer Usability Satisfaction Questionnaire (see Lewis 1995)

However, these methods have very limited value for iterative design and evaluation purposes, since they often focus on high-level usability aspects relevant to finished products, and questions do not elicit sufficient information to facilitate re-design of parts of a prototype. Furthermore, most of these questionnaires focus on the design of *visual* interfaces, and thus have limited use for non-visual information systems.

#### ***2.4.7.3 Questionnaire and Interview Design***

Since these existing questionnaire-based methods are limited for the formative design stages of non-visual systems, most investigators develop their own questionnaire or interview schedule to assess users' reactions to their systems. However, most published studies do not contain sufficient detail to allow others to use the same questions, and informal discussions with researchers indicates that these questions are often high-level and do not cover very specific aspects of the design which might allow designers to make user-driven changes to the prototype.

The questions asked during formative evaluations therefore must elicit several levels of detail about a prototype, (see for example, McClelland 1990, Monk, Wright, Haber & Davenport 1993, the GUIB Project Final Report 1995), for example:

- High-level questions about usability - which might include ease of learning, ease of use, satisfaction and so on, based on the five subjective usability aspects proposed by Nielsen (1993) see Section 2.4.6.2.)
- Detailed, low-level questions concerning specific aspects of each part of the prototype

The inclusion of both types of question enables designers to collect data on both the current usability of the design, as well being able to stimulate and collect ideas for proposed improvements.

There are many guidelines on the design of questionnaires and interviews, which can shape the development of semi-structured interviews for usability evaluations, for example Oppenheim (1992), Lindgaard (1994), Monk, Wright, Haber & Davenport (1993), and Wood (1997). Their main recommendations are combined here.

A semi-structured interview allows high levels of interaction with users following standard questions and topics to be covered, whilst allowing scope for digression into relevant areas and putting ideas into context. However, questions should be carefully ordered such that contextual and order effects are minimised where possible, and that questions are suitably worded (for example, no double-barrelled questions which cannot be answered with a single response, no ambiguous wording, and no jargon or technical words). Since the use of closed questions or those requiring 'yes/no/don't know' answers can be restrictive, the use of open and closed questions provides a mix of responses, to cater for both anticipated responses and more spontaneous, individual responses.

A useful addition to semi-structured interviews is the use of attitude measurement scales, so that the *extent* of participants' opinions can be gauged. Likert rating scales are the most common method of attitude measurement, although their formal use (of using item analysis and refinement to create a reliable, valid scale), is not always necessary in usability studies. In many cases it is sufficient to use the original 1-5 scale on which participants can place the extent of their opinion, to guide the developer as to which problems are considered to be most severe by users. Questions should be consistent with the available response categories as far as possible, so that participants can easily know which category corresponds to their opinion.

Open-ended, neutral probes should be used (as during task performance) such as: “Can you tell me a little more about..”, or “Why was that?”, whilst attempting to maintain objectivity and avoiding the use of leading prompts. Responses can be recorded in a variety of ways; notes by the interviewer, audio or video-tape, although transcription from video and audio is very time consuming, so detailed notes may be preferable as the primary method of recording with other media as back-ups.

Piloting is considered vital to the development of good questionnaire and interviewing schedules to ensure the order, wording and length of the schedule is appropriate, that the briefing, training and debriefing sessions are satisfactory, and that the interviewer has developed suitable inter-personal techniques for conducting the session.

## **2.4.8 Participants**

### ***2.4.8.1 Range of Users or Designers***

It is generally recommended that users are selected to be representative of the target end-user group; concerning both physical and psychological aspects, and also variations in the expected patterns of product use, for example, novice to experienced, levels of experience, levels of cognitive ability (Gould & Lewis 1985, Hewett 1986, McClelland 1990, Monk, Wright, Haber & Davenport 1993). Children or novices may be more open to creative design suggestions than adults or experts, who tend to compare prototypes with existing products (Brouwer-Janse, Suri, Yawitz, de Vries, Fozard & Coleman 1997), and experts also tend to be relatively more critical (Nielsen & Levy 1994). It is important to note that Virzi (1992) found large differences in the number of problems different users were able to identify in think-aloud tasks - for example, one user found only 8% of all known problems, whereas another found 71%. These findings all indicate that a variety of users should be chosen to take part in evaluations to maximise the number and type of usability problems identified, and to develop a range of solutions to suit different types of user.

For non-user evaluations, such as heuristic evaluation, a multi-disciplinary approach is recommended (Bias 1994, Mack & Nielsen 1994) - such that a range of people is included to bring fresh and different perspectives to the evaluation; designers, evaluation experts, and even end-users; as a precursor to user-testing.

### 2.4.8.2 Number of Users or Designers

Several conclusions can be drawn relating to the required number of participants needed in order to identify the majority (over 75%) of usability problems in an interface, based on five studies using different methods (Wright & Monk 1991, Virzi 1992, Nielsen 1992, Nielsen & Landauer 1993, Nielsen 1994b). Table 2.1 compares the main recommendations from these studies, indicating the type of evaluations and evaluators involved, and the recommended number of participants for optimum cost/benefit ratio.

**Table 2.1: Optimum Participant Numbers for Different Evaluation Methods for Best Cost/Benefit Ratio**

Study	Type of Evaluation	Type of Participants	Optimum Number of Participants per Iteration
Wright & Monk (1991)	Cooperative Evaluation (Tasks and Informal Think-Aloud)	Users	3-5
Virzi (1992)	Tasks and Think-Aloud	Users	5 (severe problems ) 12 (low-severity problems)
Nielsen (1994b)	Tasks and Think-Aloud	Users	4-6
Nielsen (1992)	Heuristic	Double Specialists: Single Experts: Naïve evaluators:	2-3 3-5 up to 14
Nielsen & Landauer (1993)	Combined Studies of Heuristic and User Testing	Designers (heuristic): Users (user tests):	3-5 3-4

*Users.* the general finding is that about 80% of all problems will be revealed by the first 5 or so participants; with additional users finding fewer and fewer problems; although some low-severity problems may require as many as 12 to be identified (Virzi 1992).

*Experts.* If experts are conducting heuristic evaluation of an interface, then between 2 and 5 are required, depending on their level of expertise; since 2 or 3 double-experts (experts in both the evaluation method and the system being assessed) can identify up to 90% of problems (Nielsen 1994b). Designers are also better at identifying and understanding users' problems in their own interfaces than are naïve evaluators (Wright & Monk 1991).

### 2.4.9 Multi-Faceted Iterative Testing

Despite the very recent debate about the validity of the studies comparing different usability evaluation methods (see Olson & Moran 1998), it is generally agreed that different methods of usability evaluation reveal different types and numbers of problems. For example, user testing and heuristic evaluation (by experts) seem to be the most effective and efficient at finding problems (including severe and recurring usability problems), whereas cognitive walkthroughs and interface guidelines tend to find many minor problems, and miss general and severe problems - although team walkthroughs are more effective than single walkthroughs (for example, Jeffries, Miller, Wharton & Uyeda 1991 compared heuristic, user testing, guidelines and cognitive walkthrough methods for assessing a pre-release of a UNIX interface; Karat, Campell & Fiegel 1992 compared cognitive walkthroughs and empirical user testing of GUI office software; and Desurvire, Lawrence & Atwood 1991 compared three heuristic methods with user testing of a phone-based system). Desurvire et al also highlight that although heuristic evaluations are “effective at identifying tasks where specific usability problems occur ... heuristic evaluations are not good at finding solutions”.

These comparisons suggested to the researcher that a multi-faceted, iterative evaluation design would be most useful: for example, using heuristic evaluations and walkthrough-type methods early in the design process to identify usability problems and to remove any obvious usability problems. User testing of the redesigned interface should then be conducted to find any new or remaining problems in context of real use which can be used to develop solutions (a similar conclusion was also reached by Nielsen 1994d).

**Implications:** User-testing should be incorporated at each major iteration of the design, using observed performance and subjective measures. The cooperative evaluation approach involves designers and users, set tasks, informal think-aloud, and semi-structured interviews to assess usability and to develop solutions. Since standard subjective assessment questionnaires are not appropriate for the formative design of non-visual systems, questions should be devised which cover both high-level usability and detailed feature usability using open-ended and ratings scales. A multi-faceted design and evaluation approach should be taken, involving three experts inspecting the interface before user-testing (even at an informal level), followed by user-testing with a range of about five representative end-users.

#### 2.4.10 Methodology - A Discussion and Definition of the Term

This research draws strongly upon the principles of applied psychological research, where the term ‘methodology’ is a high-level term referring to a type of approach employed in an empirical setting in order to answer a particular question, consisting of a set of different available techniques or methods (see for example, Gardner 1985, Snodgrass, Levy-Burger & Haydon 1985). Like the present researcher, many HCI practitioners with a background in empirical research also use this term to refer to a high-level approach to design and evaluation which has a particular focus and comprises a number of types of methods, or procedures, as expressed by Olson & Moran (1998): “The field of HCI is characterized by a diversity of methodological and theoretical approaches...”, and by Gray & Salzman (1998):

“The multitude of empirical methodologies is a strength of the HCI research community, and one of our most potent methodologies is the experimental method.” (p. 247)

Here, the experimental method consists of a range of specific techniques or methods for investigating problems. Similarly, Karat (1988) describes software evaluation methodologies, and presents a detailed description of different techniques which can be applied in each of the different methodologies, and Whiteside, Bennett & Holtzblatt (1988) termed their usability engineering approach (which consists of several methods) a methodology:

“The methodology for creating usability objectives that we have described and illustrated here is intended to facilitate communication and decision making among engineers.” (p. 798)

The implication of this usage of the term ‘methodology’ is that parts of the approach may, or may not be, highly defined or listed as a detailed series of procedures. Indeed, part of the concept of a methodology in this sense is having an understanding of the framework in which the investigations are taking place, as well as the knowledge of how to apply the available techniques within that framework.

However, confusingly, the term ‘methodology’ is often used interchangeably by some HCI practitioners with other high-level terms such as ‘approach’ or ‘paradigm’, or conversely, with more specific terms such as ‘method’, or ‘procedure’, which can make it difficult to determine exactly what is meant by ‘methodology’.

**Implications:** Since the current research has such a strong background in empirical psychological research, throughout this thesis the term 'methodology' is used to refer to an 'overall approach to design and evaluation involving a range of techniques / methods'.

It is interesting to note that although other published research often makes use of *several* of the evaluation methods reviewed in this chapter, there is little evidence of research involving *all* these methods which makes the approach of the current research somewhat unique.

## **2.5 Part IV: Lessons from Hypermedia Design and Evaluation**

The discussion so far has concentrated on generic methods of design and evaluation of interfaces, but there are some specific aspects of hypermedia systems which make their design and evaluation a little different, and it is useful to present a brief overview of hypertext/hypermedia<sup>3</sup> evaluation work to highlight the main issues relevant to the current research.

### **2.5.1 Brief Overview of Hypertext/Hypermedia**

The original proposals for hypertext systems (Bush 1945, Nelson 1981) have led to a proliferation of hypertext and hypermedia systems for a range of purposes, including education, training, leisure, and information storage and retrieval systems (Nielsen 1990a, Woodhead 1991). Two basic categories of system exist (Romiszowski 1993): (1) Instructional (such as text-books and training programs), and (2) Information Retrieval (such as encyclopaedias, guidebooks and museum guides).

The essence of hypertext/hypermedia is the non-linear structure of nodes and links as a medium of thinking and communication for users (Conklin 1987) which allows the presentation of information in an open, exploratory information space. The benefits of such presentation are varied, since material can be traversed by users according to their

---

<sup>3</sup> The term 'hypertext' strictly refers to text-only hypertexts; and 'hypermedia' to systems containing linked nodes of different media such as graphics, audio, and video. However, the terms are often used interchangeably (e.g. Nielsen 1990a).

own interests, tasks, and inclinations (Nielsen 1990a, 1995). The idea of blind people using hypertext using a braille display was first discussed by Nelson (1965).

According to the 'Three Golden Rules of Hypertext' (Shneiderman 1989, cited in Shneiderman 1992), material can be usefully presented in hypertext format if:

- It is a large body of information organised into numerous fragments
- Fragments relate to each other
- User needs only a small fragment at one time

Conklin (1987) identified the now often-cited problems of interacting with hypertext of firstly, knowing where you are in the network, and secondly knowing how to get to some other place that you know (or think) exists in the network. He emphasises that hypertext systems have the potential to cause disorientation and high cognitive overhead because of the increased flexibility they offer in terms of information presentation. Many support features have been designed to support users working in large unstructured information spaces which Wright (1991) termed 'cognitive prostheses', and these might include personalisation facilities such as annotations, bookmarks, creating one's own links, the use of metaphors, guided tours, history lists, graphical maps and overviews, hierarchical menus, and indexing - each designed to support a particular aspect of a user's task.

### 2.5.2 Types of Hypermedia Evaluations

The literature on the evaluation of hypermedia systems is vast, and much is outside the scope of this thesis. Many reported studies suffer from similar limitations as the research already reviewed - often only high-level measures are taken, late in the design of a system, and evaluation methods are often not reported in sufficient detail to be used by others.

However, there seem to be four main strands of hypermedia evaluation research which address different aspects of usability (for reviews see Nielsen 1989, Perlman, Egan, Ehrlich, Marchionini, Nielsen & Shneiderman 1990, Nielsen 1995, Chen & Rada 1996):

- *Benchmark Comparisons* of hypermedia systems with other types of information presentation methods; such as comparisons with electronic text files, paper, or lectures; searches for targets in text, graphics or headings; with menuing systems, or different screen layouts.

- *Effectiveness of Tools*, for example, for tools for navigating or for information retrieval, such as graphical overviews, indexing, table of contents, metaphors, search tools.
- *Assessment of the Educational Benefit* of hypermedia systems by measuring learning outcomes (such as essay or test scores or ratings of learning experience). The use of hypermedia in education is reported to improve learning, understanding, motivation and allow learners to make better and more personal use of material (for example: Landow 1990, Ess 1991, Leventhal, Teasley, Instone, Rohlman & Farhat 1993, Marchionini & Crane 1994, Shneiderman, Alavi, Norman & Borkowski 1995, U.S. Dept of Education 1996).
- *Individual Differences or Task Differences*. Nielsen (1990b) identified two main factors affecting usability in 92 hypertext comparison studies: (1) individual differences and (2) different tasks. Evaluations exploring these factors might include the use of hypermedia systems and tools by different users for different tasks (such as by novices or experts; young or more adult users; methods used when browsing, searching, or when essay writing; for short-term or long-term use; users with different spatialisation ability).

### 2.5.2.1 *Interface Versus Contents*

When considering the design and evaluation of a hypertext system Nielsen (1990b) and Barker (1991) propose that it may be useful for designers to examine two separate aspects of the system:

- a) The usability of the engine (for example, the interface design and its functionality, concerning input and output devices, and commands)
- b) The usability of the contents and structure (for example, the type of structure in the information, and the media in which the information is stored)

The successful interplay between these two components of a hypermedia system is considered vital to its usability, and the cognitive overhead imposed by working in hypermedia requires special attention in the design of the interface (Wright 1991). Although *users* may not be able to identify whether a usability problem is caused by the

design of the interface or by the organisation or media of the content material, the designer should be able to distinguish between the two.

It is interesting to note that when learners focus on *learning* from the content of a hypermedia system, they are often unable to concentrate on using advanced navigation commands, and use only a small number of available commands (Mayes, Kibby & Anderson 1990). However, it should also be noted that the short-term focus of most evaluations and their relatively simple evaluation tasks may not *require* users to learn to use efficient and sophisticated methods (Nielsen & Lyngbæk 1990, Hardman 1995).

### ***2.5.2.2 Multi-Faceted, Iterative Design and Evaluation***

Although fundamental to usability engineering is the measurement of performance, using methods such as performance time captured by computer-logging, time data is not recommended in isolation for explaining the use of hypermedia systems, and rapid iterative refinement coupled with direct observation of user performance is reported to lead to the most dramatic increases in usability (for example, as reported by Shneiderman, Brethauer, Plaisant & Potter 1989, Landauer, Egan, Remde, Lesk, Lochbaum & Ketchum 1993, Instone, Teasley & Leventhal 1993). Evaluation methods often include a selection of informal/formal lab studies or field studies, using several evaluation methods to investigate many aspects of the usability of hypermedia systems (as recommended by Reeves 1993, Nielsen & Lyngbæk 1990, Nielsen 1990b, Perlman, Egan, Ehrlich, Marchionini, Nielsen & Shneiderman 1990, Chen & Rada 1996). Several systems have been reported which include evaluations, including for example:

- Perseus: Marchionini 1990, Marchionini & Crane 1994
- Hyperties Museum Guide: Shneiderman, Brethauer, Plaisant & Potter 1989
- HyperHolmes: Leventhal, Teasley, Instone, Rohlman & Farhat 1993
- SuperBook: Landauer, Egan, Remde, Lesk, Lochbaum & Ketchum 1993
- StrathTutor: Mayes, Kibby & Anderson 1990
- York HitchHiker's Guide: Hammond & Allison 1989
- Intermedia: Ess 1991, Landow 1990
- Glasgow On-Line: Edwards & Hardman 1989

From this collection of research, a list of evaluation measures and methods of data capture can be compiled, presented in Table 2.2.

**Table 2.2: Examples of Measures and Data Capture Methods Used in Hypermedia Evaluations**

<b>Measures</b>
Time taken to complete tasks. Time spent in different modules or activities. Error rates Efficiency. Frequency of commands used. Commands and methods used. Subjective high-level opinion (ease of use, ease of finding information etc). Educational benefit. Longitudinal use (weeks, months, years). Pre- and post- comparisons.
<b>Data Capture Methods</b>
Computer logging. Video evidence. Diary studies. Think-aloud. Questionnaires. Essay tasks. Free recall of content. Multiple choice tests of content. Free recall of headings. Recognition of true/false headings. Observation of exploratory learning. Observation of walk-up and use. Wizard-of-Oz. Card laying or concept maps.

### 2.5.2.3 Guidelines for Evaluation

When involving users, Nielsen (1990b) proposes five usability heuristics (discussed earlier in Section 2.4.6.2), and Preece (1993b) suggests assessing the following aspects:

- do users achieve their own goals?
- do users learn?
- are users motivated and enjoy using the system?
- can users find their way around the system?
- identify features which help / inhibit use of the system.

Hardman & Sharratt (1990) present several design principles for the development of hypertext systems, similar to Nielsen's ten usability heuristics for heuristic evaluation (see Section 2.4.6.2). These could also be used to guide the focus of evaluations:

- Consistency - consistent presentation, and sequences of actions

- Mental processing - minimise mental load and support information gathering
- Ease of learning and use - enable proficient use with minimal training and practice, and minimise steps or actions required for expert users
- Flexibility - design for different types of users and levels of experience, and provide multiple paths through the material
- Task compatibility - present information in a suitable way for readers' tasks, and allow suitable navigation around information in a way that conforms to users' expectations

Barker & King (1993) review high-level methods of assessing interactive multimedia courseware, but Cress & Goltz (1989b) suggest more specific areas to evaluate when choosing educational software for users with special needs. Their list covers:

- Usefulness and overall quality (does the program suit the teaching requirement)
- Teaching techniques
- Presentation style (menus clear and logical; presentation is clear and effective; user response is cued correctly; instructions and feedback are provided and accurate; error messages are not negative; hard-copy output is possible)
- Flexibility and user control (multiple input and output devices, as well as presentation method, order of tasks and content is variable etc)
- Program requirements
- Motivation and emotional effects; particularly important for children
- Documentation
- Technical quality (response is consistent, fast and accurate, bug-free etc)

**Implications:** During design and evaluation, the usability of the interface and the content should be assessed separately if possible, using guidelines relating to presentation style, user-control, mental processing, and different task types. The provision of only basic commands might be sufficient for beginners. User-testing should involve a variety of measures, both objective and subjective, to assess different aspects of the usability of the system.

### 2.5.3 What Tasks Are Supported by Hypermedia?

The literature contains many indications of the types of tasks which hypermedia systems support, and these can be used as scenarios to assess whether a system facilitates these types of activities. Jonassen & Grabinger (1990) point out that three types of process seem to be supported by hypermedia: (1) Information seeking, (2) Knowledge acquisition, and

(3) Problem solving; and different types of user goals have been identified, for example, Canter, Rivers & Storrs, cited in McAleese (1989):

1. Scanning (cover a large area without depth)
2. Browsing (follow a path until a goal is achieved)
3. Searching (striving to find an explicit goal)
4. Exploring (finding out the extent of the information given)
5. Wandering (purposeless and unstructured globetrotting)

Different tools have been designed to support these types of task (such as tours, maps, indexes, and search facilities), and exploratory tasks tend to lead to use of browsing tools, and directed tasks to search-type tools (Hammond & Allison 1989). As learners become more familiar with the topic, they move from using tours to maps to following links through the material (Hammond & Allison, *ibid.*). Thus, depending on the structure of the material and the type of task, different tools should be provided (Dillon 1990, Wright & Likorish 1990).

#### 2.5.4 Navigation and Orientation

The issues of high cognitive overhead and being lost in hypertext systems (Conklin 1987, Wright 1991) can lead users to ask a number of questions relating to their orientation within the system (based on Elm & Woods 1985, Edwards & Hardman 1989, Fischer & Mandl 1990, McKerlie & Preece 1992 - cited in Preece 1993b):

- Where am I?
- How did I get here?
- What can I do here?
- Where can I get to from here?
- How do I get there?
- What have I seen so far?
- What else is there for me to see?

However, there is evidence that rather than *users* feeling lost in hypertexts or on the web, they feel that the *information* itself is hard to find, and ask more questions like 'where is it?', and find it difficult to get back to information already visited (Cunningham, Duffy & Knuth 1993, Pitkow & Kehoe 1996). Edwards & Hardman (1989) suggest that good navigational skills involve the ability to: generate specific routes as the task demands;

traverse or generate new routes as skilfully as familiar ones; and develop orientation skills - an awareness of 'here' in relation to other places.

The use of navigational cues when working in hypertext systems has been discussed by Dillon, McKnight & Richardson (1993), who propose that four types of knowledge representation are formed by users as they become more familiar with the organisation of the content, helping them to navigate through the material: (1) Schemata - basic knowledge for general situations; (2) Landmark - identifying stable, conspicuous environmental features; (3) Route - using landmark knowledge to know how to get from A to B; and (4) Survey or Map knowledge - general directions and relationships.

#### ***2.5.4.1 Headings: Navigational Aids and Measures of Incidental Learning***

The importance of using good node headings and link names as navigational aids, or 'landmarks' (Dillon, McKnight & Richardson 1993) has been highlighted by Hannemann & Thüring (1995), and several investigations have assessed users' memory for node headings as landmarks, and as measures of incidental learning. For example, Leventhal, Teasley, Instone, Rohlman & Farhat (1993) asked HyperHolmes users to identify headings they would have seen and not seen, and compared with paper-book users, they correctly identified and rejected significantly more headings. Similarly, users of other hypertext books were able to free-recall more node or section headings and content than users working with other formats (Hendry, Carey & TeWinkel 1990, Egan, Remde, Landauer, Lochbaum, & Gomez 1989). These findings indicate that users are learning about the structure and organisation of the hypermedia books using the headings, which helps them to learn about the scope of the material and to orient themselves within it.

**Implications:** During design and evaluation, user-scenarios should be based on the tasks which hypermedia usually supports (for example, different types of searching and browsing). Effective navigation and orientation through the material should be supported, for different users at different times.

---

## **2.6 Part V: Contribution to the Field Made by This Research**

### **2.6.1 Design Issues**

This review opened by identifying that a large number of blind people, particularly students, would benefit from effective interfaces to structured electronic information such as hypermedia material and digital talking books. It is clear that although a range of non-visual information systems exist which provide access to some forms of plain text, hypertext, hypermedia, or digital materials, they vary in their functionality and usefulness. Non-visual access to hypermedia material in particular is currently limited to either a custom browser - which has many usability faults and is not sufficiently powerful to support advanced users; or to a Windows screenreader with Netscape - which is difficult for novices to use, and is also unreliable and ineffective. Therefore a system designed from scratch, based on user requirements is likely to provide a more effective solution.

For educational purposes, it is clear that a range of input devices could be usefully provided by a system, but it is not known how to create a good interaction mapping for each input device, nor how to create an interface which can be used in a consistent manner by all input devices. A variety of output methods should also be used, both for the interface and the content material; digitised audio, tactile pictures with verbal descriptions can be used alongside synthetic speech to create interest and variety, but it is unclear how effective these methods will be. There is no consistency in the ways in which existing systems (a) present links or structure in material, (b) make use of non-speech sounds to reduce verbosity and provide information and feedback, and (c) allow users to control the amount of information presented to them at one time. These issues need to be explored and tested by users. Available publications generally do not report the development of an interface, only the design of the final version. It is therefore difficult to know how fundamental commands, such as those for reading, navigation and orientation, should be most effectively designed and implemented, and it seems sensible to explore these first, leaving more advanced commands to a much later prototype.

The first major contribution to the field made by this research is that DAHNI-1 and DAHNI-2 will be the first demonstrations of a non-visual hypermedia interface to be used with a range of input devices which can support students with different levels of computer experience. The evaluation of the DAISY Playback Software will be the first usability

evaluation of the prototype, resulting in recommendations to improve the design. The design implications from these systems will be useful to other researchers developing non-visual interfaces.

### **2.6.2 Evaluation Issues**

It is clear from this review of products, prototypes, and evaluation methods that although there is a substantial body of literature on evaluation methods for general human-computer interfaces and for hypermedia systems, there is very little usability evaluation work actually conducted (or at least reported) on non-visual interfaces for blind users. Most designers know that they should involve users throughout the design process, and should conduct iterative design and evaluation cycles - but the published documentation and anecdotal evidence confirms that the majority of non-visual interfaces are not evaluated in any great depth, nor sufficiently early in the design cycle of a prototype to make a difference. Therefore since there are almost no evaluations being conducted (or published) on non-visual interfaces (but see Edwards 1987, and Stevens 1996), it is impossible to 'borrow' an existing methodology and apply it to the design and evaluation of the interfaces described in this thesis.

However, it is possible to take aspects of a variety of evaluation methods in order to develop a generic, iterative design and evaluation methodology which might be suitable for assessing prototype non-visual interfaces at various stages of their development. For example, usability inspection methods should be used by a team of developers during design to ensure usability before user-involvement. User-testing should involve at least five representative end-users, completing set tasks to allow observation of performance with an informal think-aloud method, followed by a questionnaire-based interview to gather subjective opinions on the usability of the prototype.

The aim of this type of generic methodology is to be able to identify usability problems and develop solutions for the next version of the prototype, for a further iteration of design and evaluation. It is intended that this methodology can be applied to any type of non-visual interface, and once the evaluation methodology is developed and applied to several non-visual interfaces as reported in this thesis, it will be possible to determine whether the methodology is effective and generic.

The second major contribution to the field is therefore the development of a generic, iterative design and evaluation methodology, which can be used to identify usability problems in a non-visual interface and develop design improvements for the next version of the prototype.

## ***2.7 Coming Next...***

The following chapter outlines the development of the generic iterative design and evaluation methodology for non-visual interfaces based on the material reviewed in the current chapter. Later chapters describe how this methodology was applied to the evaluation of three prototype non-visual interfaces.

### **3 Design of A Generic Iterative Design and Evaluation Methodology for Non-Visual Interfaces**

### **3.1 Chapter Overview**

This chapter presents the design of a generic iterative design and evaluation methodology developed to assess the usability of non-visual prototypes. During design, the designers should use guidelines and informal usability inspection methods to identify and remove interface problems before users are exposed to the prototype. When a prototype is at a suitable stage for user-testing, participants should be selected as representative of the target end-user group, a training procedure designed, evaluation tasks developed to assess the usability of each component of the prototype using a type of cooperative evaluation approach, and an evaluation questionnaire developed to gather further subjective opinions and ratings of usability - all with the intention of identifying usability problems and designing solutions. Where possible, this process should be iterative so that design improvements are assessed by further rounds of inspection by designers and user-testing.

### **3.2 Introduction**

Based on the different types of evaluation methods reviewed in Chapter 2, a generic design and evaluation methodology<sup>1</sup> was developed to assess the usability of non-visual prototypes for blind users at different stages of development. This resulted in evaluations of two successive versions of the ACCESS hypermedia non-visual interface DAHNI (pronounced 'Danny') - DAHNI-1 and DAHNI-2, and a non-visual digital talking book browser, the DAISY Playback Software. This generic methodology was applied to the design *and* evaluation stages of DAHNI-1 and DAHNI-2, although only the methodology for the evaluation stage could be applied to the DAISY Playback Software since the researcher was not involved in the actual design of this prototype. The features of the generic methodology were designed such that they could be tailored to the features of each specific prototype, and these common features are presented here. Any specific differences between the generic evaluation methodology and the precise methods used for each prototype will be presented in the relevant chapters.

---

<sup>1</sup> The term 'methodology' is taken from experimental psychology, used to refer to an empirical approach consisting of a variety of specific methods or techniques - discussed in Chapter 2, section 2.4.10.

The generic design and evaluation methodology concerned the following areas:

- Testing without users: which inspection methods should be used by designers to aid in the design and assessment of the prototype before user-involvement?
- Participant selection (users): who should evaluate the prototype?
- Personal data collection: what information should be collected from each participant?
- Briefing: what is required to introduce participants to the research?
- Training: how should participants be trained to use the prototype?
- Evaluation tasks: what activities should participants be asked to complete with the prototype to assess its usability?
- Evaluation questionnaire: what should participants be asked in order to assess the usability of the prototype?
- Measures: what measures should be taken, and how should they be recorded?
- Personnel: who should conduct the evaluations?
- Data collation and analysis: what sort of findings will emerge and how should they be analysed?

### **3.3 Goals of Iterative Design and Evaluation**

The overall purpose of the usability evaluations described in this thesis was to investigate the usability of the design of non-visual prototypes when used by blind people. More specifically, the evaluations sought to:

- Identify usability problems, and
- Allow the development of alternative designs to improve the usability of future versions of the prototypes

This meant not only *identifying* the actual usability problems which arose in use, but attempting to *explain* the reasons for these problems, using both objective and subjective measures. In this way, the existing design could be reconsidered, and alternative designs developed which might reduce these types of problems. It was desirable to assess every aspect of the prototypes at this early stage in their design, including input and output

methods (such as keyboard, joystick and touchtablet); presentation of information (for example, using synthetic and digitised speech); and available commands.

To prevent users from having to assess prototypes which have obvious usability problems, designers should test their prototypes (see Section 3.4) and refine them if possible before user-testing commences. Later, to provide a thorough analysis of each prototype, both objective usability data of user performance should be gathered together with users' subjective opinions about the usability of each aspect of the system.

In addition, since the prototype systems had been designed for use by a range of blind users with potentially very different abilities and requirements, it was important to ensure that the systems were usable by different types of person. Where the prototype systems were found to be lacking in supporting individual user requirements, proposals were made for re-design or additional features to support different types of user.

Finally, it is important to appreciate what these evaluations were *not*. None of the evaluations was intended to be comparative - that is, they were not feature or efficiency comparisons with competitive systems, or between successive versions of the same system, and usability metrics (such as measurements of time, accuracy or efficiency, and criterion for acceptable usability scores) were not required. There were three reasons for this: firstly, DAHNI-1, DAHNI-2 and the DAISY Playback Software were prototypes under development and were not at a suitable stage to be compared with other systems; secondly, at the time of this research neither system had any competition with which to be compared; and thirdly, the purposes of these evaluations was to identify usability problems and to design solutions in order to *improve* usability - by any amount.

### **3.4 Testing Without Users**

In order to maximise the initial usability of a prototype, it was considered important that designers should follow interface design guidelines and heuristics throughout their design. In order to assess the design of prototypes without users, a team of 2-3 designers from different backgrounds used scenarios and informal jogthrough methods to imagine specific users completing specific tasks, to assess the usability of every aspect of the interaction. Where possible, designs were refined before user-testing commenced, and where not practical, these problem areas would be specifically addressed in user-testing.

### **3.5 Participant (User) Selection**

To ensure validity of the usability results it was crucial to assess the prototypes in use by people representative of the target end-user group. For DAHNI-1 and DAHNI-2 the target user-group was blind students at school or in Further Education (aged 11 years plus) who would be likely to have a range of computer experience. For the DAISY Playback Software the target user-group was potentially much wider: *any* blind person wishing to read audio books on their computer; however, the software was mainly targeted at users requiring access to complex structured books for work, education or leisure purposes; rather than users wishing to read books with relatively simple structure such as light fiction novels. However, in both these groups potential users would have a range of technical experience and ability, affecting how easy they would find the prototypes to use, and therefore a range of suitable participants were contacted through schools and colleges for blind students, personal contacts and e-mail lists.

The reviewed literature indicates that the most cost-effective number of participants in a user-evaluation is around five, although as many as 12 might be needed to identify all low-severity problems in addition to the frequent and severe problems identified by the first few users (see Chapter 2, Section 2.4.8.2). Therefore for early prototypes, the use of five participants with a range of experience is likely to be sufficient, and more finished prototypes should be evaluated by larger numbers of representative participants to ensure that all individual differences and preferences have been taken into account.

### **3.6 Personal Data Collection**

Detailed personal data was gathered about each participant to ensure that a representative range of users was included in the evaluations, and so that an individual participant received suitable briefing and training. A 'Participant Characteristics Questionnaire' was designed for each evaluation to collect information based around the following topics:

- Basic demographic details; such as age, gender, level of vision, braille and audio reading experience
- Technology experience; such as types of hardware and software used, frequency and purpose of use, and so on.

The questionnaire was delivered orally in the form of an interview, and data recorded directly onto the questionnaire.

### **3.7 Briefing**

The initial briefing stage was designed to put participants at their ease, to introduce them to the research project, the system under development, and its relevance to the currently available technology. The briefing was also designed to stress that the role of the participant was as a co-evaluator - to evaluate the system and highlight areas which they liked and disliked and would like improved - rather than being under observation to assess their ability. The type of phrases used to encourage this cooperative approach included:

- “We are interested in the way that the system makes it hard or easy for you to do something; and what we can do to make the system better”,
- “We want to know what you like and dislike about the system”
- “If you find something difficult to do, or hard to remember, then it’s our fault; we need to work together to find out how to make it easier to use”

The overall plan for the remainder of the session was then outlined, to familiarise participants with the types of evaluation tasks and questions they would be asked to complete. Participants were informed that their performance and comments were completely confidential, and that they were free to withdraw at any time without repercussions. The participant’s permission was requested to video-tape each session.

### **3.8 Training**

#### **3.8.1 Rationale**

Blind people were generally unfamiliar with the concepts of systems such as DAHNI-1, DAHNI-2, and the DAISY Playback Software, since these prototypes were under development and there were no similar systems available on the market at the time. However, some blind people may have had experience with related systems, such as GUI or text-based web-browsers using a screenreader, and standard cassette-based Talking

Book Players. Exploratory learning was not considered to be an effective method for users to learn new systems (see Widenbech, Zila & McConnell 1995, Arons 1997), and therefore a training procedure had to be developed.

### **3.8.2 Content and Training Style**

The researcher devised a training session based on any existing documentation or help system provided, and from her own experience with the system. The researcher adapted the style of training delivery from her experience of successfully teaching blind people to use other non-visual information systems (such as MS-Windows). This followed the general approach to training of presenting basic concepts first and gradually building up to the most advanced commands and features, tailored to suit each participant.

Rather like the 'training-wheels' approach to learning software (Carroll & Carrithers 1984), training was initially restricted to teaching only the most basic commands using restrictive material (such as a small hypermedia module for DAHNI-1, or a digital talking book with only simple structuring for the DAISY Playback Software). Where the system offered more advanced commands, training progressed only when participants were comfortable with the basic commands, then making use of larger and more structured material (a larger and more complex hypermedia module for DAHNI-2, and a book with complex structuring for the DAISY Playback Software).

Where a prototype offered a number of input devices (such as DAHNI-1 and DAHNI-2 which use the keyboard, joystick and touchtablet), the order of presentation of those devices during training was counter-balanced across all participants to avoid influencing participants' preferences or opinions of device usability.

It was considered important that participants were comfortable using the system independently, and therefore training sessions consisted of tuition and demonstration followed by hands-on practice tasks.

### **3.8.3 Tactile Diagrams**

During training, where concepts were difficult to grasp or relied on having an understanding of the spatial relationships or visual presentation of items, tactile diagrams were designed to illustrate certain concepts: for example, of nodes, units and links for DAHNI-1 and DAHNI-2; and of nested headings for the DAISY Playback Software.

### **3.8.4 Piloting and Training Time Allocated**

Each training procedure was piloted with sighted participants and refined where necessary to ensure that the length of the session, the order, content and level of language used was appropriate and suitable for different types of participant. A maximum of one hour was considered to be a suitable time for a training session so that all features were covered and practice tasks completed, but the participant would not be tired unnecessarily.

## **3.9 Evaluation Tasks**

### **3.9.1 Rationale**

As already indicated, the participants' unfamiliarity with these types of systems led the researcher to believe that most participants would be unable to generate sufficient activities themselves to be able to assess the usability of each specific feature, especially while learning to use them. Therefore, representative tasks were devised specific to the features of each system, such that participants were directed to using each feature either in isolation or combined into a series of activities (as recommended by Monk, Wright, Haber & Davenport 1993).

These evaluation tasks not only ensured that participants would experience each feature of the system (and thus could comment on its usability), but also allowed the researcher to observe the participant completing the tasks using each feature. This was considered vital for identifying usability problems in context and attempting to find the causes of these problems as they occurred. The main areas to be addressed include: input and output methods, each command and feature of the system, and the presentation of information.

Where a prototype made use of several input devices (for example, DAHNI-1 and DAHNI-2), tasks were completed with each device, and to minimise order effects (Harris 1986) several balanced tasks were designed so a different task could be completed with each input device. As a last resort the same task was repeated with each input device.

All participants used the systems non-visually (regardless of their level of vision), since all systems were designed specifically for auditory use and did not have suitable visual interfaces for partially sighted users.

### **3.9.2 Types of Evaluation Task**

Tasks were designed to be representative of the tasks which the prototype was able to support, and which would allow participants to navigate through the content material in realistic ways. The types of task used could vary between systems, depending on: (a) the number and scope of the commands available, and (b) the size and structure of the content material available (that is, the hypermedia module for DAHNI1 and DAHNI-2, or the digital talking book for the DAISY Playback Software), and could therefore range from simple to more difficult and structured tasks. Four levels of task direction could be considered for different size prototypes, described in the following sections.

#### ***3.9.2.1 Directive and Explicit Tasks***

For early prototypes with only a limited number of commands (such as DAHNI-1) there were only a small number of tasks which could be constructed. Tasks for a restricted prototype were therefore explicitly directive: specifying exactly what the participant should do next, one step at a time, without actually naming the command required. For example:

- “Can you go back to the previous node to hear more about the Queen?”
- “Skim through the units in this node to the third unit and select the link to the Tower of London.”

#### ***3.9.2.2 Guided Tasks (Directive, Non-Explicit)***

For more advanced prototypes with a greater number of commands (such as DAHNI-2) guided tasks consisting of directive, but non-explicit instructions were designed which

allowed participants greater independence when choosing commands to complete the task. Similarly, tasks could combine several steps, rather than requiring just a single command, and the task might not explicitly state the steps required to complete the task. For example:

- “In the City of London Node there is a link to the Great Fire of London. Can you go there and select it?”
- “Can you return to the Cultural Activities node and then go and hear what is on in the concert halls?”

### ***3.9.2.3 Completely Free Tasks***

In prototypes which were sufficiently advanced to provide a wide range of commands and were almost fully-functional (such as DAHNI-2 and the DAISY Playback Software) participants might be able to use the systems independently and choose their own activities and paths through the content material (Leventhal, Teasley, Instone, Rohlman & Farhat 1993, and Marchionini & Crane 1994). This was anticipated to increase participants’ engagement and motivation with the task. Completely free tasks were therefore designed so that independent use of the system could be observed, for example:

- For DAHNI-2: “What was your favourite node? Can you take me there and let me hear it too?”
- For the DAISY Playback Software: “Have a read through the headings in this book, so you can choose where you go and what you read”.

### ***3.9.2.4 Generic Tasks***

Participants might not be able to generate sufficient free tasks to make use of all commands in a system, so the researcher had a list of generic tasks available which participants might be asked to complete if a particular command had not been used - but in the context of independent, free tasks. For example, when using the DAISY Playback Software, participants might be asked:

- “Can you get to Section 1 in the headings (table of contents), and put a numbered bookmark there so we can get back to it later on?”
- “What other topic are you interested in reading about in this book? Let’s do a Find task and see if we can find anything on that.”

### 3.9.2.5 *Content Questions*

In an attempt to reduce 'passive listening' commonly experienced by audio readers, questions about the content of the material were occasionally interspersed with the evaluation tasks (for DAHNI-1 and DAHNI-2). For example:

- **Task:** Can you read through the units in this node and select the link to the Queen?  
**Question:** In which month was the Queen born?  
**Question:** What was the link in that unit?
- **Task:** The Last Night of the Proms is held in one of London's concert halls; can you take us there?  
**Question:** What sorts of songs are heard at the Last Night of the Proms?  
**Question:** What was the link in that unit?

### 3.9.2.6 *Separate Investigations*

Where a system offered components which require individual assessment, separate investigations could be designed to explore these components within the main usability study. These might concern recall of information from material (Egan, Remde, Landauer, Lochbaum & Gomez 1989); recognition of true or fictitious information (Leventhal, Teasley, Instone, Rohlman & Farhat 1993); comparisons of the memorability of non-speech sounds used for example (similar to Mynatt 1994, Petrie & Morley 1998); or investigations into the amount of information recalled from pictures, text, or from tactile graphics (see Instone, Teasley & Leventhal 1993, Pring & Rusted 1985).

For example, DAHNI-2 provided a range of non-speech sounds and was used with hypermedia nodes of different media (synthetic speech, audio clips, and descriptions of pictures with tactile pictures). In order to explore these specific features of this particular prototype separate investigations were designed to assess the memorability of: non-speech sounds; the information from nodes of different media; and headings.

### 3.9.3 **Protocol Elicitation (Informal Think-Aloud)**

Following the cooperative evaluation approach (Monk, Wright, Haber & Davenport 1993, see Chapter 2, Section 2.4.7.1) participants were encouraged to consider themselves as

testing the system for its good and weak points. It was important to assess participants' opinions in context of undertaking the tasks rather than solely after the event. Thus, rather than requiring participants to complete tasks thinking aloud without any interaction with the researcher, as used in the pure 'Think-Aloud' approach (Ericsson & Simon 1980, van Someren, Barnard & Sandberg 1994), participants did think-aloud but in an informal way, in cooperation with the researcher, who could prompt the participant and attempt to elicit usability opinions in context.

Thus, while participants completed the evaluation tasks, the researcher would prompt the participant to expand where further explanation or description of a problem was required, and participants were able to ask the researcher for help or information. However, the researcher tailored their responses to be initially vague and non-directive, encouraging the participant to think for themselves, which also helped to minimise demand characteristics (Orne 1962) and experimenter bias (Rosenthal 1967). Neutral prompts included:

- "What do you want to do?"
- "How might you do that?"
- "Why are you trying X?"
- "What will happen if you do X?"
- "What happened then?"
- "What did you expect to happen when you did X?"

When a participant could not continue with a task unaided, the researcher would increase the level of information provided in their responses, becoming more explicit, for example:

- "What other commands might do this?"
- "How did you do this before when we were doing X?"
- "Can you remember the difference between the commands A and B? - So, which one would be more appropriate to use here?"
- "What about the X command - what would you expect that to do?"
- "One command is to do C and the other is to do D - which is the right one to use here?"

### **3.9.4 Piloting and Task Time Allocated**

The evaluation tasks were piloted with sighted participants using the systems non-visually, to ensure that the tasks assessed each command or feature of a system; that the wording of tasks was clear and easy to understand even for novices; and that the tasks were not too difficult nor too easy. The tasks and prompts were refined as necessary, and the total time considered appropriate for evaluation tasks was a maximum of 45 minutes, followed by a break before the evaluation questionnaire was delivered.

### **3.9.5 Measures Taken**

Several measures were taken during task performance. Firstly, observations of the methods chosen to complete a task were noted in terms of methods used, difficulties, errors, and activities which were well-supported; together with suggested reasons for these observed behaviours. Secondly, the details from verbal protocol of participants during task performance (the informal think-aloud) was noted, relating to usability and preferences for different aspects of the system, and any suggestions for improvements proposed by participants themselves.

Time taken to complete tasks was difficult to measure for some prototypes (such as for DAHNI-1 and the DAISY Playback Software) since no computer-based event logging was available, and particularly since the informal think-aloud disrupted pure time-based measures. However, rather than measure task time, it was considered more important to concentrate on the types of problems or difficulties participants had when trying to complete a task, and to identify where the system did or did not support the participants' goals. For the same reason, although DAHNI-2 did contain basic computer-based event logging (useful for double-checking participant's use of the system), the time data collected was much less informative than the data collected from observed task performance and the questionnaire for the purpose of developing further designs for the prototype.

### **3.10 Evaluation Questionnaire**

#### **3.10.1 Rationale**

Participants' performance on the evaluation tasks would indicate objectively how usable the system was, but it was considered important to also investigate participants' individual subjective opinions about the usability of the system and suggestions for improvements. The combination of objective and subjective measures was intended to provide two types of complementary data which might not be revealed by one method in isolation. Vague questions about the prototype were avoided, such as "what did you like/dislike?", since these would not provide the level of detail required to develop design improvements specific to each feature. Instead an evaluation questionnaire was designed tailored to the features of each prototype. The questionnaire (delivered as an interview) was used to prompt participants to consider and express their subjective opinions on the usability of each aspect of the system, with the goal of identifying and explaining usability problems, and to design solutions.

#### **3.10.2 Topics Covered and Measures Used**

For each prototype a list was made of important and potentially interesting aspects of the system which could be addressed, concerning for example, its commands and features, its input and output devices (such as keyboard, joystick, touchtablet, synthetic and digitised speech, non-speech sounds), and the presentation of information. In addition, where alternative designs were possible, or where existing designs were known to be problematic, potential alternatives were proposed to participants in the questionnaire for their consideration.

Questions were designed to elicit closed and open-ended answers, and for many of these topics participants would also be asked to rate their strength of feeling concerning various aspects of usability, for example: their ease of use; their memorability; their level of satisfaction; how much they liked/disliked a feature, and so on (based on Nielsen 1993). A 5-point Likert rating scale was chosen (see Table 3.1) after piloting revealed that participants found a 1 to 5 scale easier to use than a 1 to 7 scale, and that the findings from this scale would be adequate for comparing strength of opinion.

Many blind people had not come across Likert rating scales before, and a simple explanation was sufficient to illustrate how to use them.

**Table 3.1: A 5-Point Likert Rating Scale**

1	2	3	4	5
Very Low	Fairly Low	Moderate	Fairly High	Very High

The general areas addressed in the evaluation questionnaires would include topics from the following list:

- overall ease of use
- overall ease of learning
- overall enjoyment
- memorability of commands
- ease of use of each command
- usefulness of commands
- ease of use of each input device, and each output method
- quality of output
- ease of use of information presentation methods
- usefulness of non-speech sounds
- memorability of non-speech sounds
- usefulness of support material (help, tutorials)
- the potential usefulness of proposed solutions or design alternatives

### **3.10.3 Piloting and Evaluation Time Allocated**

The evaluation questionnaire was piloted with sighted participants and the questions refined until the wording was considered suitable for a range of participants such that useful information would be elicited. It was felt that as far as possible the questionnaire session of the evaluation should take no more than 60 minutes, including a break and any separate investigations conducted, to avoid tiring the participant. For a small prototype (such as DAHNI-1) it was likely that the evaluation time would be considerably shorter than this, but the questionnaire for larger prototypes (such as DAHNI-2 and the DAISY Playback Software) addressed a larger number of issues and therefore the session might last as long as 90 minutes.

### **3.11 Recording Methods**

If possible, training and evaluation sessions were video-taped (with permission of the participant), but in all cases detailed notes were taken by the researcher about participants' task performance and their comments during the tasks and during the questionnaire-based interview, which were combined for analysis. Basic computer logging (as provided in DAHNI-2) was also useful for checking a participant's use of the system.

### **3.12 Debriefing**

At the end of the evaluation questionnaire session participants were debriefed using open-ended questions to ensure that they had reported everything they had thought of during the sessions. The confidentiality of their data was also reiterated.

### **3.13 Personnel**

Although one researcher could have conducted the training and evaluation sessions alone, there were considered several advantages to having two researchers taking part in the evaluations; the principal researcher and a supporting researcher. Firstly, as one researcher conducted a session taking their own notes of the participant's performance and comments, piloting revealed that detailed note-taking was obvious (making the pilot participants feel self-conscious) and disturbed the flow of the procedure. A supporting researcher acting as a silent observer for the session was very useful for taking detailed notes to supplement those made by the principal researcher. Secondly, the use of two independent note-takers would provide two accounts of the same event, increasing the reliability of the results and possibly providing alternative explanations for the findings. Thirdly, to reduce the fatigue of the researchers, they alternated running the training and evaluation sessions; which had the additional advantage of minimising any researcher bias. Finally, it was considered advantageous that the researcher(s) were experienced with the design of the systems since it was likely that they would be expert at recognising and understanding the types of problems participants experienced (Wright & Monk 1991).

### **3.14 Data Collation and Analysis**

The observed performance data and the subjective opinions about the usability of each feature of the system were collated, such that the behaviours, ratings and comments of each participant could be compared for each topic on the questionnaire. Comments made by participants during task performance and during the questionnaire-based interview were combined and grouped relating to different usability issues. The ratings and spread of ratings gave an indication of the extent of a usability problem, and statistical comparisons of ratings were made where relevant - for example, when participants rated the usability of different input devices, or output methods, or compared the potential usefulness of new features.

Based on these complementary sets of data a range of possible alternative designs was developed for each usability problem identified, which could be implemented in a future version of the prototype.

### **3.15 Summary of the Generic Design and Evaluation Methodology**

The generic design and evaluation methodology developed for this research combines a number of approaches, to collect a large amount of complementary data about the usability of each feature of a prototype to allow further design and development. All participants completed a training session, a series of representative realistic tasks, followed by a questionnaire-based interview assessing the usability of each feature of the system, sometimes with additional investigations assessing specific components of a system. The observed performance and subjective usability data was collated and analysed, focussing on identifying and explaining usability problems and developing solutions. The general stages of the generic design and evaluation methodology can be summarised as follows:

1. **Design:** Designers follow guidelines, and conduct informal usability inspections using types of heuristic evaluation, scenarios and jogthroughs to identify problems, develop solutions, and the system is re-designed if possible
2. **User-Testing:** Session commences with personal data collection
3. Briefing
4. Video-recorder turned on (if used)
5. Training and practice session

---- Break ----

6. Evaluation tasks
7. Evaluation questionnaire (and possible separate investigations)
8. Debriefing
9. Data collation and analysis
10. Identification of usability problems and proposals for design improvements, for possible implementation in a future version of the prototype
11. Repeat design and evaluation cycle from step 1

### ***3.16 Coming Next...***

The following chapter presents the design of the first prototype of the ACCESS hypermedia non-visual interface, DAHNI-1, and the evaluation of DAHNI-1 is presented in Chapter 5.

## **4 Design of DAHNI-1: The First ACCESS Hypermedia Non-Visual Interface**

## **4.1 Chapter Overview**

Partners from the ACCESS Project (not including the University of Hertfordshire) designed mock-ups of non-visual interactions with hypermedia commands and links, using a keyboard, joystick and touchtablet, in order to test basic interaction design ideas. The evaluation methodology described in Chapter 3 was applied by the researcher in an informal way, with three blind students assessing the interaction and presentation methods. The results from these evaluations led the researcher to develop a specification of the design of the first ACCESS hypermedia non-visual interface, DAHNI-1 with a spatial layout of commands on a workspace, to be used with the same three input devices, together with a small hypermedia module about the history of London.

## **4.2 The Development of Mock-Ups**

### **4.2.1 Design of Initial Mock-Ups**

On the basis of the ACCESS Project's user requirements study and their survey of the functionality of hypermedia systems for sighted users (reported in Free, Graziani, Lauder, Majoe, Morley & Petrie 1995), partners from the ACCESS Project (not including the University of Hertfordshire, UH) developed mock-ups of small parts of a non-visual hypermedia system, to explore very basic design issues. The researcher was only involved in a minor way during this early design stage, although she then designed and conducted an informal evaluation of these mock-ups, and later played a key role in the design of DAHNI-1.

The mock-ups attempted to present a visual display in a non-visual manner (based on an early design decision of the ACCESS Project), and since the potential use of a variety of input devices had been enthusiastically received in the user requirements study, three devices had been selected which were commonly found in schools: a standard keyboard, a standard joystick and a touchtablet. Rather than use an existing touchtablet (such as a Concept Keyboard), the ACCESS Project produced their own custom touchtablet (described in Section 4.5.5). The mock-ups included a non-visual sample of a hypermedia screen, of commands and links, and sample interactions for reading through hypermedia material, described in the following sections.

#### 4.2.1.1 Commands and Links

The mock-up of a hypermedia 'screen' is presented in Figure 4.1, illustrating a row of commands across the top of the display, and links presented spatially around the display - as they might appear on a visual display, for example, on a contents page of a CD-ROM encyclopaedia. The methods of non-visual interaction with these commands and links with the keyboard, joystick and touchtablet are listed in Table 4.1. Commands were spoken in digitised human speech, and the links were presented in synthetic speech. The commands and links were non-functional in this mock-up.

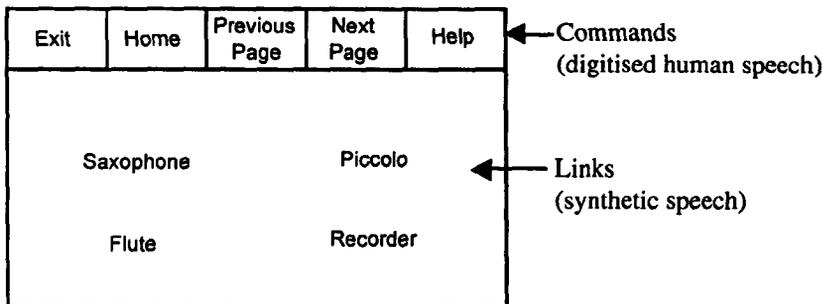


Figure 4.1: Mock-Up Layout of Commands and Links

Table 4.1: Mock-Up Implementations of Keyboard, Joystick and Touchtablet to Find and Execute Commands and Links

	Keyboard	Joystick	Touchtablet
<b>Find Commands</b>	Function keys <F1-F5>. Lead to system prompt "are you sure?"	Move around in free space: commands along top edge	Move finger over surface: commands along top edge. Tactile symbols on an overlay <sup>1</sup> could indicate position
<b>Find Links</b>	<Tab> link-to-link	Move around in free space: links spread around 'screen'	Move finger over surface: links spread around 'screen'
<b>Select Command or Link</b>	<Return>	Press Trigger	Double-press on desired spot

<sup>1</sup> An overlay is a sheet of paper which is placed on the surface of the touchtablet with tactile markers to indicate specific locations on the display.

#### 4.2.1.2 *Hypermedia Material and Links*

The ACCESS team was aware that it was not sufficient to present only commands and links: users had to be able to read through hypermedia material. Two issues were considered to be important:

- User control over the amount of information presented at one time
- The presentation of links within continuous textual material

The mock-ups presented a small amount of information in several nodes<sup>2</sup> which could be read using only the joystick to execute reading commands. In an effort to provide control over the amount of information presented, significant phrases were output one at a time - such as a heading, or a paragraph, or a link - and then the output stopped. In order to make the links stand out, the output stopped before the link, a non-speech sound was played before the link was spoken, and the output stopped immediately after the link.

Different non-speech sounds were used to indicate links to different types of node (for example: a link to a textual node (“*arrow*”); a link to an audio clip (“*whistle*”); a link to a short textual definition (“*bing*”). Additional sounds were used to indicate the structure of the node: a paragraph (“*fanfare*”), a heading (“*trill*”), and the end of the node (“*boing*”).

In order to hear the next phrase, users nudged the joystick to the right to hear the next phrase (the reading command ‘Read Next’), and nudged it to the left to hear the previous phrase (the ‘Read Previous’ command). These commands were named to be similar to reading the next sentence on a braille page, for example. When sitting on a link (that is, when the link had been heard and the output had stopped), the user could select it by pressing the Trigger button, and could return to the previous node (that is, go ‘Back’), by pressing the Thumb button on the top of the joystick. Most nodes were presented in synthetic speech, but the destination nodes from the links ‘bagpipes’, ‘clarinet’, and ‘musical’ (see Figure 4.2) were audio nodes containing musical clips.

---

<sup>2</sup> A node is the equivalent of a hypertext page of information, consisting of text, audio or a graphic.

Figure 4.2 illustrates the output in the mock-up for two paragraphs in a node. Non-speech sounds are shown in italics, and links are shown underlined. The output halts at the places marked with (Stop), waiting for the user to execute a reading command to continue. The underlined links were functional, jumping to musical nodes.

*"Fanfare"* Paragraph One. (Stop) *"Trill"* The Woodwind Family. (Stop) Woodwind instruments use vibrating air to produce a rich variety of musical sounds. (Stop) Despite their name they are not always made of wood, they may also be crafted from metal, bone and ivory. (Stop) They are played either as flutes or with a reed. (Stop) Examples of the woodwind family are (Stop) *"Arrow"* Bagpipes (Stop) *"Arrow"* Clarinet (Stop) Flute and Oboe. (Stop)

*"Fanfare"* Paragraph Two. (Stop) *"Trill"* The String Family. (Stop) The string family is named for the (Stop) *"Bing"* gut (Stop) wire or nylon cords that are stretched over the instrument. (Stop) Striking, bowing, plucking or strumming the strings produces (Stop) *"Whistle"* musical (Stop) sounds that are amplified acoustically or electronically. (Stop) End of document one. (Stop) *"Boing"*.

**Figure 4.2: Mock-Up for Reading Hypermedia Material with the Joystick**

#### 4.2.2 Evaluation of Mock-Ups

A short and informal application of the evaluation methodology described in Chapter 3 was carried out by the researcher, with three blind students aged 14-18 assessing these mock-ups. The evaluation is reported in detail in an ACCESS report (Free, Majoe, McNally, Morley & Petrie 1995), and since only the results are important for the purposes of explaining how DAHNI-1 was designed, rather than present the method in full here, a summary is provided, with a more detailed description of the results. Participants received a briefing and a short training session, and were then asked to try to find and select each of the commands using each of the input devices, and to read through the hypermedia material using the joystick (the keyboard and touchtablet were not implemented for reading). Task performance was observed coupled with an informal think-aloud procedure, and participants were interviewed about their opinions on the current mock-ups and on alternative designs they might have suggested; addressing the method of presenting and selecting commands and links with each input device, and for presenting and reading through hypermedia material.

### **4.3 Results and Recommendations from Evaluations of Mock-Ups**

The full evaluation results of initial design possibilities as illustrated in the mock-ups are presented in an ACCESS report (Free, Majoe, McNally, Morley & Petrie 1995), and the key findings of the researcher are reported here with recommendations which go on to form the basis of DAHNI-1.

The findings are grouped into three sections, described in turn: (a) the presentation of commands and command functionality; (b) the presentation of hypermedia content; and (c) the presentation of links.

#### **4.3.1 Presentation of Commands and Command Functionality**

##### **4.3.1.1 Spatial Presentation of Commands**

The fixed spatial layout of commands along the top of the work area worked well with the joystick and with the touchtablet when used with an overlay indicating the location of the commands. Participants found it easy to locate the commands, and the spatial layout seemed to help them to remember which commands were available and where to find them. However, searching over free space on the touchtablet without an overlay was very time-consuming and difficult, and participants preferred to have the tactile markers which an overlay provided. However, links spread in unknown locations over the display were not easy to locate using either the touchtablet or the joystick (and since the position of links would change from display to display, tactile markers would not be appropriate). The use of function keys to access commands with the keyboard was easy, and the use of the <Tab> key to jump link-to-link was also easy, but the keyboard implementation was not consistent with the spatial joystick and touchtablet implementation, which might make it difficult to learn to use all three devices concurrently.

**Recommendation:** Any spatial arrangement of commands must be in a known configuration, and easily accessible by all three input devices using a consistent design so that they are easy to use interchangeably. A specific shape of commands, presented on an overlay on the touchtablet, navigated by moving the joystick around that specific shape, and using the arrow cursors on the keyboard, would allow such consistency between devices.

#### **4.3.1.2 Use of Digitised Speech for Commands**

Participants liked the digitised speech to present commands, stating that it made it easy to distinguish the commands from the content of the hypermedia module (which consisted of synthetic speech and music clips).

**Recommendation:** Make use of digitised speech for the interface commands, to keep them distinct from the hypermedia content.

#### **4.3.1.3 Length of Interactions**

Finding and selecting a command led to a prompt “Are you sure?” to which users had to respond using another keypress. Participants considered these prompts too time consuming and unnecessary for each and every command.

**Recommendation:** Reduce the amount of interaction required to execute a command. Command selection should lead to immediate execution, except for certain commands such as ‘Exit’ for example, which should provide a confirmation prompt to avoid inappropriate actions.

#### **4.3.1.4 Reading Hypermedia Content**

Only the joystick had been implemented to read through the hypermedia content and participants said that executing the reading commands on the joystick was very easy, and that they could imagine an implementation on the keyboard using the cursor keys to be as easy to use. However, participants said that it became tiring having to make repeated commands in order to read through a node, and that the output was very disjointed because it kept stopping after only very short phrases. Sometimes participants wanted to hear the last phrase again, but the ‘Read Previous’ command took them back to the *previous* phrase, rather than to the start of the phrase last output. Several participants found this confusing and not very efficient.

**Recommendations:** (a) Users must be able to control how much material they receive with one command. One solution is to provide different commands for reading larger and smaller chunks of information at once (for example, word, sentence, paragraph); or a modal implementation could be used, so that a single reading command can present

different amounts of information depending on which mode the user is in. (b) Output should not stop at each link. Although this allowed easy identification of the link word, the output was too disjointed, disrupting comprehension, and required too many reading commands. (c) Users must be able to re-hear the phrase which was last output. Either a 'Repeat' command is required, or the 'Read Previous' command could return to the start of the last phrase and subsequently jump to the start of the previous phrase.

#### **4.3.1.5      *Selecting Links***

Only the joystick had been implemented for selecting links within a hypermedia node. The actual selection of the link was very easy (when the link was heard and the output stopped, the Thumb button was pressed, thus selecting a link). However, the method of presentation of the links was very cumbersome since the output stopped both before and after the link word (which was very disruptive, as described above).

Recommendations: Selection of links should remain as simple as this for any input device, but the presentation of links should be less disruptive (see Section 4.3.3).

#### **4.3.1.6      *The 'Back' Command***

The 'Back' command was only implemented on the joystick, and problems were caused if participants pressed the wrong button (for example, the Thumb button instead of the Trigger). There was no way for participants to reverse the command, or to get back to a known starting point to re-orient themselves. 'Back' also placed the participant at beginning of the sentence containing the link they had selected (often in the middle of the node). This often confused them, since they found themselves in the middle of a piece of text, and had expected 'Back' to go back to the beginning of the previous node.

Recommendations: (a) 'Back' should take the user to the beginning of the previous node, rather than to the start of the sentence of the link followed. An advanced implementation of 'Back' might allow differentiation between Back-to-Beginning-of-Node, and Back-to-Start-of-Link-Sentence. (b) New commands are required to jump 'Forward' in one's history, 'Home' to jump to the starting node, and 'Top' to jump the beginning of the current node to provide quick methods of jumping to other locations for re-orientation.

## 4.3.2 Presentation of Hypermedia Content

### 4.3.2.1 *Synthetic Speech*

The use of synthetic speech to present textual information was considered acceptable, especially with the use of non-speech sounds to provide additional information about the structure of the information (for instance, the paragraph, heading and link sounds, described in Sections 4.3.2.3 & 4.3.3.1) without increasing verbosity. Participants requested a facility to change the rate of the speech output, and to change the voice to suit their mood and the type of reading material.

Recommendations: (a) A new command is required to allow users to control the rate of the speech output 'Change Rate'. (b) Users might want to change the voice used as well with a 'Change Voice' command.

### 4.3.2.2 *Digitised Audio*

Participants liked the digitised audio musical nodes because they added variety and interest to the textual nodes presented in synthetic speech, and suggested that the future use of spoken human audio for some of the nodes would make the content more pleasant to listen to.

Recommendation: Make use of human digital audio as well as musical nodes, and add sound effects to human speech nodes to increase interest and variety in the content material.

### 4.3.2.3 *Non-Speech Sounds to Indicate Structure*

Participants found the additional information about structure that the sounds provided (paragraph, heading, and dead-end) helped their orientation within the node, without having to listen to additional verbal output. Participants said that these sounds were not difficult to learn, although the fanfare sound seemed too 'grand' a sound for a paragraph, giving the impression that it might be something more important, like a title for example. The verbal message 'end of node' was considered redundant and could easily be replaced by the dead-end sound.

**Recommendation:** Continue to use non-speech sounds for structural cues, but consider the 'importance' that a sound conveys when choosing a sound for a particular structural element.

### 4.3.3 Presentation of Links

#### 4.3.3.1 *Non-Speech Sounds to Indicate Links and Link Type*

Participants did not find the different arbitrary sounds for links difficult to learn and liked the additional information they provided about a link which would help them decide whether or not to follow it. One participant thought that naturalistic sounds (such as a typewriter for a link to a text node) might be easier to associate with links than these arbitrary sounds. Participants thought that a change in voice might be an acceptable alternative to a sound for presenting links; although this would obviously not convey as much information about the type of link as is possible using sounds.

**Recommendations:** Non-speech sounds should be explored as a method of presenting links, but the use of a change of voice should also be considered.

#### 4.3.3.2 *'Current Link' Concept*

As already described, the presentation of hypermedia material in short phrases with breaks before and after links was considered too disruptive, and appears to be unnecessary for the identification of links when non-speech sounds are used. However, the problem then remains of how a user can find a particular link and select it, since the output is transitory and now in longer chunks, and the user can no longer 'sit' on a link as they could when it had breaks around it.

**Recommendation:** The provision of a list of links is not an ideal method (by itself) to present links in auditory form, nor is it sensible to have to provide one of each link type in each node (see Arons 1991, and Barker & Sutherland 1996), and therefore alternative designs had to be considered. An innovative solution to the problem of finding and selecting transitory links is the concept of an active or 'current link'; such that only one link at a time is active and selectable at any time, even when the output is more continuous in larger chunks. For example, when a link is output, it remains the 'current link' until a

further link is heard, when that link becomes the new active current link. This would remove the need for breaks around the link word and permit continuous output, whilst allowing users to easily select one link at a time. A similar approach was later used for hypervideo links by Sawhney, Balcom & Smith (1996) although these are based on temporal or spatial links (where video links remain active for a specified number of seconds, or a certain area of the screen is active at a given time).

#### **4.3.4 Conclusions from Mock-Up Evaluations**

Some of the basic design ideas tested in these mock-ups were shown to be useful, for example, the spatial presentation of commands took advantage of the affordances of the joystick and touchtablet (Gaver 1991) making them reasonably intuitive and easy to use, although the implementation with the keyboard was not consistent with the spatial interaction of the other two devices. This might be a problem when the three input devices are to be used interchangeably, since users would not be able to benefit from a consistent interface layout (Yankelovich, Levow & Marx 1995). A consistent, spatial display is plausible, since it helped participants to remember the location of commands, although the presentation of links must be more efficient - using the novel concept of a 'current link', with more continuous presentation of hypermedia material. The use of digitised and synthetic speech and non-speech sounds are recommended for the provision of an informative multimedia display, with a range of multimedia nodes to provide an interesting, varied hypermedia module for students. Interactions with most commands should be simple, quick and immediate, and further navigation and output control commands are required.

#### **4.4 Development of DAHNI-1**

The evaluation results of the ACCESS mock-ups coupled with knowledge of existing non-visual information systems for blind and sighted users (as reviewed in Chapter 2), and the ACCESS user requirements questionnaires and interviews with blind students, their teachers, and blind computer experts, resulted in a list of user requirements for a non-visual hypermedia interface (reported in detail in Free, Graziani, Lauder, Majoe, Morley & Petrie 1995, and published in Petrie, Morley, McNally, Graziani & Emiliani 1996). These led to the development of DAHNI-1, the first ACCESS hypermedia non-visual interface.

The user requirements results are outlined below, followed by a description of the design of DAHNI-1.

#### **4.4.1 User Requirements Identified for the Design of DAHNI-1**

Similar to other later user requirements studies (for example, Arató, Barkaszi, Buday & Vaspöri 1996), students were satisfied with talking books for leisure reading, but for study purposes they would prefer to use electronic text read by their text-to-speech system on a computer. The types of features of a hypermedia system for blind students might therefore include:

- It should be easily learned and used by both novices and more experienced users
- Multimodal interface using a variety of input devices and output devices
- Multimedia presentation of the material (synthetic and digitised speech, sound effects etc)
- Distinct interface (so that content and interface are easily distinguishable)
- Flexibility and control over the presentation of the content material (for example, speed, voice, interruptability)
- Flexibility in the amount of information presented (for example, character, word, sentence, paragraph, whole node)
- Methods for overviewing material (for example, link-to-link navigation, navigation through headings in a module, summary of node contents)
- Use of non-speech sounds to provide information and feedback
- Different methods for finding and selecting links
- A history list, with easy methods of going backwards and forwards through it, as well as being able to review the history list contents
- A quick way of getting to the starting node (going 'home')
- On-line support material (for example, tutorial and context-sensitive help) to provide quick, relevant support and advice.
- A 'logical path' through the material, so that students can read material in a logical, progressive route

- A 'guided path' through the material, so students are guided to the most relevant material.
- Use of metaphor (perhaps to explain concepts of hypermedia which could be extended to command names and so on)
- Advanced features: a simple editor; personal annotations; find; index; bookmarks; save; print; adding own links to the content.

#### **4.4.2 Design Principles and Usability Inspection**

During the design of DAHNI-1, the researcher and the programmers used design guidelines and usability inspection methods (outlined in Chapter 3), to ensure simplicity, consistency, and ease of use of every design decision. The researcher used informal methods of scenarios, jogthroughs and heuristic evaluations to assess design possibilities with the design team, and when agreement was reached on the exact design, the programmer implemented the chosen method.

#### **4.4.3 Interface Design and Hypermedia Content**

DAHNI-1 was designed based on these user requirements and on the researcher's practical experiences with the mock-ups. For the purposes of analysis and description of such complex systems, it is useful to consider the design of the interface and the content material separately (Nielsen 1990b, and Barker 1991). Therefore the following sections describing DAHNI-1 will firstly concentrate on the design of the interface, and secondly on the design of the hypermedia content. The issues cover:

- 1) *Interface Design* - commands are presented in digitised speech; non-speech sounds are used for information; a range of basic navigation and reading commands are provided; for use with the keyboard, joystick and touchtablet in a consistent interface.
- 2) *Hypermedia Content* - material is presented in synthetic speech and digitised speech with sound effects, music clips, and pictures with descriptions presented in synthetic speech.

## **4.5 Interface Design of DAHNI-1**

### **4.5.1 Basic Reading, Navigation and Output Control**

From the many possible commands for reading, navigation and output control (as illustrated in the review of related systems in Chapter 2), a small range of commands was selected by the researcher, intended to provide the fundamental commands required for working non-visually with hypermedia material. The design of these nine commands and related issues are described in the following sections.

#### **4.5.1.1 The 'Unit' Concept**

Evaluations of the mock-ups had indicated that participants were generally happy to receive one chunk of information at a time, rather than the whole node, although presenting only short phrases and stopping the output before and after the links was considered too disruptive. One solution would be to provide separate reading commands for reading different sized chunks (for example, character, word, paragraph, whole node) although this was not considered useful for novices since they would have to learn a large number of commands. An alternative solution is the concept of a 'unit', such that each reading command outputs one unit, with for example, a paragraph set as the default unit size, and the user could change the unit size at any time. This means that a node can contain any number of units.

For DAHNI-1 it was not possible to use real-time text-to-speech conversion to read textual material<sup>3</sup>, and therefore recorded WAV files of synthetic speech were played, so that users might feel as if the system was actually producing real text-to-speech conversion. Each unit/paragraph was therefore a single pre-recorded WAV file (a similar approach is taken with recorded human speech in hybrid books such as the ReadOut program and DigiBook, described in Chapter 2). The 'current unit' is the unit which is currently playing, or has just been played, and can be repeated using the 'Repeat' command described later in Section 4.5.1.5.

---

<sup>3</sup> No text-to-speech program existed for Windows 95 at this stage of the development of DAHNI-1.

#### 4.5.1.2 *Reading Commands*

**‘Speak Right’** and **‘Speak Left’**. The mock-up commands **‘Read Next’** and **‘Read Previous’** were renamed to **‘Speak Right/Left’** in an effort to help users determine the difference between reading units within the same node, and jumping to new nodes using navigation commands. Skimming is possible by executing these commands quickly in succession, which interrupts the current unit and skips to the next unit. If there are no further units to hear when either command is executed, the **‘dead-end’** sound is played **“Uh-Oh”**. The dead-end sound in the mock-ups was **“Boing”**, and for DAHNI-1 **“Uh-Oh”** was chosen as an alternative.

#### 4.5.1.3 *Finding and Selecting Links*

The mock-up evaluations showed that the use of non-speech sounds could be used to identify link words (see Section 4.3.3), although some participants had said that a change in voice would also be acceptable. DAHNI-1 therefore presented links in a higher pitched synthetic voice than the normal reading voice. The innovative **‘current link’** (described in Section 4.3.3.2) is the link contained in the **‘current unit’** - that is, when the user requests the next or previous unit, the link in that unit becomes active and can be selected at any time, even if the link word hasn’t yet been presented. The ACCESS Project authoring tool limited the number of links in each unit to one; this was acknowledged to be an unrealistic scenario for real use, but would allow the assessment of the basic presentation issues and the feasibility of having the **‘current link’** concept.

**‘Select’**. The current link can be followed at any time by selecting it with the **‘Select’** command. Executing this command immediately halts the output, and jumps to the heading of the destination node of the current link. If there is no current link to select (for example, in a node without any links), the dead-end sound (**“Uh-Oh”**) is played when this command is executed.

#### 4.5.1.4 *Navigation Commands*

**‘Back’**. If there are no links in the current node, or the user wishes to retrace their steps through their history, the **‘Back’** command can be used to jump to the heading of the previous node. This was chosen in preference to jumping to the sentence of the followed link (as used in the mock-ups, since that seemed to be disorienting). If there are no previous nodes in their history, then the dead-end sound (**“Uh-Oh”**) is played.

**'Forward'**. Once the 'Back' command has been used to retrace the user's steps through their history, they can re-visit nodes on their history (as long as they have not branched off it), using the 'Forward' command. This places the user at the heading of the next node in their history (or if there is no node for them to go to the dead-end sound "*Uh-Oh*" is played).

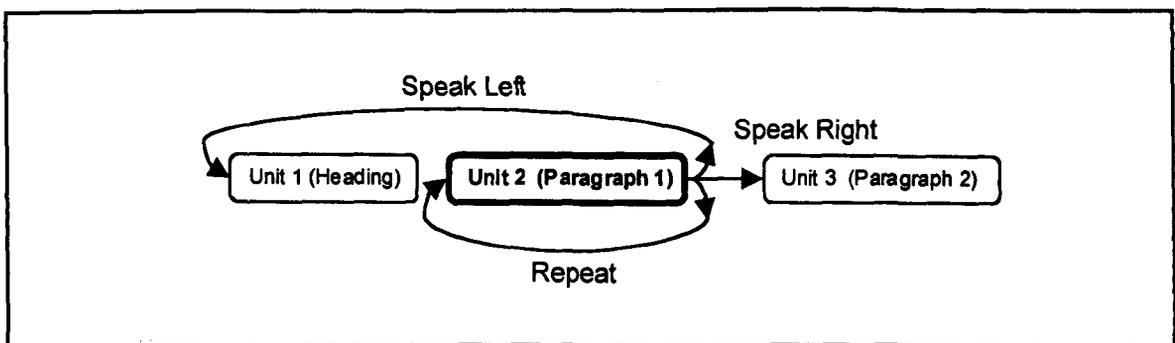
**'Top'**. If users are reading in the middle of a node, they may wish to jump to the top of that node, to re-read the heading for example. The 'Top' command jumps to the first unit of the current node, the heading.

**'Home'**. In order to jump quickly to the starting node, commonly called the home node, the 'Home' command jumps the user immediately to the heading of this first node, providing quick navigation to a known location.

#### 4.5.1.5 *Output Control Commands*

**'Stop'**. Although the output is presented in paragraph-sized chunks, the user must be able to stop the output immediately. Therefore the 'Stop' command halts the output immediately and the playback position is returned to the beginning of the current unit.

**'Repeat'**. In order that users can specify whether they re-read the previous unit or the current unit, separate commands were designed. The 'Repeat' command outputs the current unit again (in comparison to the 'Speak Left' command which jumps to the beginning of the previous unit). The use of the 'Speak Left', 'Repeat' and 'Speak Right' commands is compared in Figure 4.3, where Unit 2 (in the centre) is the current unit.



**Figure 4.3: The Repeat, Speak Left and Speak Right Commands**

### 4.5.2 Potential Commands For Later Versions

A number of other commands were considered useful for navigation and user support which might be implemented in later versions of the prototype, when the initial design ideas had been investigated. It was considered more important however at this point to focus on basic navigation and presentational issues before implementing a full set of commands. However, these more advanced commands might include:

- Exit (to leave the application and return to Windows 95)
- Help (On-line general help, and context-sensitive help)
- Current Link (read out the current link)
- Change Unit (change size of unit from default paragraph to: character, word, sentence, paragraph, whole node)
- Change Rate (change speed of speech output: slow, normal, fast, very fast).
- Editor (for making notes while working, supporting copy and paste for example)
- Bookmarks (allows users to place-hold favourite or important nodes)
- Add Note (annotate a node with users' own comments)
- Find (search for text string in current node, or whole system)
- Print (to an ink-printer, or a braille embosser)
- History List (review node headings and jump to node from list)
- Save (to a local file)
- Find (local search)
- Next/Previous Node (in a Guided Tour or Logical Path specified by the author or teacher)

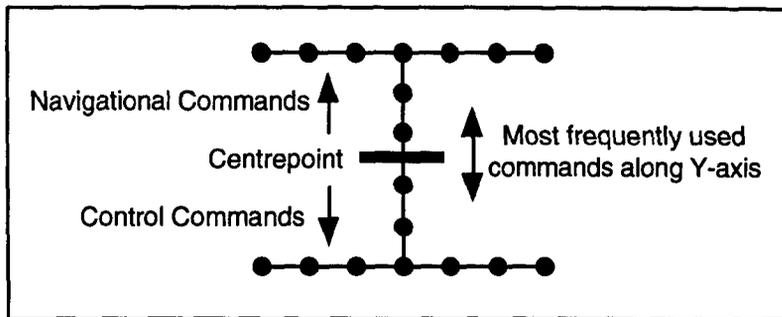
### 4.5.3 Interface Layout: The Workspace

The evaluations of the mock-ups had shown that participants could work with a spatial layout of commands, but in order to locate them easily the commands had to be in organised, marked positions. Although the Function Keys on a keyboard (for example, F1), or shortcuts (for example, Ctrl+H) are common methods for executing commands, these might not be easily learned or located by novice keyboard users, and cannot be easily translated into commands for use with the joystick or touchtablet. Continuing the initial idea of a spatial presentation of commands (which worked well with the touchtablet and joystick), the concept of a 'workspace' was developed: a virtual presentation of commands arranged in a fixed, symmetrical layout. This would allow consistency between the different input devices, helping novices to learn the position of commands, and offering a method for grouping related commands together to aid location of commands.

The workspace began development as a sideways 'H'-shape, with a neutral 'centrepoint' in the middle of the arrangement from which orientation point users would work around the workspace. Centrepoint is in the centre of a vertical column of commands, and at both the top and bottom of the column is a horizontal row of commands. In order to aid quick learning, maximise orientation and minimise memory load, commands were grouped on the workspace according to four principles:

- 1) Related commands are grouped together
- 2) Navigational commands are located above centrepoint
- 3) Control commands are located below centrepoint
- 4) Frequently used commands are located near centrepoint for quick access

Figure 4.4 illustrates the proposed shape of the workspace and the design principles governing the location of commands on the workspace. A layout such as this would support the addition of new commands (especially in pairs, to maintain the symmetry of the workspace). In addition, the shape should be easy to learn and remember, allowing even novice users to locate commands easily with any input device.



**Figure 4.4: Proposed Shape and Organisation of the DAHNI-1 Workspace**

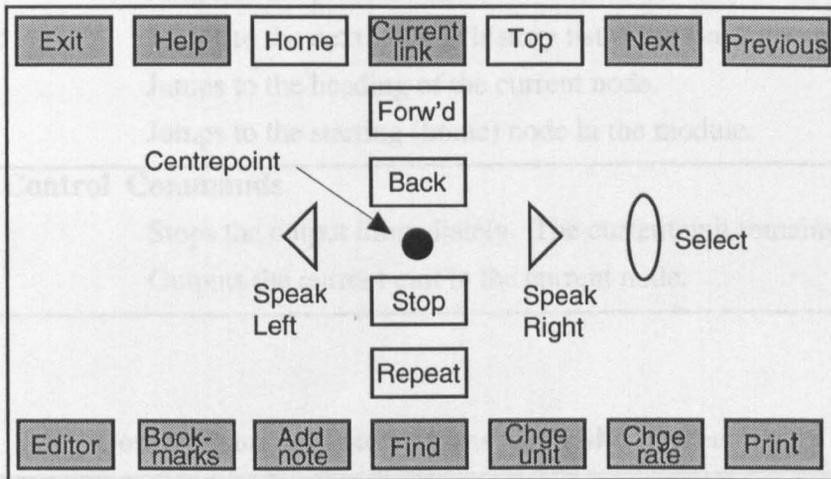
The nine basic commands chosen for inclusion in DAHNI-1 and the commands set aside for later implementation were arranged around the workspace, following the four principles of location outlined above: navigational commands were positioned above centrepoint (Home, Top, Back and Forwards); reading commands are either side of centrepoint (Speak Left and Speak Right) - and for the touchtablet overlay, the Select command is to the right of centrepoint to match the keyboard layout of the <Return> key; and control commands are below centrepoint (Stop and Repeat). The resulting configuration is illustrated in Figure 4.5 (commands in grey were non-functional commands which could be implemented in a later version of DAHNI), and the nine implemented commands are listed in Table 4.2 with a description of their functions.

#### 4.5.4 Using the Workspace with the Three Input Devices

The workspace was designed specifically to be semantically consistent across the three input devices, and therefore the method of interaction with the commands on the workspace was designed to be appropriate for each device, but also consistent with other devices. In this way, it was intended that users (particularly novices) could easily swap between the devices, and easily transfer their knowledge of using the workspace with one device to another, with minimal training and experience.

Users are placed at centrepoint, the neutral point in the middle of the workspace, and can read through the hypermedia material, or explore the commands on the workspace using its spatial layout. As each command is reached it is spoken in a digitised human voice, and becomes the 'active command', which can then be executed with the 'Select' command. A digitised human voice was used to present commands to maintain distinction of the

interface and content material. When the centrepoint position is reached, a non-speech sound “Ping” is played to confirm the location as a type of auditory landmark (a term used by Arons 1993, 1997 whose system provided a sound cue when returning to a normal skimming speed). Users can jump quickly to centrepoint for re-orientation while exploring the workspace. If the user tries to move in a direction where there are no further commands, the dead-end sound “Uh-Oh” is played. To allow easy comparison across the three devices, the methods of interaction with each input device are presented in Table 4.3.



**Figure 4.5: The DAHNI-1 Workspace**

For use with keyboard, joystick, touchtablet. NB: Commands in grey were not implemented; and the ‘Select’ command is only present on the touchtablet overlay (this command is executed with the Trigger button on the joystick and the <Return> key on the keyboard).

Command	Keyboard	Joystick	Touchtablet Overlay
Select Current Link	<Return>	Click trigger while at centrepoint	Double-press on 'Select'
Finding Commands on Workspace	From centrepoint, up/down cursor, left/right arrow	From centrepoint, push forwards/backwards, left/right	Read commands on overlay, single-press-to-left/return
Selecting Commands on Workspace	press <Focus> then on desired command	Hold over desired command and click trigger	Don't double-press on desired command
Return to Centrepoint ('Ping')	<Spacebar>	Release joystick to return position	Find centrepoint marker on overlay

**Table 4.2: The Nine Functional Commands in DAHNI-1**

\* To skim read, execute several reading commands in succession

Command Name	Command Function
<b>Reading Commands</b>	
Speak Right*	Outputs the next unit in the current node.
Speak Left*	Outputs the previous unit in the current node.
<b>Navigation Commands</b>	
Select	Selects the current link & jumps to the heading of the new node.
Back	Jumps to the previous node in the history.
Forward	Jumps to the next node in history list (after Back was used).
Top	Jumps to the heading of the current node.
Home	Jumps to the starting (home) node in the module.
<b>Output Control Commands</b>	
Stop	Stops the output immediately. The current unit remains current.
Repeat	Outputs the current unit in the current node.

**Table 4.3: Comparison of Interactions with the Three Input Devices**

Command	Keyboard	Joystick	Touchtablet with Tactile Overlay
<b>Speak Right</b>	<X>	Nudge right	Double-press on 'Speak Right'
<b>Speak Left</b>	<Z>	Nudge left	Double-press on 'Speak Left'
<b>Select Current Link</b>	<Return>	Click trigger while at centrepoint	Double-press on 'Select'
<b>Finding Commands on Workspace</b>	From centrepoint, up/down cursor, then left/right cursor	From centrepoint, push forwards/backwards, then left/right	Read commands on overlay, single-press to hear name
<b>Selecting Commands on Workspace</b>	press <Return> when on desired command	Hold over desired command and click trigger	Double-press on desired command
<b>Return to Centrepoint ("Ping")</b>	<Spacebar>	Release joystick to resting position	Find centrepoint marker on overlay

### 4.5.5 Input Device Specifications

DAHNI-1 made use of a keyboard, a joystick and a touchtablet. The standard keyboard (either on a desktop PC or on a laptop) had tactile markers on the keys for controlling using DAHNI-1: the <X> and <Z> keys, the arrow cursors and the <Return> key. A standard Microsoft games joystick was used. A custom-made touchtablet (designed and produced by ACCESS partner MA Systems and Control Ltd) was used with a pressure-sensitive membrane reacting to both single and double presses. The sensitive area of the touchtablet measured 25cm by 21cm, with a wooden border of 6cm on each edge. However, the touchtablet was not fully functional at the time of the evaluations and therefore had to be used with a Wizard-of-Oz type procedure, with the researcher copying the user's commands on the touchtablet on the computer keyboard. All three devices are shown in Figure 4.6.

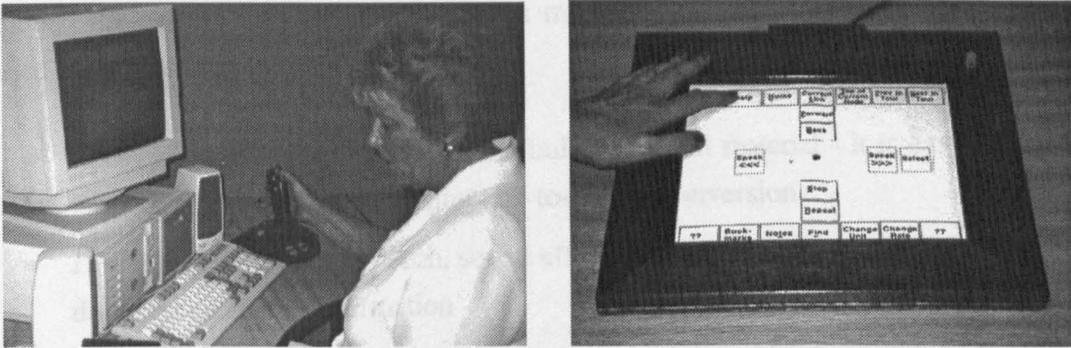


Figure 4.6: The Keyboard, Joystick and Touchtablet used with DAHNI-1

## 4.6 Hypermedia Content

The hypermedia content for use with DAHNI-1 was designed to investigate the different presentation methods possible for use with blind students, and to explore one particular structural model - an encyclopaedia-type hypermedia. This design choice partly reflected the structure of many CD-ROMs available for educational (or edutainment<sup>4</sup>) purposes, and was also determined by the ACCESS Project hypermedia authoring tools which were more suited to developing short nodes in a web structure than sequential pages of information with several levels of heading as might be found in a hypermedia textbook for example.

<sup>4</sup> Edutainment is the term sometimes used to describe hypermedia applications which provide educational material in an entertaining format (Nielsen 1995).

The term 'hypermedia module' was used to refer to the collection of material about a particular topic, such as might be found on a CD-ROM. A module is made up of a number of nodes (for example, one might think of a Help module, a Geography module, or a Business Studies module). The tools created in the ACCESS project used to implement the hypermedia material restricted the structure and organisation of the module, and these limitations are outlined later in Section 4.7. Nevertheless, the tools did allow the creation of a small hypermedia module making use of different presentation methods. The following sections present the design choices for the hypermedia module used with DAHNI-1.

#### **4.6.1 Presentation Methods**

The requirements for the presentation of the hypermedia content to be used with DAHNI-1 included the use of a range of presentation methods designed to make the information varied and interesting to listen to:

- *Text*: synthetic speech used for the bulk of textual material - it is easy to generate large amounts of materials using text-to-speech conversion
- *Digital Audio*: human speech, sound effects, music clips - adds variety, clarity and dramatic quality to information
- *Pictures*: with descriptions read in synthetic speech and tactile pictures - to illustrate for example, photographs and fine art, adding variety and additional information to textual material.

#### **4.6.2 Structure of Hypermedia Content**

A small hypermedia module was developed about the history of London; 'A London Double Decker Bus Tour' with an encyclopaedia-type structure, consisting of nine nodes of different media (see Figure 4.7). The first unit in each node is the main heading of the node. Headings are considered important as signposts to the content of a node, and are presented as an individual unit so that users are given a short piece of information when arriving at a new node, rather than presenting the next unit immediately. This allows users the chance to consider whether to read into the node or to go back to the previous node. However, the ACCESS tools permitted only one heading in a node, at the start of each

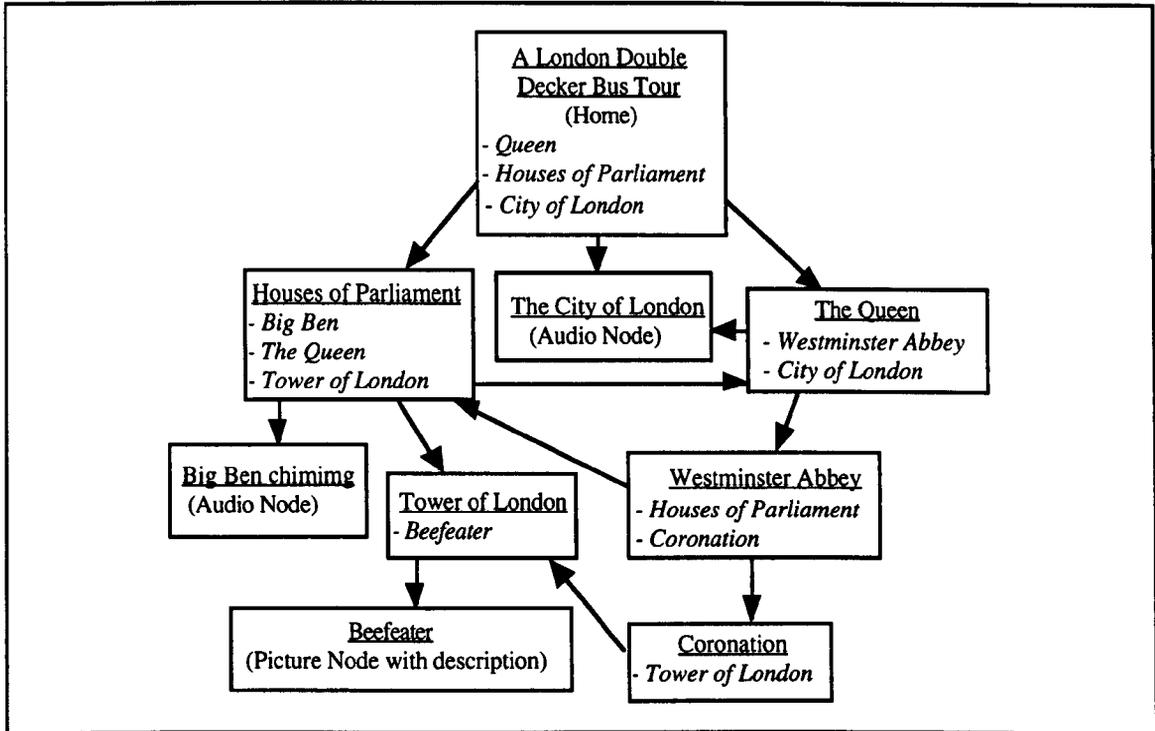
node; and only one link from each unit; no links were permitted from audio or picture nodes; and nodes consisting of only one type of media (that is, text, audio or a picture description)<sup>5</sup>.

The six textual nodes consisted of 1-7 units, and although each unit could contain one link (or no link), most textual nodes contained between 1 and 3 links. There were two audio nodes (of two units each - a heading and the content), containing an audio clip of Big Ben chiming, and an interview about the City of London with office sound effects, and one picture node containing a description of a Beefeater presenting details about his uniform. The accompanying tactile picture of the Beefeater was drawn freehand on swell-paper with the Erika 'Thermo-Stift' heat pen, indicating the important parts of his uniform and the verbal description presented the detail of the picture (see Figure 4.8).

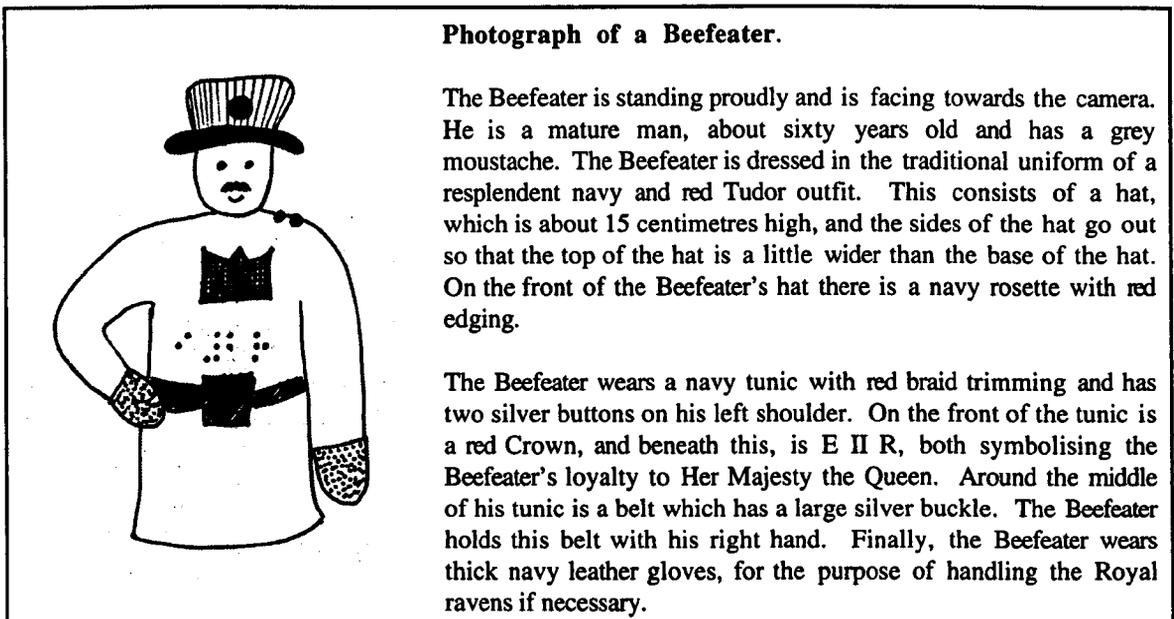
These nine nodes were linked together in a small web structure, starting from a home node containing three links, illustrated in Figure 4.7 (where node headings are underlined; links from the node are shown in italics and arrows indicate the destination nodes; and the audio and picture nodes are labelled).

---

<sup>5</sup> The restrictions of supporting only one link per unit, and the inability to support a mixture of media in the same node are not considered to be critical to the assessment of fundamental interaction and presentation methods. However, in a finished product, the ACCESS tools would eventually have to allow the creation of more than one link in a unit, and a mixture of media within one node.



**Figure 4.7: Structure and Content Overview of the Hypermedia Module "A London Double Decker Bus Tour" used with DAHNI-1**



**Figure 4.8: Tactile Picture and Verbal Description of a Photograph of Beefeater**

### 4.6.3 Sample Output

The reading commands have been described earlier, and Figure 4.9 illustrates the output from the home node, of four units, starting from the heading. The output stops at the end of each unit, marked with (Stop), and the links (presented in a higher-pitched voice) are shown underlined.

A London Double Decker Bus Tour. (Stop)

Edward the Confessor was King of England between 1042 and 1066 and made London the official capital of England. Since that time, London has been the main home of the Royal Family and the Queen (Stop)

London is also the seat of British Politics. The Houses of Parliament are strategically situated overlooking the river Thames and comprise two Houses: The House of Commons and The House of Lords. (Stop)

The historic division between London's centres of commerce and government occurred when Edward the Confessor established his court in Westminster and the tradesmen set up institutions and guilds in a small area known as The City of London. (Stop)

**Figure 4.9: Output of the Home Node from “A London Double Decker Bus Tour” Hypermedia Module**

## 4.7 Limitations and Justifications

For these investigations into non-visual access to hypermedia material, the use of a stand-alone system has both advantages and disadvantages. The benefits of designing a stand-alone system are that it can be used in isolation from existing applications which might be troublesome in their own right - for example, trying to provide non-visual access to an existing Windows-based web browser would involve many layers of complexity which are not essential to understanding non-visual interaction with hypermedia material. Similarly, issues of badly written, inaccessible web pages further compound the issues of non-visual browsing. In addition, users do not have the cognitive overhead of learning the Windows environment in order to test this prototype. However, DAHNI-1 as a stand-alone application (under Windows 95) with its own interface and controls, has the drawback of being inconsistent with the look and feel of other Windows applications. Although this is unimportant while investigating the issues of non-visual access to hypermedia material, this would become important if the prototype is developed for marketing in the real world, where consistency across different applications is becoming increasingly important.

The design of DAHNI-1 is limited to the nine most basic commands which were considered to be fundamental to auditory navigation and control of hypermedia. Although the addition of many other commands might be useful and supportive (in some cases even essential) when using a larger hypermedia module or when working with material on the WWW, these nine basic commands were chosen and implemented to assess basic navigation and control issues before spending significant effort on designing and implementing further commands. The hypermedia module 'A London Double Decker Bus Tour' used with DAHNI-1 contains a mixture of textual, audio and pictorial nodes, however, it consists of only nine nodes. Although there is some cross-linking to make this a web-like structure, the hypermedia module is limited because of its size and its relatively restricted amount of content. Nevertheless, this is considered beneficial rather than a problem, since by using a small but realistic hypermedia module, users are less likely to be concerned about navigating through a large information space, and the focus of the investigation can remain on basic navigation and control commands.

As already described, the ACCESS Project authoring tools imposed a number of restrictions on the structure and presentation of the content material, leading to hypermedia nodes which were not quite typical of nodes which might be found on CD-ROMS or on the WWW. For example, nodes could contain only one heading at the start of the node; each unit could contain only one link; audio or picture nodes could not contain links; and the speech output paused slightly both before and after the link word. These issues would not pose a problem at this early stage in the investigations into non-visual access to hypermedia material, but would not be appropriate if the prototype was developed into a marketable product. In summary, although there are a number of limitations on the structure and presentation of the hypermedia material because of the ACCESS tools, the resulting hypermedia module and non-visual interface DAHNI-1 are sufficiently functional and representative to allow an assessment of the basic navigation and control commands and of the different presentation methods for hypermedia material for blind students.

#### ***4.8 Coming Next...***

The following chapter presents the evaluation of DAHNI-1 using the evaluation methodology described in Chapter 3 to assess: the usability of these nine commands; the three input devices; and the various presentation methods for the hypermedia content. The desired outcomes from these evaluations are recommendations to improve the design.

## **5 Evaluation of DAHNI-1**

## **5.1 Chapter Overview**

This chapter presents the evaluation of DAHNI-1 by seven blind and partially sighted students, using the evaluation methodology developed for assessing the usability of non-visual interfaces described in Chapter 3 in order to identify and explain user problems and to develop design solutions. Usability issues were explored in four key areas: general usability; usability of the workspace; usability of the three input devices (keyboard, joystick and touchtablet); and the presentation of links and the hypermedia material. Results indicate that DAHNI-1 has some useful design features for interface presentation and interaction with the three input devices, although recommendations are made to improve the usability of the commands, input devices and the hypermedia content.

## **5.2 Introduction**

As described in Chapter 3, DAHNI-1 consisted of nine basic reading, navigation and output control commands (as listed in Chapter 4, Table 4.2), to be used with a small hypermedia module consisting of nine nodes about the history of London (see Chapter 4, Figure 4.7). DAHNI-1 was evaluated following the evaluation methodology described in Chapter 3 developed specifically for the purpose of assessing the usability of non-visual interfaces, with the emphasis on examining the usability of each feature of the prototype. The goals of the evaluation were to identify usability problems and attempt to explain why users were having problems, in order to develop solutions to overcome these problems.

### **5.2.1 Features to be Evaluated**

The main aims of these evaluations were to investigate:

- 1) *The usability of the overall interface:* in terms of ease of learning to use, ease of use and enjoyment. If DAHNI-1 is usable and liked by the student participants for whom it was designed, who will have a range of skill and experience, the basic design principles should be maintained for future versions. Problematic areas can be re-designed or refined on the basis of these evaluations.

- 2) *The usefulness of the workspace concept.* The workspace was designed to provide a consistent interface for use with three input devices, and as an alternative to traditional function key or menu-driven interfaces which require a reasonable knowledge of the keyboard layout, and often more considerable computer experience to use - skills which some blind and partially sighted students do not have. Therefore if the workspace is shown to be supportive and effective for the most inexperienced participants as well as usable by the more experienced participants, the concept will remain as a feature of the interface.
- 3) *The usability and effectiveness of the commands.* The nine basic commands were designed to involve simple interactions to allow fundamental navigation and control when working non-visually with hypermedia. It is important to investigate how easy to use and to learn they are, and how effective they are at allowing users to work non-visually with hypermedia material. Both observed behaviours and subjective opinions will be used to identify problem areas allowing the researcher to speculate on possible causes and offer suggestions for improvement.
- 4) *The usability of the three input devices.* The keyboard, joystick and touchtablet were implemented to allow participants to move around the commands on the workspace and execute commands in simple and consistent ways even if they were not experienced computer users. The usability of the different input devices will be examined to determine firstly whether it is worth continuing to make use of a range of input devices, and secondly whether the implementations are usable.
- 5) *The presentation of links and hypermedia material.* It is important to establish whether links can be effectively presented using the change in pitch, and selected using the 'current link' concept, and whether the presentation of material in paragraph-sized units with nodes of different media is useful for blind and partially sighted students.

## **5.3 Method**

### **5.3.1 Design**

A sub-set of the evaluation methodology presented in Chapter 3 was applied, with each participant undertaking a briefing and training session, and then being observed completing a series of set tasks, in an informal think-aloud setting. Participants were then interviewed about various aspects of the design and implementation of DAHNI-1 using an evaluation

questionnaire involving questions and rating scales addressing the usability of each aspect of DAHNI-1.

### **5.3.2 Participants**

Participants were selected to be representative of the target end-user group for DAHNI-1: blind and partially sighted students at secondary school or in further education, aged 11 years and up. Seven students were selected from schools and institutions expressing an interest in the research, who had a range of computer experience. Their personal characteristics were gathered using the Participant Characteristics Questionnaire (see Appendix 1.1), and their full details are reported in Table 5.1, and summarised below.

#### ***5.3.2.1 Age, Gender, Level of Vision, and Braille Experience***

Seven participants took part, aged between 12 and 17 years ( $\bar{X} = 15$  years 10 months,  $sd = 1.64$ ), including five males and two females (this male:female ratio was a function of the number of students interested in information technology and available to participate). Three participants were congenitally blind, and all were fluent braille readers. Three participants were congenitally partially sighted, able to read very large print materials, but required screen enlargement software or synthetic speech output to work easily with a computer, and were therefore included in these evaluations also using DAHNI-1 non-visually.

#### ***5.3.2.2 Computer Experience***

None of the participants had evaluated the ACCESS mock-ups, and they had a wide range of computer experience; from as little as 1 year up to 6 years (mean length of computer experience was 3 years, 5 months,  $sd = 1.99$ ). Many participants had started to use computers at the age of 10, and only two participants did not know the layout of a computer keyboard well enough to touchtype. Many participants had experience with a range of applications, although few had any direct experience of web browsing or CD-ROMs. Two of the three partially sighted participants regularly used talking non-visual programs such as word processors and dictionaries. Five participants had used a joystick before (mainly with games), and two participants had very limited experience with a touchtablet (the Concept Keyboard) with a BBC computer.

**Table 5.1: Participants' Characteristics in DAHNI-1 Evaluations****Key to Abbreviations for Sight:**

C.Bl = Congenitally Blind

A.Bl = Adventitiously Blind

C.PS = Congenitally Partially Sighted

A.PS = Adventitiously Partially Sighted

<b>P #</b>	<b>Sight</b>	<b>Age &amp; Sex</b>	<b>Courses studied</b>	<b>Level of computer experience</b>	<b>Software and devices used</b>	<b>Used Windows?</b>	<b>Internet, CD-ROMS?</b>	<b>Braille / Large Print?</b>
<b>P 1</b>	C.Bl	16 F	GNVQ Business Foundation	Low-moderate, 1yr, touchtypist.	WordPerfect, Dataworks. HAL5, Apollo. KB only.	One session with Windows, Outspoken.	Email. 1 session with a CD-ROM via sighted adult	Hard braille
<b>P 2</b>	C.PS	17 M	GNVQ Business Foundation	Moderate, 3 yrs, not touchtypist.	WordPerfect, Games. Lunar. KB, Mouse, JS.	Several sessions with sighted person.	Email.	Large print/ Screen enlargement
<b>P 3</b>	A.Bl	17 M	GNVQ Business Foundation	Low-moderate, 2 yrs, touchtypist.	WordPerfect, Spreadsheet Works. Eureka, Jotta, HAL5, Apollo. KB, TT once.	Only heard of Windows	Email. ETNA. Only heard of CDs	Hard braille
<b>P 4</b>	C.Bl	17 F	GNVQ Business Foundation	Moderate, 6 yrs, touchtypist.	WordPerfect, Games. HAL5, Apollo. KB, JS.	Only heard of Windows	CD-ROM via sighted adult	Hard braille
<b>P 5</b>	C.PS	16 M	GCSE's	Experienced, 4 yrs, touchtypist.	WordPerfect, ClarisWorks spreadsheet, drawing, games. KB, JS, TT.	Mac and IBM: Out-Spoken for Mac, large display for IBM.	Netscape, email, FTP software/files for work/ games. CD-ROMS: Encarta, games.	Large print/ Screen enlargement
<b>P 6</b>	C.PS	16 M	GNVQ Catering Foundation	Experienced, 6 yrs, not touchtypist.	ClarisWorks wordprocessor, games. KB, JS.	1 yr using Windows, using screen enlargement	Email, Netscape, CD-ROMS on Mac and IBM, Encarta, games.	Large print/ Screen enlargement
<b>P 7</b>	C.Bl	12 M	pre-GCSE, 12 subjects	Experienced, 2 yrs, touchtypist.	WordPerfect, 1 game, programming, and sound effects on BBC. HAL, Apollo. KB, JS (rarely).	Some sessions with sighted person.	Netscape with sighted person to download e-books. Wildlife and Encarta CD-ROMS via sighted adult	Hard braille

### 5.3.3 Hardware

The evaluations were run on a Pentium 100MHz laptop, with an 810MB hard disk, 16MB RAM, and a SoundBlaster-compatible soundcard. A standard Microsoft games analogue joystick was attached. The eight keyboard keys required for DAHNI-1 commands were made obvious using tactile and large print symbols. The custom-built touchtablet was not ready for connection to DAHNI-1 and was therefore tested using a type of 'Wizard-of-Oz' technique (described in Chapter 4, Section 4.5.5).

### 5.3.4 Materials

#### 5.3.4.1 *Tactile Diagrams and Pictures*

Tactile diagrams were designed to illustrate the concepts of hypermedia, such as nodes linked together forming a web-structure, and the structure of an individual node broken into a heading and units. The tactile overlay for the touchtablet indicated the position of the commands on the workspace with braille labels, in the layout shown in Chapter 4, Figure 4.5. The picture node (of a Beefeater) was illustrated using the tactile line diagram on swell-paper (see Chapter 4, Figure 4.8), to be explored when listening to the description of the picture.

#### 5.3.4.2 *Training Schedule*

The briefing and training schedule covered basic hypermedia concepts and details about how to use DAHNI-1. The training schedule covered the following topics:

- 1) Introduction of concepts underlying hypermedia using terms and analogies appropriate to the knowledge and experience of each participant. Includes reference to CD-ROMs, WWW, nodes and links, and the concept of a 'unit' of information.
- 2) Presentation of the layout of commands on the workspace, illustrated by the tactile or large-print diagrams.
- 3) Introduction of the three input devices and how they are used with the workspace.

- 4) Demonstration of one of the three input devices to move around commands on the workspace and to select commands. The order of presentation of the input devices is balanced to control for order effects which might affect later device preference.
- 5) Participant to practise each of the nine implemented commands while working through the hypermedia module, in the following order: 'Home', 'Speak Right', 'Speak Left', 'Select' (link), 'Top', 'Back', 'Forward', 'Stop', 'Repeat'.
- 6) Participant to repeat all nine commands in the same order using the remaining input devices (with continued balanced ordering of device presentation).
- 7) Participant allowed to practise or repeat any aspects as required.

#### **5.3.4.3 Evaluation Tasks**

Standard evaluation tasks were constructed so that they formed a reasonably coherent set of realistic activities using only the implemented nine commands. The tasks used were directive and explicit (as described in Chapter 3), since with so few commands and a small hypermedia module there was little possibility for participants to work more freely. Three sets of tasks were devised (one for each input device) which required the use of each command and which would allow the participant to experience the different types of node contained in the hypermedia module. An attempt was made to make the sets sufficiently different that the tasks would not become boring; however, given the small size of the hypermedia module this was almost unavoidable. Questions about the content of the node were also included to encourage participants to listen carefully to the output, and which might require the use of additional commands to answer.

Each set of tasks contained between 7 and 10 sub-tasks presented using standard wording and in a balanced order to avoid bias and order effects. The full set of three tasks is given in Appendix 1.2, and Task 3 is presented in Table 5.2 as an example, together with the commands required.

**Table 5.2: Example of Evaluation Task for DAHNI-1 (Task 3)**

Sub-Tasks	Commands Required
Let's check we are at Home.	HOME
In this node there's a link to the City of London in the third unit, please read through and select it. You may want to skim past the first two units.	SP>> (Speak Right) SP>> SP>> SELECT
Let's hear the City of London node.	SP>>
Try and see if there are any more units in this node.	SP>>
You can only go back to the previous node - can you do this?	BACK
We are back in the Home node can you read through until you come to the Houses of Parliament link, and select it?	SP>> SP>> SELECT
Can you read through and select the link to the Queen?	SP>> SP>> SELECT
Q: In what month was the Queen born? Q: What was the link?	REPEAT or SP<< (Speak Left) then SP>>
Follow the link to the Abbey.	SELECT
Read through the first unit.	SP>>
Q: What was the link?	REPEAT or SP<< then SP>>
We've already been here, so we won't follow it but can you confirm the heading of this node?	TOP or <<SP
Let's go back Home.	HOME

#### 5.3.4.4 Evaluation Questionnaire

The evaluation questionnaire was developed following the methodology described in Chapter 3, and is presented in full in Appendix 1.3. The questionnaire was presented as a semi-structured interview, and covered the following topics:

- Overall usability: ease of use, ease of learning, and enjoyment of using the system
- Usability of the workspace
- Usability of the three input devices (keyboard, joystick, touchtablet)
- Methods of presenting links (both current and potential methods)
- Methods of selecting links
- The use of synthetic speech
- Interface presentation (digitised commands)
- Methods of presenting hypermedia content: digitised nodes, sound effects, descriptions of pictures and tactile pictures

Both open and closed questions were included, with many questions requiring an additional rating on a 1-5 Likert rating scale (1 = low, 5 = high) to indicate the participant's strength of feeling about an issue.

### **5.3.5 Measures Taken**

Task performance was observed and noted in detail by the researcher concerning the method chosen by the participant, problems they experienced, comments they made, and suggestions for why participants may have been confused or what they may have misunderstood, and the sessions were also video-taped (with permission). Participants' comments during the questionnaire-interview were recorded in detailed notes and were later combined with the think-aloud comments. The rating scales offered a means of measuring the extent of severity of each usability issue.

### **5.3.6 Procedure**

Each participant completed an individual training session and evaluation session, which together lasted around two hours including a break period. The sessions were conducted in a quiet room at the participants' school, college or home. Participants were encouraged throughout the training and evaluation session to: test their own ideas and to think aloud; to explain what they were doing; to ask questions and make suggestions when they thought of them; and to be openly critical and say which features they liked and disliked.

#### ***5.3.6.1 Introduction and Training Session***

The session began with a briefing session, followed by the collection of personal data using the Participant Characteristics Questionnaire (see Appendix 1.1). This was followed by a training session (using the training schedule outlined in Section 5.3.4.2). The order of task presentation during training was counter-balanced to avoid order effects. As described in Chapter 3 participants were asked to think-aloud during the training session, and to ask questions and give comments when they thought of them. After practising using DAHNI-1, participants were given a short break.

### **5.3.6.2 Evaluation Session**

Although participants included both blind and partially sighted students, everyone used DAHNI-1 non-visually relying on the auditory output alone. After the break participants were asked to recall how DAHNI-1 worked, and any additional revision or practice was conducted as necessary to ensure that participants were comfortable using the prototype and each device. The evaluation session then began with one of the three tasks (see Appendix 1.2) with one input device, and the remaining two tasks were completed with each of the other input devices. The order of tasks and input device presentation was counter-balanced, and at the start of each task with a new device participants were asked to summarise how the device was used. Neutral prompts were used if a participant could not continue unaided, or if they had stopped thinking aloud. Once all three tasks had been completed the participant was interviewed using the Evaluation Questionnaire (see Appendix 1.3). At the end of the evaluation participants were debriefed, and any remaining issues were discussed.

### **5.3.6.3 Personnel**

For the reasons given in Chapter 3 two researchers alternated conducting the training and evaluation sessions (the principal researcher and a supporting researcher). While one led the session and took detailed notes, the other observed and also took detailed notes. Both researchers had been involved in the design of DAHNI-1.

## **5.4 Results and Discussion**

Participants' task performance, their think-aloud comments and their responses on the questionnaire have been combined and are reported together. The mean ( $\bar{X}$ ) and standard deviation ( $sd$ ) of their ratings are given, together with the spread of the ratings. This data is given here rather than in an Appendix for ease of reference. Where comments from specific participants are included, the participant numbers will be given in brackets, for example (P1, P6). Most ratings are from 7 participants ( $n = 7$ ), and where different, the number of participants is stated. Raw data of participants' ratings is available from the researcher.

### 5.4.1 Ratings of Blind and Partially Sighted Participants

The ratings of blind and partially sighted participants did not differ significantly on the three main usability questions (easy to use, easy to learn, and enjoyable) shown by a Mann-Whitney U-test on the summed ratings on these three questions ( $U = 4.5$ ,  $p = 0.6286$ ). On the basis of this equivalence (and the small number of participants), the ratings of blind and partially sighted participants are combined throughout this chapter. If any differences between the performance or ratings of blind and partially sighted participants emerged during the evaluations, they are reported where relevant.

### 5.4.2 Overall Usability

Participants rated the system as fairly easy to use, fairly easy to learn, and gave fairly high enjoyment ratings, as shown in Table 5.3. These differences were not significant (Friedman chi-square = 1.1429,  $df = 2$ ,  $p = 0.5647$ ), and a combined mean usability score of 4.38 (0.22) indicates that DAHNI-1 was considered very easy to use.

**Table 5.3: Mean Ease of Use, Ease of Learning and Enjoyment Ratings**

General Usability	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Ease of Use	4.14 (0.90)	2	2	3
Ease of Learning	4.57 (0.53)	-	3	4
Enjoyable	4.43 (1.51)	1	-	6
<b>Combined Mean</b>	<b>4.38 (0.22)</b>			

Several participants felt that DAHNI-1 was very easy to learn to use and to use because it was so simple and easy to remember since the workspace diagram (or the tactile overlay for the touchtablet) helped them to learn the layout of commands (P1, P4, P5, P6, P7). Several participants mentioned that they would be more comfortable if they had more practice with DAHNI-1 (P3, P6). Most participants commented that the system was at least as easy to learn to use and to actually use as the applications they were already using for reading electronic documents. The single low enjoyment score was given by a partially sighted participant, who said that he found the WWW and CD-ROMs more interesting and enjoyable to use than the small hypermedia module provided with DAHNI-1. All the other participants said that the system was very enjoyable, particularly because of the non-speech

sounds, sound effects, digitised voices and different input devices which made the system more interesting and varied to listen to and to use compared with other applications they were familiar with.

#### *5.4.2.1 Effective Command Use*

Participants were observed to be able to remember the function of most of the implemented commands, and generally used them correctly across devices. This was particularly evident with certain commands: 'Speak Right' and 'Speak Left', 'Home', 'Stop', 'Select' and 'Forward'. In addition most participants had a good understanding of the arrangement of commands on the workspace, and were able to locate commands easily. By the end of the session many participants (both experienced and the less-experienced computer users) were using efficient methods for operating the system. For example, participants were observed to:

- Skim read through units using successive 'Speak Right' and 'Speak Left' commands.
- Use the 'Stop' command to interrupt the output once they had heard the required information rather than waiting and listening until the very end of the unit before selecting the link.
- Know the locations of specific commands and get to them very quickly without having to explore around the workspace.
- Use the 'Repeat' command to output the current unit when they had not heard particular information in the current unit.
- Use the 'Top' command to jump to the heading of the node instead of successive 'Speak Left' commands.
- Use the <Spacebar> to get back to centrepoin when exploring the workspace with the keyboard, rather than working around the shape back to centrepoin.
- Use 'Back' and 'Forward' more confidently with practice. The implementation of returning to the heading of the previous or next node seemed to be more effective than the mock-up method of returning to the unit from which the link had been selected, and participants using DAHNI-1 were not confused or disoriented.

#### 5.4.2.2 *Command Confusion*

Despite the fairly high ratings for ease of use the differences between some of the commands were clearly difficult for some participants to remember, and some commands were observed to be easily confused, for example:

- Instead of using the 'Repeat' command to output the current unit again some participants tried to use 'Back' (jump to previous node), or 'Speak Left' (read the previous unit in the current node).
- Instead of using 'Speak Right' to read the next unit in the current node some participants tried to use 'Select' (which follows the current link).
- Instead of using 'Top' to jump to the heading at the top of the current node, sometimes participants tried to use 'Back' (which jumps to the previous node) or 'Home' (which jumps to the Home node).

These problems seemed to be partly caused by a mis-match between the command name and its function (a problem of not 'speaking the user's language' in Nielsen's terms, Nielsen 1994d) such that users could not easily associate the appropriate command with a task they wished to achieve. This problem may also have been caused by a lack of structural information about a participant's position within the node; for example, if a participant heard a heading and thought it was a link, they would use the wrong command to hear the next unit.

**Recommendations:** (a) Some of these commands should be re-named to make their function more obvious and more closely related to the users' view of how the system works, for example; 'Top' to 'Go To Heading'; and 'Repeat' to 'Read Current Unit'. (b) The training procedure should address these commands in more detail. (c) The use of non-speech sounds might be beneficial to provide structural information about the node without interfering with the content of the node to help orient users within the node and to help them determine which command to use. For example, a different sound could be used to indicate a heading, a link, and to reinforce reading movements within nodes and larger navigational jumps between nodes. (d) Another possible aid to orientation might be the use of a command providing an overview of the structure of the node; for example, giving the heading, the number of units and links. This is information which sighted users obtain merely by glancing over the page, and this type of command might help blind users obtain

a similar overview. A similar approach was later used in the non-visual WWW browser, pwWebSpeak (see Hakkinen & De Witt 1996).

### 5.4.3 Usability of the Workspace

#### 5.4.3.1 Usefulness of the Workspace

Participants were somewhat positive about the usefulness of the layout of commands over the workspace, see Table 5.4.

**Table 5.4: Ratings for Usefulness of Workspace**

Usability Question	$\bar{x}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Usefulness of layout of commands on the workspace	3.86 (1.35)	1	4	2

Most participants were observed to be confidently working around the workspace, although they occasionally forgot the exact location of some commands. Participants said that it was generally easy to find commands just by exploring even if they were not familiar with the keyboard layout (P2, P6) which made DAHNI-1 very easy to use, and P6 even felt that it was much easier than menus or shortcut keys. However, some participants felt that it was difficult to find commands, particularly with the joystick (P5, P7) - see next section - and P5 also said that there seemed to be a lot of wasted space on the touchtablet and suggested that commands should be closer together so they were easier to find<sup>1</sup>. Problems were observed concerning the layout, when certain commands were not located where participants expected them to be: for example, participants sometimes tried to find the 'Back' command behind (back from, or below) centrepoint; especially when using the joystick; and the 'Home' command which was used quite frequently was a long way from centrepoint, making it time-consuming to find and select this command.

**Recommendations:** (a) The workspace clearly has benefits, especially for inexperienced computer users, although the workspace could be reduced in size for more efficient use with the touchtablet. (b) Commands should be arranged so that users can make intuitive

<sup>1</sup> The problem was the *size* of each command on the touchtablet, rather than the presence of non-functional commands on the workspace; indeed more experienced participants were relieved to see that further commands were planned.

guesses about their location, for example, 'Back' should be below centrepoint, and 'Forward' symmetrically in front of centrepoint; and commands used frequently such as 'Home' should be nearer centrepoint.

#### 5.4.3.2 Effectiveness of Workspace with Different Input Devices

The shape of the workspace is largely consistent when used with the three input devices, and participants were observed to be generally successful in transferring their knowledge of the workspace from one device to another, and liked this feature of DAHNI-1 (P1, P3, P5, P7). However, the location of three commands was not consistent across the three input devices - 'Speak Right', 'Speak Left', and 'Select' - which differed slightly due to the physical nature of the different devices. Participants were sometimes initially confused about how to find and execute these three commands when working with one device after another, although this problem diminished with practice.

**Recommendation:** If the location of the 'Select', 'Speak Right', and 'Speak Left' commands cannot be made consistent across all three input devices, the training procedure will have to specifically address the different position of these commands to make them more memorable.

#### 5.4.3.3 The Dead-End Sound

The dead-end notification (using the non-speech sound "Uh-Oh") was rated as being very useful when navigating around the commands on the workspace, see Table 5.5.

**Table 5.5: Ratings for Usefulness of Dead-End Sound**

Usability Question	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Usefulness of Dead-End Sound ("Uh-Oh")	4.86 (0.38)	-	1	6
Likeability of the "Uh-Oh" Sound	4.71 (0.49)	-	2	5

Participants said that the sound was very useful since it was a quick way of signalling a dead-end without the need for a longer verbal message or having to repeat the current command name (P1, P3, P6, P7). Participants also said that it was easy to learn the meaning of the sound (P3, P6) and they liked the actual sound used (see Table 5.5) which many found amusing. Alternative sounds proposed by some participants included: glass

smashing, a bump, a buzzer, a ping or beep, or simply repeating the command name. One drawback with this particular “*Uh-Oh*” sound is that for some participants in some situations it was observed to have a negative connotation making them nervous and uncomfortable (P1, P3, P6). A simple solution would be to allow users to choose their own sounds. The dead-end sound was also observed to be an effective means of reinforcing the layout of commands on the workspace while exploring, as well as providing immediate feedback.

**Recommendation:** The dead-end sound is obviously useful, although individual preferences for the sound used should be supported.

#### 5.4.3.4 Digitised Speech for Commands

The use of digitised speech for the commands was rated as being somewhat helpful (see Table 5.6), with several participants saying that it was very important to be able to easily distinguish the commands from the hypermedia material, and the use of the digitised voice made this easy and helped to prevent confusion (P1, P2, P4, P5, P6).

**Table 5.6: Ratings for Importance of Digitised Speech for Commands**

Usability Question	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Importance of having digitised speech for commands	3.86 (1.68)	2	1	4

In addition, the digitised voice was also reported to help relieve the monotony of the synthetic speech output (P2) and was more pleasant to listen to (P7), especially for commands which were heard frequently. However, two participants thought that it was not important to use different voices and said they were happy to use synthetic speech throughout the system (P3, P7). One participant said that they would have liked *all* the hypermedia material to be read in the digitised voice as well (P7).

**Recommendation:** Since most participants favoured the use of digitised speech for commands to maintain distinction between the commands and the hypermedia content, commands should continue to be presented in digitised speech.

#### 5.4.4 Usability of the Three Input Devices

The use of alternative input devices in addition to the keyboard was enthusiastically received by all participants. The keyboard and touchtablet were equally well liked, but the joystick in its current implementation did not have as much appeal. The mean ratings for each device on five usability questions can be compared in Table 5.7, together with the mean summed usability rating for each device (maximum possible = 25) and for each usability question (maximum possible = 15).

**Table 5.7: Ratings for Three Input Devices on Five Usability Issues**

**Key:** KB = Keyboard, JS = Joystick, TT = Touchtablet

Usability Question	Mean Rating for Each Device $\bar{X}$ ( <i>sd</i> )			Mean Summed Question Rating
	KB	JS	TT	
Ease of Learning to Use	4.43 (1.13)	3.57 (1.27)	4.71 (0.76)	12.71 (1.50)
Ease of Reading in Hypermedia Material	4.86 (0.38)	3.71 (1.38)	4.86 (0.38)	13.43 (1.40)
Ease of Selecting Links	4.86 (0.38)	4.29 (1.50)	4.43 (0.79)	13.57 (1.90)
Ease of Finding Commands on Workspace	4.43 (0.53)	3.14 (1.35)	4.29 (0.95)	11.85 (1.68)
Ease of Executing Commands	4.71 (0.49)	3.71 (1.50)	4.71 (0.49)	13.14 (1.21)
<b>Mean Summed Usability Rating for Each Device</b>	<b>23.29 (1.70)</b>	<b>18.43 (6.11)</b>	<b>23.00 (2.58)</b>	

There was no significant difference between the mean summed usability scores on each device (Friedman chi-square = 5.4286,  $df = 2$ ,  $p = 0.0663$ ), although the joystick was obviously the least preferred device. The difference between the mean summed question ratings was also non-significant (Friedman chi-square = 7.0571,  $df = 4$ ,  $p = 0.1329$ ) indicating that DAHNI-1 is fairly easy to use on all five aspects of usability. Each input device is discussed in the following sections.

#### 5.4.4.1 Keyboard

The keyboard was rated as very easy to use on all 5 usability questions (see Table 5.7), and most participants liked the use of the <arrow cursor> keys to explore commands on the workspace, particularly for familiar, frequently used commands - all except P2 and P4 who didn't like using the workspace shape with the keyboard - P4 was an experienced keyboard user, and preferred shortcuts, but P2 was not familiar with the keyboard layout, so this was a surprising response. Participants all liked the simple methods of selecting links with <Return> and while exploring the workspace were observed to use the <Spacebar> to jump quickly back to centrepoint (with the non-speech sound "Ping") to quickly re-orient themselves.

The main problems relating to the usability of the keyboard concern the use of the left-hand to operate the reading keys <Z> and <X> and the right-hand for navigation around commands on the workspace using the <arrow cursor> keys and the use of the 'Select' command <Return>. Despite giving reasonably high usability ratings for the keyboard, the separation of these reading keys and workspace navigation keys were observed to make it difficult for participants to remember which keys to use for which commands and some specifically mentioned this as a problem (P1, P3, P4, P6). The other main problem was caused by the lack of shortcuts for quick command execution, and some participants said they would rather use shortcuts than the arrow keys (P2, P4, and P5 - another experienced keyboard user), whereas others stated that they would like to have both the workspace and shortcuts available to suit them at different times, probably learning the layout first (P1, P3, P6, P7).

Recommendations: (a) The reading keys <Z> and <X> should be re-located to the <arrow cursor> keys to make the reading commands on the keyboard consistent with the positioning of the reading commands with the other devices - either side of centrepoint. (b) Shortcuts for each command should be designed to support fast command execution, particularly for experienced keyboard users. (c) The use of the <Spacebar> and the non-speech sound for getting back to centrepoint should be retained.

#### 5.4.4.2 Joystick

Although it was fairly easy to select links with the joystick (Ps 1-7), and to read through hypermedia material (P1, P3, P6) as shown in Table 5.7, it was observed (and reported by

all participants with vehemence) that it was particularly difficult to control when locating and selecting commands on the workspace. Very fine hand-movements were required, and some participants were not able to achieve this without extensive practice (P1, P4, P6). Similarly, selecting commands was difficult since the user had to hold the joystick steady over the desired command and press the top button on the joystick; again this was something that was difficult for many participants to do, and participants frequently moved the joystick slightly while pressing the button, and thus selected a neighbouring command by mistake. This sensitivity of the joystick caused much frustration amongst almost all participants and slowed down their otherwise successful task performance. Furthermore, after executing a command and releasing the joystick to centrepoint, the system would read out the commands on the workspace, interrupting the flow of synthetic speech output and disrupting comprehension. Nevertheless, most participants were able to look beyond these problems and assess it for its potential, and despite these implementation problems the joystick received encouraging ratings.

**Recommendation:** The implementation of the joystick must be made less sensitive, so that extremely fine hand movements to find commands and steady positioning over a command to select it are not required.

#### **5.4.4.3 Touchtablet**

The touchtablet (in the Wizard-of-Oz situation) was rated as highly as the keyboard on all usability questions (see Table 5.7), and was especially easy to learn to use (P1, P3, P5, P6, P7), and was observed to help reinforce the shape of the workspace. Participants seemed to appreciate the ability to sit back away from their desk and interact with their computer in a more relaxed position. Participants said they liked the distinction between single and double-clicking on commands ( $\bar{X} = 4.71$ ,  $sd = 0.49$ ), where a single click simply outputs the command name, whereas a double-click executes the command. Participants thought that this was helpful for novices when learning the commands, and also for more proficient users who can execute commands quickly without having to hear the command name (Ps 1-7). The main drawbacks with the touchtablet were that it took time to read the overlay to locate commands because of its large size (25 x 21 cm), and that the position of the 'Select' command was not easy to remember (P1, P7) since it was different from the implementation with the joystick and touchtablet. Participants felt that a slightly smaller overlay with full command names (or initials once they were familiar with

the full command names) would be useful to make it faster to find commands. The Wizard-of-Oz type of situation would obviously not have identified technical usability issues, but the potential methods of operation have been tested.

**Recommendations:** (a) The touchtablet should use a slightly smaller workspace, but still provide full braille labels on the overlay, so that it is not so time-consuming to locate commands. (b) A very small device might allow users to easily carry their touchtablet between school and home.

### 5.4.5 Presentation of Links and Hypermedia Material

#### 5.4.5.1 Methods of Presenting Links

Participants found it quite easy to identify links using the current method of a higher-pitched voice (P1, P3, P4, P5, P7) as shown in Table 5.8, and this was the most favoured option closely followed by the researcher's proposed potential methods of playing a tone throughout the link, and playing a sound before the link; although these differences were not significant (Friedman chi-square = 1.5857,  $df = 3$ ,  $p = 0.6626$ ).

**Table 5.8: Ratings for Identifying Links (Current and Potential Methods)**

Usability Question	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Current Method: Ease of Identifying Links in Higher Pitch Voice	4.00 (1.15)	2	2	3
Potential Usefulness of Tone Played while Link Spoken	3.71 (1.38)	2	3	2
Potential Usefulness of Sound Before the Link	3.43 (1.40)	4	1	2
Potential Usefulness of Sound Before and After the Link	3.14 (1.68)	4	1	2

The change in pitch of the synthetic speech seemed effective as a type of auditory highlight in indicating the links, and it was observed that the different voice helped participants to remember the links after they had listened to a whole node (probably due to the distinctiveness of the word spoken in a different voice, Handel 1989). However, the general poor quality of the synthetic speech and the higher pitched voice led to poor pronunciation of the links, making many incomprehensible (P1, P2, P5, P6). The potential use of non-speech sounds would remove the distortion of using a different voice,

and P2 likened the use of a beep before and after the link to the formatting markers such as {start bold} {end bold} in WordPerfect for example, and this idea could be described as an ‘auditory bracket’ around the link. However, some participants were concerned that sounds might be more distracting than a change in voice (P5, P6).

Participants were asked if they had any other suggestions for indicating a link, and several alternatives were put forward: the links could be slower, or louder than the normal speech; or a siren or a tune could be played before, around, or during the link word; and P7 suggested a ‘list all links’ command.

**Recommendations:** Despite the fact that the change in voice was effective at both presenting the link and at helping participants to remember the links in the node, the change in pitch caused too much distortion to be used in future. Non-speech sounds should be tested again (as used in the mock-ups), and the use of tones; or sounds before, or before and after the link could be explored; and ideally the system should be able to support user preferences for the sounds used.

#### 5.4.5.2 Methods of Selecting the Current Link

The current link concept allowed participants to select the link in a unit at any time with the ‘Select’ command. Participants found it very easy to select the current link with all three input devices, as shown in Table 5.9, and the mean ratings did not differ significantly (Friedman chi-square = 0.6429, df = 2, p = 0.7251). A combined mean rating for ease of selecting links indicated that it was very easy to do ( $\bar{X} = 4.53$ ,  $sd = 0.30$ ).

**Table 5.9: Ratings for Ease of Selecting Links with the Three Input Devices**

Ease of Selecting Links	$\bar{X}$ ( $sd$ )	Spread		
		1-3	4	5
Keyboard	4.86 (0.38)	-	1	6
Joystick	4.29 (1.50)	1	1	5
Touchtablet	4.43 (0.79)	1	2	4
Combined Mean	4.53 (0.30)			

Participants were frequently observed to work quickly - to hear the link word and immediately execute the 'Select' command to follow that link without listening to the remainder of that unit, and in some cases participants navigated through material they knew well by selecting the current link even before they had heard it. Most participants did not find the 'Select' link command difficult to execute with any of the three input devices, although in some cases the simplicity of implementation of the command led to participants forgetting the method of execution and being pleasantly surprised when reminded that it involved simply pressing <Return>; or the top button on the joystick; or finding the 'Select' command on the touchtablet overlay. Some participants occasionally forgot the location of the 'Select' command on the touchtablet since this is one of the commands which is not consistent across devices (P1, P5, P7).

**Recommendations:** (a) The 'current link' concept seemed to be an effective method of presenting auditory links, allowing users to follow a link quickly, without even having to hear it, and should be retained. (b) DAHNI-1 only permits one link per unit, which is too restricting for full hypermedia modules, and therefore to support multiple links in one unit, it might be preferable that a link becomes active only when it has been heard - in that way each link remains active and can be selected until the next link is heard. (c) Just as users can currently skim read unit-to-unit, a method of allowing users to skip from link-to-link in the node might also be useful so that users can quickly determine what links exist (for example, just as sighted users skim the page looking for links underlined in blue in WWW browsers to see where they can go to from that page). (d) In addition, in order to find out the current link, rather than having to listen to the entire unit again, a command which simply output the current link might be useful.

#### 5.4.5.3 Link Types

Participants had divided opinions about the potential importance of indicating different link types (for example, to a textual node, to a graphic or audio node), see Table 5.10.

**Table 5.10: Ratings for Link Type Information**

Usability Question	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Importance of knowing type of link	3.57 (1.51)	4	-	3

Half the participants thought that they didn't need to know the link type (P1, P2, P3, P7), indeed P7 particularly liked the surprise of following unknown links; but the other half felt that it was very important so that blind users could choose which links they follow - for example, they might want to ignore picture nodes (P4, P5, P6). P4 also commented that this type of information would be useful to clarify the link destination if the wording of the link was ambiguous, helping them to choose their path effectively.

#### 5.4.5.4 The 'Current Unit' Concept

The concept of a unit seemed to allow participants to read through the information in reasonably manageable chunks. Units were defined as paragraph-sized chunks in DAHNI-1, and this seemed to be an appropriate amount of information to deliver at one time; and participants did not complain that it was too much, or too little. Nevertheless, it is appreciated that users will require additional control over the amount of information they receive with one reading command, for example, to suit reading different types of material.

**Recommendations:** (a) Retain the current unit concept, with the default paragraph size, but provide a command to allow users to choose the size of the unit as they are reading. (b) The provision of many separate reading commands for a character, word, paragraph, sentence, whole node might be too difficult for novices to learn; and therefore a modal command which cycles between these different unit sizes might be preferable.

#### 5.4.5.5 The Use of Synthetic Speech Nodes

Although most participants were familiar with synthetic speech output many rated the synthetic speech output in DAHNI-1 as being very difficult to listen to, see Table 5.11.

**Table 5.11: Ratings for Synthetic Speech**

Usability Question	$\bar{x}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Ease of listening to information in synthetic speech	2.71 (0.95)	6	1	-

Criticisms of this particular synthetic speech included its poor clarity, poor pronunciation, lack of intonation, and lack of suitable pauses (Ps 1-7), which all contributed to impaired comprehension of the material and reduced concentration of some participants. The pre-recorded synthetic speech nodes were reading at approximately 140 words per minute, and

the majority of participants reported that this was an appropriate speed which they found easy to comprehend. However, two participants found this reading rate too fast (P2, P3).

**Recommendation:** It has to be remembered that DAHNI-1 was not using true text-to-speech software, only pre-recorded synthetic speech units, which may have contributed to the poor quality of the output and the sometimes slow response of the reading commands. The future implementation of new text-to-speech software under Windows 95 is likely to improve the quality of the output, and allow the user to control the speed of output and also the voice used.

#### 5.4.5.6 Digitised Audio Nodes

Participants were highly in favour of digitised audio nodes of real human speakers for the hypermedia material (see Table 5.12) which added interest and variety to the material, and increased their enjoyment of the system (Ps 1-7).

**Table 5.12: Ratings for Digitised Audio Nodes**

Usability Question	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Ease of listening to digitised audio nodes	4.43 (0.79)	1	2	4

The majority of participants said that they had no trouble understanding the (real human) speaker of the digitised node, since it was clearer and at a more appropriate pace than the synthetic speech, with natural intonation and appropriate pauses making it more pleasant to listen to. However, P4 found the narration hard to hear because of the background sound effects (see next section).

There is a significant difference between ratings for the digitised and synthetic nodes, see previous section (Wilcoxon  $Z = -2.2014$ ,  $p = 0.0277$ ), indicating that participants greatly preferred listening to digitised human speech than to synthetic speech.

**Recommendation:** Make use of digitised audio nodes in future hypermedia modules to create variety and greater clarity in the content material.

#### 5.4.5.7 Sound Effects

Overall, the sound effects in digitised nodes (for example, the background office noise in the City of London node) were well-received, see Table 5.13.

**Table 5.13: Ratings for Sound Effects**

Usability Question	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Usefulness of Sound Effects in Digitised Nodes	4.43 (1.13)	1	1	5

Most participants said that the sound effects were useful and fun and made the node more interesting (P1, P2, P5, P6, P7). However, some participants had reservations about the use of sound effects; stressing that they must be of a high quality and must not distract them from the information presented in the digitised node (P3, P5) - for example, P4 found that the background noises in the digitised node (the office sound effects) masked the speaker's voice and thus reduced its intelligibility.

**Recommendation:** Make use of sound effects in future hypermedia modules for interest and variety, but care should be taken that they do not mask the main narration of the node.

#### 5.4.5.8 Picture Nodes, Verbal Descriptions and Tactile Pictures

The four blind participants rated the picture node with tactile picture and verbal description quite highly, see Table 5.14

**Table 5.14: Ratings for the Picture Node**

Usability Question	$\bar{X}$ ( <i>sd</i> ) n = 4	Spread		
		1-3	4	5
Usefulness of the tactile picture	3.75 (0.50)	1	3	-
Quality of the tactile picture	3.75 (1.26)	1	2	1
Effectiveness of the verbal description	4.75 (0.50)	-	1	3

Participants said that the tactile picture was useful with the verbal description, but not by itself, and it was considered too small and not sufficiently clear by two participants (P1, P7). The verbal description was more widely effective, with all four participants stating that the description really helped them to imagine the Beefeater.

**Recommendations:** (a) Make use of picture nodes with tactile pictures and detailed descriptions in future hypermedia modules to add variety and interest, and to provide access to visual information which otherwise blind students might miss. (b) Ensure that tactile diagrams are uncluttered, simple and sufficiently large to be effective.

## **5.5 Conclusions**

### **5.5.1 General Findings**

Overall, the evaluation results showed that DAHNI-1 has several useful design features which make it a suitable basis for a non-visual hypermedia system for blind users. Participants were generally impressed with DAHNI-1 and its potential, and rated it as fairly easy to learn, easy to use straight away, and enjoyable to use.

The workspace concept provided a reasonably consistent interface for use with three input devices, and provided an easy method of command execution particularly for inexperienced keyboard users (although this was perhaps not the most efficient method for experienced keyboard users). The touchtablet was well-liked as an alternative input device to the keyboard, and was rated as very easy to use, and although the joystick was considered difficult to use, participants liked the idea of using one. The multimedia presentation of the hypermedia module made the system interesting and varied, and participants seemed motivated to use DAHNI-1 because of this. They found it reasonably easy to remember the function of most of the commands and were generally able to use them correctly with all three input devices.

The nine implemented commands seemed to be adequate for non-visual navigation at the most basic level, and might be a useful set of commands for new users to learn first, although may require re-naming and re-locating on the workspace to increase their memorability. Concepts such as the 'current unit' and 'current link' were found to provide information in manageable and effective chunks, allowing participants to read and select links easily. Although these nine commands provided basic non-visual access to hypermedia material, they were clearly not sufficient to provide full support for working in hypermedia material. Two areas in particular require attention: (1) overview and locational information, and (2) finding and selecting links, described below.

### ***5.5.1.1 Overview and Locational Information***

There were occasions when participants required information to orient themselves within the node which DAHNI-1 did not provide. Such orientation is provided for sighted users by visual formatting on a page. While working with the hypermedia module, participants seemed to require information about the structure of the node - for example, to allow them to distinguish between a heading, a unit and a link - and the use of non-speech sounds might be an effective method of providing short cues of this type. In addition, a command summarising the structure of a node (for example, stating the heading, the number of units and links, and the current unit number) might help orient users within the node.

### ***5.5.1.2 Finding and Selecting Links***

Additional commands are required to provide methods of overviewing the links in the node, to compensate for the lack of visual scanning possible on a screen. A list of links would not be consistent with the simple interaction methods DAHNI-1 provides, and has not been effective in other auditory systems (for example, Arons 1991 and Barker & Sutherland 1996) and a method of skipping from link-to-link would allow users to quickly jump through the links in a node in a similar way to reading unit-to-unit. In addition, users may need to hear the current link quickly, and rather than having to listen to the whole unit, a command which outputs the current link might be supportive.

## **5.5.2 Methodology**

The evaluation methodology described in Chapter 3 proved to be fairly effective at providing a range of objective and subjective measures which allowed the usability of each aspect of DAHNI-1 to be explored in detail, and it is recommended that a similar approach be used in future evaluations. Some general comments can be made about various aspects of the methodology:

*Participants:* The use of both experienced and less-experienced computer users was beneficial since preferences and opinions of different types of user were gathered about the usability of DAHNI-1. The more experienced participants tended to be most critical; comparing DAHNI-1 to existing products they were familiar with; whereas less experienced participants tended to assess DAHNI-1 on its own merit. This range of

assessment was valuable, since it allowed the researcher to focus on aspects which would be immediately useful in supporting effective use, and keep in mind a list of more sophisticated features to support more advanced users in future versions.

*Training:* The training period was felt to be too long and tedious (for both participants and the researchers), and one solution might be to design a group training session for all participants to attend, with only the actual tasks and questionnaires being conducted individually. An on-line tutorial might also be a useful way to allow individuals to learn about the system by themselves at their own pace as part of a training session, and on-line help materials might support users working individually.

*Set Tasks:* The use of the three set tasks proved useful in providing participants with realistic tasks with several achievable sub-tasks to allow them to test each command and each input device, and the level of prompting from the researcher allowed participants sufficient autonomy that they could use the system in a realistic manner. The counterbalancing of task and device presentation seemed to provide a testing environment with minimal order effects to enable participants to experience all aspects of DAHNI-1.

*Questionnaire:* The participants' ratings and comments on the questionnaire generally matched their performance on the tasks, although the tasks allowed an objective view of the usability of DAHNI-1, and the questionnaire provided a more in-depth evaluation of the participants' opinions of the problems and potential solutions and their preferences than would have been provided by task observation alone.

*Personnel:* The use of two researchers alternating training and evaluation sessions was valuable for reducing fatigue and minimising bias, and for providing two accounts of the evaluations.

*Objectivity:* Despite the researchers' best efforts to maintain objectivity and detachment from DAHNI-1, the possibility remains that the evaluation tasks, prompts and interview questions may have cued the participants to respond in a particular way. However, participants were strongly encouraged to be open and to identify aspects they both liked and disliked in the system throughout the training and evaluation sessions, and their ratings and comments provide a fair amount of evidence that participants were not shy of being openly

critical. Therefore the researcher is confident that reasonably high levels of objectivity were obtained.

*Size Limitations and Scope of Evaluations:* (a) The prototype is small, with only a few commands and a small custom-build hypermedia module, with a number of limitations caused by the ACCESS programming tools and the lack of text-to-speech software. However, the evaluations have shown that the basic design principles are feasible, and the stand-alone nature of DAHNI-1 has allowed the researcher to focus on fundamental design decisions without having to deal with extraneous usability issues relating to, for example, the design of WWW pages. (b) Participants had received only a small amount of practice with DAHNI-1 before completing the evaluation tasks and giving their opinions on its usability. It would be interesting in the next stage of the research to see how participants feel when additional commands and a larger hypermedia module are provided, and if they are given more time to become more familiar with the system.

### 5.5.3 Future Development

The workspace concept will be retained for the development of the second version of the prototype, DAHNI-2, since the workspace supported a range of users with three different input devices and DAHNI-2 will use digitised speech for the presentation of commands, and non-speech sounds for the centrepiece and dead-ends. However, there are some areas of the design of the system and of the training and evaluation procedures which could be improved, and the following points summarise the main recommendations from these evaluations.

- 1) *Improve Command Names.* Rename certain commands to make more explicit and more distinct from each other, particularly 'Speak Right', 'Speak Left', 'Repeat', and 'Top' - aiming to 'speak the user's language' (Nielsen 1994d).
- 2) *Make Use of Non-Speech Sounds for Information and Feedback.* (a) Add non-speech sounds to reinforce the difference between certain commands, and to provide information about such as 'Back', 'Speak Right/Left', 'Home', 'Top', and the location of links. (b) Maintain the use of the non-speech sounds for centrepiece and a dead-end when working on the workspace and in hypermedia modules.

- 3) *Provide Orientation and Navigation Commands.* (a) Add commands to provide locational information: to report the current link; to state the current location; and to provide an overview of the current node. (b) Use non-speech sounds to provide locational information about headings and links.
- 4) *Improve Methods of Finding and Selecting Links.* (a) Test alternative methods of link presentation, such as using a non-speech sound and a different voice rather than the higher pitched voice. (b) Add a command to improve methods of finding and selecting links, using a link-to-link feature.
- 5) *Improve the Control of Auditory Presentation.* Add commands to control the output in terms of: size of unit, speed and voice of synthetic speech - all with simple interaction methods.
- 6) *Improve the Usability of the Input Devices.* (a) Add shortcut keys to all commands to increase efficiency for keyboard-literate users. (b) Move the keyboard reading keys to improve their memorability and to make consistent with other devices. (c) Reduce sensitivity of the joystick when moving around the workspace and when executing commands. (d) Test a smaller touchtablet with a small overlay to improve command location time.
- 7) *Re-Design the Layout of the Workspace.* Relocate certain commands on the workspace to improve ease of access, for example, 'Back' and 'Home', and create a logical arrangement which includes all the new commands.
- 8) *Develop Support Commands and Materials.* Develop tutorial and help features to help users learn and to use the application.
- 9) *Provide User Configuration.* Allow configuration of the presentation of the interface, for example, so users can choose the non-speech sounds used.
- 10) *Develop a More Realistic Hypermedia Module.* Develop a larger hypermedia module, making further use of digitised nodes, sound effects, pictures with descriptions and tactile pictures.
- 11) *Extend the Training Procedure.* (a) Adapt the training procedure to include group introductory sessions, making use of any on-line training materials for individual learning and practice. (b) The training procedure should specifically address and

reinforce differences in workspace layout across the three devices. (c) Increase participants' familiarity with DAHNI-2 before evaluations are conducted.

- 12) *Extend the Evaluation Procedure.* (a) Extend the evaluation procedure to include further usability and preference issues but maintain a similar methodology. (b) Develop new evaluation tasks for the new hypermedia module, to test all implemented commands, with longer components of the task under participant control.

## **5.6 Coming Next...**

The following chapter outlines the development of DAHNI-1 into the second prototype, DAHNI-2. The design decisions are based on the results of these initial evaluations to provide a larger and more complex interface and hypermedia module. The usability evaluation of DAHNI-2 will be reported in Chapter 7.

**6 Design of DAHNI-2: The Second ACCESS Hypermedia  
Non-Visual Interface**

## **6.1 Chapter Overview**

This chapter presents the design of the second ACCESS non-visual hypermedia interface, DAHNI-2, based on the results of the evaluations of DAHNI-1. The improvements included: renaming and re-locating commands on the workspace; adding non-speech sounds to provide structural information and command feedback; the provision of new commands to improve orientation and navigation, for finding and selecting links, and for controlling the auditory output; improved input and output methods; the addition of on-line Tutorial and Help systems; the provision of user configuration; and the development of a larger and more varied hypermedia module.

## **6.2 Introduction**

The evaluations of DAHNI-1 showed that although most elements of the design were effective for basic non-visual navigation through hypermedia, there were several usability issues which needed to be addressed. These included not only improving the usability of existing commands and input devices, but also designing additional commands to provide a greater level of support when working non-visually with hypermedia material. Furthermore, participants using DAHNI-1 had sometimes found it difficult to distinguish between some of the commands because of a lack of feedback and information, and solutions were required to improve the level of information users receive.

The previous chapter outlined the problem areas together with proposals for solutions, and this chapter presents the design of the revised interface, DAHNI-2. In designing solutions it was important that it continued to make use of simple interactions for all commands to support users who may have very little computer experience, but it was also important that DAHNI-2 provided interactions suitable for more experienced computer users who require more efficient means of working, particularly with the keyboard. Therefore, commands were designed without Windows-style menus which would require more sophisticated levels of interaction and which were also not easily consistent across different input devices.

Several design improvements are to be addressed in this chapter, attempting to relieve the problems found with DAHNI-1, and to create a non-visual interface which supports effective navigation through hypermedia material with three input devices. These improvements concern:

- 1) Command renaming
- 2) The addition of non-speech sounds to provide structural information and command feedback
- 3) New orientation and navigation commands
- 4) New methods of finding and selecting links
- 5) New commands for controlling the auditory output
- 6) New and re-designed input and output methods
- 7) Re-design of the workspace
- 8) User support features - Tutorial and Help systems
- 9) User configuration
- 10) The development of a larger and more varied hypermedia module.

The design methodology of DAHNI-2 is summarised first in Section 6.3, and as with DAHNI-1, the design of DAHNI-2 itself includes two components, which will be described separately in this chapter:

- The Interface - described in Section 6.4
- The Hypermedia Content - described in Section 6.5

### **6.3 Design Methodology**

The principal researcher who had designed and conducted the evaluations of DAHNI-1 proposed changes and additions, discussed various possible implementations with the UH ACCESS team based on her proposals. Before implementation, the design team (from a range of backgrounds) worked through each possible design assessing its feasibility using design guidelines and usability heuristics, and conducted informal scenarios and jogthroughs to test whole sequences of interactions with specific tasks and specific users in mind (using the methodology described in Chapter 3). When some agreement had been reached (for example, as to the most suitable interaction method, command name, or location of a command on the workspace), the proposed methods were implemented by the

UH programmer. The researcher then performed bug-testing and informal usability inspection tasks in a range of different task situations to ensure that the implementations were usable and reasonably stable. Where problems or weak design areas were revealed, the researcher proposed alternatives to the design team, and the iterative cycle of feasibility testing, implementation and bug-testing began again. In this way DAHNI-2 was tested fairly thoroughly before being used by blind participants.

## **6.4 Interface Design of DAHNI-2**

This section describes the development of improved and new commands, but for ease of reference Table 6.1 compares the commands and feedback available in DAHNI-2 with those previously available in DAHNI-1, and the following sections describe the development of these aspects of DAHNI-2, indicating any similarities to other systems.

### **6.4.1 Command Re-Naming**

As described in the previous chapter, participants evaluating DAHNI-1 found the function of the majority of the nine basic commands easy to remember, although several proved to be particularly problematic. Based on observations of participants' performance and their own responses on the usability evaluation questionnaire many of the problems stemmed from a mis-match between the naming of these commands and their function, which did not aid memory or guesswork - in Nielsen's terms (Nielsen 1994d) these commands were not 'speaking the user's language'. Solutions include:

- The 'Top' command should be renamed 'Heading', since 'Top' was not easily associated with jumping to the top (to the heading) of the current node. 'Heading' is a more explicit command name which matches the functionality of the command, and therefore should be easier for users to remember.
- 'Repeat' should be renamed 'Read Current Unit'. 'Repeat' was not easily associated with repeating the current unit, particularly when participants had stopped the output before listening to any of the current unit, so the command name 'Repeat' was actually meaningless in that situation. Again, a more explicit command name is likely to be easier to remember in any reading situation.

**Table 6.1: Comparison of Commands and Feedback in DAHNI-1 and DAHNI-2**

DAHNI-1 Command	DAHNI-2		
	Command	Function	Sound
Speak Right	Read Right	Outputs the next unit in the current node	"Paper Riffle"
Speak Left	Read Left	Outputs the previous unit in the current node	"Paper Riffle"
Select	Select	Selects the current link & jumps to the heading of the destination node	
Back	Back	Jumps to the previous node in history	"Upwards Zoom"
Forward	Forward	Jumps to the next node in history (after Back was used)	"Downwards Zoom"
Top	Heading	Jumps to heading of current node	"Swoosh"
Home	Home	Jumps to starting (home) node	"Transporter"
Stop	Stop	Stops output immediately	
Repeat	Read Current Unit	Outputs the current unit	
	Overview	Outputs heading of current node, the number of units & links present in current node	
	Where Am I?	Outputs heading of current node & the current unit number generated by DAHNI-2	
	Read Current Link	Outputs current link	
	Change Unit*	Changes size of unit: word, paragraph, whole node	
	Change Rate	Changes output rate: slow, normal, fast, very fast	
	Change Voice	Changes synthetic voice: male, female	
	Context-Specific Help	Outputs short help information about last command executed	
	General Help	Switches to General Help Module	
	Tutorial	Switches to Tutorial Module	
	Skip link-to-link*	Jumps from link to link in current node	
DAHNI-1 Feedback	DAHNI-2 Feedback		Sound
Link (voice in higher pitch)	Link		"Bing" & different voice
Centrepoint ("Ping")	Centrepoint		"Pop"
Dead-End ("Uh-Oh")	Dead-End		"Donk"
	Arriving at a heading		"Ta-Da"

\* Both these features were designed but unfortunately not implemented in time for the evaluations

- ‘Speak Right’ and ‘Speak Left’ should be renamed ‘Read Right’ and ‘Read Left’, making the commands sound more appropriate for reading educational materials (‘Speak’ sounded a little unsophisticated to several DAHNI-1 participants). The directional aspects of these commands (Left and Right) did not seem to cause any difficulties for DAHNI-1 participants, and seemed to help them to distinguish between reading within a node and jumping backwards and forwards in their history.

#### **6.4.2 Non-Speech Sounds For Information and Feedback**

Observations of DAHNI-1 participant task performance had highlighted a number of problems relating to correct command usage. The function of several of the commands was difficult to distinguish and this was concluded to have two main causes: the lack of distinction between the command names themselves, discussed above in Section 6.4.1; and a lack of information about the participant’s current location in the hypermedia material and a lack of feedback of the results of certain commands.

The use of non-speech sounds to indicate dead-ends and centrepoin on the DAHNI-1 workspace had been shown to support orientation and provide short, effective feedback, and therefore sounds were further investigated to help improve the usability of other commands - particularly those which had caused DAHNI-1 participants some confusion. Since both blind and partially sighted participants had liked the use of iconic sounds (auditory icons) in DAHNI-1, the emphasis was on finding similar sounds to represent commands and events in DAHNI-2.

For each command or event several iconic sounds were considered which could represent the target command or event, with the requirement that they were short and easily distinct from each other. The UH research team performed informal trials amongst themselves with the different sounds, and the final sounds selected with consensus opinion. DAHNI-2 included nine non-speech sounds to provide information and feedback (see Table 6.1), described in the following sections. All sounds in DAHNI-2 are output immediately after a command is executed, followed by the information in the node.

#### **6.4.2.1 Structural Information: Presentation of Links**

The presentation of links in DAHNI-1 using a change in pitch of the synthetic voice had allowed participants to identify and remember the links, but this presentation method had a tendency to distort the pronunciation of the link, making it difficult to comprehend some words. Therefore an alternative double-method of presenting links was considered: the use of a sound immediately before the link together with the link spoken in a *different* voice (rather than the same voice in a higher pitch); in order that the link word could be clearly signalled without distortion. The use of both a non-speech sound together with a change in voice might seem to lead to redundancy, but each has its own function: the sound will alert the reader to the presence of a link, and the change in voice makes the exact wording of the link explicit. If the link were presented merely with the non-speech sound, the end of the link would not be indicated, and depending on the exact wording of the link, users may or may not wish to select it.

Criteria for choosing the sound to indicate a link were that it be short, distinct but not distracting, and pleasant to listen to since it would be heard so frequently. There was no obvious iconic sound appropriate for a link, and since this sound would be heard many times it should not be ‘gimmicky’, which might start to irritate users. Possible sounds to indicate link words included short non-iconic sounds such as simple beeps and tones of different timbres and pitches.

- The final sound chosen to indicate a link was a simple short subtle “*Bing*” played immediately before the link word, which was itself presented in a different voice from the rest of the synthetic speech output

#### **6.4.2.2 Structural Information: Dead-Ends**

DAHNI-1 participants had liked the use of the dead-end sound (“*Uh-Oh*”) when working around the workspace for reinforcing its shape and confirming that they were at the end of a node. However, if DAHNI-2 could alert the user to the end of a node without them having to execute a redundant reading command, reading would be more efficient. In addition, although the “*Uh-Oh*” sound itself was reported to be amusing and participants seemed to enjoy hearing the sound, a few participants felt that the sound had negative connotations as if they had made a mistake, and made them uncomfortable.

- It was therefore decided to move the dead-end sound to the end of the last unit so that it played immediately at the end of the paragraph, rather than only being output if the user executes a further reading command.
- As an alternative sound, several ‘hitting’ sounds were considered by the research team, and their favourite was a soft “*Donk*” as if a milkbottle had been hit with a soft stick. The sound was soft and unobtrusive and quite short, but was distinct enough to be heard above background noise in an average room. Arons (1993, 1997) used a cartoon-type “*Boing*” to indicate dead-ends, but it was felt that this sound could potentially annoy users.

#### **6.4.2.3 Structural Information: Headings**

Participants using DAHNI-1 were observed to be confused sometimes about which command to use when they heard a heading. The brevity of some headings made them sound like links, leading participants to execute the ‘Select’ command rather than a reading command to read the next unit. This confusion was interesting since it was expected that the lack of a non-speech sound around a heading would indicate that the phrase output was *not* a link; but clearly participants needed additional information; they needed information about ‘auditory landmarks’ (Gaver & Smith 1990). A method was therefore required to help users to distinguish between structural elements like headings and links. If non-speech sounds are to be used to indicate links, a sound could also indicate the presence of a heading. Since each node has a main heading at the start, considered an important signpost as to the contents of that node, a sound has to be chosen which conveys the importance of this piece of text.

- Several options for indicating the heading were considered, and the final sound chosen was a short fanfare sound “*Ta-Da*”. This was played immediately before the heading was presented.

#### **6.4.2.4 Command Feedback: ‘Heading’**

The renamed ‘Heading’ command (previously ‘Top’) required additional feedback to help users distinguish it from the ‘Home’ command, particularly important when working in unfamiliar material where the user might not recognise the information output. A sound played when the user executes the ‘Heading’ command would have to provide feedback

that the user had moved *within* the current node rather than jumped to a new node. Just as sighted users drag a slider up a scroll-bar to change the view of their document on the screen, sounds were considered to convey sliding up to the heading at the top of the node.

- The final sound chosen was a swooshing sound - “*Swoosh*” (like something being dragged across a wooden floor), to give the impression of sliding up the page from the readers’ current location to the heading. The command feedback is played immediately after the ‘Heading’ command is executed, followed by the non-speech sound to indicate arrival at a heading (“*Ta-Da*”) and the heading itself.

#### **6.4.2.5 Command Feedback: ‘Home’**

To help users distinguish the ‘Home’ command from ‘Heading’, sounds were considered to provide feedback for the ‘Home’ command. The sound had to convey jumping from wherever the user is positioned straight back to the starting node of the module. An obvious iconic sound to represent this very fast and discrete jump is based on the ‘Star Trek’ Transporter sound which transported crew back to the spaceship from anywhere outside.

- An electronic sound which resembled the original Transporter sound was designed, and when the ‘Home’ command is executed the “*Transporter*” sound is output, followed by “*Ta-Da*” indicating the presence of a heading and the heading itself. Similar transporter sounds have been used by Gaver & Smith (1990) in SharedArk, and as part of an entire genre of Star Trek sounds in ShareMon by Cohen (1993).

#### **6.4.2.6 Command Feedback: Reading and Navigational Commands**

The ‘Speak Left’ and ‘Back’ commands were easily confused by some DAHNI-1 participants (as were the opposite commands ‘Speak Right’ and ‘Forward’), despite deliberate repetition of the differences between them during the training sessions. Although renaming these commands (for example, to ‘Previous Unit’, and ‘Jump to Previous Node’) makes them more explicit, these longer and more technical terms may be more difficult for some students to learn to use.

The researcher favoured the addition of non-speech sounds to each of these commands so that users are given immediate feedback as to the result of their commands. This should

help to make them more distinct and therefore easier to learn and to remember. To reinforce the differences between a small within-node reading movement such as 'Read Right' and 'Read Left', and the larger between-node reading movements such as 'Back' and 'Forward' various sounds were explored. The final sounds chosen by the team were:

- A "*Paper Riffle*" sound to represent reading within a node (for both 'Read Right' and 'Read Left') (a similar sound was used to indicate moving from note to note in VoiceNotes - Stifelman, Arons, Schmandt & Hulteen 1993), and an electronic "*Zoom*" sound to represent between-node jumps such as 'Back' and the new command 'Forward'.
- The sound chosen for 'Back' and 'Forward' was reversed, to reflect the tracing and re-tracing of one's path, so 'Back' was represented by an "*Upwards Zoom*" sound, and 'Forward' by a "*Downwards Zoom*" sound. Similar sounds were used by Arons (1993, 1997), and Roy & Schmandt (1996).

#### **6.4.2.7 Command Feedback: Centrepoint**

The sound for centrepoint "*Ping*" in DAHNI-1 had been found to be useful for reorientation while working around the workspace (particularly with the keyboard), providing participants with very short, unobtrusive feedback about their current location. However, some participants recognised it as the Windows default error sound, and therefore alternatives were considered to make the sound more iconic when returning to centrepoint.

- A short deep "*Pop*" sound was chosen to confirm that the user had returned to the middle of the workspace, and this sound was quite appealing to the research team.

#### **6.4.3 Orientation and Navigation Commands**

There were many occasions during DAHNI-1 evaluations where participants were not confident about their current location because the system did not provide sufficient information to them. In addition to the non-speech sounds implemented in DAHNI-2, additional commands were designed to support effective orientation and navigation.

### **6.4.3.1 *Initial Welcome Message***

Rather than jump straight to the Home node when DAHNI-2 loads, a welcome message was designed to provide orientation information to users about the available options. A welcome message is likely to support novices who can be given a summary of important commands when they start the system, but might become intrusive to more experienced users who wish to simply start working in the hypermedia module straight away. If this is the case, this message could be removed in the user configuration file (see Section 6.4.9) and the home node loaded immediately.

- One such welcome message might read: “Welcome to DAHNI. Press Control T to go to the Tutorial; press Control H for the Home Node; Control G for the General Help Module; and Control X to exit at any time”.

### **6.4.3.2 *‘Where Am I?’ Command***

DAHNI-1 participants sometimes became slightly disoriented even in the small nine-node hypermedia module, and sometimes needed to be reminded of their current location. They would ask the researcher for the heading of the current node and sometimes where they were in the node. Interruptions while working in real life would mean that this information might be frequently required, and a command to provide orientation information about the users’ current position was designed.

- The ‘Where Am I?’ command presents (in synthetic speech) the heading of the current node and the current unit number - generated by DAHNI-2.

### **6.4.3.3 *‘Overview’ Command***

In addition to the current position information provided by the ‘Where Am I?’ command, a command was designed to provide a replacement for visual scanning of the size and structure of a node to give users an overview of the current node.

- The ‘Overview’ command presents (in synthetic speech) the heading of the current node, and the number of units and links present in the current node. This was anticipated to help users quickly determine the structure and size of the current node. A similar approach was taken in pwWebSpeak with their ‘Page Summary’ command (see Hakkinen & De Witt 1996).

#### 6.4.4 Finding and Selecting Links

The 'current unit' and 'current link' concepts were retained for DAHNI-2, such that as each unit becomes active, the link in that unit becomes the current link, which can be selected at any time using the 'Select' command. However, there were times when DAHNI-1 participants did not want to listen to the whole unit or whole node and just wanted to hear the current link, or find out what links were present in the current node. Therefore two commands were designed and implemented to support more efficient link location and selection, described in the following sections.

##### 6.4.4.1 'Read Current Link' Command

To provide a quick method of determining the current link, the 'Read Current Link' command was designed and implemented.

- This command outputs in synthetic speech: "The current link is: Thames" for example. Since the current link can be selected at any time users can follow that link after this message using the 'Select' command, and this interaction will often be faster than listening to the whole unit to determine the current link.

##### 6.4.4.2 Link-To-Link Navigation

In addition, just as sighted users scan their eyes over a page to read the blue, underlined links to find out where they can go from the current page, participants using DAHNI-1 also sometimes wanted to be able to listen to all the links in the current node. This also provides a type of content overview, since links often provide contextual information about the surrounding material (if they are well-written). To maintain the simplicity of interactions provided in DAHNI-2, navigational commands similar to the reading commands were designed, to jump from link-to-link in the current node. In this way, users could gain a quick overview of the links in the node, and would be able to immediately read the surrounding material using the normal reading commands if they wished to.

- A simple keyboard implementation method for this feature was chosen using the normal reading commands adapted with the <Shift> key. The touchtablet and joystick implementations were intended to be equally simple, although they were not implemented in DAHNI-2. A similar method of skipping link-to-link can be found in

pwWebSpeak (see Hakkinen & De Witt 1996), although users have to switch into a 'list links' mode to do this and cannot read surrounding material easily while jumping link-to-link.

#### **6.4.5 Control of Auditory Presentation**

The auditory display is unlike the visual display which offers a vast amount of information at one time, and can be easily read by the sighted user simply moving their eyes across the screen, spending more or less time on particular information depending on their current interest. The auditory system must support users in determining what information they read, how much they read, in which voice and at what pace. All Windows screenreaders now provide features to allow users to review whole documents, the current paragraph, sentence, word, or character for example, usually in a range of voices with different speed settings. Such fine level of control will eventually be required, but a selection of auditory control commands were designed for DAHNI-2 to provide some of the required control.

##### **6.4.5.1 'Change Voice' Command**

To allow users to change the synthetic voice used to present textual material, a simple command was designed to cycle between a range of different voices.

- The 'Change Voice' command toggles between a male and a female voice. Additional voices could easily be added if supported by the speech synthesiser. Each time the command is executed, the voice is changed with a confirmation message: "Voice of speech changed to: male / female". Thus, users can listen to a sample of the new voice without having to change their reading position in the hypermedia module, and with more voices could continue changing the voice until they find one they like, and then continue reading in the module.

##### **6.4.5.2 'Change Rate' Command**

Similarly, to allow users to easily change the rate of output a simple cyclical command was designed.

- The 'Change Rate' command cycles between four reading speeds: slow, normal, fast and very fast. These speeds were chosen from the default settings of the synthesiser used and were anticipated to provide four suitable speeds for the majority of students. The new rate is confirmed in a message: "Rate of speech changed to: slow / normal / fast / very fast".

#### **6.4.5.3 'Change Unit' Command**

In the same way, rather than having several different commands for reading the character, word, sentence, paragraph, or whole node, which might be difficult for novices to learn, one command was designed which cycled between these options.

- The 'Change Unit' command cycles between the current default unit size (a paragraph); the whole node; a character; a word; a sentence; and back to paragraph. However, the ACCESS programming tools proved limiting, and as a consequence, although the command could be executed to hear these different options, only the default paragraph size was functional and therefore users would not actually be able to read units of different sizes in DAHNI-2.

#### **6.4.6 Improvements to the Input and Output Devices**

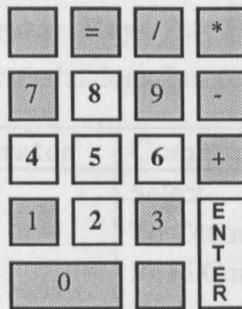
##### **6.4.6.1 Text-To-Speech Conversion**

DAHNI-1 had been unable to use true text-to-speech conversion, but DAHNI-2 made use of newly available software and hardware supported by the ACCESS programming tools: the TextAssist text-to-speech program under Windows 95, output through a Creative Labs Soundcard. This provided several benefits. It allowed user-control over the output in terms of output rate, voice, and the editing of pronunciation dictionaries to improve the quality of pronunciation.

##### **6.4.6.2 Keyboard**

a) *Re-Location of Commands to the Numpad.* The first main problem with the keyboard in DAHNI-1 was that the reading keys <Z> and <X> were not easy to remember because they were separated from the <arrow cursor> keys used to move around the workspace;

and the placement of the keyboard commands was inconsistent with using the joystick or touchtablet, where the 'Speak Left' and 'Speak Right' commands were located either side of centrepoint on the workspace. The numpad (the numeric keypad on the right-hand side of the keyboard) was a suitable alternative for these commands, since the keys can be used as directional cursors (for example, 8 = up, 2 = down), there is a central key (5) which can be used for jumping back to centrepoint, and the <Enter> key can be used to select commands and links, as shown in Figure 6.1 where the six implemented keys are shown in white. This would make the placement of keys for command execution more consistent with the other devices.



**Figure 6.1: Numpad Keys Required for DAHNI-2 Commands**

*b) Implementation of Shortcuts.* The second usability problem found in DAHNI-1 was that the more experienced participants found it time-consuming to work around the workspace to find and execute each command, especially for commands which they used frequently. Keyboard shortcuts were therefore designed which would be easy to learn and use to improve the speed of each interaction. Although the use of function keys, such as <F1-F12> was a possibility, evaluations of the mock-ups indicated that some users found it difficult to remember the commands on function keys, and it seemed preferable to design shortcuts with an accelerator key<sup>1</sup> for each command to make them more intuitive and memorable. To match Windows 95 application hotkeys, the <Ctrl> key was selected as the modifier key<sup>2</sup> together with a memorable accelerator key.

<sup>1</sup> An accelerator key is a unique alphanumeric key for each command, such as 'S' for Save.

<sup>2</sup> A modifier key, such as <Ctrl> modifies the function of an alphanumeric key to perform an alternative function, for example in many word processors <Ctrl + S> executes the Save command.

The accelerator keys were chosen according to the following principles: the initial letter was chosen for the most common commands, avoiding conflicts; such as <H> for 'Home', <B> for 'Back', <F> for 'Forwards', <S> for 'Stop' and so on. For the remaining commands, the initial letter was chosen where possible, or a letter which was obviously memorable to each command, such as <X> for 'Exit', <Y> for 'History List', for example. Where two or more commands have similar names, the accelerator key was chosen to make the commands distinct and the accelerator key memorable; for example: <L> for 'Read Current Link', and <U> for 'Read Current Unit'. The final accelerator keys used with the <Ctrl> key are listed in Table 6.2.

**Table 6.2: Accelerator Keys for DAHNI-2 Commands**

\*Not implemented for evaluations, but present on the workspace

Command	Accelerator	Command	Accelerator
Home	H	Select	Numpad Enter
History List*	Y	To Centrepont	Numpad 5
Bookmarks*	M	Read Current Unit	U
Overview	O	Back	B
Read Current Link	L	Tutorial	T
Heading	D	General Help	G
Exit	X	Context-Specific Help	C
Forward	F	Where Am I?	I
Stop	S	Change Unit	N
Read Left	Numpad 4	Change Rate	A
Read Right	Numpad 6	Change Voice	V

#### 6.4.6.3 Joystick

The main usability problem with the joystick in DAHNI-1 was its sensitivity, which made it difficult for participants both to find and to execute commands and caused much frustration. However, participants were keen to use a device such as the joystick because it added a game-like dimension to working with the system, and therefore the analogue joystick was replaced with a more sophisticated model - a Microsoft Sidewinder 3D Pro digital joystick - which would hopefully be easier to use. This joystick also had a number of additional buttons which could be used instead of the standard trigger and top buttons, making it easier for participants to execute commands using whichever button suits their hand size. In addition to this new hardware, DAHNI-2 was also changed so that each

command had a larger area on the workspace, to help users to find and to select commands even if their hand movements were not completely accurate or steady.

#### **6.4.6.4 Touchtablet**

The Wizard-of-Oz evaluation of the DAHNI-1 touchtablet could not reveal implementation problems, but evaluations did reveal that the size of the original touchtablet (25cm x 21cm) was considered too large for efficient use, since it took too long to search over such a large area to locate commands. For this reason, two new touchtablets were developed: firstly, a slightly smaller, lighter prototype with a touch-sensitive area of 19.5cm x 14.5cm which could be used with an overlay displaying abbreviated command names (or their shortcuts for example); and a second, much smaller (non-functional) mock-up touchtablet of 12cm x 9cm, which could easily be carried between work and school, but which was only large enough to display one or two letters, or dots, for each command. Initials or dots were considered suitable since users could check the command by single-pressing on a letter/dot before selecting it by double-pressing. It was anticipated that users would prefer these smaller touchtablets since they would be able to find commands on the overlays much faster.

#### **6.4.7 Re-Design of the Workspace**

Several features of the DAHNI-1 workspace were retained in DAHNI-2 since they had provided sufficient support enabling participants to find and execute commands, even if they were not experienced computer users. The design features retained include: the basic design of the workspace shape; the digitised speech to present commands; and non-speech sounds to indicate centrepoint and dead-ends. The shape also allowed fairly consistent and effective interaction with three different input devices.

However, DAHNI-1 evaluations indicated that the layout of commands must help users to remember the location of commands, and to guess where to find commands, and a more intuitive placement of commands would facilitate this. For example, 'Back' should be behind centrepoint, and frequently used commands such as 'Stop' should be very close to centrepoint. The 'Home' command in DAHNI-1 was inconveniently located, and should be placed somewhere easy to find - for example, top left, to mimic the placement of the <Esc> key on a keyboard which is very easy to locate.

The initial principles for arranging commands on the workspace were intended to aid quick learning, maximise orientation and minimise memory load when using the workspace, and these were updated slightly to include the intuitive placement of commands for arranging commands on the DAHNI-2 workspace. The resulting workspace layout is illustrated in Figure 6.2, and the function of each command is listed in Table 6.1. The accelerator keys used with <Ctrl> are shown as underlined letters for relevant commands, and the 'Select' command is only placed to the right of 'Read Right' on the touchtablet overlay. The two commands not implemented are shaded.

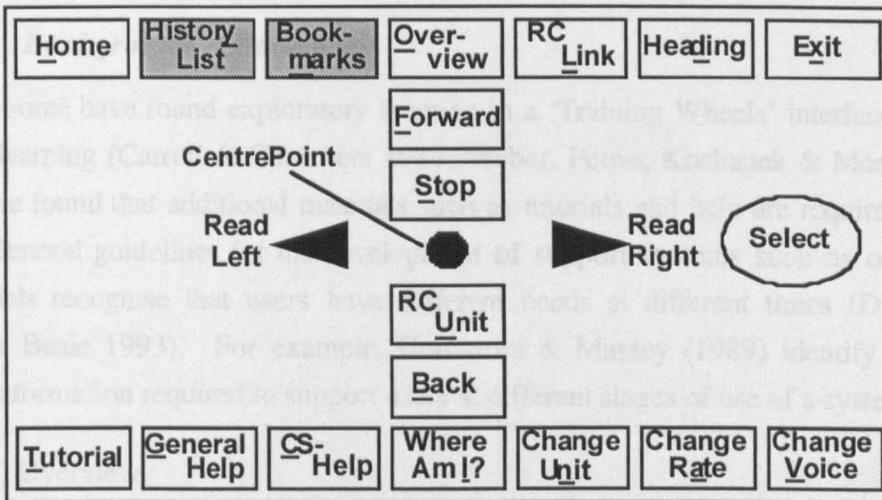


Figure 6.2: The DAHNI-2 Workspace

Key:

'R.C. Link' = 'Read Current Link';

'R.C. Unit' = 'Read Current Unit';

'C.S. Help' = 'Context-Specific Help'.

The two commands not implemented (Bookmarks and History List) were considered as potentially useful commands for later versions, and were therefore left on the workspace to illustrate that these commands might be implemented later. The facility to add and view lists of a user's bookmarks are available in all existing WWW browsers and will be an important feature for blind and visually impaired users, in order that they can quickly locate important or favourite nodes. Many WWW browsers also allow users to review a list of the node headings they have visited which can be used to quickly jump back to a specific node (view history list, for example). This type of menu-based interaction has so far been avoided in DAHNI-1 and DAHNI-2 and therefore both these commands would require careful design.

### 6.4.8 Support Features

In order to help users learn to use the interface and to provide them with help while using the system and to provide a more supportive system several features were developed by the researcher for DAHNI-2: an on-line tutorial; a context-specific help command; and an on-line general help module. These are presented in detail in two ACCESS reports by McNally, Morley, O'Neill & Petrie (1996a and 1996b), and the background to their design is given here.

#### 6.4.8.1 Background Literature

Although some have found exploratory learning in a 'Training Wheels' interface facilitates effective learning (Carroll & Carrithers 1984, Weber, Petrie, Kochanek & Morley 1994), others have found that additional materials such as tutorials and help are required (Rieman 1996). General guidelines for the development of support systems such as on-line help and tutorials recognise that users have different needs at different times (Dix, Finlay, Abowd & Beale 1993). For example, Herrstrom & Massey (1989) identify four basic types of information required to support users at different stages of use of a system:

- (1) Overview
- (2) Tutorial
- (3) Procedural
- (4) Reference

A selection of guidelines for the development of help and tutorial systems was compiled from various sources, used to guide the design of the DAHNI-2 Help and Tutorial modules (Elkerton 1988, Herrstrom & Massey 1989, Cherry & Jackson 1989, Redish 1989, Dix, Finlay, Abowd & Beale 1993, Lindgaard 1994, Roesler & McLellan 1995, McGraw 1997), and these include:

- Support should be available at all times, but unobtrusive; indicate that support material is available
- Integral to the application, and in a similar, consistent format
- Easy to enter
- Small and compact, presenting a minimum of information at each step

- Organised effectively: with accurate informative titles, and activities grouped into tasks and functions, then into specific topics, with groups of 5-7 items
- Consist of as few levels as possible where hierarchies are used
- Support novice and expert users: allow several methods for formulating help requests and getting to information; and provide information at several levels of detail
- Provide overview information (for general orientation)
- Provide brief instructions for common tasks
- Provide concrete descriptions; step-by-step (for tasks and devices)
- Provide a list of keywords and commands
- Use carefully selected (and piloted) vocabulary
- Easy to leave; and allow users to resume where they left off

#### ***6.4.8.2 On-Line Tutorial Module***

An on-line tutorial module was developed by the researcher to help users to learn about DAHNI-2 by themselves, and which could be used during the training period. As a hypermedia module within DAHNI-2, the tutorial would allow users to learn about DAHNI-2 in-situ, covering both basic concepts and how the various commands and input devices worked in DAHNI-2. The material in the tutorial was based on the training methodology developed for DAHNI-1, and covered material in a progressive, step-by-step manner - and could be used without any knowledge of DAHNI-2 or hypermedia. The basic structure of each node was consistent with the London hypermedia module: a heading followed by several units. The last word in each unit was usually a link to the next topic with instructions about how to select the link.

The tutorial module is opened using the 'Tutorial' command, and the same command is used to exit from the Tutorial module (returning the user to the heading of the node they were in previously)<sup>3</sup>. Throughout the tutorial terms are explained in simple ways and the keyboard commands are given repeatedly so that learners become very familiar with the command names and how to execute them. Learners are told where the commands can be found on the workspace as well as their keyboard shortcuts. Methods of using the joystick

---

<sup>3</sup> Returning the user to the heading of the previous node (rather than to the unit the user was in) was designed to provide re-orientation information; but it was appreciated that users might sometimes feel disoriented and frustrated at losing their place.

and touchtablet are taught at the end of the tutorial. As well as being able to practise the commands while working through the tutorial, learners are encouraged to test their knowledge at the end of the tutorial by answering 10 self-assessment questions. These were designed to help learners to consolidate their learning, and the responses would provide an indication to the trainer / teacher as to the success of the training procedure, and whether certain aspects should be revised. There is also a link to these self-assessment questions from the first node in the tutorial for easy access.

#### **6.4.8.3 Context-Specific Help**

A 'Context-Specific Help' command was designed to provide quick relevant help on the most recently executed command. This type of information was found to be required during the training sessions, where on occasions participants would request confirmation about their command execution from the researcher. This command would help the user by confirming their action; for example, if the 'Back' command has just been executed, the 'Context-Specific Help' command outputs a short auditory pop-up message in synthetic speech concisely describing the command:

“The Back command has taken you back to the heading of the previous node that you visited. *Donk*”

The non-speech sound for the dead-end sound “*Donk*” is played automatically at the end of the message, and the help message then closes automatically, returning the user to their place in the hypermedia module. This removes the need to cancel or close the message (in keeping with the other simple interactions in DAHNI-2).

#### **6.4.8.4 On-Line General Help Module**

An on-line General Help module was developed by the researcher in the same format as the London hypermedia module and the on-line tutorial. This Help module was intended to support users once they had learned the very basics of using DAHNI-2 from the tutorial, and was written following the guidelines reviewed above and the researcher's own experience of writing documentation for blind computer users.

A list was devised of common topic areas and questions which users of different skill levels might ask. Each topic area was further divided into smaller topics, which gave

detailed information, for example, about specific commands or a specific device. A paper mock-up of the structure was developed and the researcher used scenarios to test whether the answer to a help question could be found easily, and whether the help was phrased correctly with the correct amount and level of information. If particular answers were hard to locate, topics were reorganised, reworded or removed, sometimes putting the same information (often redundantly) in several places so that users could find the same answer even if they asked different questions. For each command, its location on the workspace and its keyboard shortcut was given to aid efficient command location and execution.

To open the General Help module, the user executes the new 'General Help' command and the same command is used to return the user to the London hypermedia module (to the heading of the node they were in). When the General Help module is opened, users hear a welcome message instructing them which commands and keys to use to read through the information, and how to select topics. Each item listed is a link and therefore can be selected in the normal way. Three final main Help sections were chosen to support users finding different types of information: Index; Task Help; and Device Help; and the contents of each section are listed below:

- *Index*: an alphabetical list of commands and terms. Each one is a link to a new node containing information about that topic.
- *Task Help*: groups of common activities as links leading to new nodes describing how to complete each task. For example, 'How to read through hypermedia'; 'How to find out where you are'; 'How to change the output' and so on.
- *Device Help*: lists the three input devices as links leading to new nodes describing how to read through hypermedia and how to find and execute commands with each device.

When the 'General Help' command is executed again the user is returned to the London hypermedia module, at the heading of the node they were in previously.

#### **6.4.9 User Configuration**

The evaluations of DAHNI-1 revealed strong individual differences in preferences for the use of digitised and synthetic speech messages and the use and type of non-speech sounds, and therefore configuration is an important component of any system designed for a range

of users. Thus, a configuration file (DAHNI.INI) was developed where amongst other things, the filenames of all system messages, digitised messages and non-speech sounds were stored, which can be replaced or deleted as the user requires. This configuration file is a text file which can be edited in any text editor or word processor, but this does require some knowledge of .INI files. In addition, if a blind user wishes to make changes a screenreader will be required to present the information. In a final version of DAHNI-2 these configuration changes should be available from within the interface itself if possible so that users can make choices independently.

### ***6.5 Hypermedia Content: A Tour Around London - Past and Present***

In order that participants could test DAHNI-2 with its increased range of commands, a larger, more realistic hypermedia module had to be developed. The DAHNI-1 evaluations had shown that participants were very positive about the use of multimedia presentation of information, using digitised speech, sound effects and pictures with descriptions. Therefore significant efforts were made to ensure that a number of nodes were presented in these alternative formats to provide a varied, interesting and entertaining hypermedia module about the history of London and current issues of interest in London, containing information that might be used in a classroom setting.

The researcher compiled information in textual, audio and pictorial form and put it into the hypermedia form required for use with DAHNI-2 using the ACCESS hypermedia authoring tool A-DEV. The components of the new London hypermedia module 'A Tour Around London - Past and Present' are described here. The new hypermedia module contained information about the history of London, famous landmarks, people and events, both historical and current. The original nine-node module was extended to 37 nodes, linked in a web structure (see Appendix 1.4 for its full contents), and an overview of the content and structure is shown in Figure 6.3. The contents included:

- 17 textual nodes presented in synthetic speech.
- 6 digitised spoken nodes, some with sound effects
- 8 musical audio nodes
- 6 picture nodes of photographs or fine art with descriptions presented in synthetic speech, together with tactile pictures



### **6.5.1 Structure of Nodes**

The structure of each node was similar to that of the nodes in the hypermedia module used with DAHNI-1; each node starts with an informative heading read in synthetic speech and the remaining information in the node is divided into units, with the default unit size being a paragraph. Digitised information in a node is always one whole unit (since it is an entire .WAV file) and cannot contain links. At the end of the last unit the dead-end sound is played automatically to avoid users having to execute redundant commands at the end of a node. The ACCESS programming tools still placed a restriction on the number of links in a unit to one, and links themselves could only consist of one word. If there are no links in the node the user can only go backwards to the previous node using the 'Back' command, or return to the Home node using the 'Home' command.

## **6.6 Limitations and Justifications**

DAHNI-2 is known to be somewhat limited in its functionality, and these limitations are mainly due to the ACCESS programming tools which determined how DAHNI-2 could be implemented. One such restriction is the inability to change the size of the reading unit from the default paragraph size, and the others concern the presentation of links: only one link per unit is permitted, and the link itself can be only one word. None of these situations would be normal or appropriate for a standard hypermedia system. Nevertheless, the functionality of these commands has been designed in advance such that once these restrictions are removed and the commands are fully functional, they will be as simple to use as the other commands in DAHNI-2. The prototype does, however, provide a self-contained environment for the continued exploration of functionality and presentation issues, which should transfer to other situations reasonably well.

## **6.7 Coming Next...**

The following chapter presents the evaluation of DAHNI-2 which investigates the usability of the workspace, commands and input and output devices, and the presentation of hypermedia information, and provides recommendations for future design improvements.

## 7 Evaluation of DAHNI-2

## **7.1 Chapter Overview**

This chapter presents the evaluation of DAHNI-2 and addresses more high-level usability issues than was possible with DAHNI-1. An extended training and practice procedure allowed nine participants to become more familiar with DAHNI-2, and an extended evaluation procedure allowed the investigation of: overall usability; the usability of the input and output methods; the non-speech sounds; the on-line help and tutorial modules; and preferences for media for learning. The results indicate that DAHNI-2 has many useful and supportive design features for non-visual interaction with hypermedia with different input devices, but there are some areas where its usability could be further improved by slight re-design and with the addition of new features, which would improve its longer-term use. The chapter concludes with a summary of design recommendations.

## **7.2 Introduction**

### **7.2.1 Summary of DAHNI-2 Features**

In summary, the features present in DAHNI-2 consist of a set of 17 functional commands designed to support non-visual interaction with a 37-node hypermedia module "A Tour Around London - Past and Present" with two hypermedia support modules: an on-line Tutorial and a General Help module. These functional commands can be conceptually grouped for convenience into four categories, as listed in Table 7.1 - reading, output control, support, and navigation and orientation. See Chapter 6, Table 6.1 for full details.

Since the basic design issues had already been evaluated in DAHNI-1 the evaluations of DAHNI-2 concentrated on exploring more advanced issues of design, with participants using a larger, more realistic hypermedia module.

**Table 7.1: Functional Commands in DAHNI-2**

<u>Reading Commands</u>	<u>Navigation and Orientation Commands</u>
Read Left	Heading
Read Right	Overview
<u>Output Control Commands</u>	Where Am I?
Stop	Select (link)
Change Rate	Read Current Link <sup>1</sup>
Change Voice	Home
Read Current Unit	Back
<u>Support Commands</u>	Forward
Tutorial	
General Help	
Context-Specific Help	

### 7.2.2 Refined Methodology

The methodology described in Chapter 3 was again applied, although there were four main differences between the methodology used for testing DAHNI-1 and DAHNI-2, summarised in the following sections.

#### 7.2.2.1 *More Efficient Training Procedure*

The training session was made more efficient by designing a group training session to cover basic topics, involving greater repetition and reinforcement of particularly difficult concepts and commands to a group of participants (rather than to one participant at a time as previously). This was followed by participants using the on-line tutorial individually to learn the details of using DAHNI-2.

#### 7.2.2.2 *Practice Period*

Participants were given the opportunity to become very practised at using DAHNI-2 before evaluations by introducing a 2-week practice period between the training session and the evaluation session, requiring participants to complete 20 set tasks in the hypermedia module using DAHNI-2 by themselves. This was designed to explore longer-term

<sup>1</sup> Unfortunately, although the link-to-link navigation command had been designed, it was not implemented in time for the evaluations, and was only tested informally by one blind expert after these evaluations.

usability (as recommended by Shneiderman 1992, and Nielsen & Lyngbæk 1990). Participants' use of DAHNI-2 was recorded by its automatic computer-logging.

### **7.2.2.3 More Realistic Set Tasks**

Guided tasks were designed to require greater participant initiative (directive, non-explicit tasks), and free tasks were also included, as described in Chapter 3. These were intended to assess more realistic use of DAHNI-2, and to motivate participants to follow their own line of interest through the hypermedia module:

*The Guided Task.* The guided task required participants to locate several pieces of specific information from within the London hypermedia module in a realistic way, as if for example, they were completing a classroom assignment on the history of London. In addition, the specified information was always requested in stages, so that the participant was able to complete several achievable sub-tasks during the guided task. These small tasks within the framework of a larger activity were designed to provide positive reinforcement for the participant during the task. In addition, content questions were interspersed with the tasks to ensure that participants were listening to the output of the nodes. Whereas in the evaluations of DAHNI-1 the task instructions given to participants were quite precise and explicit and often helped participants to choose which commands to use, the instructions given for the guided task in DAHNI-2 were deliberately high-level, leaving the participant to determine not only how to locate the information but also which commands to use. This was to ensure that participants were using DAHNI-2 in a fairly realistic and independent way.

*The Free Task.* The aim of the free task was for the participant to identify a node (or nodes) they had liked and would like to show the researcher, for example their favourite node. The intention was that the participant would navigate to their chosen node by themselves, without any direction from the researcher. To prevent participants from deliberately choosing easy-to-find nodes close to the Home node, participants were first asked to name their favourite node, and then to demonstrate their ability navigating there.

#### **7.2.2.4 Separate Investigations**

As described in Chapter 3, separate investigations were designed to assess specific aspects of DAHNI-2 which could not be easily addressed by task observation or interviewing:

*The Memorability of Information Presented in Different Media* (that is, as digitised audio or descriptions of pictures). Participants were required to recall information from certain audio and picture nodes, and recall was combined with participants' subjective opinions to provide an indication of whether these media are effective.

*The Memorability of Headings.* Participants were required to identify true and false headings from the London hypermedia module to assess how memorable the headings are. When combined with observed task performance, this gave an indication of whether headings are used as orientation aids when working in hypermedia material.

*The Memorability of Non-Speech Sounds.* Participants were required to identify the referent of each sound used in DAHNI-2, and to rate the memorability of each sound. This tested how well participants remembered the sounds used and whether they correctly associated the sounds with their referents.

As before, particular attention was paid to identifying problem areas and developing alternative designs, and participants were asked to propose their own solutions.

#### **7.2.3 Features to be Evaluated**

Specifically, the researcher set out to investigate the following questions:

- Overall Usability. What types of strategies did participants use, and what sorts of mistakes did they make?
- Input Devices. Did participants find the improved implementations of the input devices easy to use?
- Workspace. Was the reorganised workspace and its renamed commands easy to use and were the commands memorable?

- Synthetic Speech Output. Was the new text-to-speech output more suitable for participants, and were the control commands effective?
- Picture Nodes with Descriptions and Digitised Audio Nodes. Did participants find these nodes interesting, useful and valuable?
- Navigation and Orientation. Were participants able to use DAHNI-2 to navigate through a larger more complex hypermedia module? Were the commands appropriate? Were participants disoriented, or lost, and what strategies did they use for orientation and navigation? Were headings memorable, and did they aid navigation and orientation?
- Non-Speech Sounds. Did the non-speech sounds help participants to orient themselves while navigating through hypermedia? Were the sounds easy to remember and to associate with their referents?
- Preferences for Media for Learning. Did participants have a preference for future provision of materials for studying - such as electronic text, braille, or hypermedia?
- Support Features: On-Line Tutorial, Context-Sensitive Help and General Help Module. An in-depth assessment of these support features was not required since they had received a full evaluation in a separate piece of research led by the researcher (see Petrie, Morley, O'Neill, McNally, Lauder, Graziani, Palchetti & Burzagli 1997). However, remaining questions included: did participants use these support features when using DAHNI-2 by themselves, and if so, what was their opinion of their usefulness and quality?

## **7.3 Method**

### **7.3.1 Design**

Each participant attended a group training session, then completed the on-line tutorial individually, followed by a 2-week practice period during which participants had been asked to complete 20 set tasks using DAHNI-2. The evaluation session involved observation of each participant completing a series of set tasks (guided and free tasks) in an informal think-aloud setting. Sessions were recorded in detailed notes, video-taped, and also logged by computer. Several separate investigations were also conducted involving

memory tests (both recall and recognition). Participants were then interviewed about various aspects of the design of DAHNI-2 using the evaluation questionnaire with open and closed questions and rating scales.

### **7.3.2 Participants**

Participants were again selected to be representative of the target end-user group; visually impaired students at school or college. Their personal characteristics were gathered using the Participant Characteristics Questionnaire (see Appendix 1.5), and their full details are shown in Table 7.2, and summarised in the following sections.

#### ***7.3.2.1 Age, Gender, and Level of Vision***

The nine visually impaired student participants who completed the evaluation of DAHNI-2 were aged between 13 and 19 years ( $\bar{X}$  = 16 yrs, 8 months;  $sd$  = 1.80), including 7 males and 2 females. Six participants were congenitally blind, one with an additional hearing impairment who wore a hearing aid, and three participants with congenital very low vision. Five of the nine participants had taken part in the evaluations of DAHNI-1, however, DAHNI-2 was sufficiently different that it was considered appropriate for them to participate again, with few disadvantages of repeat participation. An adult blind computer expert performed a very informal additional evaluation of DAHNI-2, and his comments will be included where relevant.

#### ***7.3.2.2 Computer Experience***

Participants had quite diverse computer experience, with a third having used computers for 5 to 9 years, and two participants had only 1 or 2 years experience but were already reasonably proficient users. However, one blind participant had never used a computer before the training session for DAHNI-2, and two of the six blind participants did not have sufficient keyboard skills to be able to locate specific letters on the keyboard. All the blind participants who used computers relied totally on speech-only output<sup>2</sup>, and all three partially sighted participants used speech-output and screen-magnification to access computer applications.

---

<sup>2</sup> As opposed to output on a refreshable (electronic) braille display.

Table 7.2: Participants' Characteristics in DAHNI-2 Evaluations

P #	Age & Sex	Sight	Exp-erience	Apps Used	WWW	CD ROMs	Software & Problems	Input & Output Used
1	19 M	CB	1 yr	WP, S, CD	0	10-20	With sighted help. Tables poor in speech	KB-All SP-All
2	18 M	CB	2	WP, S, D	0	0	Hard to work with columns in speech	KB-All SP-All
3	17 M	PS	9	WP, S, E, W, CD, G	10-20 times	>50 (games) Windows	Uses Windows OK. Sometimes hard to understand speech	KB-All, JS-QO (games), SP-NVO
4	17 F	CB	9	WP, S,	0	0	-	KB-All SP-All
5	18 F	CB	7	WP, S, E, CD, G	0	10-20 times	With sighted help; plays audio for her	KB-All JS-NVO SP-All
6	15 M	CB HI	2 weeks	-	-	-	-	KB-All SP-All
7	17 M	PS	6	WP, S, E, W, CD, G	0	10-20 (games)	Netscape Win95. Too many fiddly commands	KB-All JS-NVO (games) SP-QO: Talking diction'y
8	16 M	PS	8	WP, S, E, W, D, G	10-20 times	1-5 times	Netscape Win95	KB-All JS-NVO (games) SP-QO: Talking diction'y
9	13 M	CB	5	WP	1-5 times	0	With sighted help	KB-All JS-NVO (games) SP-All
-	41 M	CB	15	All	>100	>50		KB-All JS-NVO SP-All

**Key to Abbreviations:****Sight**

CB=Congenitally Blind  
 PS=Partially Sighted  
 AB=Adventitiously Blind  
 HI=Hearing Impaired

**Apps (Applications) Used**

WP=wordprocessing (WP5.1)  
 S=spreadsheets  
 E=email  
 W=WWW  
 CD=CDROMs  
 D=database  
 G=games

**Input & Output - How Often Used**

All = all the time  
 QO= quite often  
 NVO=not very often

Five participants were familiar with the joystick and touchtablet from evaluations of DAHNI-1, and in addition all the partially sighted and two blind participants had other experience of using a joystick for games. Two of the experienced computer users (both partially sighted) had worked with a range of applications, including the WWW and CD-ROMs, and criticised existing hypermedia applications for being too complex, providing too many commands and an unreadable display, using too many graphics, and requiring the use of a mouse.

### **7.3.3 Hardware and Software**

The evaluations were run on PCs set up at the evaluation sites. One site used a 486 PC with a 250 MB hard disk, and 14 MB RAM, and the other a Pentium PC with a 1 GB hard disk, with 16 MB RAM. Both PCs had a SoundBlaster-16 card with the text-to-speech software TextAssist, a standard keyboard, a Microsoft Side-Winder 3D Pro digital joystick, and a custom-built touchtablet measuring 19.5cm x 14.5cm. Both installations included the three hypermedia modules in the proprietary ACCESS format; the London hypermedia module, the on-line Tutorial, and the General Help module.

### **7.3.4 Materials**

#### ***7.3.4.1 Tactile Diagrams and Pictures***

Tactile diagrams were again used during the training sessions to illustrate the concepts and structure of hypermedia. The new functional touchtablet (see Chapter 6, Section 6.4.6.4) used a tactile and large print overlay to indicate the location of commands on the workspace (as illustrated in Chapter 6, Figure 6.2). Tactile diagrams (line drawings on swell paper as used with DAHNI-1) were provided for blind participants to explore when listening to the descriptions of pictures in the London Hypermedia module; of a Beefeater, the Houses of Parliament, and paintings by Goya, Da Vinci and Monet.

#### ***7.3.4.2 Training Schedule and On-Line Tutorial***

The content of the group training schedule covered basic hypermedia concepts and terms together with the overall design of DAHNI-2 and how it was used with the three input

devices. The on-line tutorial was then used to teach each participant the details of using DAHNI-2, progressing through each feature of DAHNI-2: how to read; how to select commands; the function of each command; and how to use each input device for these activities.

#### **7.3.4.3 Questions for the Practice Period**

The 20 questions set for the practice period were left with participants in braille or large print, and required participants to find answers from various nodes around the London hypermedia module. Examples of these practice questions include:

- Which famous composer used to play the organ at Westminster Abbey?
- How heavy is the bell called Big Ben?
- Which concert hall in London held the largest ever indoor gig when Oasis played there this year?
- Who wrote diaries at the time of the Great Fire of London which later became famous?
- What is the name of London's first stone bridge over the Thames, and when was it built?

#### **7.3.4.4 Evaluation Tasks**

As described in Section 7.2.2.3, two types of task were developed to allow participants to use and assess DAHNI-2; a guided task (directive and non-explicit) to guide participants to a particular node without giving them the exact steps required; and a free task which participants created for themselves.

*The Guided Task.* The guided task and content questions which directed participants through the hypermedia module without listing the required steps are shown in Table 7.3, and can also be found in context in Appendix 1.6.

*The Free Task.* The instructions for the free task were firstly a request for the participant to identify and talk about a node which they had enjoyed, and secondly, to demonstrate getting to that node from the Home node and listening to it, for example:

Researcher: "Can you tell me about your favourite node?"

Researcher: "Can you take me there and show me?"

**Table 7.3: The Guided Evaluation Task for DAHNI-2**

Task	Notes
1. Make sure that you are at Home	Inserts time stamp in logging file
2. <i>Home Node.</i> Read into the second unit. Q: Approximately what year did the Romans start building the Great Roman Wall of London? Can you select the link to the City of London?	Answer: 100 AD
3. <i>City of London Node.</i> In the City of London node there is a link to the Great Fire of London. Can you select it please?	
4. <i>Great Fire of London.</i> Listen to the audio clip and listen for how many wooden houses were burnt during the fire.	Answer = 13,000
5. Now, I want you to go to completely different area of the hypermedia. What do you think is the best thing to do? Can you do this please?	Home or Back
6. <i>Home Node.</i> From this node, go off to cultural activities to find out about the art galleries in London.	
7. <i>Cultural Activities to Galleries.</i> In the Tate gallery is a picture by Monet, can you go and listen to the description of one of his pictures?	
8. Can you return to the cultural activities node because now we are going to hear what is on in the concert halls.	Back, Back
9. <i>Cultural Activities Node.</i> The Last Night of the Proms are held in one of London's concert halls, can you take us there?	
10. <i>Concert Halls.</i> Can find out what sort of songs are sung at the Last Night of the Proms?	
11. Can you listen to the audio clip?	
12. Let's go back Home. <i>(time stamp) End of task</i>	Inserts time stamp in logging file

#### 7.3.4.5 Evaluation Questionnaire

The questionnaire design was similar to that used for DAHNI-1, with the aim of identifying subjective opinions of the usability problems in DAHNI-2 to allow the design to be further improved. The full questionnaire can be found in Appendix 1.7 consisting of open and closed questions and rating scales. The main areas addressed in the questionnaire included the usability of: the on-line tutorial module; each input device; the synthetic speech output;

the output control commands; the on-line Tutorial, General Help module and Context-Specific help command; the workspace and commands; the tactile pictures and descriptions; non-speech sounds for commands and events; digitised audio nodes with sound effects; orientation and navigation commands; and preferences for media for learning (hypermedia, electronic text, braille).

#### 7.3.4.6 *Separate Investigations*

*Memorability of Information Presented in Different Media.* Of the 12 digitised spoken nodes and picture description nodes, 8 were selected if they contained several sentences of information (rather than being very short nodes), and the node headings presented to participants for content recall are listed in Table 7.4.

**Table 7.4: Audio and Picture Nodes for Information Recall**

Node Type	Node Contents
DIGITISED AUDIO	The Great Fire of London
"	Trading in London
"	Clip from Hamlet
"	Cockney Londoner
"	Imports into London
PICTURE DESCRIPTION	Photo of the Houses of Parliament
"	Painting by Monet
"	Photo of Changing of the Guard

*Memorability of Headings.* The 10 headings which participants had to identify included five taken directly from the London hypermedia module, and five written to be plausible but fictitious, see Table 7.5.

**Table 7.5: True and False Headings Presented**

Type	Heading
TRUE	St Paul's Cathedral
"	Cultural Activities in London
"	Westminster Abbey
"	The River Thames
"	Royal Events
FALSE	An Audio Clip from Macbeth
"	Famous Pubs in London
"	An Audio Clip of Blur Playing at the Hippodrome
"	A Picture by Picasso
"	Prince Charles

*Memorability of Non-Speech Sounds.* The nine sounds used in DAHNI-2 which participants had to identify and rate for memorability are listed in Table 7.6.

**Table 7.6: Non-Speech Sounds Tested**

<b>Non-Speech Sound</b>	<b>Referent</b>
<i>Paper Riffle</i>	Read Left/Right
<i>Donk</i>	Dead-End
<i>Bing</i>	Link
<i>Ta-Da</i>	Heading
<i>Transporter</i>	Home
<i>Pop</i>	Centrepoint
<i>Upwards Zoom</i>	Back
<i>Downwards Zoom</i>	Forward
<i>Swoosh</i>	Heading Command

### 7.3.5 Measures Taken

The multi-faceted nature of the evaluation involved a range of data collection methods, each providing specific and complementary information about the usability and effectiveness of DAHNI-2. The researchers took detailed notes, and evaluations were video-taped (with permission) and logged by computer. Comments obtained during the informal think-aloud task completion and from the evaluation questionnaire were combined. Measures taken included:

- Observed task performance - time taken, methods, mistakes, confusions, use of devices, workspace, commands.
- Subjective ratings and opinions recorded on the evaluation questionnaire (see Section 7.3.4.5).
- Separate investigations - the number of headings correctly identified as true/false; the number of sounds correctly identified and the mean memorability rating for each sound; and the number of details recalled from nodes of different media.

### **7.3.6 Procedure**

#### ***7.3.6.1 Group and Individual Training***

Participants were briefed in groups where possible, and received basic training in DAHNI-2 as a group following the training schedule outlined in Section 7.3.4.2. This group training session lasted around 30 minutes. The individual training session then commenced with a private interview to collect personal information using the Participant Characteristics Questionnaire (see Appendix 1.5). Each participant then worked individually through the on-line tutorial and its self-assessment questions at their own pace. The tutorial was generally completed within 40 minutes, and any additional revision was provided by the researcher on a one-to-one basis.

#### ***7.3.6.2 Practice Period***

Participants were then encouraged to complete the 20 practice tasks during the 2-week practice period between the training and evaluation sessions. The equipment and supporting documentation were left at school/college for the duration of the practice period and the participants' teacher and the researcher were available during this time to provide support if required. Computer-logging was running while DAHNI-2 was used during the practice period.

#### ***7.3.6.3 Evaluation Session***

The same generic methodology was used as in DAHNI-1 evaluations. The order of the DAHNI-2 evaluation session is outlined below:

- 1) *Briefing and Revision.* Each participant was briefed about the evaluation procedure, and asked to describe how to use DAHNI-2 to ensure that they were sufficiently knowledgeable to be able to use it independently. Any practice and revision required was conducted at this point.
- 2) *Guided Task.* The participant initially completed the guided task with their chosen input device, and the researcher used the standard wording of the task for each participant (see Table 7.3). The researcher only resorted to prompting a participant if they could not continue unaided, which merely consisted of encouragement to the

participant to think about the situation and what might be suitable commands rather than specifying the required commands. Participants were encouraged to think-aloud during the tasks, and to raise issues for discussion in context.

- 3) *Free Task*. The free task was then completed, and every participant used the keyboard. The participant was asked to tell the researcher about their favourite node, and then to demonstrate finding that node from the Home node using the informal think-aloud method. If the participant chose to visit a node which was close to the Home node (requiring little command use), they were asked to identify another node they had liked, and demonstrate getting to that node. Any prompting by the researcher was again merely to encourage the participant to think about suitable commands which might help them to achieve their goal, rather than to provide explicit direction.
- 4) *Guided Task (repeat)*. If time permitted, the guided task was then completed again, this time using one of the remaining input devices, at the participant's own choice. An attempt was made to counter-balance the amount and order of device usage across all participants to minimise order effects.
- 5) *Evaluation Questionnaire Part 1 - Overall Usability Questions*. The participant was then interviewed about the overall usability of DAHNI-2 (see Appendix 1.7 for the full evaluation questionnaire) covering many usability aspects of DAHNI-2. The participant was encouraged to be open and critical when giving their opinions, and asked to identify both good and bad design features.
- 6) *Memory for Headings Investigation*. The participant was told that the researcher wanted to explore the usefulness of the headings used in the London hypermedia module. They were told that of the 10 headings they would hear (see Table 7.5, and Appendix 1.7.1), half were taken straight from the hypermedia module and the other half were fictitious, and that they had to state whether they thought each heading was real (true) or made-up (false). The headings were presented one at a time in a random order.
- 7) *Evaluation Questionnaire Part 2 - Non-Speech Sounds Questions*. The participant was then asked questions about the usability and usefulness of the non-speech sounds in DAHNI-2 (see Appendix 1.7.2).

- 8) *Memorability of Non-Speech Sounds Investigation.* The participant was told that the researcher was investigating whether the sounds were easy or difficult to remember. Each of the sounds used in DAHNI-2 was played one at a time in a random order, and the participant was asked whether they could name the command or event each sound referred to (see Table 7.6, and Appendix 1.7.3). A list of the commands and events was available for reference if the participant could not immediately recall the referent of the sound. Once they had recalled, recognised or been told the referent, they were also asked to rate how easy it was to remember the sound for that referent, with reasons.
- 9) *Memorability of Information From Different Media Investigation.* The participant was informed that the researcher was exploring the value of presenting information in alternative formats, such as digital audio and picture descriptions. The participant was asked whether they had visited any of the eight listed nodes containing either digitised human speech or descriptions of pictures (see Table 7.4, and Appendix 1.7.4), and asked to recall as much information from the nodes as they could.
- 10) *Evaluation Questionnaire Part 3 - Navigation in Hypermedia and Preferences for Different Media Questions.* The participant was then asked about their feelings of orientation, and strategies for orientation and navigation within the hypermedia module, and about their preferences for hypermedia, standard electronic text and hard-copy materials for study purposes (see Appendix 1.7.5).
- 11) *De-Briefing.* The participant was debriefed about the evaluation, and any remaining issues discussed. Assurances of confidentiality were repeated, and the participant was thanked and awarded for their involvement with a Record of Achievement.

#### **7.4 Evaluation Results and Discussion**

Participants' task performance, their think-aloud comments and their responses on the questionnaire have been combined and are reported together. The mean ( $\bar{X}$ ) and standard deviation (*sd*) of their ratings are given, together with the spread of ratings. This data is given here, rather than in an Appendix for ease of reference. Where specific participants are discussed or their comments reported, their participant numbers are given, for example, P1, P3. Most ratings are from 9 participants ( $n = 9$ ), but where different the number of

participants is stated. Raw data of participants' ratings is available from the researcher. These findings are published in Morley, Petrie, O'Neill & McNally 1998a).

### **7.4.1 Overall Usability**

Participants started using the system very quickly and efficiently during the practice and evaluation sessions, and seemed very comfortable using DAHNI-2 even if they were not experienced computer users, as shown by their task performance and supported by their responses on the evaluation questionnaire. They seemed to find the majority of commands easy to learn and to use, particularly with two of the three input devices (the keyboard and touchtablet), and found the presentation of the hypermedia material interesting and varied. There were very few occasions when participants got lost within the hypermedia module and most were observed to be able to use appropriate commands to help regain their orientation.

It was rewarding to observe some of the less computer-literate students using DAHNI-2 very quickly with complete confidence, after only 60 minutes of training and practice using the on-line tutorial (and often with very little independent practice<sup>3</sup>). In addition, the adult blind computer expert was also able to use DAHNI-2 very quickly, and generally found it to be an acceptable prototype, although he made several suggestions for improvements which are included in the relevant sections.

#### **7.4.1.1 Overall Usability Score**

Unfortunately, general usability questions about DAHNI-2 were omitted from the evaluation questionnaire (such as those asked in DAHNI-1 evaluations: overall ease of use, ease of learning, and enjoyment), because of an oversight on the researcher's part, and therefore direct comparisons cannot be made between the ratings for the two systems.

However, nine usability questions were selected as the major usability questions on the questionnaire: ease of use of (1) keyboard; (2) joystick, and (3) touchtablet; (4) usefulness

---

<sup>3</sup> Despite the researcher's best efforts to ensure that participants in these evaluations had more experience of using DAHNI-2 than just the training session and using the on-line tutorial, a third of the participants did not use DAHNI-2 during the practice period. Therefore, some were no more experienced with DAHNI-2 than participants had been with DAHNI-1, but two-thirds were more practised.

of the workspace; (5) usability of synthetic speech output; usefulness of sounds (6) initially and (7) later; (8) ease of finding information; and (9) frequency of knowing one's location in hypermedia module. An overall usability score was calculated from the mean ratings of these nine questions, see Table 7.7.

**Table 7.7: The Nine Components of the Overall Usability Score for DAHNI-2**

Usability Question	$\bar{X}$ ( <i>sd</i> )	<i>n</i>
Ease of use of keyboard	4.76 (0.50)	9
Ease of use of joystick	3.20 (1.10)	5*
Ease of use of touchtablet	4.67 (0.58)	3*
Usefulness of workspace	4.11 (1.05)	9
Satisfaction with speech output	3.78 (1.30)	9
Usefulness of non-speech sounds initially	4.56 (0.73)	9
Usefulness of non-speech sounds later when more experienced	4.11 (1.17)	9
Ease of finding information in the hypermedia module	4.33 (0.52)	6*
Frequency of knowing location in the hypermedia module	4.11 (0.60)	9
<b>OVERALL USABILITY SCORE (Mean of 9 usability questions)</b>	<b>4.17 (0.47)</b>	

\* Although 5 participants used the joystick for the tasks and rated its usability, for various reasons the task time of 3 of these 5 participants was not recorded (see Section 7.4.3.1). Only 3 participants used the touchtablet for the tasks and rated its usability, and only the 6 participants who had used DAHNI-2 during the practice period answered the question about finding information in the module.

The overall usability score of 4.17 ( $sd = 0.47$ ) indicates that DAHNI-2 is considered quite highly usable in a range of areas. Participants felt that the keyboard, the touchtablet, and the non-speech sounds were all very easy to use and useful, they considered it easy to find information in the hypermedia module, and knew where they were most of the time. The weakest aspects of DAHNI-2 as shown by these ratings were the usability of the joystick and satisfaction with the speech output, but these mean ratings were still above the midpoint of the 1-5 scale, and overall, although improvements might be beneficial, the current design is reasonably usable. These nine usability issues are discussed in detail in the remainder of the Results section.

### **7.4.2 Ratings of Blind and Partially Sighted Participants**

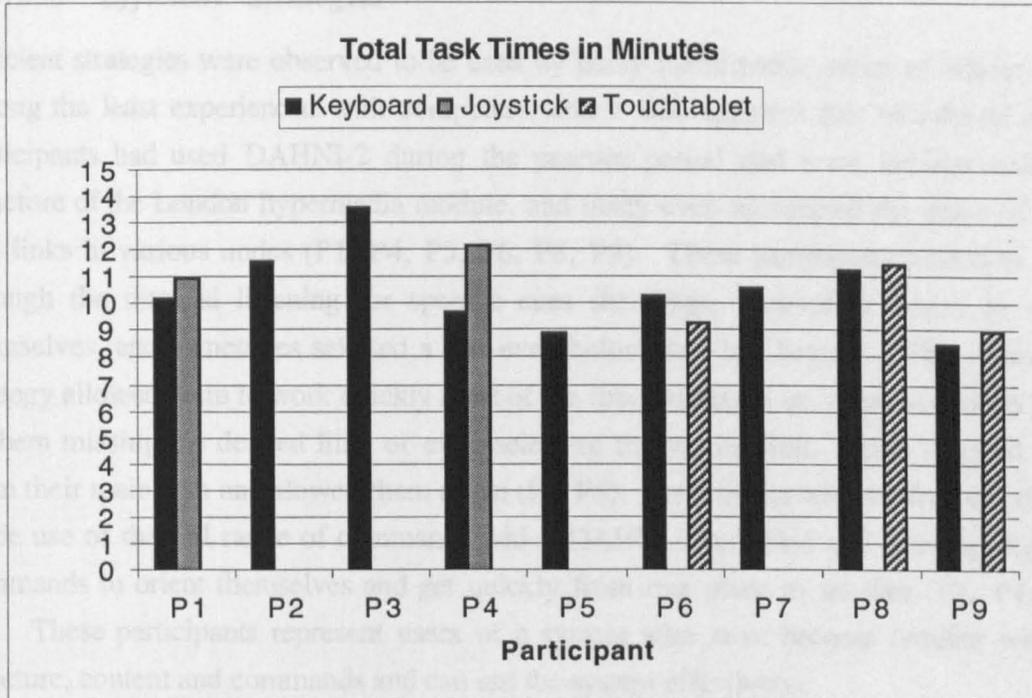
The ratings of blind and partially sighted participants did not differ significantly on these nine questions, shown by a Mann-Whitney U-test on the summed ratings ( $U = 4.0$ ,  $p = 0.1892$ ). Therefore, the ratings of blind and partially sighted participants will be combined throughout and any differences between the groups will be highlighted where relevant.

### **7.4.3 Overall Task Performance**

Performance on the evaluation tasks was recorded in the computer logging file and in the detailed notes of the researchers. Total task time was calculated and used in conjunction with the records of the methods used to provide information about the usability of DAHNI-2.

#### **7.4.3.1 *Times and Methods***

Total task times ranged from 8.5 to 13.6 minutes, and the total task times for each participant are displayed in Figure 7.1 for comparison across participants and devices. It was not possible to make statistical comparisons of these times because of insufficient data (DAHNI-2 crashed on occasion rendering the logging file useless; and some participants were not available for sufficient time to complete guided tasks with different devices). However, the graph of raw task times gives an indication that the touchtablet and keyboard allowed participants to complete tasks in about the same time, but for P4 in particular, the task undertaken with the joystick took noticeably longer than with the keyboard, and the joystick caused more usability problems than the other devices (see Section 7.4.4).



**Figure 7.1: Times Taken to Complete the Guided Tasks with the Three Input Devices**

The variability in total times depended partly on the usability of the actual device used, and also on the method the participant chose to execute commands. For example, performance with the keyboard was fastest when the keyboard shortcuts were used to execute commands (P4, P5, P9), and slowest when the numpad arrows were used to find and execute commands on the workspace (P3, P8). This was to be expected, since the shortcuts were designed specifically to be faster to use than the commands on the workspace. Similarly, several participants (P1, P4, P5, P9) were working effectively by skimming through units rather than listening to whole units, which made their task performance faster.

The total task times were not very useful at this stage for identifying and explaining usability problems and developing solutions, and therefore the remainder of this chapter will focus on the methods participants used (from observed task performance), and their comments.

#### **7.4.3.2 Efficient Strategies**

Efficient strategies were observed to be used by many participants, some of whom were among the least experienced with computers, and it was apparent that two-thirds of the participants had used DAHNI-2 during the practice period and were familiar with the structure of the London hypermedia module, and many even recognised the order of units and links in various nodes (P1, P4, P5, P6, P8, P9). These participants tended to skim through the material listening for specific cues (headings, phrases or links) to orient themselves, and sometimes selected a link even before they had heard it. This skimming strategy allowed them to work quickly most of the time, although on some occasions it led to them missing the desired link, or even selecting the wrong link, which diverted them from their main task and slowed them down (P1, P8). Participants who worked effectively made use of the full range of commands which DAHNI-2 provided and used appropriate commands to orient themselves and get quickly from one place to another (P1, P4, P5, P9). These participants represent users of a system who have become familiar with its structure, content and commands and can use the system effectively.

#### **7.4.3.3 Cautious Strategies**

Some participants tended to be more cautious in their use of DAHNI-2, relying on the commands on the workspace (rather than using the keyboard shortcuts for example), and listened to all the output to make sure they were getting all the available information (P2, P3, P7). These three participants were those who had not used DAHNI-2 very much (or not at all) during the practice period, and were therefore less familiar with the structure and organisation of the London hypermedia module and the available commands than were the more practised participants. These participants also relied heavily on a small range of commands in DAHNI-2, and only slowly began to make effective use of other commands. These participants represent beginner users who are exploring the content of a new hypermedia module and are learning how to use the system to full advantage.

Of course, although participants generally used one method more than another, most participants used a combination of the efficient and cautious methods while working with DAHNI-2, depending on their task and how familiar they were with the content material and appropriate commands at each stage of their task. In fact, P8 alternated between using keyboard shortcuts for commands they could remember, and the workspace for the others.

#### 7.4.3.4 *Types of Mistakes*

The mistakes observed during the tasks could be classified into three types with different causes:

- 1) *Misunderstanding or Lack of Knowledge*: a mistake made because a participant misunderstood a situation; or could not remember the functionality of a command, which command to use, or how to use an input device correctly.
- 2) *Slip*: a mistake made when working too quickly - such as selecting the wrong link while skim-reading.
- 3) *Device Problem*: a mistake made because an input device was difficult to use - such as selecting the wrong command because the joystick was too sensitive; or executing too many commands because the output was too slow and seemed to be unresponsive.

Of the three types of mistakes, the first is the most severe, because it indicates that participants are unable to use DAHNI-2 effectively for some reason. As already indicated in previous sections, the least practised participants were observed to be frequently confused over which command to use and where they could go from a particular node (P2, P3, P7) - and this was a frequent problem, particularly with the more advanced commands. These types of mistakes may be rectified with additional training, or even just further practice using DAHNI-2. This was illustrated by participants who had used DAHNI-2 during the practice period, who were very confident about the commands, and were more likely to make (infrequent) slips while working too quickly (P1, P4, P5, P6, P8, P9). This is the type of mistake which all users make when over-confident in their ability, and is a reminder to users that sometimes they have to slow down to be effective. Mistakes caused by device problems can be addressed by examining the usability of each input and output device (see Section 7.4.4).

One isolated incident suggests that some users might find it difficult to grasp the difference between the workspace concept and the structure of the hypermedia module: when asked to go to the Home node of the hypermedia module, P3 confidently jumped to centrepoint on the workspace. This may be a simple misunderstanding which would be easily resolved with practice, but it raises the question of the compatibility of a physical layout of commands being used to work in a structured information space, and this should be monitored in any future evaluations.

#### 7.4.4 Input Devices

Participants were asked to rate the three input devices for their ease of use and to rate how much they liked using them. The mean ratings are shown in Table 7.8 and Table 7.9, and although small numbers meant that statistical comparisons could not be made, the figures do indicate the relative usability of the devices.

**Table 7.8: Ease of Use Ratings for Input Devices**

Input Device	Ease of Use $\bar{X}$ ( <i>sd</i> ) n	Spread		
		1-3	4	5
Keyboard	4.67 (0.50) 9	-	3	6
Joystick	3.20 (1.10) 5	4	-	1
Touchtablet	4.67 (0.58) 3	-	1	2

**Table 7.9: Likeability Ratings for Input Devices**

Input Device	Likeability $\bar{X}$ ( <i>sd</i> ) n	Spread		
		1-3	4	5
Keyboard - numpad arrows	4.11 (0.93) 9	3	2	4
Keyboard - shortcuts	4.78 (0.44) 9	-	2	7
Joystick	3.00 (1.22) 5	4	-	1
Touchtablet	4.67 (0.58) 3	-	1	2

The keyboard and touchtablet were the preferred input devices and it was clear from observations and participants' comments that the joystick suffered from implementation problems which reduced its usability and likeability ratings, discussed in the following sections.

##### 7.4.4.1 Keyboard

All participants used the keyboard considerably more than the other two devices, and found it very easy to use (see Table 7.8 and Table 7.9). However, participants were divided over the likeability of the numpad arrow cursors: half liked them particularly when learning the commands (P2, P5, P4, P9), and when they could not remember the shortcuts (P9), although others found them too slow and occasionally forgot their position on the workspace while using them (P1, P6). All participants liked using the shortcuts stating that they were easy to learn and quick to use.

However, the overall ratings of likeability of the numpad arrows and the shortcuts were not significantly different (Wilcoxon  $Z = -0.8257$ ,  $p = 0.0679$ ), and participants were divided almost equally between those stating a preference for the numpad arrows (P3, P6, P7, P9); for using the shortcuts (P1, P5, P8); and for using both methods at different times (P2, P4).

One critical usability problem was observed: participants found it very difficult to find the 'Stop' keyboard shortcut (<Ctrl> + <S>) since both keys were quite difficult to locate quickly and accurately, thus preventing participants from halting the output immediately. At times like these, it was clear that a single key, as used in other speech applications, such as <Ctrl> or <Esc> might be more effective. Similarly, keys such as <Home>, <End>, <PgUp> and so on might be useful as shortcuts for common commands.

#### **7.4.4.2 Joystick**

The joystick was rated as being only moderately easy to use and was not very well-liked (see Table 7.8 and Table 7.9), and there was no difference between the overall mean usability ratings for the joystick of DAHNI-1 and DAHNI-2 (Mann-Whitney  $U = 11$ ,  $p = 0.3434$ ). Even with the improvements made to the implementation of the joystick many participants still found it too sensitive and difficult to control, making it time-consuming and frustrating to find and select commands (P1, P4, P5, P9). With practice, some participants were observed to develop some control, but P4 and P5 were unable to achieve the steady hand required to operate it successfully. Nevertheless, participants liked the concept of using the joystick to find and execute commands on the workspace which gave the system a game-like feel. The joystick might usefully be replaced by an analogue device which 'clicks' onto each command, much like a remote control car handset, with a separate button to select the command when it is found. The workspace shape would thus be well-defined, and participants could not fail to find and select commands successfully.

#### **7.4.4.3 Touchtablet**

The touchtablet received identical high ratings for both ease of use and satisfaction from the one partially sighted and two blind participants who had used it (see Table 7.8 and Table 7.9), and participants were observed to be able to operate DAHNI-2 in less time than with the other input devices, presumably because it was so simple and self-evident to use.

Participants said they liked being able to use a different device (P5, P8) and seemed to enjoy being able to sit back away from their desk and operate the computer. The tactile markers were considered unnecessary by P6, who said that dots would be sufficient to indicate the position of commands, especially since the single-press and double-press gave two types of information. However, the slight time-delay between selecting a command and system output frustrated participants (P6, P9). The touchtablet is likely to be an attractive alternative input device, especially for novice keyboard users, providing the response time is improved, and different sized touchtablets and overlays are provided to suit different users.

#### 7.4.5 The Workspace

Participants generally found the layout of commands on the workspace useful as shown in Table 7.10, and there was no difference between the ratings for the DAHNI-1 workspace and the DAHNI-2 workspace (Mann-Whitney  $U = 28$ ,  $p = 0.7577$ ).

**Table 7.10: Ratings for Usefulness of Workspace**

Usability Question	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Usefulness of Commands arranged on the Workspace	4.11 (1.05)	2	3	5

Some participants reported that they found the workspace useful and very easy to use because it was easy to work round a “circuit” (P3); there was nothing to remember in order to find commands (P6, P7); the symmetry helped them to find commands (P8), and it was particularly useful for being able to select commands for which the shortcuts had been forgotten (P2). Several participants found it more useful than the keyboard shortcuts or traditional menus because they were always available and they did not have to know specific shortcut keys (P2, P7, P8). However, other participants preferred the shortcuts stating that they were quicker to use (P1, P5).

The workspace was clearly beneficial to most participants at least while learning to use the commands, and for some remained the preferred method of interaction, although took longer than using the keyboard shortcuts for example. As discussed in Section 7.4.4, the workspace was easier to use with the touchtablet and keyboard numpad arrows than with the joystick, but the concept allowed participants to have the same mental model of the

interface when using these different devices. On the whole participants were observed to transfer their knowledge of the interface correctly across devices, making it easy for them to work with a new device quickly.

The clear majority of participants (7 out of 9) preferred commands to be presented in a human voice than in synthetic speech, commenting that it was clearer and nicer to listen to and helped keep the commands separate from the hypermedia content, and the remaining two participants felt that it didn't matter (P1, P2). The use of the dead-end sound "*Donk*" when moving around the workspace was observed to be useful to reinforce its shape, and removed the need to execute additional commands to find out that there were no more commands in a particular direction.

#### 7.4.6 Hypermedia Presentation Methods

Participants rated their satisfaction with the different presentation methods for the London hypermedia module - synthetic speech, picture nodes with descriptions, and digitised audio nodes - and their mean ratings are given in Table 7.11, and discussed in the following sections.

**Table 7.11: Ratings for Hypermedia Presentation Methods**

Usability Question	$\bar{x}$ (sd) n	Spread		
		1-3	4	5
Likeability of Synthetic Speech	3.78 (1.30) 9	3	3	3
Likeability of Picture Nodes with Descriptions	4.38 (0.74) 8	1	3	4
Quality of Tactile Pictures	4.00 (0.00) 5	-	5	-
Likeability of Audio Nodes (human, musical, sound effects)	5.00 (0.00) 9	-	-	9

##### 7.4.6.1 Synthetic Speech and Output Control Commands

*Satisfaction with Speech.* Participants were fairly satisfied with the synthetic speech output (see Table 7.11) which presented much of the material in the hypermedia module, and was considered reasonably clear and intelligible to both novice and experienced computer users (P4, P6, P7, P9). Criticisms of the speech output included poor pronunciation of some words, a lack of pauses, a dislike of the American accent of the output, and a dislike of the female voice used to present links which still sometimes made the links difficult to comprehend (P1, P2, P3, P5, P6, P8, P9).

*Change Voice and Change Rate Commands.* Many participants said that it was quite useful to be able to change the voice and rate of the output using the 'Change Voice' and 'Change Rate' commands, see Table 7.12.

**Table 7.12: Ratings for Change Voice and Change Rate Commands**

Usability Question	$\bar{X}$ (sd) n	Spread		
		1-3	4	5
Usefulness of 'Change Voice' Command	4.00 (0.93) 8	1	5	2
Usefulness of 'Change Rate' Command	3.88 (0.64) 8	2	5	1

Participants said that although it was good to have a choice available of voices and speed to provide variety while reading (P1, P4), a wider choice of voices should be available (P8), and almost all participants preferred the male to the female voice saying that it was easier to understand. Participants also felt that it was useful to be able to change the rate of the output easily, but almost all participants used the normal rate throughout the training and evaluation session (although this rate was considered too slow by the adult computer expert who found the faster rates more suitable).

*Missing Commands.* The adult expert computer user suggested that a 'pause' feature would be useful to temporarily pause the output and then resume play from exactly the current location (rather than from the beginning of the current unit using 'Stop' and 'Read Right'). In addition, the lack of a volume control within DAHNI-2 was a problem when working in the school environment with background noise, particularly for the participant with a hearing impairment. Two volume commands should be available, 'Increase Volume' and 'Decrease Volume', which work in small increments.

#### 7.4.6.2 Picture Nodes with Descriptions

The picture nodes with descriptions were well-liked by almost all participants (see Table 7.11), both blind and partially sighted, and the blind participants also liked the quality of the tactile pictures, although the addition of labels would add clarity (P1). Participants reported that they liked the descriptions for being simple, clear and full of detail (P5, P6), although P8 (partially sighted) found the descriptions too long and detailed. Participants seemed excited to hear about famous artwork, or find out what famous buildings looked like, and were able to point out the main features of the tactile picture having listened to the verbal description, (although they said that this would not have been possible using the

tactile diagram alone). Participants said that they would like to see more use of such descriptions and tactile pictures, so they could work like their sighted friends (P1), because it was interesting (P5) and so they could get information which they might otherwise miss (P4). The descriptions and tactile pictures together therefore seemed to be a powerful combination, adding interest and variety to the hypermedia material.

#### 7.4.6.3 Digitised Audio Nodes

Participants significantly preferred the digitised audio nodes to the synthetic speech nodes (Wilcoxon  $Z = -2.2014$ ,  $p = 0.0277$ ), and all participants gave the audio nodes the highest rating possible (see Table 7.11). Participants reported that they made the content more interesting (P1, P4, P6, P9), and the digitised speech was clearer and easier to understand with more expression than synthetic speech (P2, P4, P5, P6, P9). They were observed to be excited to discover audio nodes, and seemed to enjoy listening to them. Concern was raised about the background sound effects in some nodes making the speech difficult to hear (P8, P9).

#### 7.4.6.4 Memorability of Information from Audio and Picture Nodes

Participants seemed to be able to recall details accurately from audio nodes more easily than from picture nodes (see Table 7.13) although the difference was not significant (paired-samples t-test,  $t = 1.04$ ,  $df = 8$ ,  $p = 0.331$ ).

**Table 7.13: Detail Recalled From Picture and Audio Nodes**

Node Type	Mean Number of Details Recalled by Each Participant ( <i>sd</i> )	Range of Details Recalled		
		0-4	5-7	8+
Picture Nodes	2.89 (2.85)	8	-	1
Audio Nodes	4.00 (2.88)	5	3	1

P5 recalled the highest number of details from both picture and audio nodes (totalling 9 details from each node type), whereas the other participants ranged from recall of 0-4 details from picture nodes, and 0-7 details from audio nodes<sup>4</sup>. Three participants were noticeably worse than the others, recalling only 1-4 details (P1, P2, P3), and may not have

<sup>4</sup> Participants were not pressed for recall of detail because of time constraints, and it is possible that with prompting they could have recalled many more details than are reported here.

visited these nodes or paid much attention to the contents. In contrast three participants were easily able to recall reasonably high numbers of detail: 8-18 details (P4, P5, P7).

Some details were recalled almost verbatim - particularly from audio nodes (P4, P5, P8, P9) - and this could be valuable when creating material which must be accurately remembered. Several participants recalled *more* information than was contained in a digitised spoken node (P1, P5, P6), and were in fact also quoting from the surrounding textual nodes (presented in synthetic speech) related to the same topic as the digitised spoken node. This integration of material could be considered a useful side-effect of multimedia presentation when presenting information in small chunks; users seem to find it easy to assimilate small chunks of information into more meaningful larger topic areas.

Some participants were able to recall the main details from picture nodes, relating to both the content and the style of the picture, and were quite enthusiastic about the use of such picture descriptions in their education (P2, P5, P6, P7). However, it is possible that since the descriptions are presented in synthetic speech, it makes the information less memorable than presentation in digitised speech - a point to consider when authoring material.

The high level of detail recalled from both digitised spoken audio nodes and descriptions of pictures indicates that these types of nodes are appropriate to include in educational hypermedia material for three reasons. Firstly, they provide a higher level of access to curriculum material; secondly, they provide a motivating effect on the students; and thirdly, they seem to facilitate the assimilation of information from different nodes into larger, more meaningful topics.

#### **7.4.7 Navigation and Orientation**

##### ***7.4.7.1 Navigation Strategies***

Six participants reported that they found it fairly easy to find specific information in the hypermedia module during the practice period (see Table 7.14). Participants said that it was easy just to read through and follow links which sounded plausible to find information (P4, P6).

**Table 7.14: Ratings for Ease of Finding Information**

Usability Question	$\bar{X}$ ( <i>sd</i> ) n	Spread		
		1-3	4	5
Ease of Finding Information in Module	4.33 (0.52) 6	-	4	2

As already described in Section 7.4.3.2, some participants were observed to be confidently using appropriate commands to get to their desired location, and navigating effectively using the information given by headings and the non-speech sounds to orient themselves (discussed further in Sections 7.4.7.5 and 7.4.8). Many participants had a fairly good understanding of the organisation of the hypermedia module, even down to the unit number of the required link, and were able to re-orient themselves if necessary if they deviated off their desired path (particularly P1, P4, P5, P6, P9).

Participants were observed to be comfortable using the 'Read Right' and 'Read Left' commands to read and skim-read within the node, together with 'Select' to follow a link, and many used 'Home' and 'Back' confidently to jump between nodes. Participants were even selecting links in a unit before hearing the link itself because DAHNI-2 made each link 'active' as soon as the unit was loaded. This concept of the current link therefore allowed users to work quickly, especially in units they knew well, and the 'Select' command made selecting the current link very easy. The command 'Read Current Unit' was rarely used, and many participants either forgot that this command was available, or its function, and tried to use 'Read Left' to hear the current unit again. This may be because many participants were familiar with the RW function on CD-players which works like this. Perhaps the reading commands should match this implementation to be more consistent with other audio devices.

#### 7.4.7.2 Feelings of Orientation

Participants felt fairly confident that they knew where they were most of the time in the hypermedia module, although several participants reported less frequently knowing where they were within a single node, see Table 7.15 (where 1 = never, 5 = all the time).

**Table 7.15: Ratings for Orientation**

Orientation Question	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Frequency of knowing where you are in the module	4.11 (0.60)	1	6	2
Frequency of knowing where you are in a node	3.67 (1.00)	4	3	2

The difference between these mean ratings was not significant (Wilcoxon  $Z = -0.9435$ ,  $p = 0.3454$ ).

#### 7.4.7.3 Level of Concern if Disoriented

Participants were not very concerned if they did feel disoriented either within the hypermedia module, or within a node (see Table 7.16, where 1 = not at all concerned, 5 = very concerned). This difference was also non-significant (Wilcoxon  $Z = -0.4472$ ,  $p = 0.6547$ ).

**Table 7.16: Ratings for Concern if Disoriented**

Orientation Question	$\bar{X}$ (sd)	Spread		
		1-3	4	5
Level of concern if you did feel lost in the module	2.11 (0.33)	9	-	-
Level of concern if you did feel lost in a node	2.22 (0.67)	8	1	-

#### 7.4.7.4 Orientation Strategies

These orientation ratings were borne out by observations of participants' performance, where the majority were working confidently around the system using the navigational and support commands competently. Participants reported that there were several commands which they used if they felt unsure of their current location and to re-orient themselves; "to start from the beginning" (P5, P8), or to "find out where you are" (P4).

- a) Participants listed the following commands which they used for re-orientation in the hypermedia module (frequency in brackets): 'Home' (8), 'Back' (5), 'Where Am I?' (4), 'Read Right' (2), 'Read Current Unit' (1), 'Read Current Link' (1), and 'Help' (1).
- b) A different selection of commands were mentioned for re-orientation within a node: 'Read Left' (3), 'Where Am I?' (2), 'Read Right' (2), 'Read Current Unit' (2), 'Heading' (2), 'Back' (1), 'Read Current Link' (1), and 'Help' (1).

Clearly participants were more likely to jump either to the Home node or to the previous node if lost overall, but if unsure of their position within a node, would be more likely to read surrounding material and ask for information about their location (but no-one actually used the 'Heading' command for orientation during the tasks).

Several participants felt less confident about their location within a node itself (P3, P5, P7, P8) and from observations, this seems to be because there were no signposts through the units in a node while reading through it - whereas they were clearly using headings and links to orient themselves on a larger scale within the hypermedia module. The 'Where Am I?' and 'Overview' commands were designed to provide this within-node orientation information, and several participants did use the 'Where Am I?' command to find out the current node heading and the unit number (P1, P3, P9), but participants rarely used the 'Overview' command. This may be because the hypermedia module was small and many participants had become very familiar with the content, and therefore did not require such overview commands (or they forgot its function - P2, P5). However, it is likely that other users working in larger hypermedia modules will require such orientation information. It might be useful therefore, to combine the information from these two commands into a single 'Where Am I?' command, which lists the node heading, the current unit number and the total number of units in the node, the number of links and perhaps also the current link.

#### 7.4.7.5 Headings as Navigational Aids

As indicated already, participants were clearly learning about the content and structure of the hypermedia module and using these as landmarks to help them get around. This conclusion is supported by observation of task performance and in their high accuracy rates of identification of true and false headings: 83.4% of headings were correctly identified, and only 8.8% were mis-identified (see Table 7.17, and Appendix 1.8.2 for the raw data).

**Table 7.17: Identification of True and False Headings**

	<b>Correct ID (hits)</b>	<b>Incorrect ID</b>	<b>Unsure</b>
True Headings	44.4 %	4.4 % (miss)	1.1 %
False Headings	39.0 %	4.4 % (false positive)	6.7 %
<b>Total Identification Rate</b>	<b>83.4 %</b>	<b>8.8 %</b>	<b>7.8 %</b>

If the results had shown a high false positive recognition of headings, it would indicate that the headings were not useful as landmarks and orientation aids through the material. However, it is encouraging that so many participants were able to correctly distinguish between even very similar headings. Headings which were mis-identified (either a miss or a false positive) were those which were worded so that they were very similar to a real heading in the module and relied on accurate memory or subject-area knowledge to

distinguish. For example, if participants had only visited a node once (such as the audio clip from Hamlet), then heard the false heading (an audio clip from Macbeth), participants could easily have mistaken them if they could not remember the name of the play from which the quotation was taken. In fact, the participants who mis-identified this heading could often cite the quotation (“To be, or not to be...”), but failed to recognise the heading as false. In addition, the majority of ‘unsure’ responses were to false headings, where participants had doubts about the authenticity of these particular headings.

All participants were able to correctly identify 7 or more of the 10 headings ( $\bar{X} = 8.33$ ,  $sd = 1$ ), even though participants were not told in advance that they would be tested on their memory for the headings. This indicates that the headings were quite easily memorable even without conscious effort, and these results could also be used as a measure of incidental learning.

#### 7.4.8 Non-Speech Sounds

##### 7.4.8.1 Usefulness

Participants found the non-speech sounds very useful, both when using DAHNI-2 initially, and later when more experienced (see Table 7.18), and the difference between ratings was not significant, Wilcoxon  $Z = -0.9129$ ,  $p = 0.3613$ . An overall mean score for usefulness of 4.33 ( $sd = 0.97$ ) was obtained by combining the means of initial use and later use when more experienced.

**Table 7.18: Ratings for Usefulness of Non-Speech Sounds**

Usability Question	$\bar{X}$ ( $sd$ )	Spread		
		1-3	4	5
Initial Usefulness of Sounds	4.56 (0.73)	1	2	6
Later Usefulness of Sounds with Experience	4.11 (1.17)	3	1	5
<b>Overall Usefulness of Sounds (Mean)</b>	<b>4.33 (0.97)</b>			

Participants reported that they liked having sounds to “tell you what’s what” (P2), to tell them what the commands had done (P4), which gave them more confidence and information (P7), although two participants said it took them a while to get used to the sounds and stop mixing them up (P1, P5). For five participants, the sounds were rated as being equally useful at all times (P2, P3, P4, P5, P7). For two participants, the usefulness

of the sounds *increased* with experience as they now knew what the sounds meant and started to rely on them (P1, P2); whereas for three participants (P6, P8, P9) the sounds became *less useful* as they became familiar with DAHNI-2 and the structure of the hypermedia module, and said that some of the sounds could now be removed: centrepoint (“Pop”), ‘Home’ (“Transporter”), and a heading (“Ta-Da”).

Observations indicated that participants were clearly listening to the sounds to inform them about their current situation, and in many cases were not waiting to listen to the speech output and were relying purely on the non-speech sounds for command confirmation and feedback about their location. This helped them to work very efficiently, and with experience participants did not seem to make any conscious effort to draw meaning from the sounds. In addition, participants using DAHNI-2 seemed to be more comfortable and confident about the results of their commands and their location in the hypermedia module compared to participants using DAHNI-1 (although there is no quantitative data to support this). None of the sounds was reported to be annoying.

The sounds which were reported to be the most useful were for: a dead-end (6); ‘Read Right’ and ‘Read Left’ (4); ‘Home’ (3); ‘Back’ and ‘Forward’ (2); the heading in a node (1); centrepoint (1); and a link (1). It was interesting that participants did not list as many sounds as they had been observed to make use of - another result which supports the decision to use both observation and interviews.

#### **7.4.8.2 Inconsistent Sound Implementation**

An interesting mis-association was made by a significant number of participants (P1, P2, P3, P5, P8): the “Ta-Da” sound (intended to indicate arrival at a heading after following a link or using the ‘Heading’ command) was instead felt to be attached to the execution of the ‘Select’ command when following a link. When either of these commands was executed DAHNI-2 output “Ta-Da” followed by the actual heading. Table 7.19 highlights the inconsistency of the “Ta-Da” sound by presenting the context surrounding most sounds (using ‘Read Right’ and ‘Heading’ as illustrations), and the context surrounding the “Ta-Da” sound.

**Table 7.19: Inconsistent Sound Implementation**

Command Selected	Output Heard
'Read Right' to output the next unit	" <i>Paper Riffle</i> " This Gothic building of pinnacles and towers is...
'Select' to follow a link	" <i>Ta-Da</i> " The Houses of Parliament.
'Heading' to jump to the heading of the current node	" <i>Swoosh</i> " " <i>Ta-Da</i> " The Houses of Parliament.

Most sounds in DAHNI-2 confirm the execution of the prior command (for example, "*Paper Riffle*" and "*Swoosh*"); whereas "*Ta-Da*" was intended to indicate arrival at a heading, rather than being a confirmation of the 'Select' command to follow a link - and it is this inconsistency which seems to have led to the mis-association. While it did not cause any *confusion* while working with DAHNI-2, sounds should be consistently implemented to maximise their effectiveness.

#### 7.4.8.3 User Preferences

It was very obvious that each participant had their own preferences for the sounds while they learned how to use DAHNI-2 and as they became more familiar with it, and therefore any system should allow users to configure the sounds used to suit their level of hearing, current task, current environment and individual choices for each sound. This will be difficult to implement with the simple toggle commands which are a feature of DAHNI-2, and may require some Windows-type of dialog box interaction so far avoided in DAHNI-1 and DAHNI-2.

#### 7.4.8.4 Dead-Ends and Links in a Node

All participants said that they found the dead-end sound "*Donk*" useful for informing them that they had reached the end of a node, as it saved them having to execute a further reading command. They seemed to like the sound itself, and were observed to respond to the sound without much effort. In fact, several participants were disappointed that the cartoon-style "*Uh-Oh*" sound for dead-ends had gone; this had been removed because it was anticipated to become annoying! One participant (P8) and the adult expert said that they would have liked to try using DAHNI-2 with a sound at the end of each *unit* to indicate the opposite information - that they could *continue* reading. This could be indicated by a

continuation sound similar to an auditory ellipsis for example, using three very short tones. In this case, the dead-end sound at the end of the node might be redundant since the absence of the continuation sound would indicate that there were no further units, but some users might prefer to be given redundant information.

The sound to indicate a link seemed to be used quite effectively, and participants were usually very certain of the link word, as the sound “*Bing*” was observed to alert them that a link was coming, and the change in voice for the presentation of the link word itself identified the exact link and made it easily memorable. However, several participants said that the non-speech sound to indicate the link would be sufficient for identifying the link (P6, P8, P9), and suggested removing the change in voice for reading link words. However, the sound alone would not indicate the exact wording of a link, which would not allow users to make informed choices about which links to follow.

#### 7.4.8.5 Memorability of Non-Speech Sounds

The sounds were found to be reasonably easy to identify and were rated as being very memorable, although some were rated as significantly more memorable than others (Friedman chi-square  $F = 13.7037$ ,  $df = 7$ ,  $p = 0.0567$ ). Table 7.20 presents the numbers of participants correctly identifying the referent of each sound, the mean memorability rating for each sound, and the overall sound memorability rating. The sound for the heading command was not correctly identified by any participant (since participants rarely used this command) and therefore has been excluded from the calculations of the mean sound memorability rating. The raw data is given in Appendix 1.8.3.

The sounds were reasonably easy to identify, especially for sounds which were attached to frequently-used commands or events. All nine participants correctly named the referent of 5 or more of the 9 sounds ( $\bar{X} = 6.89$ ,  $sd = 1.27$ ), although three participants were noticeably less confident at recognising the sounds than the other participants (P1, P2, P3) but their ratings and performance provided no indication of why this might be. It may be that some sounds were difficult to identify or were easily confused when heard out of context, despite observations of participants using the information the sounds effectively when actually using DAHNI-2, and these were especially true of “*Pop*”, “*Bing*” and “*Donk*” when heard in isolation during the test.

**Table 7.20: Identification and Memorability of Non-Speech Sounds**

Non-Speech Sound	Referent	Correct ID (# Ps)	Memorability Rating $\bar{X}$ ( <i>sd</i> ) 9 Ps	Spread		
				1-3	4	5
<i>Paper Riffle</i>	Read Left/Right	9	5.00 (0.00)	-	-	9
<i>Donk</i>	Dead-End	9	4.89 (0.33)	-	1	8
<i>Bing</i>	Link	8	4.67 (0.71)	1	1	7
<i>Ta-Da</i>	Arriving at Heading	8*	4.44 (0.73)	1	3	5
<i>Transporter</i>	Home	8	4.33 (1.12)	2	1	6
<i>Pop</i>	Centrepoint	8	4.32 (1.11)	2	2	5
<i>Upwards Zoom</i>	Back	7	3.89 (1.05)	3	3	3
<i>Downwards Zoom</i>	Forward	5	3.56 (0.13)	4	3	2
<i>Swoosh</i>	Heading Command	0	-	-	-	-
<b>Mean Sound Memorability Rating (of the 8 remembered sounds)</b>			<b>4.39 (0.49)</b>			

\* As mentioned in Section 7.4.8.2, the “*Ta-Da*” sound to indicate a heading was frequently mis-associated with executing the ‘Select’ command to follow a link - but since these two events amounted to the same thing, this particular mis-association was ignored when calculating correct identification scores.

There was no difference between ratings of blind and partially sighted participants (Mann-Whitney  $U = 5.5$ ,  $p = 0.3810$ ), although overall individual differences emerged: some participants rated all sounds as being very highly memorable (P4, P5, P7, P9), and others considered them to be less memorable (P3, P8). However, the overall memorability rating for all 8 remembered sounds was quite high ( $\bar{X} = 4.39$ ,  $sd = 0.49$ ,  $n = 8$ ), and even the ‘Forward’ sound (which was not heard very frequently) was not rated as very difficult to remember since participants remembered that it was the reverse of ‘Back’ (P9).

Since none of the sounds was particularly difficult to identify or rated as being particularly difficult to remember, these sounds seem to be effective at providing information and feedback for their referents.

#### 7.4.9 Preferences for Media for Learning

For most participants this was their first opportunity to discover the diversity of information available in hypermedia format, and almost all said they would like to use hypermedia material in future when studying, stating that the different media provided variety, allowed them to follow their own line of interest, and they found it interesting to have pictures described and allowed them to make their own interpretation of information

presented as audio clips (P1, P2, P3, P5, P6, P9). The only two disadvantages of hypermedia mentioned were that it was not possible to listen to the whole content in a linear fashion (P4), and that it was not as portable as a braille book (P4, P9). In addition, participants realised that most of the material they required for their education was not available in accessible hypermedia format, and stated that unfortunately they would still have to be reliant on braille hard-copy, or electronic plain text files for their study.

#### 7.4.10 Support Features: On-Line Tutorial and Help Features

Two participants used the General Help module (P2, P4) during the practice period, and two participants had worked through the on-line tutorial again to refresh their memories about certain commands in DAHNI-2 (P2, P8). These participants said they preferred the teaching-style presentation of the tutorial which told them everything in a step-by-step manner, rather than having to define their own query in the help module. The ratings for the usefulness of these support features are given in Table 7.21.

**Table 7.21: Ratings for Usefulness of Support Features**

Usability Question	$\bar{X}$ ( <i>sd</i> ) n	Spread		
		1-3	4	5
Usefulness of Tutorial for New Users	4.00 (1.00) 9	2	4	3
Usefulness of General Help System	4.00 (1.15) 4	2	-	2
Usefulness of Context-Specific Help Command	4.33 (0.58) 3	-	2	1

Participants rated the tutorial as being useful for completely new users because it took users from the basics through each specific command (P7), and P5 thought that every new user should work through it, although P6 said that it would only be useful after initial one-to-one training. Criticisms included that it was too long and was broken into too many separate nodes and units, and that a search feature would be useful (P3, P6, P7, P8, P9). Two participants had used the General Help module over the practice period, and rated it as quite easy to use because they were able to find their answer simply by choosing the relevant heading and following instructions (P2, P4), although P4 found the listing of headings sometimes confusing. Three participants tried using the 'Context-Specific Help' command and found this particularly easy to use, and helpful for explaining commands they had executed such as 'Forward' which sometimes confused them, without having to lose their place in the hypermedia module (P4). However, no participants used it during the evaluation tasks.

Although only a few participants had used the on-line support modules, they rated them as being fairly useful and easy to use, and it is likely that complete novices who have not received any training in DAHNI-2 would be well supported by the on-line tutorial and general help modules. These modules could be made more appealing, for example, with the use of multimedia presentation such as digitised audio nodes (and for more recommendations see Petrie, Morley, O'Neill, McNally, Lauder, Graziani, Palchetti & Burzagli 1997).

### **7.5 Limitations**

Although these evaluations have provided support for the design and implementation of many parts of DAHNI-2, it is recognised that there are limitations to how these results can be interpreted and applied. Since DAHNI-2 is a stand-alone prototype it is possible to draw conclusions and propose design recommendations about future versions of DAHNI-2 and for similar prototypes. However, care should be taken if attempting to extrapolate these findings to the design of WWW browsers for example, since a number of additional issues are likely to be important which go beyond the scope of DAHNI-2 (such as the accessibility of web pages, the provision of many levels of heading and so on). Some of the important limitations of this design and evaluation work are outlined here.

Firstly, DAHNI-2 may create high cognitive overhead for some users with the mental effort required to hold in mind a virtual layout of commands on the workspace as well as navigate around a structured hypermedia module, although this was not found to be a common or severe problem for these participants. Secondly, the hypermedia modules used with DAHNI-2 were still relatively small and although major orientation and navigational difficulties did not arise in these evaluations, different orientation issues may be revealed when working with a much larger module or on the WWW. Thirdly, advanced commands were not available in DAHNI-2 such as bookmarking or history list capabilities, saving, printing, or annotating, which might be required to make effective use of a large hypermedia system. Nor were participants able to change the size of the unit (from the default paragraph size), and although participants in these evaluations did not seem to consider this a problem, it makes it impossible to make a comparison of the usefulness of the 'Change Unit' feature with other implementations of the required functionality - such as

having separate commands for 'read word', 'read sentence', 'read paragraph', for example.

The most severe limitations in DAHNI-2 relate to the methods of finding and selecting links; due to the ACCESS programming tools. Firstly, links were limited to only one word, and units themselves could only contain one link. This is clearly not realistic of real-world hypermedia material and would be difficult both to author and to use effectively. Secondly, the link in the unit became active as soon as the unit was loaded (which helped participants to work quickly), but would not be appropriate when multiple links in a unit are supported. In this case, links should become active only once they have been heard, remaining active until the next link is output. Finally, the link-to-link feature was also not available, making it impossible to skip quickly through links in the current node.

## ***7.6 Conclusions and Design Recommendations***

The combined evidence of performance and subjective opinion indicates that DAHNI-2 provided an effective non-visual interface to hypermedia material. For example, participants learned to use DAHNI-2 quickly, were able to use the input devices reasonably well, could navigate through the material easily to find information, did not frequently feel lost within the hypermedia material, and were able to easily re-orient themselves, using a range of methods and commands. If appropriate information and feedback is provided with clear headings and non-speech sounds, blind users should not get lost in hypermedia material.

The findings from the evaluations of DAHNI-1 and DAHNI-2 have been distilled into a detailed collection of specific design recommendations, which include improvements to the existing design and new ideas for future versions of DAHNI-2 or similar systems (and includes approaches from other relevant research). In all cases, the features should be designed in the same manner as existing commands in DAHNI-2, such that all interactions are extremely simple, require very little knowledge, and if possible only require one step to execute a command.

### **7.6.1 The Workspace**

Maintain the consistent workspace concept to support a range of input devices and users with limited keyboard skills; use digitised voices for commands to maintain distinction from hypermedia content; and non-speech sounds for orientation to indicate dead-ends and centrepoint. Increase emphasis during training on the difference between centrepoint on the workspace and the home node in the hypermedia module to minimise conceptual confusion; alternatively, remove the centrepoint position from the workspace.

### **7.6.2 Input devices**

#### **7.6.2.1 Keyboard**

Continue to use the numpad if possible to keep all commands in one location without requiring users to know the layout of the Qerty keyboard; and also provide keyboard shortcuts to support experienced keyboard users. All keys should be labelled (with tactile markers) to aid location. Re-implement the 'Stop' command using a single key, such as <Ctrl> or <Esc> for easy location and to halt the output immediately. Consider the implementation of common commands on dedicated keys on the keyboard, such as <Home>, <End>, <PgUp>, <PgDn> and so on.

#### **7.6.2.2 Joystick**

Increase training in how to move the joystick back and forwards in straight lines, and how to hold it steady while selecting commands. Alternatively, develop an absolute device which only moves forwards-backwards, left-right along the fixed workspace shape, clicking onto each command, with a separate button for selecting commands. This should provide a well-defined workspace with easy command selection.

#### **7.6.2.3 Touchtablet**

Create alternative overlays for the touchtablet (for example, braille, initials, dots, and so on) to suit individual preferences; and consider a more portable small touchtablet using a dots-only or initials-only overlay. The touchtablet should lead to immediate command execution or output (with no delays).

### **7.6.3 Hypermedia Presentation Methods**

#### ***7.6.3.1 Synthetic Speech and Refreshable Braille Output***

Choose a good quality speech synthesiser with easy-to-understand pronunciation and intonation, preferably with a British English accent and a range of voices. Consider implementing braille output to supplement the auditory text-based output, which would offer users a way to read at their own speed, and read for fine detail (to check spelling) for example. Symbols could be used to indicate headings and links, and if the braille display incorporated routing keys, links could be selected using direct manipulation. As each unit is loaded onto the braille display, non-speech sounds would indicate the number of links in the current unit for example.

#### ***7.6.3.2 Content Material***

Continue to make use of digitised nodes (speeches, music etc). Care should be taken that any background sound effects do not mask the main speaker in the node. Also make further use of picture nodes with descriptions and tactile pictures if possible. Consider providing a brief summary of the picture together with a link to a more detailed description to suit different readers' interests.

Develop the authoring tools so they can support the inclusion of mixed media within one node to allow larger more varied nodes to be created using combinations of text, audio and pictures; and of different levels of heading within a node to cater for different types of educational material. Encourage authors to write accurate and useful headings for each node which can act as signposts aiding users' orientation through the material; and to word links appropriately to give an indication of the destination node. Avoid creating hypermedia modules from material which is better presented in a linear or sequential manner. Modules work best if information is easily chunked and can be read in (almost) any order.

## 7.6.4 Links

### 7.6.4.1 *Presentation of Links*

Explore different methods of link presentation, for example, using verbal messages (such as “link” ... “end link”), non-speech sounds, tones played during the link word(s), changes of voice, and so on. The links should be easily distinct, but not so obtrusive that comprehension of the surrounding material is disturbed, and should be easily changeable by the user. It should be noted that a single sound before a word mid-sentence may be mis-heard at another location (Moore 1989) and therefore may not be ideal for indicating a link; and a change in synthetic voice for a single word mid-sentence can be very disruptive to comprehension (Moore *ibid.*). However, alerting the user to a link with a sound *and* changing the presentation of the link should allow accurate sequential grouping (Bregman 1990) caused by the discontinuity of the auditory signal (Handel 1989), and therefore enable accurate identification of the link. Consider methods of implementing links within audio files, where a specific phrase links to another node. Such issues have recently been discussed for web TV as ‘sonic hyperlinks’ by Braun & Dörner (1998), where a link is indicated by a continuous sound, and remains sensitive (selectable) for a certain time while the sound is playing and for a short time afterwards.

### 7.6.4.2 *Finding and Selecting Links*

The concept of the ‘current link’ was very effective, but should be extended to support multiple links in one unit - whereby each link becomes active only once it is output, and then remains active until the next link is output. In addition, link-to-link navigation should be implemented, to skip from link to link within the current node. This simple interaction might involve the reading commands used with an additional key, such as <Shift>. Consider adding contextual information to the ‘Read Current Link’ command so that the user firstly hears the current link, and then also hears the sentence containing the link.

## 7.6.5 Non-Speech Sounds

### 7.6.5.1 General Sound Guidelines

A full discussion of the use of non-speech sounds in DAHNI-1 and DAHNI-2 is presented in Morley, Petrie, McNally & O'Neill (1998b), and a summary is given here of the main findings.

Continue to include non-speech sounds for information and feedback for at least the same commands and events with sounds in DAHNI-2. However, sounds should only be included where there is a perceived need for additional information or feedback to be given to users, rather than adding sounds to *every* command or event. Users should be able to easily choose which sounds are used in their interface from a selection (for example, as provided by the Windows 95 SoundSchemes). The use of both auditory icons and earcons should be maintained, especially when intended users are students who might be motivated by the 'fun' nature of some auditory icons. Events for which there are no obvious auditory icons could be assigned an earcon forming part of a more coherent grammar of sounds.

The choice of sound should be appropriate to each event (importance, distance travelled and so on), and piloted with a range of users - in context - to confirm their success at conveying the desired information. This would ensure that the selective sounds are effective, easy to learn, easy to identify, and easy to remember. Frameworks such as AHA (Audio HTML Access) (James 1998) can help designers to choose the number and types of sound used for structured documents, and which structural elements should be indicated with sound or voice.

The selected sounds should be carefully implemented to ensure consistency; in terms of length, volume, and placement with a command or event, so that the user is always clear about the relationship of a sound and its referent. Training sessions must teach sounds thoroughly (as also found by Brewster 1997). The total number of sounds used in the interface should be carefully considered, so that users are not overwhelmed by many sounds in a noisy and unusable interface. There is likely to be a threshold for learning and remembering sounds of about 7-10 sounds (Patterson 1982).

### ***7.6.5.2 Sounds for Structural Information and Command Feedback***

In addition to indicating links and different levels of heading with non-speech sounds, information could also be given using sound to improve orientation, for example, the users' current location through a node; and being able to continue reading after a unit is output.

Consider filtering sounds to indicate additional information; for example that a particular node has already been visited during the session, or that a particular link has already been followed. Parameters to be varied might include pitch (although this is not very accurate, Moore 1989), timbre, rhythm, tempo or even location in a 3D sound-space (Handel 1989).

Consider methods of presenting an aural overview of the structure of complex nodes (for example, those with several levels of heading, large numbers of units and links), using earcons for example - much like the algebraic glances developed by Stevens, Edwards & Harling (1997). This could possibly be extended to an aural overview of the structure of the whole hypermedia module, allowing users to explore material of interest using a type of aural fisheye view, a method explored by Fernström & Bannon (1997).

Include sounds for feedback for any commands which are likely to be easily confused. For example, to help users distinguish between small within-node reading commands and larger jumps to other nodes.

## **7.6.6 Commands: Improvements and Additions**

### ***7.6.6.1 Output Control Commands***

Provide digitised speech for the commands on the workspace to maintain distinction between interface and hypermedia content. A range of four speeds of speech output on one cyclic command seemed to suit most participants, therefore 'Change Rate' should remain as is. However, additional voices should be provided for 'Change Voice'. Implement the alternative unit sizes in the 'Change Unit' command, from the default paragraph size to a character, word, sentence, paragraph or whole node. Also consider implementing separate commands for reading these different unit sizes.

Implement 'Increase Volume' and 'Decrease Volume' commands which change the volume in small fixed increments; and a 'Pause/Resume' command so that the output can be immediately paused and restarted without having to return to the start of the unit. This should be an easy-to-locate key and close to centrepoint on the workspace.

#### **7.6.6.2 Reading Commands**

Retain the 'Read Left' and 'Read Right' commands since they were effective for reading units, and for skim-reading quickly through units. However, they should be re-implemented so they are more similar to a video or CD player; such that 'Read Left' jumps to the start of the current unit, and a second execution jumps to the start of the previous unit; and 'Read Right' jumps to the start of the next unit. This would remove the need for the 'Read Current Unit' command.

#### **7.6.6.3 Orientation and Navigational Commands**

Provide just one 'Where Am I?' command (remove 'Overview') which provides a range of orientation information: the current node heading, the current unit number and total number of units, the number of links in the node, and the current link. If multiple headings within a node are supported, provide heading-to-heading navigation (as in the DAISY playback devices, see Chapter 8), providing non-speech feedback about its level as each heading is reached. Consider a new 'How Did I Get Here?' command which outputs a list of nodes in the users' history, starting from the current node heading. Consider a feature which remembers the user's last position in the hypermedia module when they exit the system (as seen in the DAISY playback devices).

Consider a command which offers users a content summary of the current node, which for example, could be automatically computed using the most frequently used non-trivial words in the node (Zajicek, Powell & Reeves 1998). Consider methods of skimming through the actual content of units hearing the output. For example, users could skim-read through material by listening to only the important words, such as content rather than function words - a feature once included in the Apollo synthesiser (Blenkhorn 1998, Personal Communication); or by speeding up the rate of the output similar to a tape fast-forwarding (demonstrated by Asakawa & Itoh 1998).

#### **7.6.6.4 Support Systems**

Provide both on-line tutorial and help systems, to support users seeking both tuition and answers to specific questions. These might also cover advice on how to make best use of this new media - such as how to find and assimilate information from many nodes in a hypermedia module. Consider presenting support systems with many digitised nodes, to create the impression of human coaching. Consider re-implementing the 'Context-Specific Help' command to give users information about commands *before* they execute them, rather than afterwards. For example, the command might toggle in and out of the context-specific help mode and by moving through the commands on the workspace, each command name would be spoken followed by a brief summary of the command's function (the JAWS for Windows screenreader now provides such a 'key identifier' - see the Henter Joyce JAWS web page).

#### **7.6.6.5 Potential Advanced Commands with Simple Implementations**

*Copy and Save.* Copies the information from the current text-based node into a text editor and automatically save the file with a set filename in a specific location. Each 'Copy and Save' command would append the textual contents of the current node to the existing saved file.

*Print.* The textual or pictorial information in the current node is sent to a braille or ink-print printer.

*Find.* Searches for a phrase in the current (textual) node, and jumps to the start of the unit containing the term. Users could jump between search hits using new commands 'Find Next' and 'Find Previous'. A more complex implementation might allow users to search over the whole hypermedia module, and jump between the headings of the nodes where the target was found.

*Bookmark.* A simple bookmark is inserted at the current node, replacing any existing set bookmark. The 'Goto Bookmark' command jumps to the current bookmark, and this location is remembered by the system when it is shut down (as found in the DAISY stand-alone playback devices).

*Annotate.* Inserts a link 'annotation' after the heading of a node, and creates a new node in which the user can type an annotation. This is saved as soon as the user leaves the annotation node.

### **7.6.7 Additional Further Research**

In addition to the research opportunities described in the previous sections, the resulting prototype should then be re-evaluated using a similar methodology as used for DAHNI-1 and DAHNI-2. In addition to conducting usability evaluations in order to further develop the prototype, comparisons with existing products or competitive prototypes would be interesting, in terms of feature comparisons, their learnability and ease of use, and provision of feedback and so on. Such prototypes could be tested by both blind and sighted users with the view to developing effective auditory information presentation and navigation for different types of users in different situations.

### **7.7 Coming Next...**

At this stage in the present research, DAHNI-2 reached the end of its life-cycle and the researcher's involvement with the prototype therefore ended. At the same time, a prototype non-visual information system was released by the DAISY Consortium, enabling blind users to play digital talking books on a stand-alone player and on a PC. Since the researcher had developed a successful evaluation methodology for development purposes of such interfaces, she was invited to conduct a usability evaluation of the system and to recommend design solutions. The following chapter presents firstly a brief overview of the design of the prototype PC-based DAISY Playback Software, and secondly a full account of the usability evaluation conducted applying the same methodology used to evaluate DAHNI-1 and DAHNI-2.

## **8 Evaluation of the DAISY Playback Software**

## **8.1 Chapter Overview**

This chapter firstly outlines the existing design of the prototype DAISY Playback Software for the benefit of readers unfamiliar with its functionality, to enable the evaluation results to be put into context. The remainder of the chapter presents the evaluation conducted, based on the methodology used successfully to evaluate DAHNI-1 and DAHNI-2. Thirteen blind participants worked freely with several DAISY books, with the researcher ensuring that 18 generic evaluation tasks were completed at some point during the session. Current usability and opinions of proposed improvements were assessed, and while the software was generally found to be easy to use, a few major usability problems were highlighted, especially relating to navigation through headings. The usability of each feature of the DAISY Playback Software is discussed together with proposals for design improvements, and the chapter concludes with a summary of recommended design proposals.

## **8.2 Introduction**

Since the researcher had designed and conducted successful usability evaluations for the development of non-visual interfaces (reported in the previous chapters), she was invited by the Royal National Institute for the Blind to conduct a usability evaluation of the prototype DAISY Playback Software and to recommend design improvements to the DAISY Consortium.

This chapter contains a discussion of the evaluation results which was not presented in the report containing recommendations submitted to the consortium (Morley 1997a), nor in the published paper (Morley 1998). As outlined in Chapter 3, the software was designed by Labyrinten in Sweden (see Labyrinten's Home Page), and is Windows 95-based software installed on the user's PC allowing them to read and navigate through narrated structured books on CD-ROM.

The DAISY Playback Software was designed to support readers who require sophisticated access to their talking books in terms of both navigation and integration with their existing computer applications, and has a number of benefits over stand-alone playback devices, such as the PlexTalk Player (see Chapter 2, Section 2.2.7.4):

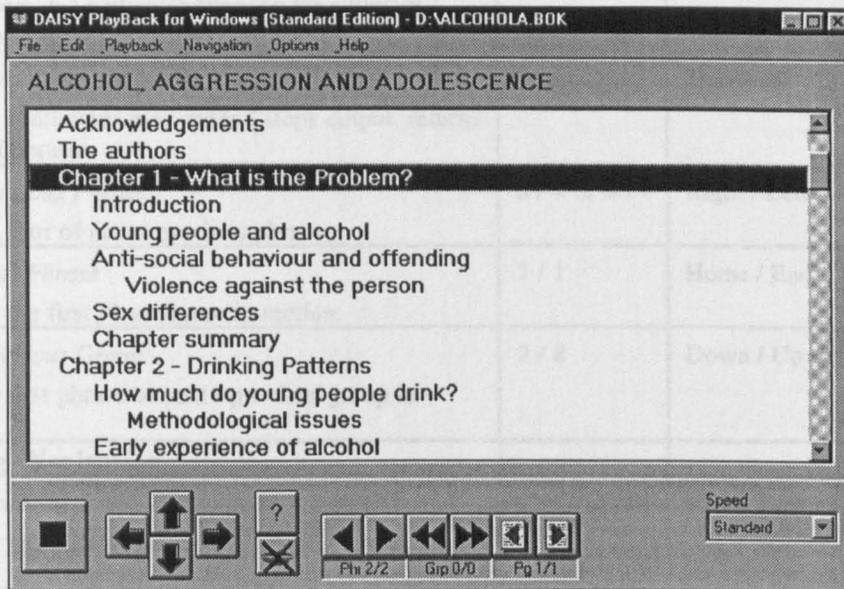
- The software is easily integrated into the user's PC and is self-voicing (produces all required output including system messages in digitised human audio) and therefore a separate screenreader is not required.
- The software is usable by blind, partially sighted and normally sighted users, since it is both mouse and keyboard driven, with a visual interface capable of displaying a range of font sizes, and the visual interface has a standard Windows look and feel (see Figure 8.1).
- Text searches in the headings of books which have had their heading text coded can be performed using the PC keyboard (not possible using the stand-alone devices which have no alpha-keys).
- The software has a reasonably transparent interface, since it does not have modal commands (as provided by the PlexTalk Player). Instead, the different commands for heading navigation, bookmarks, time and page information, each use separate keyboard commands which are generally mnemonic to their function.
- Finally, the software provides a wider range of commands than the PlexTalk Player, making it easier to work effectively and independently.

The following section provides an overview of the design of the DAISY Playback Software so that the evaluation results can be put into context, and if required, details of the full functionality can be found in Appendix 1.9, taken from the visual on-line help system. If the reader is already familiar with the functionality of the DAISY Playback Software, they may choose to skip directly to Section 8.3.6 which outlines the potential usability problems identified before the evaluations.

### ***8.3 Design of the DAISY Playback Software***

The DAISY Playback Software has a visual interface in addition to the auditory interface, illustrated in Figure 8.1. The commands for reading, heading navigation, orientation, bookmarking, searching, output control and help can be executed on the visual display using the icons near the bottom of the window, or from the menu bar. Figure 8.1 shows some of the section headings in the book "The Facts about Alcohol, Aggression and

Adolescence”<sup>1</sup> where the current reading position is in ‘Chapter 1: What is the Problem?’ (shown highlighted), and the sub-sections are shown indented from their parent section. The text of all headings is searchable.



**Figure 8.1: The Visual Interface of the Prototype DAISY Playback Software, Version 1.0**

Commands in the non-visual interface are executed using either the numeric keypad (numpad) or alpha-numeric keys (shortcuts) such as the <arrow cursors>, <Home>, <PgUp>, <C>; and some commands require the additional use of the <Ctrl> key. Table 8.1 lists the commands in the DAISY Playback Software together with a brief description of their functions and the non-visual interaction methods for executing each command using both the numpad and shortcuts. The layout of commands on the numpad is illustrated in Figure 8.2, together with their shortcut equivalents (although some commands listed in Table 8.1 can only be executed with shortcuts, not via the numpad). The following sections briefly describe each of these commands.

<sup>1</sup> By Nyle Coggans and Susan McKellar, originally published by Castle Books 1995.

**Table 8.1: Commands in the DAISY Playback Software**

Command	Numpad	Shortcut
<b>Reading</b>		
<i>Open / Quit</i> Opens book on a particular drive / quits software, returns to Win95.		O / Q
<i>Play / Stop</i> Puts into continuous play mode / stops output, returns to start of phrase <sup>2</sup> .	0	Spacebar
<i>Next / Previous Phrase</i> Jumps to start of next / previous phrase.	6 / 4 or + / -	Right / Left Arrow
<i>First / Last Phrase</i> Jumps to the first / last phrase in section.	7 / 1	Home / End
<i>Next / Previous Group</i> <sup>3</sup> Jumps to first phrase of next / previous group in section.	2 / 8	Down / Up Arrow
<b>Heading Navigation</b>		
<i>Next / Previous Section</i> Jumps to next / previous section heading in current level.	Ctrl + 2 / 8	Ctrl + Down / Up Arrow
<i>Level Up / Level Down</i> Jumps to heading at higher or lower section level.	Ctrl + 4 / 6	Ctrl + Left / Right Arrow
<i>First / Last Section</i> Jumps to first or last section heading in current level.	Ctrl + 7 / 1	Ctrl + Home / End
<i>Jump Forwards / Back</i> Jumps forwards or backwards 15 sections (includes all levels)	Ctrl + 3 / 9	Ctrl + PgDn / PgUp
<b>Orientation</b>		
<i>Section Information</i> Outputs current heading. Repeated execution outputs all parent headings.	5	I
<i>Current Position</i> Outputs assigned section number for current heading.	Ctrl + 5	C
<i>Page Information</i> Outputs current print page number (if coded).		P
<i>Goto Page ...</i> Jumps to specified page number (if coded).		G + number
<i>Next / Previous Page</i> Jumps to first phrase of next / previous printed page (if coded)	3 / 9	PgDn / PgUp

(ctd over ...)

<sup>2</sup> A phrase is the smallest unit of a DAISY book, and usually approximates to the size of a sentence.<sup>3</sup> A group is a group of phrases, which usually approximates to a paragraph.

Command (ctd)	Numpad	Shortcut
<b>Bookmark</b>		
<i>Set Bookmark ...</i> Inserts specified bookmark at phrase.		Ctrl + number 1-9
<i>Goto Bookmark ...</i> Jumps to specified bookmark and outputs phrase.		Number 1-9
<b>Search</b>		
<i>Search For ...</i> Enter text string; searches heading text, jumps to first heading containing string.		F
<i>Search Next / Previous</i> Jumps to next / previous heading containing search string.		V / R
<b>Voice Control</b>		
<i>Mute</i> Halts output immediately. Returns to start of phrase.	Enter	Enter or Esc
<i>Low, Standard, Brisk, High, Turbo</i> Changes output rate.		L, S, B, H, T
<b>Help</b>		
<i>Audio Help</i> Into DAISY format audio help system.		F1
<i>Visual Help</i> Into Windows-95 style visual help system.		Shift + F1

Key Alone	<b>7 / Home</b> First Phrase in Section <i>First Section</i>	<b>8 / ↑</b> Previous Group <i>Previous Section</i>	<b>9 / PgUp</b> Previous Page <i>Jump Back 15</i>
With Ctrl	<b>4 / ←</b> Previous Phrase / - <i>Level Up</i>	<b>5</b> Section Information / I <i>Current Position / C</i>	<b>6 / →</b> Next Phrase / + <i>Level Down</i>
Key Alone	<b>1 / End</b> Last Phrase in Section <i>Last Section</i>	<b>2 / ↓</b> Next Group <i>Next Section</i>	<b>3 / PgDn</b> Next Page <i>Jump Forward 15</i>
With Ctrl	*	<b>0 / Spacebar</b> Play/Stop	#

**Figure 8.2: Numpad Commands and Shortcut Equivalents**

The following sections present a brief description of how these commands work which will enable the evaluation results presented in detail in Section 8.5 to be put into context.

### 8.3.1 Reading and Navigation Commands

When the DAISY Playback Software is first opened, an initial dialog box with a system message states the current drive and the first title on that drive, “Books on drive D” “The Facts About Alcohol, Aggression and Adolescence”. A different drive can be selected using its initial letter, and the first title on that drive is output. The user can choose between titles using the <up/down arrow> keys, and <Enter> opens the selected title. To open a new book without quitting the software, users press the <O> key to go into the ‘Open Book’ dialog box. Users quit the software using <Q>, leading to a system message to confirm leaving the software “Exiting Program, press Y to confirm”.

There is the simple option to play the book continuously using the ‘Play/Stop’ command; <Spacebar>; and while the book is playing users can jump through sections, phrases and groups of phrases and the book will continue playing from the new location. The keys for reading small chunks of information such as phrases and groups of phrases seem to reflect the visual and tactile presentation of text on a page, in a left-to-right, top-to-bottom order. For example, to move phrase-to-phrase (approximately sentence-to-sentence), the user executes the ‘Next Phrase’ command; the <right arrow> cursor or numpad 6; and to go to the next group of phrases (approximately paragraph by paragraph), the user executes the ‘Next Group’ command using the <down arrow> cursor or numpad 2.

Similarly, the interaction model used for navigating through the headings seems also to reflect the visual display of headings in print books and on the DAISY Playback Software display; where sub-sections are indented to the right of their parent heading. For example, to go to a lower level (for example from section 2.1 to section 2.1.1), the user executes the ‘Level Down’ command; <Ctrl> together with either the <right arrow> cursor or numpad 6; and to go to a higher level (for example from section 2.1 to section 2), the user executes the ‘Level Up’ command; <Ctrl> together with either the <left arrow> cursor or numpad 4. To jump between headings at the *same* level <Ctrl> + <up/down arrow> cursors are used.

The software allows users to navigate through headings without continuous playback, by putting it into ‘Stop’ mode (using the ‘Play/Stop’ command <Spacebar>), and then as the user navigates through groups or headings the software outputs only the phrase or heading reached. If the user tries to jump to the next sub-section or the next group when in fact there is no further sub-section or group, the software jumps to the next heading it can find.

Thus users never find 'dead-ends' (they never discover that there are no more headings at the current level), since the software automatically takes them to the next suitable item for reading.

In addition to the standard navigation commands described above, with the numpad or cursor navigation keys users can also jump to the 'First/Last Phrase' in a section; to the 'First/Last Section' heading in the current section; to the 'Next/Previous Page' according to the page numbers in the print book; jump 'Forwards/Backwards' 15 sections (including any sub-sections). To jump to a specific page number the user simply presses <G> for the 'Goto Page' dialog box with a system message "Goto Page Number?", where the user types in the desired page number and presses <Enter>.

### **8.3.2 Orientation Commands**

Users are provided with several orientation commands to help them to gain an overview of their current location. For example, 'Section Information' (<I> or numpad 5) presents the current section heading, and repeated executions announce all parent headings; 'Current Position' (<C> or <Ctrl>+ numpad 5) announces an assigned number for the current section heading (the software assigns a number to each heading in a book, according to its level); and 'Page Information' (<P>) announces the current printed page number if coded. The software remembers the last reading position of each book, and starts the book at that location when the book is next opened.

### **8.3.3 Bookmarks and Search Facilities**

All bookmarks, up to a maximum of nine, have to be given a number by the user. Setting a bookmark is achieved using the 'Set Bookmark' command, using <Ctrl> with a number 1 to 9. To move to an existing bookmark ('Goto Bookmark') the user simply presses the bookmark number and the software moves to the bookmark and outputs the phrase at which the bookmark was set. There is no means of deleting bookmarks other than re-assigning them, nor a way to skip between bookmarks.

The use of a standard keyboard with the DAISY Playback Software allows users to perform a text-based search in the headings of books coded in this way. The 'Search'

command is activated by pressing <F> leading to a 'Find What' dialog box with a system message "Search For?" where the user simply types in the string they wish to find (full or part-words), and presses <Enter> to execute, or <Esc> to cancel. The user can hear the string in the editfield spelled with <Alt> + <R>. The software jumps to the first occurrence of the string in the headings from the current reading position. The 'Find Next' and 'Find Previous' commands are executed using <V> and <R> respectively which jump to the next or previous heading containing the search string.

### **8.3.4 Voice Control Commands**

Unlike the stand-alone PlexTalk Player, the DAISY Playback Software does not allow users to change the tone of the output, and users cannot hear the speech speeded up in the same way that is possible in the Player using the 'Fast Forward/Rewind' commands. However, whereas the PlexTalk Player changes the actual rate of the output, in contrast, the DAISY Playback Software instead changes only the length of the pauses between phrases; reducing or lengthening them as required (except at the highest speed when some speech compression is used). The DAISY Playback Software offers five speeds of output, low, standard, brisk, high and turbo, each activated by its initial letter: <L>, <S>, <B>, <H>, <T>. The output of the book can be halted immediately with the Mute command (<Esc>, <Enter>, or <Ctrl+M>).

### **8.3.5 Help Commands**

The DAISY Playback Software provides users with a thorough audio on-line help system in DAISY format. The audio help system is accessed with <F1> and is navigated in the same way as a normal DAISY book, and starts with a list of common activities leading to lists of keyboard commands for each task. There is also a visual help system in Windows-help style for partially sighted users, accessed with <Shift> + <F1>, which contains the same information but is not spoken (see Appendix 1.9). Both help systems are closed with <Esc> returning the user to their DAISY book.

### 8.3.6 Potential Usability Problems Identified Before Evaluations

From the researcher's own experience while learning to use the DAISY Playback Software, a number of usability problems were identified prior to the evaluations which might cause difficulties for blind users. These potential difficulties and their causes can be grouped into five categories:

- *Navigation Difficulties*: caused by the lack of structural information presented to users, specifically the lack of any indication as to the level of a heading and the existence of sub-headings; and the way in which heading navigation commands cycle to other heading levels rather than finding dead-ends.
- *Reading Difficulties*: caused by limited voice control commands concerning: the method of increasing output speed; the shortcuts chosen for the speed commands; the restriction of working at the phrase level as the smallest unit of information; and the inaccessibility of the Mute command <Ctrl + M>.
- *Bookmark Difficulties*: the use of only nine bookmarks and the lack of bookmark management facilities may be insufficient for some users.
- *Orientation Difficulties*: caused by the lack of certain commands, for example: getting to the beginning of the book with a single command is not possible; time information is not available; and it is not possible to gain an overview of the structure of the current book or section.
- *Command Confusion*: caused by ambiguous and inconsistent prompts - the wording and functionality of some system messages and choice of shortcut commands is sometimes inconsistent.

These potential usability problems were considered in advance of the evaluations, and solutions for alternative designs were developed. These were proposed to participants in the evaluation questionnaire for their consideration (described later in Section 8.4.4.4).

## **8.4 Method**

### **8.4.1 Design**

The evaluation was based on the methodology developed for assessing DAHNI-1 and DAHNI-2, and was applied to the DAISY Playback Software without significant changes. Participants completed a training and practice session, followed by a series of Free and Generic evaluation tasks using the software to explore a number of digital talking books at their own initiative, being prompted to complete generic tasks to test the full range of commands provided by the software. Participants were then interviewed about the usability of each feature of the software, and asked to consider various proposed design improvements.

### **8.4.2 Participants**

Participants were selected from a wide potential end-user group<sup>4</sup>; any computer-literate person wishing to access structured digital talking books on a PC. The 13 participants (9 males, 4 females) were all totally blind and had a range of computer and talking book experience; from 18-year old students to a retired 72-year old computer expert ( $\bar{X} = 30$  yrs, 11 months,  $sd = 14.78$ ). The uneven male:female ratio was determined by the numbers of people expressing interest in participating. Four participants had taken part in the evaluations of DAHNI-2. The personal data collected from participants using the Participant Characteristics Questionnaire (see Appendix 1.10) is summarised in Table 8.2 for ease of reference.

All participants used computers for a range of activities, for work, study and leisure, with the majority using computers daily. Nine of the thirteen participants were existing RNIB Talking Book members, with six participants having used them for ten years or more. Four participants had not used RNIB Talking Books but had been listening to standard recorded books from other organisations and public libraries for several years.

---

<sup>4</sup> There were no existing users of digital talking books, since the prototype players (the DAISY Playback Software and the PlexTalk Player) were not yet available to the general public.

Although participants reported that it was very easy simply to *listen* to audio books, particularly novels, the majority reported that it was almost impossible to use any non-fiction, reference or study material on tape for serious work or study, and after initial difficult experiences had given up. They listed the following reasons, supporting those found earlier by Petrie, Morley, McNally, Graziani & Emiliani (1996): too many volumes required for one book; difficulty in locating information, on one tape, or from a series of tapes; time consuming to locate information or a specific place; poor speech quality of many books; difficulty in navigating around a book on tape; too difficult for reference or study material; low portability of the RNIB Talking Book Machine (too big and heavy to carry far, for example).

**Table 8.2: Participants' Characteristics - DAISY Playback Software Evaluation**

<b>P</b>	<b>Gender &amp; Age</b>	<b>Status</b>	<b>Braille Reader</b>	<b>Talking Book Use</b>	<b>Recorded Books Use</b>	<b>Computer Use</b>
1	M - 37	Employed	Y	10 yrs + Leisure		Daily
2	M - 40	Employed	No	-	<1 yr Calibre	2'ce week
3	M - 19	Student	Y	-		Daily
4	F - 19	Student	Y		<1 yr Orbis	Daily
5	F - 18	Student	Y	5-9 yrs Leisure	Calibre, TorchTrust	2'ce week
6	M - 18	Student	Y	1-4 yrs Leisure		Daily
7	M - 23	Employed	Y	5-9 yrs Leisure		2'ce week
8	M - 30	Employed	Y	10 yrs + Leisure		Daily
9	F - 30	Employed	Y	10 yrs + Leisure		Daily
10	M - 72	Retired	Y - slow	10 yrs + Leisure		3-5 times week
11	F - 40	Employed	Y	10 yrs + Leisure		3-5 times week
12	M - 24	Student / Employed	Y - slow	-		Daily
13	M - 32	Student / Employed	Y - slow	10 yrs + Leisure, Study	Public Lib & RNIB for study books	Daily

### 8.4.3 Hardware and Software

The evaluations were conducted on a 100MHz Pentium laptop PC under Windows 95, with 32MB RAM, a 2GB hard disk, and a SoundBlaster compatible soundcard. Since the DAISY Playback Software is self-voicing a separate Windows 95 screenreader was not necessary. All commands were executed using a standard keyboard attached to the laptop for convenience.

### 8.4.4 Materials

#### 8.4.4.1 DAISY Books

A range of DAISY books was available for participants to use, covering a variety of topics, and participants were free to choose to work with any of the following titles:

- "*Gunner Milligan 954024*" by Spike Milligan, published by Penguin Books, 1996. (very simple structure, used for all initial training)
- "*The Facts About Alcohol, Aggression and Adolescence*" by Nyle Coggans and Susan McKellar, published by Castle Books, 1995
- "*The Venice and Turin Tour Guide*", published by the European Cities Within Reach Consortium, no date given.
- "*Robin Hood: The Man Behind the Myth*" by Graham Phillips and Martin Keaton, published by Michael O'Maara Books Ltd, 1985.
- "*The Good Food Guide*" by Nigel Slater, published by Fourth Estate Ltd, 1995.
- "*The Four Gospels*", from the Authorised Version of the Bible, King James Version, published by Cambridge University Press, no date given.

#### 8.4.4.2 Training Schedule

A training schedule was developed based on the researcher's own experience using the software and the information contained in the on-line help system and other draft documentation. The training schedule followed a similar approach to that developed for DAHNI-1 and DAHNI-2; and covered basic concepts of structured digital talking books,

the overall design of the software, and how to use each command. Tactile diagrams were used if necessary to illustrate the visual presentation of headings and sub-headings. Commands were taught using both the numpad and the shortcuts, and participants were free to choose to use either method for both the training and evaluation sessions.

The basic reading and heading navigation commands to be demonstrated and practised first were restricted by using a book with minimal structuring, “Gunner Milligan 954024” since it has only one level of heading. These basic commands included: ‘Next/Previous Heading’, ‘Play/Stop’, ‘Next/Previous Phrase’, ‘Next/Previous Group’, ‘Section Information’, ‘Page Information’, ‘Goto Page’, ‘Set Bookmark’, ‘Goto Bookmark’, ‘Mute’, ‘Search’, and ‘Search Next/Previous’. When comfortable with the basic commands, participants were asked to select another title with more structuring so that the more advanced commands could be demonstrated and practised. The advanced commands included: ‘Level Up/Down’, ‘First/Last Section’, ‘First/Last Phrase’, ‘Forwards/Backwards 15 Sections’, and the different speeds. By allowing each participant to choose their own title(s) it was hoped to make the activity of working with the books more engaging and interesting.

#### **8.4.4.3 Evaluation Tasks (Free with Generic Tasks)**

Participants were required to use the DAISY Playback Software freely following their own line of interest, but in case they did not use each feature of the software, a set of 18 Generic tasks was designed (as described in Chapter 3). These tasks were presented in a flexible order, depending on the how the participant was using each particular title, and are listed in Table 8.3, and presented with the required commands in Appendix 1.11.

**Table 8.3: Generic Evaluation Tasks for the DAISY Playback Software**

- |  |
|--|
| <ul style="list-style-type: none"> <li>- Please could you insert the disk and open the book.</li> <li>- Let’s read the first part of the disk, to hear the publishing details and what the book contains to get a feeling for the book.</li> <li>- Could you try the different speech rates, and see which you prefer. You can put it back to the one you like best for the rest of the tasks.</li> <li>- Let’s jump around through the table of contents (headings), and see what information is in this book. Feel free to change the levels while you do this, if you’d like to explore the sub-sections.</li> <li>- Can you get to Section X in the table of contents (headings) and then put a numbered bookmark there, so we can get back to it later on?</li> </ul> |
|--|

- Can you show me how to read through phrases and groups of phrases from here.
- Can you find out what page we are now on?
- There's something interesting about X on page N, can you jump there?
- Can you find out the heading and parent heading of this section - using the Section Information command?
- Now, find out exactly where we are in this section we are, using the Current Position command.
- Can you skip to the next page?
- What topic are you interested in reading in this book? Let's do a find task and see if we can find anything on that.
- Shall we see if there are any other instances?
- Can you jump to the first section in this section?
- Now can you return to the bookmark we just made - can you remember where it was?
- Can you read for a little way, and then show me how to jump to the last phrase in this group of phrases please.
- Now can you return to the beginning of the disk
- Let's quit the program, and we'll re-start it later if we need to.

#### **8.4.4.4 Evaluation Questionnaire**

The evaluation questionnaire (see Appendix 1.12), was very similar to that used for DAHNI-1 and DAHNI-2, and included questions on and ratings for the usability of the following aspects of the software: general usability (ease of use, ease of learning, ease of remembering commands, and enjoyment of using the software); and the usability and usefulness of commands for reading; navigation; orientation; page information; bookmarks; search; voice control; system messages; and the audio help system.

The questionnaire included proposals for alternative designs to reduce some of the potential problems already identified (see Section 8.3.6). The proposed solutions were presented to participants in a deliberately unspecified manner to avoid biasing their opinion, and where possible, several alternative solutions were proposed and participants were asked to consider their potential usefulness.

The possible design solutions proposed to participants (discussed fully in the Results Section 8.5) included:

*Navigation Proposals:* In order that headings can be identified together with their level while reading and navigating through headings, four improvements were proposed to participants:

1. The level of a heading might be indicated, for example, using non-speech sounds.
2. The existence of sub-sections could be indicated, for example, using a type of auditory ellipsis, mimicking the 'dot dot dot' on a visual menu item.
3. Commands could be prevented from jumping out of their section so that they behave in expected ways and are consistent.
4. New commands could be added to improve general navigation, presenting an overview of the structure of the book and/or the current section.

*Bookmark Proposals:* Two aspects of bookmarking were proposed to participants which might support more advanced users:

1. The software might allow more than nine bookmarks to be used.
2. A command might be provided to help users set bookmarks more quickly, by confirming the number of the highest bookmark already set.

*Orientation Proposals:* To help users orient themselves in a book, the addition of two commands providing more information might be supportive:

1. A command to jump straight to the start of the book (this might be particularly useful since the DAISY book opens at the last reading position, possibly somewhere in the middle of the book)
2. A command indicating time information, such as time passed, time remaining and total time.
3. Information about the total number of sections when a command outputs the current section number (for example, the 'Current Position' command might output "Section 1 of 8 level one sections").

#### **8.4.5 Measures Taken**

As in evaluations of DAHNI-1 and DAHNI-2, detailed notes were made by the researcher of task performance and participants' comments during the informal think-aloud tasks, which were later combined with participants' questionnaire responses and ratings on a 1-5 scale.

### **8.4.6 Procedure**

The training and evaluation sessions were conducted by the researcher without additional help, since no other researchers were available at the time to support her, and the software was a more advanced prototype than DAHNI-2, so the sessions were not so tiring to conduct. The researcher took detailed notes, and the sessions were captured on audio-tape, but not on video since they were mainly conducted at participants' houses where video-recording was impracticable. Each training and evaluation session was conducted individually, and together lasted around 2-3 hours.

#### ***8.4.6.1 Briefing and Training Session***

Personal data was collected using the Participant Characteristics Questionnaire (see Appendix 1.10), followed by a briefing about the evaluation and training in the use of digital talking books with the DAISY Playback Software following the training schedule (see earlier Section 8.4.4.2). Each participant received about an hour's training and practice in two books - the first using "Gunner Milligan 954024" and the second in a book of the participants' choice.

#### ***8.4.6.2 Evaluation Session***

The participant chose several titles and was asked to browse one at a time as they desired - the Free task. The researcher prompted the participant to complete any of the Generic tasks if their chosen activities had not included similar tasks. When at least one book, but preferably two, had been explored thoroughly, the participant was interviewed using the evaluation questionnaire (see Appendix 1.12). At the end of the session participants were asked for any further comments, thanked for their time and co-operation, and were again assured of the confidential nature of the evaluation and their data.

## **8.5 Results and Discussion**

The usability of each feature of the DAISY Playback software is presented and discussed on the basis of subjective ratings and opinions from participants based both on their comments during the task performance and during the questionnaire-based interview, and observed task performance. Design proposals are suggested for each feature.

The mean ratings ( $\bar{X}$ ) are reported together with the standard deviation (*sd*) of the ratings, and the spread of the ratings. The majority of mean ratings are from 13 participants ( $n = 13$ ) so will not be repeated, but  $n$  will be stated where different. Where comments from specific participants are included, the participant numbers are indicated, for example P1, P5. Raw data of participants' ratings is available from the researcher.

The results section covers each the usability of feature of the software in the following sections: overall usability (8.5.1), reading commands (8.5.2), heading navigation commands (8.5.3), heading navigation problems (8.5.4) and solutions (8.5.5), orientation commands (8.5.6), bookmarks (8.5.7), search (8.5.8), voice control (8.5.9), system messages (8.5.10), audio help system (8.5.11), and user customisation (8.5.12).

### **8.5.1 General Usability**

Overall the DAISY Playback Software was well-received with participants praising the level of access it provided and its potential for using non-fiction books. Participants appreciated the stand-alone nature of the software which meant that they could use it without a Windows screenreader. In addition, many participants learned to use the software very quickly, and even participants who had not used talking books before (for example, P3) were confidently reading through phrases and groups and navigating at high levels through headings after 10 minutes of using the software. Other inexperienced participants required more practice and were slightly more hesitant, but were soon comfortable (for example, P6). The next section provides an overview of the general usability of the software, and specific features are discussed in greater detail in following sections.

### 8.5.1.1 General Mean Usability Ratings

The DAISY Playback Software was considered to be fairly easy to learn to use and to use, easy to remember commands, and participants liked using the software very much, see Table 8.4.

**Table 8.4: General Mean Usability Ratings**

Usability Question	$\bar{x}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Ease of learning to use	3.77 (0.73)	5	6	2
Ease of use	4.00 (0.82)	2	8	3
Ease of remembering commands	4.00 (0.82)	4	5	4
Liked using software	4.46 (0.78)	2	3	8

Participants' comments about general usability included:

- It was mainly easy to learn and straightforward to use, however some inconsistencies in operation made it sometimes difficult and confusing (P1, P2, P7, P8, P13).
- It was made difficult to use because of the lack of feedback about structure (P1, P10).
- Most commands were easy to learn and to remember because they were logical, but some were difficult to remember because of their function, or because the shortcuts were not intuitive (P1, P2, P4, P6, P9). These comments were particularly aimed at the heading navigation commands (see Section 8.5.3).
- Participants were very impressed with the software, saying that it was significantly better than other books, although it would be much more enjoyable and effective if the navigational problems were addressed (P1, P2, P8, P9, P10).
- Participants stressed that they found it difficult and confusing to work when different books were coded differently, and indeed some books were coded differently in each chapter. Their difficulties arose since they did not know what to expect when they executed certain commands, or which commands to use to navigate to specific locations.

### ***8.5.1.2 Features Most Liked***

Participants were favourably impressed with many aspects of the DAISY Playback Software, and expressed their satisfaction with most of the features, and each feature is dealt with separately in the following sections. However, participants were asked to list their favourite features, and responses included:

- Excellent system for reading non-fiction (Ps 1-13)
- Excellent, quick access to highly structured information (P1, P2, P5, P6, P7, P10, P11, P13)
- Good to have fine level of control of units of information (that is, phrase and paragraph) (P1, P3, P4, P8, P9)
- Lots of logical keys for commands (P2, P9, P12)
- Very good quality of digitised speech, very pleasant to listen to (P2, P4, P5, P6, P7, P13)
- Nice to have access to the printed page information, and the facility to jump to specific pages (P3, P5)
- Very useful and easy to set bookmarks and be able to jump to them so easily (P5, P10, P12)
- Excellent that can set bookmarks at the phrase level (P1, P10, P12)
- Good that Play/Stop reads the phrase from the beginning of the phrase, not mid-phrase (P10, P13)
- Generally very responsive to commands with fast access to different sections of the book (Ps 1-13)
- The search facility is potentially very useful, and it is good that it searches for part-words (P2, P3, P7, P8, P9)

### ***8.5.1.3 Use of Shortcut Keys and Numpad for Commands***

Of the two methods provided by the DAISY Playback Software for executing commands, participants generally preferred to use the standard keyboard shortcuts (for example, the <arrow cursor> keys, <P> for page information and so on) to the numeric keypad (numpad), although rated both methods as equally useful, see Table 8.5.

**Table 8.5: Ratings for Command Methods**

Usability Question	$\bar{X}$ ( <i>sd</i> ) n	Spread		
		1-3	4	5
Usefulness of shortcuts for commands	4.64 (0.67) 11	1	2	8
Usefulness of numpad for commands	4.50 (0.58) 4	-	2	2

Of the 13 participants, 9 stated that they preferred the standard shortcuts since they were more familiar with using these types of commands and since most had intuitive letters they were easy to remember, whereas the commands on the numpad had to be learned carefully (P1, P2, P3, P4, P5, P7, P8, P9, P10); 3 participants were equally happy with either method, being familiar with both keyboard shortcuts and the numpad (P6, P12, P13); and P11 preferred the numpad because all the commands were in one place. Since the numpad is used to control many screenreaders P7 was pleased that the shortcuts did not confuse them with their screenreader numpad commands. Most participants said that although they had a preference for the shortcuts they would be happy to learn to use the numpad as well.

**Design Proposals:** Since the provision of both types of command supports a range of users, both methods should remain in the software. However, several participants were frustrated that on occasion the software seemed not to respond to their keypresses. It was suggested that the software could output a soft 'click' to confirm acceptance of keyboard commands (P10, P11).

#### **8.5.1.4 Use of Supporting Braille or Electronic Text**

Participants were asked whether they would wish to have any part of their DAISY talking book available in braille or as electronic text while reading the audio book. Of the 13 participants, 7 said that the audio version alone would be usually sufficient for study or leisure purposes, although 2 participants said they would find a braille Table of Contents sent with each DAISY book useful so they knew the overall organisation and contents of the book before they started (P5, P6).

In general participants did not require full braille text of the book, but there was a definite requirement for access to the electronic version for braille or printing out parts of the book for reference purposes; for word and character reading; and for searching the full text of the book (P1, P4, P5, P6, P7, P13). One participant (P7) remarked that they would

require hard-copy diagrams or tabulated information unless the recording was able to present such information effectively.

**Design Proposals:** A braille Table of Contents could be available with each book to give readers an overview of the contents and structure of the book, and with braille copies of any diagrams or tables. Provision of the full text of the book in electronic format would be useful for printing sections for reference.

#### 8.5.1.5 Interest in Continued Use of the Software

All 13 participants said that they would like to use future versions of the DAISY Playback Software especially for study or work but also for leisure reading. Participants said that it would be easy to read novels using only the basic commands, but that the software also provided very good levels of access to difficult structured material. Several participants echoed comments made by P10:

“This is fabulous for non-fiction reading - it will transform talking books for information access, and open up a new world of information for visually impaired readers.”

#### 8.5.2 Usability of Reading Commands

The mean ratings for the three main reading commands: ‘Play/Stop’, ‘Next/Previous Phrase’, and ‘Next/Previous Group’, are presented for comparison in Table 8.6, together with the combined ease of use rating from these three commands (which are all discussed in the following sections).

**Table 8.6: Ratings for Reading Commands**

Reading Command	Ease of Use $\bar{X}$ ( <i>sd</i> )	Usefulness $\bar{X}$ ( <i>sd</i> )
Play/Stop	4.69 (0.85)	4.92 (0.28)
Next/Previous Phrase	4.92 (0.28)	4.85 (0.38)
Next/Previous Group	4.54 (0.78)	4.85 (0.38)
<b>Combined Ease of Use Rating</b>	<b>4.72 (0.31)</b>	

Participants found it very easy to execute basic reading commands, although there were several aspects of the implementation of the reading commands which could be improved slightly to reduce confusion and frustration. A combined mean ease of use rating for

reading of 4.72 ( $sd = 0.31$ ) was calculated from these main reading commands (see Table 8.6) showing that participants found reading with the DAISY Playback Software very easy.

### 8.5.2.1 Open Book Command

The 'Open Book' command was rated as being very easy to use, both to execute and to remember the shortcut <O>, see Table 8.7.

**Table 8.7: Ratings for Open Book Command**

Open Book	$\bar{X}$ ( $sd$ )	Spread		
		1-3	4	5
Ease of Use	5.00 (0.00)	-	-	13

Participants said that the system messages presented the options in the dialog box very simply, and thought that this command would be easy to use even for multi-track disks and for inexperienced users. It was observed that the messages cued the participants effectively into choosing the appropriate command to use. However, the software took some time to search the disk after the 'Open Book' command was executed, and several participants were not comfortable with the long silent delay (P10, P13). They often felt that their command had not been accepted, and some participants tried to execute the command again.

Design Proposal: To provide feedback while the software searches the disk two types of output are possible: a system message such as "searching disk"; or a non-speech sound such as the soft "bip bip" used by the PlexTalk Player.

### 8.5.2.2 Play/Stop Command

The 'Play/Stop' command was rated as being very easy to use and very useful, see Table 8.8.

**Table 8.8: Ratings for Play/Stop Command**

Play/Stop	$\bar{X}$ ( $sd$ )	Spread		
		1-3	4	5
Ease of Use	4.69 (0.85)	1	1	11
Usefulness	4.92 (0.28)	-	1	12

Several participants likened the control to that on a CD-player which made it particularly easy to use. All participants liked the use of the <Spacebar> for this command because it was easy to locate, and liked having the same control for starting and stopping the output. They especially liked the fact that the 'Play' command started reading again from the beginning of the phrase rather than from the exact location where the output was stopped (P10, P13), which helped maintain context.

However, most participants reported and were observed to find it difficult to distinguish between the two modes (P1, P2, P3, P8, P9, P10, P11), which is why one participant rated the usefulness as slightly less useful than the others. This was because even in Stop mode while reading or navigating the software might output long phrases, making the participant feel that they were in Play mode. In these cases participants often pressed the 'Play/Stop' command to halt the output (P13), which then put the software into Play mode - thus further extending the output. Participants also tried to use the 'Stop' command to halt the speech output immediately (which seems quite reasonable), but the software continued playing to the end of the phrase and then stopped. The 'Mute' command (<Ctrl+M>, <Esc> or <Enter>) was designed to halt the speech output, but many participants tried to press the <Spacebar> because it was so easily accessible on the keyboard and felt that the 'Stop' command should halt the output immediately.

Design Proposals: Several participants agreed that the two modes should be indicated (P1, P2, P8, P9, P10, P11) and possibilities include: A verbal message "Play", "Stop", although most participants stated a preference for a non-speech sound such as a high pitch tone for 'Play', and a low tone for 'Stop'; or a double tone for 'Play', and a single tone for 'Stop'. In this way users would be sure which mode they were activating and should be less tempted to put the software into the wrong mode. For the same reason, Arons (1993, 1997) added the sound of a machine starting and stopping for his Play/Stop command. Secondly, the 'Stop' command should be re-implemented to halt the output immediately and put the software into Stop mode, rather than reading to the end of the phrase and then stopping. This could be used in addition to the 'Mute' command.

### **8.5.2.3 Next/Previous Phrase Commands**

Participants greatly appreciated the fine level of access and control in a talking book provided by the 'Next Phrase' and 'Previous Phrase' commands, rating them as very easy

to use and very useful with either the <arrow cursor> keys or the <4> and <6> on the numpad, see Table 8.9.

**Table 8.9: Ratings for Next/Previous Phrase Command**

Next/Previous Phrase	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Ease of Use	4.92 (0.28)	-	1	12
Usefulness	4.85 (0.38)	-	2	11

Although all participants rated these as being very important commands, three reported that they would probably not listen to a great deal of material at this level (P7, P12, P13). However, depending on the nature of the material participants were reading, the phrase-to-phrase reading commands while in Stop mode were particularly useful; for example, for reading the ingredients of a recipe item-by-item; references in a textbook (P9); or complex phrases in a textbook. Participants also used the phrase-to-phrase reading commands while in Play mode to skip quickly through the material at a fine level and then listen to the desired section without having to change mode.

Some phrases were difficult to listen to at the phrase level in Stop mode (P12, P13) because they were obviously either too short or too long. For example, a sentence may be broken up into small phrases because the narrator has paused slightly between words, so the reader has to execute the command very frequently just to hear the whole sentence; or there may be no phrase markings in a long sentence which obviously has sub-phrases, which should have been broken up into separate phrases. In the latter example, because the phrase seemed so long participants would try to Stop the output, thinking that they had put the software into Play mode by mistake.

**Design Proposal:** Books should be recorded and coded consistently, so that as far as possible phrases are broken into appropriately sized units. This should apply both across books and within the same book.

#### **8.5.2.4 New Commands Proposed: Word and Character Reading**

The majority of participants agreed that the DAISY Playback Software should include a finer level of information access: at the word and character levels (P1, P7, P8, P10, P11, P13). Participants stressed that this would be particularly important when reading difficult

technical material for example, when it might be crucial to be able to read individual words and check the exact spelling of a word.

**Design Proposal:** Word and character reading is likely to be acceptable presented in synthetic speech, which reverts back to the audio recording when the user executes the phrase or group reading commands. The commands for reading word-by-word, or character-by-character should be consistent with existing commands for phrase-to-phrase reading, and implementation alternatives include:

- a) Holding down the <Alt> or <Shift> key together with the normal phrase reading commands to read words or characters respectively.
- b) Holding down a letter key, such as <W> for word and <C> or <L> for character/letter, with the normal phrase reading commands.
- c) A toggle key which cycles between phrase mode, word mode, and character mode, so that the normal phrase reading commands are used for three levels of reading, depending on the current mode.

The modal alternative (c) (as proposed for DAHNI-2) might be more attractive to novice or less able users, since they would not have to remember three sets of commands; however, experienced users might prefer using a dedicated key for each command so that they can navigate very quickly at the different levels.

#### 8.5.2.5 First/Last Phrase Commands

Participants found the 'First/Last Phrase' commands very easy to use, and thought that they were fairly useful, as shown in Table 8.10.

**Table 8.10: Ratings for First/Last Phrase Commands**

First/Last Phrase	$\bar{X}$ (sd) n	Spread		
		1-3	4	5
Ease of Use	4.83 (0.58) 12	1	-	11
Usefulness	4.17 (0.94) 12	4	2	6

Most participants did not use these commands very much, and had trouble thinking of occasions when they might want to use them, hence the spread of usefulness ratings. P8 found that they used 'First Phrase' more frequently than 'Last Phrase', to jump quickly to the first phrase of a paragraph.

**Design Proposal:** Despite the low use of these commands during the evaluations, participants seemed to prefer having more commands available than fewer, in case an occasion does arise when the commands might be useful, and therefore these commands should remain in the software.

#### 8.5.2.6 Next/Previous Group Commands

The 'Next Group' and 'Previous Group' commands were considered to be very easy to use and very useful, see Table 8.11.

**Table 8.11: Ratings for Group-to-Group Commands**

Previous/Next Group	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Ease of Use	4.54 (0.78)	2	2	9
Usefulness	4.85 (0.38)	-	2	11

All participants liked the feeling of being able to jump the equivalent of paragraph-to-paragraph through the book, and used these commands to get a quick overview of the contents of a particular section, using the audio book in the same way that a blind or sighted reader would use a hard-copy book to read the first parts of each paragraph to skim the page.

The participants' main complaint was that in Stop mode the commands only read the first phrase of the group rather than reading the whole group (P2, P3, P8, P9, P10, P11, P12, P13). This confused participants who felt that they may have executed the 'Next/Previous Phrase' command by accident, and frustrated participants who wanted to read the material a chunk at a time using a single command. A related problem was that despite being told that the groups were only *approximating* paragraphs, participants expected the command to jump paragraph-to-paragraph and were frustrated when this was not the case.

A further problem arose when the group-to-group commands jumped to headings and into new sections when there were no further paragraphs in the section (P1, P10, P12, P13). Since the headings were not presented in a different way from the body text it was often difficult for participants to tell that they had reached a heading and were now reading in a new section, especially for badly worded headings.

Design Proposals: The ‘Next/Previous Group’ commands should output the entire paragraph even in Stop mode, to distinguish them from the ‘Next/Previous Phrase’ commands. If users are still confused between these two commands, a short non-speech sound such as ‘Zwoop’ could be output when the command is executed to help reinforce the larger reading command of the ‘Next/Previous Group’ command. Secondly, the group-to-group commands could be restricted to groups within one section, so that if there are no further groups in the current section users have to jump to the next heading using the navigational commands to get to the next section (P1). If the headings were indicated (discussed in Section 8.5.5.2), then this command might not have to be restricted in this way.

#### **8.5.2.7 *New Command Proposed: Repeat***

Although the software allows users to repeat phrases with ‘Stop/Play’, there was no way to simply listen again to the section heading just heard. The work-around adopted by several participants was to jump to another heading and back again, which was often difficult and disorienting for some participants (P7, P8).

Design Proposal. A new command ‘Repeat’ which simply outputs the last phrase or section heading heard would be very useful. This would reduce the disorientation caused by having to move away from and return to the current section heading just to hear it again.

### **8.5.3 Usability of Heading Navigation Commands**

The problems relating to heading navigation identified by the researcher before the evaluations see Section 8.3.6 were raised by participants during training and evaluation sessions. The following sections present the usability of the commands for navigating around the headings of the book: ‘Next/Previous Section’, ‘Level Up/Down’, ‘First/Last Section’, and ‘Jump Forwards/Backwards 15 Sections’. The mean usability ratings for these heading navigation commands are compared in Table 8.12.

**Table 8.12: Ratings for All Navigation Commands**

Command	Ease of Use $\bar{x}$ ( <i>sd</i> )	Usefulness $\bar{x}$ ( <i>sd</i> )
Navigating through headings: Next Section/Previous Section commands, & Level Up/Level Down commands	2.46 (0.88)	5.00 (0.00)
First/Last Section in Level	4.77 (0.60)	4.54 (0.78)
Jump Forwards/Backwards 15 Sections	4.69 (0.85)	2.69 (1.49)

### 8.5.3.1 Next/Previous Section and Level Up/Down

Overall navigation through headings using ‘Next/Previous Section’ and the ‘Level Up/Down’ commands was rated as being particularly difficult, see Table 8.13.

**Table 8.13: Ratings for Heading Navigation Commands**

Next/Prev Section & Level Up/Down	$\bar{x}$ ( <i>sd</i> )	Spread		
		1	2	3-5
Ease of Use	2.46 (0.88)	1	7	5

Although participants said that the keyboard shortcuts for the commands themselves were fairly easy to learn (for example, P9 said that “it’s like changing lanes on a motorway, moving between the left and right-hand lanes”), in practice, participants found it very difficult to use these commands to find their way around a structured book in terms of using headings, sub-sections, and sub-sub-sections, and so on. Comments made by participants about the difficulties of heading navigation included:

- “It’s impossible - I can’t work like this.” (P11)
- “I can’t ever get an idea of the organisation of this book.” (P1)
- “It makes you feel like you’re making mistakes.” (P3)
- “Something has to change - it’s so confusing and inconsistent.” (P12)

### 8.5.3.2 First/Last Section Commands

Participants thought that the ‘First/Last Section’ commands were very easy to use and also quite useful, see Table 8.14.

**Table 8.14: Ratings for First/Last Section Commands**

First/Last Section	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Ease of Use	4.77 (0.60)	1	1	11
Usefulness	4.54 (0.78)	2	2	9

However, most participants did not use these commands very often. This was often reported to be because of the overall problem with heading navigation, although one participant said they had used 'First Section' for orienting themselves (P2) and others had used it successfully for jumping to the first heading of a particular section so they could start reading from the top of the section. One participant (P13) expected these commands to jump straight to the start or end of the book, since the shortcuts <Ctrl+Home>, <Ctrl+End> are used in word processors to jump to the start and end of the document. Additionally, there was some inconsistency of the destination of these commands, making it difficult to know where the command would take the user.

Design Proposals: With the improvements in the presentation of headings described in the previous sections, these commands should become more useful, especially if it is emphasised that these commands work within the current section. However, books should be coded consistently so that this command always takes the user to the same place; for example, to the last heading of the section, or the last phrase of the section.

### 8.5.3.3 *Jump Forwards/Backwards 15 Sections Command*

The 'Jump Forwards/Backwards' commands were the least used of all commands in the DAISY Playback Software. Although they were rated as being very easy to use, they were not considered at all useful by most participants (see Table 8.15) who couldn't understand when or why these might be useful.

**Table 8.15: Ratings for Jump Forwards/Backwards 15 Sections**

Jump Forwards/Backwards 15 Sections	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Ease of Use	4.69 (0.85)	1	1	11
Usefulness	2.69 (1.49)	8	3	2

15 sections seemed an arbitrary number of headings to move through the book, especially since it includes all sub-sections. In addition, with the existing lack of feedback about the level of headings, this command was very difficult to use effectively.

**Design Proposal:** Two participants suggested that a better method of moving through the book in discrete jumps might be to use the row of number keys to represent percentages through the book in terms of major headings (P1, P10); for example, pressing 3 jumps 30% the way through the book, 5 jumps 50%, and 0 jumps to the very end of the book. This seems to be a more useful method of moving through large chunks of a book, although users will still require feedback about the level of heading they arrive at.

#### **8.5.4 Heading Navigation Problems**

Despite the fact that the participants said that in theory the navigation commands were easy to remember, their performance and comments supported the researcher's belief that there were significant design flaws. There appear to be three main reasons for this apparent contradiction which overlap substantially, and these are described in the following sections, followed by proposals for design improvements.

##### ***8.5.4.1 Navigation Problem 1: Heading Navigation Not Hypertext***

One reason for the difficulty in navigating through headings was because some participants had a basic misunderstanding of the nature of DAISY headings, despite the researcher's best efforts during the training session to reinforce the concept that the navigation commands jump the reader through the actual headings in the book. For example, several participants experienced the headings like a hypertext table of contents - where once they were on a heading, they felt that they should press <Enter> to jump to that chapter or section. This occurred particularly with two participants (P6, P8) who had just started using the WWW, and for P1 who was an experienced WWW user.

An additional reason for this confusion was caused by the recorded Table of Contents near the beginning of the book (listing the headings in the book). This was often coded as a single group of phrases, navigated using the phrase-to-phrase reading commands. Some participants initially found this recorded Table of Contents confusing and felt (wrongly)

that they were able to start playing a section when the desired heading was read out - as if the software was navigating to the heading as it was reading them.

#### **8.5.4.2 Navigational Problem 2: Lack of Structural Information**

A second reason for the participants' difficulty in navigating through the headings concerns the lack of information given to users about the structure of headings. It was clear even before the evaluations that sighted users would be able to easily recognise the organisation of the book into sections shown by the nesting and highlighting of sections and sub-sections on the visual display (see Figure 8.1). These visual cues help sighted users to choose the correct commands to use for navigating through sections and sub-sections, who are able to distinguish a heading from a phrase simply by comparing the audio output with the visual display.

However, auditory readers are given no similar cues, and without the visual display it was impossible to accurately determine the current level of any particular heading and to navigate effectively between section levels. This became a problem both while navigating through headings themselves and while reading through the body of the book, since participants would suddenly find themselves reading at a different, unknown level of heading, and then would not know which command to use to navigate to other heading levels. Similarly, participants found it very difficult to determine whether a section contained any sub-sections without exploring.

#### **8.5.4.3 Navigational Problem 3: Overlapping and 'Jumping' Commands**

A third reason for navigational difficulty compounded the other two: that different commands frequently resulted in the same outcome (overlapped); especially 'Next/Previous Section' and 'Level Up/ Down', and others jumped from one section into another without any indication that this had happened, particularly using 'Next/Previous Phrase', and 'Next/Previous Group'. For example, if a user tries to jump to a sub-section using 'Level Down', but there is no sub-section to jump to (that is, they are at a dead-end), instead of the command failing and alerting the user that there are no sub-sections to jump to, the software jumps to the next heading it can find - which might be a heading at the same level or even at a higher level. Thus users believe the new heading to be a sub-section, which in fact it may not be, and are then unable to determine which heading navigation command to

use to get around. Similarly, at the end of a group, the 'Next Group' command jumps out of the current section to the next heading level.

Although this jumping of heading navigation and reading commands may have been designed to reduce the number of commands required for navigating, all participants found it extremely confusing, disorienting and completely unacceptable. This lack of dead-ends was also found to be problematic in the VoiceNotes device (Stifelman, Arons, Schmandt & Hulteen 1993). In addition, when talking to the DAISY participants about the organisation of the book it became clear that they often had been working with a completely incorrect model of the structure of the book, caused by these navigational problems.

### **8.5.5 Navigation Solutions**

#### ***8.5.5.1 Solution 1: Improve Understanding of DAISY Headings***

To help users learn the correct concept of DAISY headings it is important that the documentation contains explicit and repeated description of the distinction between navigating through headings in the book where reading can begin, and simply listening to the recorded Table of Contents in which headings are not linked to the body of the book. The current help system is worded ambiguously, calling the headings a 'talking table of contents', which misleads users. In addition, to relieve the confusion over the recorded Table of Contents, this could be recorded by a different narrator so that users are clear that it is a non-interactive narration, and different from using navigation commands to jump through the headings.

#### ***8.5.5.2 Solution 2: Provide Structural Cues***

As expected, participants were strongly in favour of any solution to improve the navigation in the DAISY Playback Software, and although those described in this particular section are probably the most important, it might be necessary to also implement solutions described later in Section 8.5.5.4.

There are two types of information required by the auditory user of the DAISY Playback Software while navigating through section headings and reading through the body of the book, which is presented on the visual display:

- a) Is this item a section heading, and if so, what level is it?
- b) Does this section contain any sub-sections, or is this a dead-end?

Table 8.16 shows how strongly participants were in favour of being given this information, with most participants stating that it was *essential* for effective navigation.

**Table 8.16: Ratings for Proposals of Indicating Heading Levels and Sub-Sections**

Potential Usefulness	$\bar{X}$ ( <i>sd</i> )	Spread		
		1	2	3-5
a) Indicating level of a heading	5.00 (0.00)	-	-	13
b) Indicating existence of sub-sections	4.92 (0.28)	-	1	12

Information about the level of a heading and the existence of sub-sections can be presented in two ways, using verbal messages and non-speech sounds. The proposed use of non-speech sounds to reduce the verbosity of the interface was enthusiastically accepted by 12 of the 13 participants, who felt that sounds would be a quick method of presenting the information, and two participants said this was because they found having many voices in an interface confusing (P8, P13). However, P7 preferred verbal messages to sounds unless the sounds were very short, and P6 stated that they had no preference for one method over the other. Possible implementations of each method are described below:

**a) Heading Level Indication.** Participants considered it vital to be told the level of a heading see (Table 8.16) and several possible alternatives were discussed:

**Verbal Message:** The two participants who said they would consider a verbal message to indicate the level of a heading (P6, P7) preferred the use of a voice other than the narrator's, which stated the level of a heading before it was spoken. In the following examples the narrator's voice is shown in normal type, and the inserted text or sound is shown in italics:

"Level One", "Venice".  
 "Level Two", "Transport".  
 "Level Three", "Air Travel".

However, most participants did not welcome the proposal of a verbal message, who indicated that although it would be acceptable it would take too long and might distract them from the content of the book.

Another alternative suggested by two participants (P9, P11) was to have the producer of the books insert section numbers or useful headings into the material (if the author had not provided any), which could either be recorded in the material by the narrator, or read by the software in synthetic speech or the system voice, for example:

*“Section 1”, “Venice”.*  
*“Section 1.1”, “Transport”.*  
*“Section 1.1.1”, “Air Travel”.*

However, several participants liked the fact that the DAISY books contained exactly the same material as the original printed book, and objected to proposals that the producer might insert ‘special’ material such as heading numbering for blind readers (P7, P13).

Non-Speech Sounds: Participants were asked to think about different methods of using non-speech sound to indicate heading levels. Most participants were not in favour of the use of a sound of a different pitch to indicate the different levels of heading (high pitch for highest heading, gradually descending into sub-sections), for example:

*“High Pitch Tone”, “Venice”.*  
*“Mid Pitch Tone”, “Transport”.*  
*“Low Pitch Tone”, “Air Travel”.*

Concerns were raised about the difficulty some people have in distinguishing between relative tones, such as blind users with additional hearing impairments (P1, P11). Although the use of pitched tones might be easily compared while navigating through headings, and thus work well for that activity, it might be difficult to identify the different pitches while reading the body of the book (P13). In addition, pitch is known to be difficult for listeners (particularly naïve listeners) to discriminate (Moore 1989) and therefore is not suitable for indicating different heading levels.

Another option suggested by several participants was the use of a different number of tones, or tones of different lengths to indicate heading levels (P5, P11), for example:

*“bip”, “Venice”.*  
*“bip bip”, “Transport”.*  
*“bip bip bip”, “Air Travel”.*

“beeeep”, “Venice”.  
 “beeeep”, “Transport”.  
 “beep”, “Air Travel”.

However, both of these methods are also distinctly limited in their applicability. For example, as the number of tones increases to indicate lower level headings, they are likely to be more difficult to count. Indeed, Portugal & Carey (1994) report that this method of indicating section numbering is ineffective and requires too much effort to comprehend. Similarly, although different tone lengths might be easily distinguishable for a few heading levels while navigating through headings, while reading the body of a book it would probably be difficult to judge the relative length of the tones making them indistinguishable.

Design Proposal: For these reasons the most suitable method of indicating headings with non-speech sounds would appear to be using a different timbre (instrument) for each level of heading (an option proposed to participants). Several participants liked the proposed use of short sounds of different timbres to indicate the different heading levels (P1, P13), for example:

“Piano note”, “Venice”.  
 “Flute note”, “Transport”.  
 “Violin note”, “Air Travel”.

This has the advantage that different-sounding instruments could be selected to cover any required number of heading levels, and additional parameters of the sound could be changed to create earcons, such as adding vibrato, echo, rhythm, or by combining sounds to form complex earcons, to provide additional information about the heading. This additional information could include whether a section has sub-sections, how long the section is, and so on.

**b) Indication of the Existence of Sub-Sections or Dead-Ends.** Participants also considered it very useful to know whether a particular heading contained any sub-sections; or alternatively, when a section had no further sub-sections ( $\bar{X} = 4.92$ ,  $sd = 0.28$ , see Table 8.16). Various designs are discussed here.

Existence of Sub-Sections: All participants wanted to know whether a particular heading contained any sub-sections so that they did not have to explore to determine the structure of a book. The example proposed to participants was a non-speech sound which mimicked

the visual presentation of menu items leading to dialog boxes, marked with an ellipsis, such as: [Open...]. The auditory version might use three very short soft tones such as:

“Venice” *“pip pip pip”*  
 “Transport”, *“pip pip pip”*  
 “Air Travel”, *“pip pip pip”*.  
 “British Airways.”

A very nice variation on this proposal came from P10 who suggested that the number of tones might indicate the number of levels below a heading, rather than just the mere existence of sub-sections, and when there were no sub-sections no sound is played. This would provide a great deal more structural information and would be very useful, even if the exact number of “bips” could not be counted, for example:

“Venice” *“bip bip bip”*  
 “Transport”, *“bip bip”*  
 “Air Travel”, *“bip”*  
 “British Airways”

Dead-Ends: An alternative approach is to indicate the opposite information - that there are no further sub-sections. In this case, silence indicates the existence of sub-sections, but when a heading is reached which does not contain any sub-sections, the dead-end sound is played, for example:

“Venice”  
 “Transport”  
 “Air Travel”, *“donk”*

The dead-end sound might also be used to indicate the last group in a section, or the last phrase in a group when using the reading commands, or at the last page when jumping page to page, for example.

Design Proposals: Although most participants preferred one method or the other, a few liked the idea of having both methods for maximum structural information. This would also help to reduce the number of redundant commands executed since users would not have to explore to determine that they had reached the lowest level of heading. This information could be combined, for example:

*“Piano note”*, “Venice” *“bip bip bip”*  
*“Flute note”*, “Transport”, *“bip bip”*  
*“Violin note”*, “Air Travel”, *“bip”*  
*“Oboe note”*, “British Airways”

This method provides a great amount of information, although this might potentially overwhelm users and/or distract them from the contents of the book, and the number of sounds might make them difficult to learn. Therefore, users might prefer to receive slightly less information (perhaps omitting the exact number of sub-sections in a heading), and using simple earcons to present the information more succinctly. For example, using a chord to indicate the presence of sub-sections, with a different timbre for each level of heading. A single note in a particular timbre indicates that there are no further sub-sections under a heading, for example:

*“Piano chord”, “Venice”*  
*“Flute chord”, “Transport”*  
*“Violin chord”, “Air Travel”*  
*“Oboe note”, “British Airways”*

There is a wide range of possibilities for the type of information which could be presented in this way, but this final proposal is likely to be the most effective and should be explored first.

### 8.5.5.3 *Solution 3: Provide New Structural Overview Commands*

An additional method of providing more structural information might be to provide a summary of the structure of a book or a section either in the body of the book or as a separate command. For example, in books without numbered section headings it is difficult for a reader to gain an overall impression of the structure of the book, or of a specific section. Although readers could listen to the Table of Contents, if the section headings are not numbered by the author, they are heard as a long list of headings without any indication of their structure. Participants were therefore asked how useful they would find two overview functions: one giving a summary of the structural organisation of the book; and the other an overview of the organisation of the current main section. These commands might state, for example:

*For the whole book: “This book is divided into 12 chapters (level 1 headings). Chapters are divided into further sub-sections, at both level 2 and level 3 headings. The last chapter, References, is divided into groups of phrases in alphabetical order according to the surname of the first author.”*

*For the current main section: “This section contains 4 sub-sections, and most of these have 1 or 2 further sub-sections. The ingredients can be found at the lowest level of heading, but you will not hear a heading ‘Ingredients’, since they are listed without a heading.”*

Participants considered these commands potentially quite useful (see Table 8.17), especially if a book or a section was particularly complex or unusual in its structure, and the commands would help them to find out about the structure of the book/section (P1, P7, P10, P12).

**Table 8.17: Ratings for Proposed Overview Commands**

Potential Usefulness	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Overview of Whole Book	4.38 (1.04)	3	1	9
Overview of Current Main Section	4.54 (0.97)	2	1	10

Participants tended to prefer a summary of a whole chapter rather than for smaller sub-sections (P3, P4, P5, P10, P12), to give them small chunks of local information. However, P13 expressed their dislike of adding ‘special’ material for blind users and preferred the book remained true to the original print version, and that the software instead indicated the level of headings while reading the Table of Contents and while navigating through the headings.

**Design Proposal:** Commands to present a summary or overview of the structure of the whole book or the current main section might be a useful addition to the software for many users to help give them an understanding of the overall structure of the book/section.

#### 8.5.5.4 Solution 4: Restrict Commands

All 13 participants stated that it was essential that the commands such as ‘Next/Previous Section’, and ‘Level Up/ Down’ did not behave inconsistently and jump to an inappropriate heading, even if it meant that the user would have to execute more commands to get around the book, see Table 8.18.

**Table 8.18: Ratings for Proposed Command Restriction**

Potential Usefulness	$\bar{X}$ ( <i>sd</i> )	Spread		
		1	2	3-5
Prevent commands from jumping	5.00 (0.00)	-	-	13

**Design Proposals:** When the ‘Next Section’ command is executed, and there are no further sections at that level the software should *not* jump to the next available heading at a higher level as it does currently. Similarly, the ‘Level Down’ command should *not* jump to the

next available heading when no further sub-sections are present. This would allow users to gain an accurate understanding of the structure of a book, and would also help users to remember which command to use to navigate to which heading.

As presented earlier, the use of a dead-end sound might benefit some users, so that any inappropriate command at a dead-end resulted in the non-speech sound such as “*donk*”, so that the user knew they had to move into a new section.

### 8.5.6 Usability of Orientation Commands

Table 8.19 compares the mean usability ratings for the orientation features and commands, and the spread of ratings for each command is given in each command section. Participants used various commands to help them to find out where they were if they became disoriented (due to the problems already outlined) and to get to specific locations in the book. They made good use of all the orientation commands provided in the DAISY Playback Software: ‘Section Information’; ‘Current Position’; ‘Page Number’; ‘Goto Page’; and ‘Next/Previous Page’.

**Table 8.19: Ratings for Orientation Commands**

Feature / Command	Ease of Use $\bar{X}$ ( <i>sd</i> ) n	Usefulness $\bar{X}$ ( <i>sd</i> ) n
Remembers last reading position when next open book	-	4.85 (0.38) 13
Section Information	4.92 (0.29) 12	4.83 (0.58) 12
Current Position	4.92 (0.29) 12	4.42 (0.90) 12
Page Information	5.00 (0.00) 13	4.85 (0.55) 13
Goto Page	4.92 (0.28) 13	4.62 (0.77) 13
Next/Previous Page	4.92 (0.28) 13	4.54 (0.97) 13

#### 8.5.6.1 Remembers Last Reading Position when Insert Disk

The DAISY Playback Software remembers the last reading position in each book and jumps to that position when the book is next opened. This was well liked by participants who thought that it was a very useful feature, see Table 8.20. Many participants reported that this feature made it very quick to start reading where they left off without having to remember to insert a bookmark, and two participants thought that this feature was *essential* for efficient use of the software (P8, P10).

**Table 8.20: Ratings for Remembering Last Reading Position**

Remembers Last Reading Position	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Usefulness	4.85 (0.38)	-	2	11

One participant remarked that this feature was just how sighted readers use books:

“They leave their books open on their coffee table, and would be very annoyed if every time they put it down someone closed it and they had to keep finding their place from the beginning.” (P13)

P13 also commented that the use of the non-speech sounds to indicate the current heading level (see Section 8.5.5.2) would provide important orientation information when the book was opened, since currently the software simply reads just a phrase.

**Design Proposals:** Although many participants liked the use of this feature, it is possible that sometimes having the book opened somewhere in the middle is not desirable. It might be preferable that users could choose to close the book remembering their last location, or just to close the book. This could be achieved simply by adding an extra step when quitting the software, for example, the system prompt is currently “Exiting program; press Y to confirm”. This could be amended to “Exiting program; press S to save reading position and quit, or X to just quit”. Concerns were also raised about sharing books with other readers (P13), and possible solutions might include a log-on procedure so that each readers’ personal information could be stored separately from other readers’ (see Section 8.5.12).

### 8.5.6.2 Section Information Command

The ‘Section Information’ command was used frequently when participants wanted to get an idea of their location within a nest of headings, rating it as being very easy to use and very useful, see Table 8.21.

**Table 8.21: Ratings for Section Information Command**

Section Information	$\bar{X}$ ( <i>sd</i> ) n	Spread		
		1-3	4	5
Ease of Use	4.92 (0.29) 12	-	1	11
Usefulness	4.83 (0.58) 12	1	-	11

Participants found that using this command was the only way to obtain an impression of the structure because of the structural and navigational problems outlined earlier. Participants liked the fact that repeated executions presented the parent heading until the top level heading was reached (P1, P4, P10, P11, P12, P13), helping them to gain an impression of the organisation of the book (P11). Despite the fact that almost all participants were using the shortcuts rather than the numpad for most commands, they almost all chose to use the <5> key on the numpad rather than the shortcut <I> for 'Section Information', because participants found it difficult to associate the shortcut letter with the function and name of the command.

Design Proposal: There seems to be evidence for renaming this command to make it more memorable, for example, to 'Section Heading', or 'Heading Information'.

### 8.5.6.3 Current Position Command

The 'Current Position' command (for reporting the assigned section number of a heading) was used less frequently than the 'Section Information' command, but was rated as being very easy to use and quite useful on occasion, see Table 8.22, especially if the author had not included heading numbering (P1, P10, P11).

**Table 8.22: Ratings for Current Position Command**

Current Position	$\bar{x}$ (sd) n	Spread		
		1-3	4	5
Ease of Use	4.92 (0.29) 12	-	1	11
Usefulness	4.42 (0.90) 12	3	1	8

As with the 'Section Information' command most participants chose to use the numpad command <Ctrl + 5> rather than the shortcut <C> because they had trouble remembering the name of the command (and therefore its shortcut letter).

However, this command was limited in its usefulness since the section numbers assigned in the book bore no relation to the actual sectioning of the book, which was sometimes very confusing and not very useful (P10). For example, Chapter 1 might be the 5<sup>th</sup> heading in the book, and is therefore assigned the number 'Section 5', whereas intuitively users might expect the first main chapter heading to be 'Section 1'. In addition, one participant thought

that it would be useful to be given the assigned section number and told the total number of sections in the current section, to help orient the reader (P8).

Participants were asked whether they would find it useful to be told the total number of sections at the current level, for example “Section 4.5 of 9 level 2 sections”. Participants rated this information as being potentially quite useful ( $\bar{X} = 3.92$ ,  $sd = 0.95$ ), with several participants thinking that it would help their orientation (P1, P2, P3, P7, P8), although some thought that this information would not be very helpful (P3, P11) and might be redundant if the structure of the book is made explicit (P3, P11), and one participant said that since they were unfamiliar with section numbering this information would not be much use to them (P4).

**Design Proposal:** ‘Current Position’ could be renamed to ‘Section Number’ (P7) which might help users remember the shortcut. In addition, it would be more intuitive if sections were assigned numbers appropriately, for example, coding all introductory sections as Intro 1, 2, 3... and then starting formal numbering from the first main section heading (for example, Chapter 1) as Section 1 (P10). This way, readers would know that “Section 1.1.1” is in Chapter 1, whereas “Intro 1.1.1” is part of the introductory material to the book. In addition, information about the total number of sections at the current level could be included in the ‘Current Position’ command for example, “Section 1 of 8 level one sections” as an orientation aid.

#### 8.5.6.4 Page Information Command

The ‘Page Information’ command was rated as being extremely easy to use with the shortcut <P>, and the majority of participants thought it was an essential and very useful command, see Table 8.23.

**Table 8.23: Ratings for Page Information Command**

Page Number	$\bar{X}$ ( $sd$ )	Spread		
		1-3	4	5
Ease of Use	5.00 (0.00)	-	-	13
Usefulness	4.85 (0.55)	1	-	12

All participants were pleased that the printed page numbers were encoded in most DAISY books, especially those who worked alongside sighted teachers, colleagues or family

members (P1, P10, P12), although one participant felt that they would not use this information while working by themselves (P13). The printed page numbers are likely to be very useful for finding information as well as for general orientation within the book, although on occasion it seemed that it would be useful to know the total number of pages.

**Design Proposal:** The total number of pages could be included in the 'Page Information' command, so that the system message might be "At page 37 of 90" to give additional orientation information.

#### 8.5.6.5 Goto Page Command

Participants were impressed with the facility to jump directly to specific pages, and the 'Goto Page' command using the shortcut <G> was rated as very easy to execute and very useful, see Table 8.24.

**Table 8.24: Ratings for Goto Page Command**

Goto Page	$\bar{x}$ (sd)	Spread		
		1-3	4	5
Ease of Use	4.92 (0.28)	-	1	12
Usefulness	4.62 (0.77)	2	1	10

Many participants used this command to get around the book quickly, particularly in books with page numbers to jump to the beginning of the book (for which there was no command) using 'Goto Page' 1 <Enter>. Participants also found the method of cancelling the command very intuitive using the <Esc> key. This command was made more effective in books which had the page numbers coded with each heading so that participants became familiar with the page numbers of each section.

One participant mentioned wanting to use the 'Goto Page' command to type in not only a page number but also a specific section number (P11, P12). For example, while using the 'Current Position' command they found the assigned number of a section they later wanted to return to. They had forgotten to place a bookmark, but remembered the section number, and wanted to be able to jump there quickly.

**Design Proposal:** The 'Goto Page' command could be adapted to a more general 'Goto' command. If the section numbers are included in the book by the author, then the normal

'Search' command might allow users to search for the particular section number. However, if the author did not include section numbers, readers could make use of the assigned section number, and although it would make the command slightly more complex, the user could specify *what* they wanted to go to. For example, to jump to page 11, users could start the 'Goto' command using <G> and then type in <P 11><Enter>, or to jump to section 2.4.2 press <S 2.4.2><Enter>.

#### 8.5.6.6 Next/Previous Page Commands

The 'Next/Previous Page' commands were rated as being very easy to use and also very useful, see Table 8.25, and participants thought that these would be especially useful when working alongside sighted people (P8, P13).

**Table 8.25: Ratings for Next/Previous Page Commands**

Next/Previous Page	$\bar{x}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Ease of Use	4.92 (0.28)	-	1	12
Usefulness	4.54 (0.97)	2	1	10

Participants were observed to flip through pages, listening to the first phrase on a page, much like they might skim through a braille book reading the top line of each page. However, these commands had limited applicability when the page numbers were not coded or were coded inconsistently in the book. For example, while using this command, participants expected to hear the new page number with every press of <PgDn>, and in some cases either no page number was read, or the page number and the first phrase of the page was read (P4).

Design Proposal: The coding of page numbers should be consistent throughout the book so that the 'Next/Previous Page' commands always output the page number, to improve orientation and feedback, for example "Page 11", "Page 12", "Page 13".

#### 8.5.6.7 New Command Proposed: Time Information

The potential provision of time information (such as that provided by the PlexTalk Player as to the total time of a book, time passed and time remaining) was rated overall as being only moderately useful, see Table 8.26.

**Table 8.26: Ratings for Proposed Time Information Command**

Potential Usefulness	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Time Information	3.23 (1.42)	7	3	3

Half the participants said that they were not interested in this information, with some saying that it was just not relevant while reading a book (P2, P3, P11), and that it would also not be valid when listening to the book at different speeds (P10). However, half the participants considered that this information might be useful on occasion, for example while studying (P6), or to get an idea of the length of a book and their location within it (P12), or perhaps if no page information was included in a book (P13). Several participants commented that this type of information might be more relevant when reading novels than non-fiction books.

**Design Proposal:** If the time information could be accurately calculated for the different output speeds, then the information could be included as a new command in the DAISY Playback Software, which for example, presented the current time location (time passed), the total book time, and time remaining.

#### 8.5.6.8 *New Commands Proposed: Goto Start/End of Book*

Since the software did not allow users to easily jump to the very beginning or end of the book, it was anticipated that participants would desire such commands. The majority considered that these proposed commands would be very useful, see Table 8.27.

**Table 8.27: Ratings for Proposed Goto Start/End of Book Commands**

Potential Usefulness	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Goto Start / End of Book	4.46 (1.33)	2	-	11

11 of the 13 participants thought that the 'Goto Start of Book' command in particular would be essential for quick navigation to the start of the book, especially when the book had opened in the middle. In books with page numbers coded, some participants successfully used the 'Goto Page' command to jump to page 1 (P8, P10); but otherwise it required navigation to the highest level of heading and then to the first section – a task which required great concentration and was made difficult by the lack of information about the level of headings (discussed earlier). Several participants expected the shortcut

<Ctrl+Home> to jump to the start of the book, since it is a command commonly used in word processors to jump to the top of a document.

**Design Proposal:** ‘Goto Start/End of Book’ commands would clearly provide an efficient method for users to get to the beginning and end of the book, especially valuable since the books open at the last reading position. The familiar shortcuts <Ctrl+Home> and <Ctrl+End> should be considered as the shortcuts for these commands. However, the commands currently using these shortcuts would need to be given new shortcuts.

#### **8.5.6.9 New Command Proposed: Access to Information on Status Bar**

On occasion, participants asked the researcher how many phrases there were in the current section, or the number of groups of phrases; and this information is shown on the status bar on the visual display of the software for sighted users. It might be useful to provide auditory access to this information to help users’ orientation within the book. Such a command might be called ‘Where Am I?’ and might output the entire contents of the status bar, for example: “At phrase 2 of 2, group 1 of 5, page 4 of 30”.

### **8.5.7 Usability of Bookmark Commands**

Participants were impressed with the bookmark facilities (setting and jumping to bookmarks) and the mean ratings for ease of use and usefulness of the two commands are presented in Table 8.28 and Table 8.30, and described below.

#### **8.5.7.1 Set Bookmark Command**

The ‘Set Bookmark’ command was rated as being very easy to use and very useful as shown in Table 8.28.

**Table 8.28: Ratings for Set Bookmark Command**

Set Bookmark	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Ease of Use	4.85 (0.38)	-	2	11
Usefulness	4.77 (0.55)	3	1	11

Participants stated that it was especially useful to be able to set a bookmark at the phrase level, not just at a heading or page level (P1, P10), and that it was particularly useful when studying to be able to use bookmarks for cross-referencing within the book (P12). Despite the high ease of use ratings some participants sometimes found it difficult to remember to use the <Ctrl> key to set a bookmark (P6, P10), since this command is often used in other applications for jumping to specific locations. The other main criticism of this command was that when a bookmark is set, only the number of the bookmark is output, not the phrase at which it was set (P1, P3, P10, P11). This did not seem to be sufficient confirmation of the command to assure participants that their bookmark had been correctly placed. In addition, the system message wording and intonation used to confirm the bookmark number set (“Set bookmark 3”) sounded more like a question, leading some participants to unnecessarily try to respond using <Enter> or <Y>, and P10 specifically mentioned this as a problem.

Ten participants thought that nine bookmarks were sufficient for everyday use, even in a long textbook, giving the reason that more than nine might be difficult to remember. However, three of the experienced participants thought that having more than nine bookmarks might be required in complex reference books, made usable if they could assign them names (P1, P3, P10).

**Design Proposals:** When setting a bookmark the number of the bookmark should be output in the system voice, together with the phrase at which it has been set. In addition, the system prompt should be reworded to confirm the event:

While setting a bookmark using <Ctrl 3>:

“*Bookmark 3 set at:*” “that people are more likely to be aggressive under the influence of alcohol”

Additionally, while reading through the book, the position and number of any set bookmarks should be presented (P3), for example:

While reading phrase-to-phrase in the book:

“Young People and Alcohol. Received wisdom holds that alcohol and violence go together; “*Bookmark 3*”, “that people are more likely to be aggressive under the influence of alcohol.”

There are several alternative methods of implementation of the ‘Set Bookmark’ command. For example, the command could be self-assigning, giving the next available number to each bookmark set (P10). After this, users might have to specify which bookmark they

wish to reassign. As an additional command, or perhaps as an alternative, the whole procedure for setting a bookmark could be made consistent with other commands, for example, by pressing <B> for ‘Set Bookmark’, leading to a system prompt “*Type in the bookmark number you wish to set*”, so that the user inserts the desired bookmark number, and presses <Enter> to confirm. If a bookmark already exists then the system could alert the user (P11) with a message such as “*Overwrite bookmark 3? Press <Enter> for Yes or <Esc> for No*”.

Two participants requested a naming facility for bookmarks (P12, P13) and the command might be redesigned to include an additional stage giving users the option to give a name to the bookmark number. A separate command would be required to present a list of bookmarks by name and number. More complex bookmark management could be designed, but would make what is currently a simple method of bookmarking much more difficult for less able users.

#### 8.5.7.2 *New Command Proposed: Highest Bookmark Set Confirmation*

To help users to set their next numbered bookmark a new command was proposed to participants to output the highest bookmark set. Participants rated this proposed command as being potentially very useful as shown in Table 8.29.

**Table 8.29: Ratings for Proposed Highest Bookmark Set Confirmation**

Potential Usefulness	$\bar{x}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Highest Bookmark Set	4.23 (1.17)	2	4	7

Reasons given by participants for liking this command supported the researchers’ reasons for providing this information, that it would make sure they didn’t overwrite an existing bookmark, especially when lots of bookmarks were set (P2, P3, P4, P11), and that it would help them to organise and re-use their bookmarks (P12). However, the two (experienced) participants who rated this command as being less useful (P1, P13) said that they would prefer to manage their bookmarks using a list which they could cursor through.

### 8.5.7.3 Goto Bookmark Command

The 'Goto Bookmark' command was rated as being extremely easy to use and very useful, see Table 8.30.

**Table 8.30: Ratings for Goto Bookmark Command**

Goto Bookmark	$\bar{X}$ (sd)	Spread		
		1-3	4	5
Ease of Use	4.92 (0.28)	-	1	12
Usefulness	4.85 (0.55)	1	-	12

Participants liked the extreme simplicity of this command, although they were observed to frequently forget how to execute the command. This seems to be because the command is so simple (just pressing the number of the bookmark), and is not consistent with other commands for jumping to a specific location in the software, which mainly use the <Ctrl> key, or a specific command, such as 'Goto Page'. Several participants specifically complained about this inconsistency (P10, P11).

Design Proposal: Rather than simply pressing the number of the bookmark to jump to a bookmark, the redesigned 'Goto' command <G> could be used so that to jump to bookmark 3 the user types in <G>, then <B 3> <Enter>. Additionally, users could skip bookmark-to-bookmark by for example, holding down <B> and using the <up/down arrow> cursors, hearing each bookmark and its phrase in turn, making it easy to jump to bookmarks even if their numbers are not remembered. However, if a bookmark management system is implemented users could also cursor through a list of their named bookmarks, and press <Enter> to jump to them.

### 8.5.8 Usability of Search Commands

Participants were very pleased to have a search function on their DAISY book, and a basic search task in the headings was not difficult for them to complete. The mean usability and usefulness ratings for the 'Search', and the 'Search Next/Previous' commands are shown in Table 8.31 and Table 8.32, and described in the following sections.

### 8.5.8.1 Search Command

Participants found the ‘Search’ command through headings very easy to use, but not quite as useful as they had expected, as shown in Table 8.31.

**Table 8.31: Ratings for the Search Command**

Search	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Ease of Use	4.77 (0.60)	1	1	11
Usefulness	4.23 (0.93)	2	5	6

All participants liked the fact that ‘Search’ looked for part words and was not case sensitive, which made it easy to locate strings without lengthy interactions. However, there were several issues which reduced the usability and usefulness of the ‘Search’ command. For example, most participants noticed that there was a mis-match between the shortcut used for the ‘Search’ command (<F>), and the command name and system prompt “*Search For?*”, which made the shortcut difficult to remember.

Several issues relating to the methods of presenting the typed string reduced the usability of the command: for example, when backspacing or cursoring through characters, the software simply outputs “*Delete*” when <backspace> is pressed, and nothing at all when the cursor keys are used; rather than stating the character deleted/reached. This provides no information to the user about the position of their editing cursor. Similarly, when the start of the edit area is reached the software does not inform the user. Both of these problems were noted by most participants. All participants requested that the ‘Search’ command works in the body of the book, not just in the headings, to make it even easier to locate specific information in the book.

**Design Proposals:** The command name and its shortcut must match otherwise users will find it difficult to remember the command, so the command should either be renamed ‘Find’, or the shortcut changed to <S>. Similarly, the system message must match the command name. In addition, when typing text into the edit area, the system must provide effective feedback about the position of the editing cursor, so for example, as letters are deleted they are spoken, and when the beginning or end of the edit area is reached the system states “*start/end of line*”, or alternatively, the ‘dead-end’ non-speech sound could be used. These are implementations which many blind people are familiar with in other computer applications.

The most important change for the 'Search' command should be to add full-text searching if possible. As mentioned earlier, participants requested access to the body of the book for several reasons: for printing selected parts for reference and for locating specific information within the book quickly. Even if the software could not allow searches to locate the exact position of the target word, if the book was indexed, the software could jump to the page or section containing the target.

Small refinements to the 'Search' command suggested by participants might include the option to specify whether to search only in the current section, or in the whole book (P1); whether to search from the current location (as it does now), or from the beginning of the book (P1); and allowing wildcards and pattern matching, making the search very sophisticated (P7). The ability to conduct 'sounds like' type of searches could be very useful to blind users who may have trouble knowing how something is spelt, and the ability to specify the breadth of the search could help users complete their task very efficiently.

#### 8.5.8.2 Search Next/Previous Commands

Participants had mixed feelings about these commands, stressing that although they were very useful for finding search hits quickly, the current implementation of the particular shortcuts reduced their overall ease of use, see Table 8.32.

**Table 8.32: Ratings for the Search Next/Previous Commands**

Search Next/Previous	$\bar{x}$ (sd) n	Spread		
		1-3	4	5
Ease of Use	3.92 (1.00) 12	4	4	4
Usefulness	4.92 (0.29) 12	-	1	11

Since the 'Search' command starts at the reader's current location, these commands were welcomed for quickly finding search hits (P1, P13) and participants found them useful. However, only three participants noticed the spatial relationship on the keyboard between <F> for 'Search', and <R> for 'Search Previous' and <V> for 'Search Next' (P4, P9, P11), and these participants found the commands very easy to use and rated them highly. The other participants who rated the command as fairly easy to use were able to learn the keys required, but were not aware of the spatial layout to aid their memory; and the remaining four participants who found it very difficult to remember the shortcut keys rated

these commands as particularly difficult to use (P1, P5, P8, P13). Interestingly, the researcher had also not appreciated the spatial layout of the commands, which indeed made them very memorable, and the software documentation did not include any reference to this.

**Design Proposals:** Since the choice of shortcut was the only feature reducing the ease of use of these commands, the mnemonic spatial relationship of these shortcuts should be explicitly mentioned in the documentation. Once this relationship is known, there could be little confusion over the shortcuts. Alternatively, the shortcuts could be changed so that they are more memorable with their command name, for example <V> for 'Find Previous', and <X> for 'Find Next'. One participant (P13) suggested the use of the <F> key for 'Find', and the <up/down arrows> for 'Find Previous/Next'. Any of these solutions should improve the usability of these commands.

## 8.5.9 Usability of Voice Control Commands

### 8.5.9.1 Mute Command

Participants rated the 'Mute' command as essential for efficient reading, but thought that the current implementation was not very easy to use, see Table 8.33.

**Table 8.33: Ratings for the Mute Command**

Mute	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Ease of Use	3.00 (0.82)	9	4	-
Usefulness	4.92 (0.28)	-	1	12

Participants were not able to quickly locate the <Esc>, <Enter>, or <Ctrl + M> keys to halt the output and became very frustrated. All 13 participants requested the use of a single key rather than a combination such as <Ctrl + M>, but indicated that even the use of <Esc> and <Enter> did not allow the keys to be found quickly enough.

**Design Proposal:** The <Ctrl> key is an obvious choice for a 'Mute' command since this key is used to silence output in many screenreaders, and is very easy to locate on the keyboard, and was mentioned by several participants. The other keys could be maintained for the 'Mute' command, so that users have a choice. However, as discussed for the 'Play/Stop' command, if 'Stop' halted the output immediately, then 'Mute' might be

redundant; but having two methods of muting the output would at least provide different users with familiar controls.

### 8.5.9.2 Output Speed

Participants welcomed the capability to change the reading speed of their DAISY book and liked the fact that the pitch did not change with the output speed. Although the possibility of changing speeds was considered quite useful, the current implementation was not considered easy to use, as shown in Table 8.34. The usefulness rating was divided between participants who felt that the command was extremely useful in theory, and those who felt that the current implementation was not at all useful, but should have been.

**Table 8.34: Ratings for Speed Commands**

Speeds	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Ease of Use	2.92 (1.44)	10	-	3
Usefulness	4.23 (0.93)	4	2	7

Although most participants chose to use one speed throughout the evaluation (either standard or brisk), several reported that the slower speeds with the extended pauses between phrases would be useful when reading difficult material or lists of items, since it gave them time to think between items (P11, P13).

However, there were three main complaints about the controls for changing the speed. Firstly, all participants were unhappy that the controls required five separate shortcuts since they were unable to remember the five different speed names and therefore also their shortcuts. This made it very difficult for participants to change the speed of the output easily.

Secondly, the changes in speed did not change the rate of the actual speech - they merely reduced or increased the length of pauses between phrases. None of the participants was happy with this implementation for higher speeds, since many were familiar with other applications and devices which increase the speed of the actual speech itself, and every participant requested that the speed of the speech itself is increased at higher speeds. A related concern was raised by the more experienced users of audio materials (P10, P13); that at higher speeds the length of all pauses was reduced to almost nothing, and the

original ratio of pauses (for example, between sections, groups, and phrases) was lost. The material was consequently presented in a long fast string, with almost no pauses, which was unnatural and unrepresentative of the original material, and very difficult to listen to. However, as mentioned above, at slower speeds, participants liked the extension of pauses rather than actual slower speech.

Thirdly, participants were initially surprised that there was no feedback to indicate that the speed had been changed, and they had to listen carefully to the output to tell the difference, and one participant found this a problem (P2).

Design Proposals: Firstly, the speed commands should be re-implemented to make use of either a single modal command which cycles between the different speeds, or which uses two commands for increasing and decreasing the speed. For example, to use the <S> key to cycle between the different speeds; or to press and hold <S> together with the <up/down arrows>. A single cyclic command would support less able users, whereas more experienced users might require two separate keys to change the output speed more quickly. Secondly, the implementation of higher speeds should increase the rate of the actual output rather than decrease the length of the pauses. In contrast, the slower speeds should maintain the use of longer pauses without affecting the speech speed, and care should be taken when coding books that pauses are not inserted within words at the very slow speeds as sometimes happened. Two participants suggested that the relative length of pauses should be maintained in the different speeds, such that phrase pauses are shorter than major section pauses for example (P10, P13). Thirdly, once the commands are combined (into either a single or two commands), users might benefit from a short system message confirming the new speed as it is selected, for example, “*High*”, or “*Brisk*”, rather than having to pay attention to the speed of the output as it starts playing.

### **8.5.9.3 New Command Proposed: Volume**

Participants could not change the volume of the output without knowing how to use Windows 95 and its own separate volume control. This became a problem for many participants while completing the tasks.

Design Proposal: A simple volume control should be included in the software, and could be implemented in a similar manner to the chosen speed control; for example, by holding down the <V> key and using the <up/down arrows> to increase and decrease the volume.

#### **8.5.9.4 New Command Proposed: Pitch**

Several participants asked whether they could change any aspect of the recorded voice during playback, such as pitch (P4). Blind people are used to this function being available on other voice output technology, and it might be beneficial to users who have hearing difficulties to be able to change the playback pitch to suit their individual requirements. This command could be implemented in a similar manner to the volume and speed, using <P> together with the <up/down arrow> keys.

#### **8.5.10 Usability of System Messages**

The most serious problem with the system messages was that the intonation often did not match the purpose of the message (P10), and therefore did not cue participants correctly as to what they should do next. This meant that participants did not always complete the task in the correct manner; for example, the confirmation message “*Goto Bookmark 3*” sounded like a question - leading participants to try to unnecessarily confirm the execution by pressing <Enter>. Although most participants found the female voice used to present system messages pleasant to listen to, they said that they would prefer an English accent, and faster, shorter messages.

Design Proposals: System messages should be re-worded so that extraneous and redundant words are removed, to make the messages as short as possible, and worded carefully to match the command names. They should be re-recorded with a nationally localised voice (that is, British, Japanese, Canadian etc), with intonation appropriate for the message they convey about the current task, and spoken much faster, to reduce the length of the messages.

### 8.5.11 Usability of Audio Help System

Participants were pleased to have an on-line help system with the software, rating it as being very useful, see Table 8.35.

**Table 8.35: Ratings for Audio Help System**

Audio Help	$\bar{X}$ ( <i>sd</i> )	Spread		
		1-3	4	5
Usefulness	4.85 (0.38)	-	2	11

Although participants did not make much use of the help system during the evaluations, participants thought that the provision of the audio help system would support them while working independently, and would be particularly important if no training was given with the software (P7). The tutorial nature of the first part of the help system is likely to be very useful for complete novices since it guides users through the basic commands, working up to the more advanced commands. All participants liked the fact that the help system was in the DAISY format, and they could use the same commands as normal DAISY books, and some participants particularly appreciated the additional visual help so that sighted people could learn about the software too (P12).

**Design Proposals:** Several of the more experienced participants suggested that the help system could be made context-sensitive and include a search feature to make it more useful (P12, P13). It might also be useful (especially for commands on the numpad) to include a 'key-identifier' so that in this mode each key output its command and function.

### 8.5.12 New Feature Proposed: User Customisation

For many of the proposed solutions presented in this chapter participants had different preferences and requirements, which indicates that users should be able to configure the software to suit their individual preferences. For example, the use of non-speech sounds or verbal messages should be optional, and the types of information presented could also be optional (P1, P7, P10, P11, P13), for example, heading levels, and sub-heading indication. Users might wish to annotate their books, just as Windows 95 Help allows topic annotation, and a 'Note' feature could be implemented in a similar method to bookmarks. The issue of different readers sharing books was mentioned several times by participants (P7, P13) with particular reference to saving bookmarks and the last reading

position. This situation might arise in school or library settings in particular. In order that each reader might be able to save their own settings (for example, volume, speed), bookmarks and reading position, a simple log-on procedure could be introduced.

## ***8.6 Scope and Limitations***

These evaluations were designed to test the usability of the DAISY Playback Software, and the level of detailed information elicited by the tasks and usability questionnaire has allowed many aspects of the software to be assessed, and detailed improvements to be proposed. In addition, since several usability problems had been identified before the evaluations, once participants had identified a particular problem, they were able to consider solutions proposed to them by the researcher. Although this was considered an advantage; in that potential design solutions were considered in the same evaluation, thus saving time; it could also be considered a disadvantage - in that these participants may have been led to make specific comments, or certain conclusions because they were prompted to consider certain issues. However, on balance it seems that this was a worth-while facet of the evaluations; and as a consequence some of these potential solutions could be implemented soon after these initial evaluations and assessed in a second user-evaluation for comparison, where perhaps participants should not be offered problems and solutions for consideration.

It is possible that participants required longer and more independent use of the software in order to determine the priority of certain design improvements; but given that these evaluations assessed each command so thoroughly, it is likely that if small problems are revealed and eliminated at this early stage of design of a prototype, the software will be more usable and consistent at a later stage.

These usability evaluations involved a larger-than average number of participants with a range of backgrounds and experience. It became clear that the researcher had identified several of the most severe usability problems before the evaluations, and the participants themselves reinforced these, and highlighted others.

Although the evaluations were conducted and analysed by only the researcher, which may have led to some interpretation bias, the researcher attempted to maintain objectivity by using standard wording, by leaving participants to identify problems before they were highlighted by the researcher, and by recording the participant's comments and

performance in detailed notes. Therefore, overall these results are considered to be highly valid and reliable, and the design solutions proposed in this chapter are likely to make the software significantly more usable.

## **8.7 Conclusions and Future Directions**

These evaluations have shown that generally the DAISY Playback Software has some very helpful features, is fairly easy to use, and supports a range of users working with a variety of books for different tasks. The 13 blind participants had a range of backgrounds, from young students with little experience of computers or talking books, to retired people very experienced with both computers and talking books. It was encouraging to see that so many participants were able to start using the software so quickly and enthusiastically after only a short time, and all participants were comfortable using the software after two hours of experience. All participants thought that the software would revolutionise access to information for them, and were looking forward to using the software again for study, work and leisure reading.

However, the types of usability problems identified before the evaluations and those rated as severe by participants, warrant fairly urgent re-design of several aspects of the software, and small improvements in other areas. The most severe problems relate to the methods of navigating through headings and groups, and the presentation of information about the structure of headings in a book. In order to provide auditory users with the same advantages offered to sighted users by the visual display, proposed alternative or complementary solutions include: the addition of non-speech sounds to provide information about: the level of headings; the existence of sub-headings and dead-ends; the restriction of navigational and reading commands to within the current section; and more explicit tuition given in the documentation. The implementation of a single solution might improve usability significantly, but a combination of these might prove more supportive for a wider range of users.

In addition, although a range of supportive orientation and navigation commands are provided together with a variety of support features such as bookmarking and searching, the remaining usability problems relate to how these specific commands work, the type of information they provide, and how books are coded. Several commands need slight

refinements in terms of their functionality and feedback to make them more usable, more useful and more consistent, and the implementation of several additional commands would provide further support and finer levels of navigation and control.

The following sections provides a summary of the main areas requiring further development discussed in the previous section, together with new ideas developed after the evaluations. Further usability evaluations would determine whether these proposals work together, and whether the overall consistency of design can be maintained.

### **8.7.1 General Issues**

The provision of two methods for executing commands should remain, although certain commands should be re-implemented to make them consistent and more memorable, specifically: their shortcuts, their name, and their associated system messages.

Feedback is required while the book is being searched, and a non-speech 'please-wait' sound would be appropriate such as a soft "*bip bip .... bip bip*". While reading or navigating through headings, the level of all headings and the location of bookmark should be indicated, using non-speech sounds, preferably earcons. Dead-ends should be indicated using a non-speech sound such as "*donk*". Care should be taken that any non-speech sounds used are of a suitable pitch and timbre, and are sufficiently distinct from each other to be memorable and distinguishable, even if the sounds are very short.

Access to the full text of the book is required: for full text searching; for reading at the word and character levels; and for printing or saving parts for reference. Presentation in synthetic speech is likely to be acceptable, and a method of switching between the text and the recording will be required. Consider distribution of a braille table of contents of each book illustrating the nesting of all the structured headings for quick reference.

### **8.7.2 Reading**

The 'Play/Stop' command requires feedback to confirm the current reading mode using a non-speech sound, for example, a high double and a single low tone. The 'Stop'

command must halt the output immediately, and the 'Next/Previous Group' commands must output the whole group, not just the first phrase.

Consider restricting reading commands to within the current section, such that the heading navigation commands must be used to jump to the next section; although this might be unnecessary if non-speech sounds indicate the heading level.

Provide both word and character reading modes, implemented in a consistent manner with other commands, and presented with synthetic speech output; and a new 'Repeat' command is required, particularly when navigating through headings.

### **8.7.3 Heading Navigation**

The documentation should make the heading navigation concept explicit, to distinguish it from hypertext navigation, however, the level of a heading and the existence of sub-sections should be indicated using non-speech sounds. A chord of a different timbre should be used to indicate each level with any sub-sections, and a single note in the same timbre if there are no sub-sections. Alternatively, sub-sections could be indicated by an auditory ellipsis played after the heading "*bip bip*", and if desired, the number of notes in the ellipsis could indicate the number of sub-sections contained in the section.

Navigation commands should be restricted so they only work in their intended manner; such that 'Level Up/Down' only go to a higher or lower level, they never jump to a section at the same level; and 'Next/Previous Section' only move within their current level, and never jump to a higher or lower level.

The 'Jump Back/Forwards 15 Sections' should be replaced with jumps in percentages through the book using the number keys: for example, 1 jumps to the start, 5 to the middle, and 0 to the end. New overview commands should be investigated, which present a summary of the global structure of headings in the book and the local structure of the current main section. These overviews could be written by the producer, or generated automatically by the software, but future user trials will determine what information is most useful to users.

#### 8.7.4 Orientation

A new procedure for closing the book could be considered, such that users can choose to close the book saving or not saving the last reading position. This may not be necessary if a new command is provided to jump to the start of the book. A new 'Goto Start of Book' command should be provided, either in the manner described above for navigating through the book in percentages, or with a separate command (such as using the shortcut <Ctrl+Home>).

The method of assigning section numbers to headings in the 'Current Position' command should be redesigned so the number is appropriate to the section it refers to: for example, starting at number 1 for the first main chapter heading, and numbering introductory sections as Intro 1, Intro 1.1, and so on. The information presented by the 'Current Position' command could be amended to include the total number of sections at the current level, and the command name itself changed to be more memorable (for example, to 'Section Number'). The 'Section Information' command could be renamed to make it more memorable, for example, to 'Heading Information'.

The 'Goto Page' command could be adapted to allow jumping to assigned section numbers, for example, using <G> then <S 1.2> to jump to the assigned section 1.2, or <P 30> to jump to page 30. The information presented by the 'Page Information' command could be amended to include the total number of pages in the book.

A new 'Time Information' command could be considered based on the current output speed, which calculated and output the time passed, time remaining and total time, together with a 'Where Am I?' command presenting the information from the visual status bar.

#### 8.7.5 Bookmarking

Implement a more consistent method of setting and jumping to bookmarks using a more interactive procedure similar to other commands. When bookmarks are set, the phrase should be output to confirm the location, and when reading or navigating through material, the location and number of any set bookmarks should be indicated.

Consider providing a command to output the 'Highest Bookmark Number Set', or a self-assigning bookmark command which automatically numbers each new bookmark sequentially. Consider amending the 'Goto Page' command to jump to numbered bookmarks, using <G> then <B 3> for example. Provide methods of managing bookmarks: for example being able to skip from bookmark-to-bookmark using <B> and the <up/down arrows>; and naming bookmarks.

### **8.7.6 Searching**

Provide full text searches, or at least a searchable index of keywords. Improve the command names and system messages so that they match and are consistent across commands. Provide greater feedback when editing the search string. Explain the relationship of the shortcuts for 'Search Next/Previous' to the shortcut for the 'Search' command so the shortcut commands are memorable, or change the implementation to use <F> with the <up/down arrows> for 'Find Previous/Next'. Consider providing additional search capabilities such as pattern matching and wildcards.

### **8.7.7 Voice Control**

The 'Mute' command should be implemented with the shortcut <Ctrl>. Re-implement the speed commands using fewer keys, such as <S> with the <up/down arrows> to increase and decrease the speed, and provide system feedback presenting the new speed. The higher reading rates should increase the speed of the output whilst maintaining the ratio of the original pauses. The slower speeds are acceptable simply elongating the pauses. Provide a new 'Volume' and possibly a 'Pitch' command, using the same type of shortcuts: <V> and <P> with the <up/down arrows>.

### **8.7.8 System Messages**

All system messages should be made consistent with the command name they refer to. They must be recorded spoken quickly and clearly and be spoken by a nationally localised speaker with appropriate intonation.

### **8.7.9 Help**

Consider implementing additional context-sensitive help, and a help mode where each key identifies itself and its function (particularly for keys on the numpad).

### **8.7.10 User Customisation**

If books are likely to be shared a log-on procedure should be devised so that an individual user's bookmarks, last reading position, and voice settings (volume, rate etc) can be saved. Users should be able to choose which sounds are used in the software (for example, the specific .WAV files), and which aspects of the structure they wish to have indicated (that is, heading level, existence of sub-sections, dead-ends, and so on). Consider a 'Note' command to allow users to make personal annotations. This could be implemented in the same way as bookmarks; they could be numbered, jumped to, or the user could jump note-to-note. Users are also likely to require features supporting saving and printing parts of the book for reference.

### **8.7.11 Book Recording**

Books must be recorded at a constant volume, otherwise it makes it very difficult for certain sections or headings to be heard. The narrators of some books (for example, in *The Facts About Alcohol, Aggression and Adolescence*) spelled out proper nouns and names in the body of the text (as is common in the recording of traditional talking books), and this useful practice compensates in part for the current lack of word and character navigation. Certain books (for example, in "Five Lectures on Psychoanalysis") contained many footnotes, and the narrator's approach of reading them in the body of the material as they were reached with a slight change of voice, was well-liked.

### **8.7.12 Book Structural Information**

Printed page numbers are required in all books. The recorded Table of Contents must include all page numbers, and all sub-sections, and each heading in the book should also be recorded with its page number so that users can locate specific sections quickly using their page number.

Sections should be coded as readers might expect, and topics should be separated by the producer into logical groups or sections so that they are easy to find: for example, breaking lists of items into phrases; and coding the same type of information at the same level rather than at different levels. Producers might consider adding section headings and/or numbers (such as 'Ingredients') to replace the visual cueing given by print formatting, and overview sections if the author has not included them, but should aim to remain true to the printed original.

An index of the book might help users to quickly locate key terms in the text (or at least the page on which the term appears), and the index could be navigated as if navigating through headings.

### ***8.8 Coming Next...***

The following chapter draws together the findings from the three usability evaluations of DAHNI-1, DAHNI-2, and the DAISY Playback Software, presenting a series of recommendations for a design and evaluation methodology, and for the design of non-visual interfaces. Relationships of this research with the most recent developments in non-visual information systems are described, and areas for further investigation are identified.

## **9 Recommendations for the Design and Evaluation of Non-Visual Interfaces for Blind Users**

## **9.1 Chapter Overview**

This chapter draws together the main findings and recommendations which have been made about the design and evaluation of non-visual information systems based on this research, and provides indications of where future research is likely to be required. The chapter covers firstly, the design and evaluation methodology; and secondly, issues of non-visual interface design: general interface design; input and output methods; reading; output control; orientation and navigation; finding and selecting links; and support and personalisation features.

## **9.2 Introduction**

This chapter draws together the common findings from the design of the three prototypes presented in this thesis, presenting them as a set of recommendations made by this research. Specific sections of the thesis are referenced to enable the reader to refer to examples of relevant evidence or discussions of each topic. The conclusions in each evaluation chapter present aspects of these in detail, and the interested reader should therefore also read individual chapter conclusions for interface-specific recommendations.

Nearing the end of her PhD the researcher witnessed a sudden proliferation of non-visual interfaces for browsing structured information, such as personal digital assistants, web browsers, and digital talking book browsers, some stand-alone and some based on mainstream browsers such as Internet Explorer. The available documentation indicates that many of these systems provide features which are similar to those recommended here. Therefore, throughout this chapter examples will be given of where new systems or prototypes provide similar or novel features addressing the issues raised. Many of these recommendations are proposals for additional features which need to be designed and evaluated for their usability and effectiveness, and so this chapter can also be considered as providing an overview of areas requiring further investigation.

### 9.3 Iterative Design and Evaluation Recommendations

Based on the researcher's experience with three prototype non-visual interfaces, it is possible to present a generic design and evaluation methodology which allows the detailed, systematic creation and evaluation of non-visual interfaces. The components of this methodology are described here.

To ensure that a product is designed to suit the needs of the intended users, the first stage of any product development should be to gather user requirements, and initial design specifications drawn up on the basis of the findings (see 2.2.7.4, 4.4.1). During development, design guidelines should be followed, and members of the design team should conduct informal usability inspection tests as each component of the prototype develops (see 3.3, 3.4, 4.4.2, 6.3). This can avoid prototypes containing obvious and severe problems when users get to test them (see 8.5.4). Methods for assessing the design might include interface guidelines, scenarios, jogthroughs, and heuristic evaluation, perhaps with the addition of new web-based heuristic guidelines (Instone 1997, Jones & Hewitt 1997).

In order to capture the majority of both severe and minor usability problems user-evaluations should be conducted with mock-ups, or prototypes, with at least five participants (although up to 12 may be required for near-final prototypes), representative of the end-user group - in terms of age, ability, level of technology experience and so on (see 3.5, 4.2.2, 4.3, 5.3, 5.4, 5.5.2, 7.3, 7.4, 8.4, 8.5). All sessions should be video-taped to provide accurate and lasting evidence of the evaluation (see 3.11), which can be later reviewed for confirmation purposes, and can also be shown to designers as evidence that users really do have problems which are caused by their interface (programmers sometimes need *concrete evidence* of problems in addition to usability problem reports, as the researcher, and others such as Desurvire 1994, have found). If practicable, two researchers should alternate running the evaluation sessions and be available to code the data, to ensure consistency and to reduce any bias, which might be caused particularly by the interpretation of a single researcher (see 3.13, 5.5.2). If this is not possible, steps must be taken to remove as many biases as possible - such as using a prepared script, non-leading questions and prompts, balanced tasks, presenting a variety of design solutions to participants, and making detailed accurate records of the evaluation (see Chapter 3, and 5.5.2).

To ensure that participants are familiar with the prototype, the session should start with briefing, training and practice, followed by the participant being observed completing a range of tasks of different levels of direction depending on the state of the prototype (see 3.7, 3.8, 3.9, 4.2.2, 5.3.6, 5.5.2, 7.3.6, 8.4.6). Explicit and directive tasks can be used to guide participants to the features of the prototype under investigation (see 3.9.2.1, 5.3.4.3); non-explicit and directive guided tasks leave participants to choose the methods they use (see 3.9.2.2, 7.2.2.3, 7.3.4.4); and free tasks require participants to be completely independent (see 3.9.2.3, 7.2.2.3, 7.3.4.4, 8.4.4.3). A back-up set of generic tasks might be useful to guide participants to complete certain tasks so they use commands which they might not have used by themselves (see 3.9.2.4, 8.4.4.3). If appropriate, separate investigations into specific aspects of the prototype can also be conducted (see 3.9.2.6, 7.2.2.4, 7.3.4.6). Informal think-aloud during tasks is encouraged (interaction with the researcher is permitted) to allow ideas to be discussed in context, with the researcher noting the methods used, problems encountered, comments made by the participant, and any other information to help to identify and explain usability problems (see 3.9.3, 4.2.2, 5.3.5, 5.5.2, 7.3.5, 8.4.5).

Participants should then be interviewed using a detailed questionnaire, consisting of open and closed questions and rating scales to measure the extent of a participants' opinion of the usability and usefulness of each aspect of the system. If design proposals already exist for future versions of the prototype, participants could be asked to consider these at the same time as the current implementation to guide the future designs (see 3.10, 5.3.4.4, 7.3.4.5, 8.4.4.4). If comparisons between prototypes is important, ensure that the same usability questions are asked for each (see 7.4.1.1).

Finally, a usability problem report should be developed detailing the usability of each feature of the software, indicating the problems, their severity, any solutions, and the implications of each solution to the overall design (this would be for example, a summary of sections 5.4 and 6.4; 7.4 and 7.6; 8.5 and 8.7). Formal notations such as Design Rationale (Moran & Carroll 1994) might help to avoid the dangers of iterative design and evaluation leading to a particular design without exploring other avenues (Lindgaard 1994), and Jeffries (1994) summarises aspects of good report writing to help designers understand and use the evaluation results and provides the following recommendations:

- Describe the problem and the solution separately
- Provide justifications for the problem and the solution
- Include an assessment of the severity of the problem (also Nielsen 1992, Virzi 1992)
- Explicitly consider trade-offs
- Evaluate carefully any solution that requires new functionality to be added
- Be aware of biases that the evaluator brings to the evaluation
- Try to look at each problem from multiple levels of abstraction
- Examine the problem reports as a collection, replacing local optimizations and trade-offs with general solutions that fit the application as a whole

After one iteration of design and evaluation has been conducted, the process of re-design and further evaluation should commence (see 3.3, 4.3 and 4.4, Chapters 5 and 6, 8.7). When successive versions of the same prototype need to be compared, several measures can be examined either in isolation or in combination, for example: usability ratings; the number and types of usability problems identified; the types of mistakes and confusions observed; task times; and workload ratings (as used by Stevens & Edwards 1996), among others. When comparing existing products against each other, the same comparisons could be made, but could also be coupled with methods designed for assessing the value or accessibility of commercially-available CD-ROMs and other electronic books (for example, Rowley & Slack 1997, Catenazzi, Adeo, Díaz & Sommaruga 1997, Rothberg & Wlodowski 1998).

Once the prototype is nearing completion, or released onto the market, investigations can begin into the effectiveness and efficiency of the interface for a particular purpose: for example, for supporting learning; or for browsing or fact-finding in different kinds of materials by a range of users.

## **9.4 Non-Visual Interface Design Recommendations**

### **9.4.1 General Interface Design**

The interface should be consistent in all respects: commands should be implemented in similar ways and with similar feedback (see 4.3.1.1, 5.4.2.2, 5.4.3, 5.4.4, 7.4.4, 7.4.8.2, 8.5.2.6, 8.5.3, 8.5.4, 8.5.6.3, 8.5.7.3, 8.5.8.2, 8.5.9.2); system prompts should be succinct and appropriate in tone and structure and consistent for every message (see 4.3.1.3, 8.5.7.1, 8.5.8.1, 8.5.10); and should be presented in a digitised voice different from the voice used to present the content of the system (see 4.3.1.2, 5.4.3.4, 7.4.5, 8.5.10). Where different input devices are used, the method of interaction with the system should be similar for each device, while maximising the affordances provided by each one (see 4.3.1.1, 5.4.3.2, 5.4.4, 7.4.4, 8.5.1.3). Care should be taken that the interface does not interfere with the users' model of the content - for example a spatial layout of commands may be difficult to hold in mind while working with a large structured information space such as the WWW (see 7.4.3.4, 8.5.4.1). Feedback, for example using non-speech sounds to present structural information or to give command feedback, must be implemented consistently so that users can be clear about the relationship between an event and a sound (see 7.4.8).

The design should ensure that the system can be used by a range of users in the target group, particularly so that novices can quickly and easily start to work, but also so that more experienced users requiring faster interactions with more advanced functionality are supported (see 5.4.2, 5.4.3.1, 5.4.4, 7.4.1, 7.4.3, 7.4.4, 7.4.5, 8.5.1). For example, Home Page Reader (Asakawa & Itoh 1998) is an excellent example of a very sophisticated non-visual WWW browser, with over 100 commands all available on the numpad, but novices need only eight commands to read and navigate. Browser and authoring issues are now being investigated on a global scale - see the home pages of the World Wide Web Consortium, the Web Accessibility Initiative, and the TRACE Centre.

### **9.4.2 Input Devices**

A range of input devices (or different methods using one device) should be provided so that users are able to choose different methods of interaction depending on their current situation and task (see 5.4.4, 7.4.3, 7.4.4, 8.5.1.3). The keyboard and numpad are

obvious choices, but the use of a touchtablet, a joystick or even a hand-held device which mimics the spatial movement of a joystick are also useful and interesting possibilities. Interactions should be made consistent so that users can easily transfer their knowledge from one device to another, and from one command to another (see 4.3.1.1, 5.4.2, 5.4.3, 5.4.4, 7.4.4, 7.4.5, 8.5.1.3, 8.5.2.4, 8.5.4, 8.5.6.5). In terms of keyboard implementation in particular, early on designers will have to choose the implementations of commands as having either (a) a single shortcut for each command, or (b) a modal interface where a single command cycles through different options (see 4.3.1.4, 5.4.5.4, 7.4.4.1, 8.5.2.3, 8.5.2.4, 8.5.6.5, 8.5.7.3, 8.5.8.2, 8.5.9.2). Although shortcuts may reduce the time to execute a specific command, and may generally be easier to learn (for example, Norman 1988 recommends one command per function), many shortcuts might be hard for some users to learn, thus reducing the effectiveness of providing so many commands. In this case, a modal interface might be simpler, although perhaps slightly more time-consuming to use. Evaluations will determine which method is best suited to a specific system.

Despite the popularity of voice-recognition systems for people who cannot easily use the keyboard (Hewitt 1998, Davis 1998), there has been little take-up in the use of speech input to non-visual information systems for blind people. Part of this may be a reluctance to work with a completely auditory interface (such as provided for sighted users by Arons 1991, and Yankelovich, Levow & Marx 1995), but it has great potential for completely hands-free and eyes-free interaction, and has been taken up by two prototype WWW browsers: AVANTI (see the AVANTI web site), based on DAHNI-2, which will use speech, joystick, touchtablet, and keyboard for input; and AUDIS (Kopocek 1998) to be controlled by both speech and keyboard input.

### **9.4.3 Output Methods**

English blind technology users are familiar with the American accent of the synthetic speech used in many devices, but would prefer a British English accent (see 5.4.5.5, 7.4.6.1). Where possible, both speech and refreshable braille output could be provided, to allow users to work in the ways best suited to their current task. For example, if the auditory interface cannot provide character or word navigation or spelling, a braille display would provide this required level of access (see 8.5.1.4, 8.5.2.4). Braille formatting symbols can indicate links and structure in the text, and routing buttons would allow direct

manipulation (found useful in GUI applications: Weber, Petrie & Morley 1994, Petrie, Morley & Weber 1995), such as for selecting the desired link.

Non-speech sounds should be included in non-visual interfaces to reduce the verbosity of output, whilst providing information about the structure of the content and giving feedback about the results of certain commands; for example, the level of a heading, the existence of sub-sections, and to help users to distinguish between navigational commands which might be easily confused (see 5.4.2.2, 5.4.5.1, 7.4.3.2, 7.4.5, 7.4.7.1, 7.4.8, 8.5.2.1, 8.5.2.2, 8.5.2.6, 8.5.4, 8.5.5.2). However, sounds should not be added to *every* command and interface element without evidence that there is a need for additional information to be provided (see 7.4.8.5). Although there is likely to be a limit of around 10 sounds which are easily learned and remembered (Patterson 1982), users will require some level of training (see also Brewster 1997) to make best use of the information they provide, and this includes training whether using auditory icons or earcons in the interface (see 7.4.8). Although auditory icons are limited in their applicability (since not every command/event has an obvious naturalistic sound), they can help to increase the motivation of some users - such as visually impaired students (see 5.4.3.3, 7.4.8.1). However, earcons, rather than auditory icons, are likely to be most suitable for providing structural information about the level of headings - see also Brewster 1997, and whether any sub-sections exist (see 7.4.8.5, 8.5.5.2), and the presence of links and so on, but any sounds chosen should form a coherent set within the interface, be consistently implemented so there is a clear association between an event and a sound, and be changed easily by the user (see 7.4.8, 8.5.5.2, 8.5.1.2). Guidelines such as those by Brewster, Wright & Edwards (1994) can help designers to develop musical earcons.

Sounds should be carefully selected and tested to ensure that they are easily identifiable and easily remembered (see 6.4.2, 7.4.8.5), (see Mynatt 1994, and Petrie & Morley 1998), and this may be particularly important when choosing between auditory icons and earcons, since although auditory icons may be more easily mapped to their functions, users often prefer earcons in their interfaces (Sikora & Roberts 1997). However, there is also a need to explore the effectiveness of sounds in the context of real use as well as in an isolated testing environment, since users may easily confuse sounds out of context even after using them effectively in the system (see 7.4.8.5).

Sounds should always be chosen to be appropriate for the event they refer to (see 6.4.2), for example, in terms of the importance of the event - a bold sound indicates a big important event or element (for example, arriving at a main heading), whereas a short gentle sound indicates something less critical (such as a dead-end). Frameworks such as AHA - Auditory HTML Access (James 1998) - can help designers to choose the number and type of sounds used to present structured documents and which elements should be indicated by sound or voice.

The presentation of the content material is clearly system-specific, but where possible, the use of a range of media should be used to create interest and variety - and this might take as much effort as goes into designing multimedia material for sighted users. For example, the use of digitised audio, sound effects, music clips, pictures with descriptions and tactile pictures can enhance a blind person's reading experience, and can provide access to material they might otherwise miss (see 5.4.5.6, 5.4.5.7, 5.4.5.8, 7.4.6.2, 7.4.6.3). In addition, DAHNI-1 and DAHNI-2 participants enjoyed finding these nodes, which increased their motivation to use the systems, and participants were able to recall fairly high amounts of information from these types of nodes (see 7.4.6.4), indicating that for educational purposes they would be beneficial. Where the material is the same as printed material, attempt to provide the same information as available in the print version, and consider the addition of signpost headings or summaries if authors do not provide them (see 8.5.5.3).

New prototypes promising to provide multimodal systems include: (1) AUDIS (Kopocek 1998) to be controlled by both speech and keyboard input, using synthetic speech, digitised speech for system messages, non-speech sounds to provide feedback and overviews, and a change in voice to indicate links and other text formatting; (2) AVANTI (see the AVANTI web site), which is based on DAHNI-2, and will provide speech, keyboard, joystick and touchtablet input, together with synthetic speech, braille and digitised audio output; (3) BrailleSurf (Hadjadj, Bouzidi & Burger 1998) which will provide a range of keyboards for input, and synthetic speech and braille output, with non-speech sounds for feedback; and (4) Smart-Net (Truillet, Vigouroux & Oriola 1998), which intends to provide synthetic speech and braille output and non-speech sounds to provide command confirmation.

#### 9.4.4 Reading

It is clear that in general, users are comfortable listening to chunks of information of about the size of a paragraph, although reading at much finer and larger levels of information are also required (see 4.3.1.4, 5.4.5.4, 7.4.3.2, 8.5.2). As outlined above, designers must choose between: (a) a modal implementation, where the user specifies the level at which they wish to read, and then uses a set of commands to hear the next 'unit' at that reading level, (such as now used in WebAdapter, Hermsdorf 1998, and Victor, see the Visuaide web site); or (b) separate commands for each reading unit, which has separate shortcuts for read character, word, sentence, paragraph, whole node and so on. Only user-feedback from evaluations will reveal which method is best for different systems, different types of material, and different users.

Reading commands should be implemented in the same way as FF/RW on a CD-player, such that in the middle of a 'unit' of information, the execution of the Previous Unit command jumps to the start of the current unit, and executing Previous Unit again jumps to the start of the previous unit (see 7.4.7.1, 8.5.2.3, 8.5.2.6). Commands such as Play and Stop should be differentiated using non-speech sounds so that users know which mode they are in (see 8.5.2.2) - as now used in Victor, see the Visuaide web site.

Where the coding of material does not support reading at fine levels (character and word), if refreshable braille output cannot be provided, then perhaps the use of SMIL (Synchronised Multimedia Integration Language) might be a solution (De Vendra 1998). This allows the synchronisation of structured audio with structured electronic text, which can be presented in synthetic speech - thus providing character and word access. A similar type of approach (but based on Real Audio) is being used in AudioPlus (see the Recording for the Blind and Dyslexic web site). Publishers' concerns about providing electronic text versions of books for this purpose are being addressed in the SEDODEL Project (see Engelen, Evenepoel & Wesley 1998) which include methods of encryption to protect copyright whilst providing blind users with access to the level of information they require.

Skim-reading should always be possible, for example using repeated executions of the normal reading commands in quick succession (see 5.4.2.1, 7.4.3.2, 7.4.7.1, 8.5.2.3), but other methods such as hearing the output speeded up while skimming might help users to locate information quickly (as provided by Home Page Reader, Asakawa & Itoh 1998,

and Victor, from Visuaide). Another method might be to present only short chunks of information after a heading (Zajicek, Powell, Reeves & Griffiths 1998), or to provide a series of these chunks as 'highlights' to give a flavour of the material (Roy & Schmandt 1996).

#### **9.4.5 Output Control**

Users must be able to control the output in terms of volume, rate, pitch, voice and so on, all from within the interface (see 5.4.5.5, 7.4.6.1, 8.5.9) - as now available in Home Page Reader (see Asakawa & Itoh 1998). The DAISY approach of increasing the pause length between phrases for slow speeds (rather than slowing the actual speech) seems very effective, particularly when listening to complex material. However, faster rates should *not* be produced by reducing the pause length (see 8.5.9.2), since this gap is required for perceptual processing of the information (Arons 1993). Instead, consider methods of time compression (Arons 1992). A Repeat command must be available which repeats the last output, whether a system message or a heading, a paragraph and so on (see 5.4.2.2, 7.4.7.1, 8.5.2.7). The Stop and Pause commands should be exceptionally easy to locate and execute, so that users are able to halt the output quickly without having to search for a difficult keyboard combination (see 5.4.2.1, 7.4.4.1, 7.4.6.1, 8.5.9.1).

#### **9.4.6 Orientation and Navigation**

Users must be given a way to jump both to the start and end of the current node or section, and to the start and end of the overall content (for example, to the home node, or to the start of the book), and the use of Back and Forward (or Undo/Redo) are valuable for re-tracing one's steps through structured material (see 5.4.2.1, 5.4.2.2, 7.4.7, 8.5.2.3, 8.5.2.5, 8.5.2.6, 8.5.3.1, 8.5.3.2, 8.5.6.6, 8.5.6.8). When reading or navigating all structural elements should be indicated to the user, to include headings, dead-ends, links, bookmarks, and so on (see 5.4.2.2, 5.4.3.3, 5.4.5.1, 5.4.5.3, 7.4.7.1, 7.4.7.5, 7.4.8.1, 7.4.8.4, 8.5.4.2, 8.5.5.2, 8.5.7.1). In addition, commands should be implemented such that they only work as expected, so that users can navigate appropriately and find dead-ends - in this way they can build up an accurate model of the structure of the information (see 5.4.2.2, 7.4.7.1, 8.5.4, 8.5.2.6, 8.5.5). Headings of different levels might be indicated most effectively by a non-speech sound of a different timbre; headings containing

sub-sections indicated by a chord, and a section without sub-sections by a single note (see 5.4.2.2, 7.4.8, 8.5.4, 8.5.5). Headings should be carefully written since they are used as landmarks and signposts through the material, and new headings should be added to material if the original author did not provide appropriate headings (see 7.4.3.2, 7.4.7.1, 7.4.7.4, 7.4.7.5, 8.5.4, 8.5.5). Where appropriate, page navigation and information should also be provided (see 8.5.6.4, 8.5.6.5, 8.5.6.6).

The decision about the implementation of navigation commands is similar to that of reading commands: should the user have to be in a particular mode in order to navigate through different parts of a document? For example, in pwWebSpeak (see De Witt & Hakkinen 1998), three modes are provided: (1) Page Elements, (2) List of Links, (3) Data Entry Fields. Similarly, in BrailleSurf (Hadjadj, Bouzidi & Burger 1998) three modes are provided: (1) Whole Document, (2) Abstract - only headings and links in page are available, (3) Link mode - only links are available. The alternative method is to provide users with separate commands for navigating at different levels, as provided by Home Page Reader (Asakawa & Itoh 1998). As in the case of finding and selecting links (see next section), the modal alternative seems to add an unnecessary layer of complication - it may be more effective for users to navigate through the material at any level without having to consider which mode they are in.

Commands should be provided to support both local orientation (a summary of the user's location within the current node or section), and global orientation (information about their current position relative to their history list for example) - (see 5.4.2.2, 7.4.7, 8.5.4.2, 8.5.5.3, 8.5.6). Various methods are being explored in other research about what information should be contained in these overviews, such as lists of headings, links, keywords or trigrams, bookmarks, an abridged version of the page, a summary of the structure of a page, or presenting only chunks of text under headings (Zajicek, Powell & Reeves 1998, Zajicek, Powell, Reeves & Griffiths 1998). WebAdapter (Hermsdorf 1998) provides a list of all links and a list of all headings to provide an overview and easy navigation around a page, and pwWebSpeak (De Witt & Hakkinen 1998) provides a page summary consisting of the number of links, headers, images, imagemaps, and forms on the current page.

It is interesting to speculate how a *non-verbal* overview - an aural overview - might be presented of the user's current location, and of the scope of information in the system.

Various methods hold potential, such as those used for presenting an overview of algebra (Stevens, Edwards & Harling 1997), of a CAD application (Mereu & Kazman 1996), for non-visual exploration of auditory datasets (Fernström & Bannon 1997, Kobayashi & Schmandt 1997), or as auditory landmarks in large environments (Gaver & Smith 1990).

#### **9.4.7 Finding and Selecting Links**

While reading, links should be indicated with a non-speech sound and the link itself spoken in a different voice. This alerts the user to the start of a link, and makes the exact wording of a link explicit - important to allow users to make informed choices about which links to follow (see 4.3.3.1, 5.4.5.1, 7.4.8.4). The use of two methods of indicating a link also helps identify each link when several are listed next to each other - not easily possible using any other method of link identification - and takes advantage of auditory processing abilities (Handel 1989, Bregman 1990). Links, like headings, should be carefully worded during authoring to ensure they convey the nature of the destination node (see 5.4.5.3, 7.4.7.1). The non-speech sound indicating the link could convey additional information, such as whether the link goes to a text, audio, or picture node (see 4.3.3.1, 5.4.5.3), the size of the destination node, and whether it has been followed before (Albers 1996). A simple sound is used to indicate links in the Sigtuna browser, based on the DAISY Playback Software (see Kerscher & Hansson 1998, and the Productivity Works web site), and in the Talking Reader System (Tisne, Oriola, Vigouroux, & Truillet 1998), whereas a change in voice alone is used to indicate links in Home Page Reader (Asakawa & Itoh 1998), and in AUDIS (Kopocek 1998).

Evaluations of DAHNI-1 and DAHNI-2 have shown that the concept of the 'current link' allows users to select links quickly (see 4.3.3.2, 5.4.5.2, 7.4.3.2, 7.4.3.4, 7.4.7.1), and should therefore be considered as a method of allowing link selection in other auditory interfaces. In addition, it is likely that this current link approach would support effective link selection even when there are multiple links in one unit, since one would remain active until the next link is heard. This approach has been taken for WebAdapter (Hermsdorf 1998), and Home Page Reader (Asakawa & Itoh 1998). A command should also be available which makes it possible to confirm the current link, and the sentence in which it occurs (see 5.5.1.2, 6.4.4.1, 7.4.7.4).

In terms of navigating quickly from one link to another, presented lists of links are not considered appropriate because of their serial nature. Although not formally tested, direct navigation through the links in a node is likely to be an effective method of finding and selecting links in a node, particularly since users would be able to navigate to a particular link quickly, and then read information around that link very easily. This mode-less method of navigating through links should be compared with other methods, such as the 'Links List' mode, as used in pwWebSpeak (Hakkinen & De Witt 1996 and De Witt & Hakkinen 1998), and in BrailleSurf (Hadjadj, Bouzidi & Burger 1998). An interesting issue yet to be addressed is the presentation of links in digitised audio material, which cannot be presented as recommended above. Methods of presenting time-sensitive links in web-TV are being explored by Braun & Dörner (1998) which might be suitable for digital audio links.

#### **9.4.8 Support and Personalisation Features**

The inclusion of support and personalisation features can help users to work effectively with a system. For example, an on-line tutorial and general help system in the same format as the content allows users to learn about the system and get help on the system without relying on others or having to try to access print documentation (see 7.4.10, 8.5.11, 8.5.6.1, 8.5.7, 8.5.12). The provision of some sort of context-specific help feature can be useful to give immediate help (see 7.4.10), and could either give help on the last command executed, or in a key-identifier mode which provides help on each command as it is selected (provided by Victor from Visuaide, and in JAWS for Windows, see the Henter Joyce web site). Features such as bookmarking and annotating while reading may be essential for effective learning and work (Wright 1990, 1991, Leggett, Schnase & Kacmar 1990, Adler, Gujar, Harrison, O'Hara & Sellen 1998), and coupled with searching, copying and saving, and printing, should be provided at some level. Many users would probably be satisfied with simple implementations (such as inserting only a few numbered bookmarks, and being able to skip between them or jump to a specific bookmark), whereas others may require more advanced management facilities to complete sophisticated actions (such as being able to assign names to bookmarks, or complete various kinds of search tasks) (see 8.5.7). Simple annotations are supported by AudioPlus (see the Recording for the Blind and Dyslexic web page), and by BrookesTalk (Zajicek, Powell, Reeves & Griffiths 1998), and most systems support bookmarking (or a favourites list), together with various forms of search, save and print.

Users should be able to configure the system to suit their task and preferences from within the interface (see 5.4.5.1, 5.4.5.3, 7.4.6.1, 7.4.8.3). This might include choosing the sounds, the indicated structuring, the system messages and so on. For this purpose, and when materials are being shared, the system might provide a log-on procedure so that an individual's output control, settings, bookmarks, annotations and so on are all saved.

### ***9.5 Coming Next...***

The final chapter presents a summary of this research and the main conclusions drawn from the work conducted on the three prototype non-visual interfaces for blind users.

**10 Conclusions**

## **10.1 Chapter Overview**

This chapter presents a summary of the research reported in this thesis and the main conclusions which have been drawn, covering: the development of a generic iterative design and evaluation methodology; the design and evaluation of successive versions of a prototype hypermedia non-visual interface, DAHNI-1 and DAHNI-2; and the evaluation of an existing prototype interface to digital talking books, the DAISY Playback Software.

## **10.2 Introduction**

The research presented in this thesis has achieved the aims presented in Chapter 1, and has:

- (1) Successfully developed a generic design and evaluation methodology allowing the identification of usability problems and the development of design solutions;
- (2) Designed an effective non-visual interface to hypermedia material for use with a range of input devices by both novice and more experienced student users for whom it was designed;
- (3) Easily applied the evaluation methodology to prototype non-visual information systems at different stages of development: two successive versions of an interface to hypermedia material, DAHNI-1 and DAHNI-2; and an interface to digital talking books, the DAISY Playback Software.

Since the designs of the prototypes DAHNI-1 and DAHNI-2 are based on user requirements and have been through several rounds of iterative design and evaluation with representative end-users, we can be fairly sure that DAHNI-2 now provides a fairly usable interface, although it is still somewhat limited in functionality. This iterative, user-centered process has, at the very least, led to a prototype which can be used by a range of users with three input devices, even though there may be alternative designs which might be as effective. As Hewett (1986) remarked:

“using iterative evaluation during design does not necessarily guarantee design of a good system but can help avoid designing an unusable one.” (p. 213)

Indeed, many of the usability problems found with the much more advanced prototype, the DAISY Playback Software, could easily have been removed if at least some usability evaluations had been conducted earlier during the design - even if these had been only informal usability inspection methods conducted by designers working with the software non-visually.

It is intended that other designers can benefit from this research not only by taking the conclusions from each chapter as an indication of the successful components of each prototype design, but also by learning from the detailed presentation of the development of the designs, which will alert them to the variety of issues involved in designing non-visual interfaces. This research is likely to be of value to designers of non-visual information systems of all types - whether those which access standard electronic textbooks, hypertext or hypermedia material, digital talking books, digital personal assistants; whether hand-held devices, PC-based, or using a telephone.

Although this thesis has reviewed a number of types of non-visual information system, there are of course many other potential areas where these types of design might be important, for example, in an engineering plant - the use of a mobile auditory interface to instructional information or to a fault-finding database; or for commuters - a hand-held device to allow them to listen to and navigate through structured books or broadcasts. The design of any of these types of non-visual system requires a careful consideration of the type of interface and functionality that they should provide, and how best to present structured information for auditory navigation - and the work presented in this thesis goes some way to providing guidance for such designs.

### ***10.3 Summary of This Research***

The following sections present an overview of the research reported in this thesis, highlighting the major design features and recommendations, firstly from the generic design and evaluation methodology, and secondly, from the three non-visual prototypes, DAHNI-1, DAHNI-2 and the DAISY Playback Software. Interested readers should refer back to the previous chapter (Chapter 9 - Recommendations), and to individual chapter conclusions for a detailed presentation of the design recommendations for each specific interface.

### **10.3.1 Generic Design and Evaluation Methodology**

Although there is a substantial body of literature on evaluation methods for general human-computer interfaces, there is very little evaluation work conducted (or at least reported) on non-visual interfaces for blind users. Therefore there was no existing methodology which was immediately available for formative evaluation of the non-visual prototypes described in this thesis. However, a range of design and evaluation techniques were reviewed, and components from a variety of techniques were selected to develop a generic iterative design and evaluation procedure capable of identifying usability problems and developing solutions for prototype non-visual information systems. The components of the methodology developed in this thesis are described next, followed by an account of what can be learned from this methodology.

#### ***10.3.1.1 Basis of the Methodology***

The design and evaluation methodology developed during this research strongly encourages an iterative process of testing during design development; firstly, by designers using guidelines and informal usability inspection methods to shape their designs; and secondly, through user-testing with at least five representative end-users with a range of experience, completing set tasks in an informal think-aloud setting, followed by a detailed semi-structured interview about the usability of each feature of the prototype, and proposed alternative designs. The *combination* of observed task performance and subjective data from the informal think-aloud tasks and the interview was anticipated to allow the researcher to identify usability problems and to develop design solutions easily.

#### ***10.3.1.2 Assessment of the Methodology***

The developed evaluation methodology proved immensely valuable for eliciting required information about the usability of three prototypes at different stages in their design cycle to enable design solutions to be developed. As expected, the involvement of designers assessing usability prior to user-involvement was beneficial in the case of DAHNI-1 and DAHNI-2, and the consequences of the lack of testing before user-evaluation was clear during the evaluations of the DAISY Playback Software, since it contained many usability problems which were immediately obvious to the researcher and could have been easily removed before users had to experience them.

As anticipated, the use of both observed task performance and a detailed semi-structured interview was essential, since participants' ratings and comments did not always reveal details about specific aspects of the prototype which were only captured by observation of task performance; and conversely, participants' subjective opinions about some aspects of the prototype could only be elicited by prompting during the informal think-aloud session or during the interview. The benefits of using both types of measure are highlighted by the apparently contradictory findings from the evaluations of the DAISY Playback Software - although participants were very positive about the overall features of the software (because it gave them completely new and powerful features for accessing audio books), they were very negative about the usability problems of navigating through headings, which were detrimental to successful task performance. In addition, the separate investigations conducted in DAHNI-2 evaluations allowed aspects of the interface to be explored which would not have been possible using just task observation and the interview.

The use of set tasks for DAHNI-1 and DAHNI-2 helped guide participants towards the functionality under review, and the free tasks used to evaluate DAHNI-2 and the DAISY Playback Software gave participants the freedom to use the software at their own initiative. The generic tasks for use with the free task in the DAISY Playback Software were effective at guiding participants to use specific features if they had not done so by themselves. Such a combination of tasks at different levels of direction is considered valuable when the focus of the evaluations is on the *usability* of the interface elements, rather than on the *learnability* of the interface, when exploratory learning (without training or guidance, as used by Arons 1997), would be useful.

Although task time was measured for DAHNI-2 evaluations, this was not considered very useful or informative, and could be considered an unreliable measure in the informal think-aloud setting. Rather, observations of the methods used, usability problems experienced, and comments from participants were more useful than the time taken to complete a task. When evaluations are being conducted for the purpose of improving the low-level design of an interface (such as the implementation of each command or each input device), it seems sufficient simply to focus on methods and problems rather than time taken. When comparing successive early versions of a prototype, the most effective measures of improvement are the number and type of usability problems found, and a comparison of the ratings of usability, or of different design implementations - so it is important that the same questions are asked about each prototype. If efficiency is a critical feature of a particular

interface (such as for finding diagnoses from a medical expert system), performance time could be usefully measured when the prototype is sufficiently developed to provide a near-functional system.

The number of participants in DAHNI-1 and DAHNI-2 (7 and 9 respectively) was appropriate for identifying common and severe problems as well as identifying less frequent usability problems which only a small number of participants noticed (although the actual number of problems identified by successive participants was not calculated). In comparison, when tabulating the raw data from 13 participants in the DAISY Playback Software evaluations, it was clear that the evaluations could have been conducted with about half the number of participants, with the most severe problems being identified by almost every participant. However, the inclusion of a larger number of participants with a range of experience and requirements meant that a wide range of less severe usability problems was also uncovered, and individual preferences were identified, providing a better base for proposed design solutions.

### **10.3.2 Non-Visual Interface Design**

At the start of this research there was no single non-visual information system which provided access to hypermedia information with a range of input devices and which was suitable for blind users with a range of computer experience, including complete novices. A number of systems attempted to provide varying levels of access to information with limited structuring, but there was no consistency in their designs. It was therefore unclear how to design an interface which would support effective interaction with multiple input devices; how to present links in hypermedia material; how to provide information and feedback without making the system verbose, and what feedback would be required; what levels of user-control would be required over the presentation of information; and which commands would be fundamental to auditory navigation in hypermedia material. The following sections outline the findings from the design and evaluation of the three non-visual interfaces presented in this thesis.

#### **10.3.2.1 DAHNI-1**

**Design.** DAHNI-1 was designed based on initial user requirements and evaluations of mock-ups, and provided nine commands for basic reading and navigation through

hypermedia material: Speak Right (read next unit - a chunk of information the size of a paragraph by default), Speak Left, Select (command or 'current link'), Back (to previous node in history), Forward, Top (to heading of current node), Home (to home node), Stop, Repeat (hear 'current unit' again). The novel concepts of a 'current link' and a 'current unit' were designed to create efficient selection of links and easy reading. The commands were arranged on a sideways H-shape workspace so that they could be used easily and consistently with the keyboard arrow keys, a joystick and a touchtablet. Commands were presented in a digitised voice, and non-speech sounds were used to indicate dead-ends on the workspace and the ends of nodes, and centrepoint on the workspace. A small nine-node hypermedia module about the history of London was created, consisting of text nodes read in synthetic speech, with a few nodes containing digitised audio, and a picture with description and a tactile picture. Links in the material were presented using a higher-pitched voice than the normal synthetic reading voice.

**Evaluation.** The evaluations with seven visually impaired student participants indicated that the basic concept of a workspace to present commands for use with three input devices was effective, and took advantage of the spatial affordances provided by the touchtablet and joystick (Gaver 1991), although the implementation of all three devices had to be improved. Participants were able to read and to navigate well using only these nine basic commands, and the concepts of the 'current unit' and 'current link' seemed to allow participants to read and to select links easily. However, the research led to recommendations to: re-name some commands to 'speak the user's language' (Nielsen 1994d); to provide additional commands to give users orientation information and output control, and to improve reading methods; to include non-speech sounds to provide structural information, command feedback, and to indicate a link, since the change in pitch of the voice distorted the link word. The addition of support features and user-configuration were also recommended.

#### **10.3.2.2 DAHNI-2**

**Design.** DAHNI-2 provided a much more supportive interface to a larger hypermedia module. The 17 functional commands allowed users more control over reading, navigation, orientation, output control, and access to support features: Read Right, Read Left (previously Speak Right/Left), Select, Back, Forward, Heading (previously Top), Home, Stop, Read Current Unit (previously Repeat), Overview (outputs current node

heading, and number of units and links in the node), Where Am I? (outputs the heading of the current node and the assigned number of the current unit in the node), Read Current Link, Change Rate (cycles between four speeds), Change Voice (toggles male-female), Context-Specific Help (outputs summary of last command executed), General Help, and Tutorial. The workspace layout was updated to include the new commands, and was arranged more intuitively, but commands were still presented in a digitised voice. The input devices were improved so that all commands were possible using either the numpad or shortcuts; a new digital joystick was intended to be less sensitive than previously, and commands were made larger on the workspace to make finding and selecting commands easier with the joystick; and a smaller touchtablet was provided to make finding commands on the overlay faster. Non-speech sounds were used (both auditory icons and earcons) to provide structural information as auditory landmarks (Arons 1993, 1997), indicating headings, links, and dead-ends, and to provide feedback for commands which might be easily confused (such as Read Right/Left, Back, Forward, Heading, Home).

New commands for orientation were provided: overviews of the structure of the node (Overview), and information about the user's location within the node (Where Am I?). Although the link-to-link feature had been designed, it was not implemented in time for the evaluations, but users were able to confirm the current link with the Read Current Link command. Output control was possible using Read Current Unit, Change Rate, and Change Voice, and the size of the unit could, in theory, be changed using Change Unit (from default paragraph size to whole node, character, word, and sentence), although this was also not implemented in time for the evaluations. Support features were also developed: an on-line tutorial and general help module, and a context-specific help command. The London hypermedia module was extended to form a larger, more complex 37-node module, containing a variety of text nodes read in synthetic speech, digitised audio with sound effects, music clips, and pictures with descriptions and tactile pictures.

**Evaluation.** The evaluations of DAHNI-2 with nine visually impaired student participants revealed that participants were able to use the three input devices reasonably well (although the joystick remained the least usable device), and using a range of commands and methods participants could read, skim-read and navigate through the material easily to find information, did not frequently feel lost within the hypermedia material, and were able to re-orient themselves easily. Participants were observed to be using the information provided by the non-speech sounds to navigate and orient themselves

without much conscious effort, and rated the sounds as being particularly useful, and the majority were considered easy to learn. Similarly, participants were also able to use the headings as orientation aids through the material, and were able to correctly identify a high number of true and false headings. The use of a variety of media was well-liked (digitised audio, pictures with descriptions and tactile pictures), and participants were able to recall fair amounts of information from these media, with some easily integrating information from several nodes - useful for educational hypermedia systems.

The workspace concept proved valuable for providing a consistent interface across all three input devices, helping users to directly transfer their knowledge of the command layout from one device to the next. This consistency of interface design is known to be important within the same interface (Shneiderman 1992), and when using the same application with different methods of interaction (Yankelovich, Levow & Marx 1995). The re-location of commands to the numpad and the addition of mnemonic shortcuts supported both novice and more experienced computer-users, and allowed participants to learn to use DAHNI-2 very quickly. However, the execution of certain commands, such as Stop, should be possible with a single key, not a combination which can be difficult to locate quickly. The use of a digital joystick did not improve the usability of this device, and an analogue device which clicks onto each command might be a better substitute. The touchtablet was well-liked, although smaller versions should be considered to reduce time searching the overlay for commands. The support features were not used frequently by participants, but were rated as being useful and important.

The recommendations for improvements to the design include those already mentioned, plus to provide: support for indicating and navigating through multiple levels of heading and multiple links in a node using a refined 'current link' concept - each link remains active until the next link is output; link-to-link navigation, and the ability to change the size of the default unit for reading. To re-implement the reading commands so they work like a CD-player's next/previous track functions, removing the need for the 'Read Current Unit' command; to provide a key-identifier type of help in addition to or instead of the context-specific help; to explore methods of presenting an overview of the current node and of the whole hypermedia module; and to provide annotation and personalisation facilities such as making notes, bookmarking, searching, saving and printing. User-configuration of the sounds and system messages and output control should all be possible from within the interface, not just in a separate .INI file.

### 10.3.2.3 *The DAISY Playback Software*

**Design.** The researcher was not involved in the design of the prototype DAISY Playback Software, which was a much more advanced prototype than DAHNI-2, and therefore had to learn to use its range of over 30 commands for reading, heading navigation, orientation, bookmarking, searching, output control and help. The system offers users a choice of commands using either the numpad or shortcuts, and provides many potentially useful commands for effective reading and navigation through a structured digital talking book. However, it was clear even before evaluations that when used non-visually, insufficient information and feedback was given to the user about the heading structuring, and to compound this problem, commands which were used to perform one function sometimes performed another, thus making it very difficult to determine accurately the structure of the book. These issues were identified as being potential major usability problems. Other areas were identified which might also cause problems, such as methods of controlling the output, bookmark limitations, the inconsistency of some system messages and shortcut keys, and the provision of insufficient overview-type commands.

**Evaluations.** The evaluations of the DAISY Playback Software with 13 blind participants showed that many aspects were fairly easy to use, and that it provided a range of useful features for reading and navigating through various digital talking books. It was encouraging to see so many participants able to start using the software so quickly and enthusiastically after only a short time, even if they were not experienced computer users. Some commands were particularly easy to execute, and the method of structuring the material at the phrase level, with the flexibility of reading by phrase, group of phrases, or jumping to sections seemed to suit most participants. However, some of the usability problems identified before and during the evaluations are sufficiently severe to warrant fairly urgent re-design of several aspects of the software, and with small refinements to most commands and the addition of several new commands, its usability would be significantly increased.

The first main recommendation made by this research is to include non-speech sounds to indicate the level of headings and whether they contain any sub-sections as they are reached while navigating or reading. For example, using chords of a different timbre to indicate different levels containing sub-sections, and a single note in a particular timbre to indicate a section heading with no sub-sections. A dead-end sound could be used to reinforce that there are no further sub-sections if necessary. The second main recommendation to

improve heading navigation in particular is to re-implement commands such that they only perform the function for which they are intended (such as, to jump to a lower-level section), and do not jump to another section heading if there are no further headings to jump to. In this way, users would find dead-ends while navigating at particular levels and be able to determine accurately the structure of a book. Improvements recommended for reading include that the Play/Stop commands need differentiation using a non-speech sound for each, the Mute command must be implemented on a single key which is easier to locate, and the commands to read a group should output the whole group not just the first phrase. Further orientation information could be provided by assigning sensible numbers to sections so that introductory material is numbered separately from the chapters.

Another recommendation is that many navigation commands should be re-implemented to use a similar keyboard combination. For example, all commands currently have separate shortcuts (such as five shortcuts to change the speed to the five different rates), and Search, Search Next, and Search Previous require three separate commands; and it would be sensible to implement a consistent method of execution. For example, Change Speed might be <S> with <up/down arrows>; Find Next/Previous might be <F> with <up/down arrows>, and new commands proposed such as Volume, and Jump Bookmark-to-Bookmark could be implemented in similar ways, using <V> and <B> respectively. Full text searching *is* required (searching the text of headings was useful for locating information, but was not sufficient for locating precise information in the body of a section), and the Goto command could be adapted for jumping to locations in addition to pages, for example, to an assigned section number, page number, bookmark, or a text string, using for example: <G, S2.3>, <G, P4>, <G, B5>, and <G, adolescence> respectively. Customisation facilities are also required, including saving, printing, and annotating. Issues relating to the desired consistency of production of books were raised; books should include printed page numbers, and appropriate labelling of sections if the author did not provide headings, and a braille table of contents for reference.

It was interesting to observe that the majority of participants made use of only a small range of commands, despite having over 30 available to them, many of which they rated as being useful and important to include. Other researchers have also found that users prefer to have a few well-implemented and simple commands (Roy & Schmandt 1996), and although advanced commands may not be used frequently, they should still be available to support users should the need arise.

## 10.4 Final Remarks

I hope that this account of my PhD research has been interesting, and has stimulated the reader to think about the issues of non-visual interface design and evaluation in new ways. The three prototype non-visual information systems presented in this thesis have illustrated that blind users can work effectively in hypermedia material and in digital talking books with relatively few commands - provided the right commands are implemented, and implemented consistently, and that the system provides appropriate feedback. The research recommends firstly, that researchers follow the generic user-centered, iterative design and evaluation methodology developed in this research to assess each aspect of an evolving non-visual interface, to identify usability problems and to develop design solutions. The second recommendation is the design of a consistent, multimodal interface (providing a range of input and output devices, and the use of non-speech sounds) for other new non-visual information systems, to support a range of users working with different types of material.

The findings presented in this thesis about the design of non-visual information systems fit nicely into a working definition of hypermedia usability for (visual) web-based interaction proposed by Buckingham Shum (1996), which seems to be particularly pertinent for the design of non-visual web-based interactions, and should be used to guide future design and evaluation of similar systems:

“supporting users by providing the *right information and tools* in the *right form* at the *right time*.” (p.72). His italics.

The present research has highlighted a number of areas worthy of further investigation, and I am glad that some of my recommendations have already been taken up by other researchers to improve their own interfaces (for example, WebAdapter - Hermsdorf 1998, AVANTI - see its web site, and AudioPlus - Recording for the Blind and Dyslexic). These developing systems are amongst the vast range of prototypes and products which now provide blind people with a choice of non-visual information system; a choice which was sorely lacking at the start of my research.

**Glossary**

**ACCESS Project:** Funded by the European Union, 1994-1997, with the full title: Development Platform for Unified Access to Enabling Environments. The design and evaluation of the first two prototype hypermedia browsers DAHNI-1 and DAHNI-2 are reported in this thesis.

**ASCII:** American Standard Code for Information Interchange Format. A method for creating and storing plain text files.

**Auditory Icon:** A type of non-speech sound which has a naturalistic relationship with the object or event it refers to, for example, a printing sound to represent the Print command.

**Blind:** Used to refer specifically to people who have no useful vision, who mainly rely on touch and sound.

**Braille:** The system of dots developed by Louis Braille in 1829. Following guidelines from the United Kingdom Association of Braille Producers, the spelling 'braille' will be used throughout the thesis.

**Browser:** An application which permits a user to work with hypertext or hypermedia material, such as the interface to a CD-ROM, or to the WWW. Examples of visual web browsers include Mosaic, Netscape and Internet Explorer, and pwWebSpeak is an example of a non-visual web browser.

**DAHNI:** Demonstrator of the Access Hypermedia Non-Visual Interface (pronounced Danny). The prototype was developed over two versions, DAHNI-1 and DAHNI-2 as part of the ACCESS project. The design and evaluation of the two versions of this interface to hypermedia material are reported in this thesis.

**DAISY:** Digital Audio-Based Information System. The international DAISY Consortium was set up in 1992. The evaluation of the DAISY Playback Software for playing digital talking books on a PC is reported in this thesis.

**Digital Talking Book:** A book narrated by a human reader, recorded using digital technology and stored on a CD-ROM for example. Provides some level of structured access through the book's contents.

**Digitised Speech/Digitised Audio:** Human speech or sound recorded by digital means, and stored on a computer or CD-ROM, for example.

**Earcon:** A type of non-speech sound which is a tone or a musical pattern used to represent an object or event, for example, a piano chord to represent a main heading.

**Formative Evaluation:** Assessments of a system during development, focussing on the design of its various components.

**GUI/Graphical User Interface:** Interface consisting of windows, icons, menus and pointers. Images made of pixels, rather than true text.

**HCI/Human-Computer Interaction:** The discipline which examines the way in which people work with computers and other technology.

**HTML/Hypertext Mark-up Language:** The coding used to format documents on the World Wide Web.

**Hybrid Book:** An electronic book consisting of structured electronic text linked to unstructured audio material.

**Hypermedia:** Electronic information broken into a web of non-sequential linked chunks, called nodes, which can be of different media, for example, as found on CD-ROMs or on the WWW. Often used interchangeably with 'hypertext'.

**Hypertext:** Electronic information broken into a web of non-sequential linked chunks of text-only nodes. Often used interchangeably with 'hypermedia' now most systems contain many media.

**INI File:** A computer file (text-based) used by some programs to load configuration settings.

**Link:** A word which connects one node to another in a hypermedia or hypertext system.

**Methodology:** A term taken from experimental psychology used to refer to an empirical approach consisting of a variety of specific methods or techniques. This thesis describes a design and evaluation methodology for non-visual information systems.

**Module/Hypermedia Content Module:** A term used in the ACCESS project to refer to a collection of hypermedia nodes about one theme. Example content modules include: London / Music Studies / Business Studies / Help.

**Multimedia:** Any information consisting of several media, for example, print, electronic text, audio, graphics, video.

**Multimodal:** Refers to any interface which provides several input and output devices.

**Node:** Chunk of information in a hypermedia system which may be text, audio, or a graphic with a verbal description. This equates to a 'page' of information on a CD-ROM, or on the WWW.

**Non-Speech Sound:** An auditory cue which does not contain words, such as musical notes or tones (earcons), or everyday naturalistic sounds (auditory icons).

**Non-Visual Information System:** Any technology, often computer-based, which relies on non-visual output (auditory or tactile), and non-visual input (for example, using voice, keyboard, buttons, touchtablet etc).

**Numeric Keypad:** Refers to the dedicated number keys on the right-hand side of a standard keyboard.

**Numpad:** A shortened version of 'numeric keypad' (see above), which can also refer to a set of dedicated number keys on a stand-alone or hand-held device.

**Partially Sighted:** Used to refer specifically to people who have some useful remaining vision.

**Screenreader:** Software which provides non-visual access to a computer application, presenting information in synthetic speech and/or via a braille display.

**Self-Voicing:** A system which provides all its own output (system messages etc), and does not require a screenreader in order to be used by a blind person.

**SMIL/Synchronised Multimedia Integration Language:** A new method of coding structured material which allows the integration and synchronisation of different types of media. For example, linking structured digital audio to structured electronic text.

**Summative Evaluation:** Assessment of a system once it is complete; a more high-level assessment than provided by formative evaluation, focussing on issues such as the tasks supported by the system.

**Synthetic Speech:** Speech output produced by software converting electronic text into speech via a soundcard or a speech synthesiser. Usually sounds robotic.

**Tactile Overlay:** A tactile map of commands placed on top of the touch-sensitive surface of a touchtablet to allow users to locate commands.

**Talking Book:** A book recorded onto audio tape, narrated by a human reader. It is usually highly edited for recording, with little or no structuring.

**Touchtablet:** An input device with a touch-sensitive surface usually used with a tactile overlay indicating the location of commands.

**Unit:** A term used in the ACCESS Project to refer to a chunk of information within a node, which might be a word, sentence, phrase, paragraph, depending on the functionality of the browser.

**Visually Impaired:** Generic term used to describe people within the wide continuum of sight loss. Can be used to refer to blind and partially sighted people as a group.

**WAV File:** A type of computer file containing audio information, such as recorded sounds or speech.

**Workspace:** Used in the ACCESS Project to refer to a virtual layout of commands in a fixed shape which can be used with the keyboard, joystick and a touchtablet.

**WWW/World Wide Web:** The term given to the web of documents on the web, viewed by browsers. Compare with the term 'Internet' used to refer to the connections and facilities provided by a world-wide network of computers.

**References**

---

*Note: All URLs of web sites are current as of 28<sup>th</sup> June 1999.*

- Ability, Issue 21, Summer 1997, News, p. 5. British Computer Society Disability Group.
- Adler, A., Gujar, A., Harrison, B.L., O'Hara, K. and Sellen, A. (1998). A Diary Study of Work-Related Reading: Design Implications for Digital Reading Devices. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'98. 241-248.
- Aitken, S. (1997). Access Through Technology. In H. Mason and S. McCall (Eds.). Visual Impairment: Access to Education for Children and Young People (pp. 187-195). London: David Fulton Publishers.
- Albers, M. C. (1996). Auditory Cues for Browsing, Surfing, and Navigating the WWW: The Audible Web. In Proceedings of the The Third International Conference on Auditory Display, ICAD'96. 85-90.
- Aldrich, F.K. and Parkin, A.J. (1988). Tape Recorded Textbooks for the Blind: A Survey of Producers and Users. The British Journal of Visual Impairment, 6 (1), 3-6.
- Aldrich, F.K. and Parkin, A.J. (1989). Listening at Speed. The British Journal of Visual Impairment, 7 (1), 16-18.
- Arató, A., Barkaszi, M., Buday, L. & Vaspöri, T. (1996). Hybrid Books for the Blind - a New Form of Talking Books. In J. Klaus, E. Auff, W. Kremser, and W. L. Zagler (Eds.). Computers for Handicapped Persons, Proceedings of ICCHP'96. (pp. 237-248). Vienna: R. Oldenbourg.
- Arons, B. (1991). Hyperspeech: Navigating in Speech-Only Hypermedia. In Proceedings of the ACM Conference on Hypertext, Hypertext'91. 133-146.
- Arons, B. (1992). Techniques, Perception, and Applications of Time-Compressed Speech. In Proceedings of the American Voice I/O Society Conference, 169-177.
- Arons, B. (1993). SpeechSkimmer: Interactively Skimming Recorded Speech. In Proceedings of the ACM Symposium on User Interface Software and Technology, UIST'93. 187-196.
- Arons, B. (1997). SpeechSkimmer: A System for Interactively Skimming Recorded Speech. ACM Transactions on Computer-Human Interaction, 4 (1), 3-38.
- Arter, C. (1997a). The Primary School Child. In H. Mason and S. McCall (Eds.) Visual Impairment: Access to Education for Children and Young People (pp. 97-109). London: David Fulton.
- Arter, C. (1997b). Listening Skills. In H. Mason and S. McCall (Eds.) Visual Impairment: Access to Education for Children and Young People (pp. 143-148). London: David Fulton.
- Asakawa, C. and Itoh, T. (1998). User Interface of a Home Page Reader. In Proceedings of the Third International ACM Conference on Assistive Technologies, ASSETS '98. 149-156.

- AVANTI web site - [http://www.ics.forth.gr/proj/at-hci/html/tools\\_avanti.html](http://www.ics.forth.gr/proj/at-hci/html/tools_avanti.html)
- Baldewijns, J. (1997). Vision on Assistive Technology: A Guide for the Blind and Visually Impaired and their Assistants. Leuven, Belgium: VLICT.
- Barker, P. (1991). Interactive Electronic Books. Interactive Multimedia, 2 (1) 11-28.
- Barker, P. and King, T. (1993). Evaluating Interactive Multimedia Courseware - A Methodology. Computers in Education, 21(4), 307-319.
- Barker, P. and Sutherland, G. (1996). Low-Cost Tactile Interaction with Talking Books. In D. Burger (Ed.) New Technologies in the Education of the Visually Handicapped, Vol 237, (pp. 229-234). Montrouge, France: Colloque INSERM/John Libbey Eurotext.
- Bauwens, B., Engelen, J., Evenepoel, F., Tobin, C. and Wesley, T. (1994). Structuring Documents: the Key to Increasing Access to Information for the Print Disabled. In W.L. Zagler, G. Busby, and R.R. Wagner (Eds.) Computers for Handicapped Persons, Proceedings of ICCHP'94 (pp. 214-221). Berlin: Springer-Verlag.
- Bayha, B. (1998). The Internet: An Inclusive Magnet for Teaching All Students. Oakland, CA: World Institute on Disability.
- Bentzen, B.L. (1982). Tangible Graphics in the Education of Blind Persons. In W. Schiff and E. Foulke (Eds.) Tactual Perception: A Sourcebook, (pp. 387-404). Cambridge: Cambridge University Press.
- Best, A.B. (1992). Teaching Children with Visual Impairments. Milton Keynes: Open University Press.
- Bevan, N. and Curson, I. (1997). Who Needs Usability Metrics? In Proceedings of the IFIP Conference on Human-Computer Interaction, INTERACT'97 (pp. 123-125). London: Chapman & Hall.
- Bias, R.G. (1994). The Pluralistic Walkthrough: Coordinated Empathies. In J. Nielsen and R.L. Mack (Eds.) Usability Inspection Methods (pp. 63-76). New York: John Wiley and Sons.
- Blattner, M.M., Sumikawa, D. A. and Greenberg, R.M. (1989). Earcons and Icons: Their Structure and Common Design Principles. Human-Computer Interaction, 4, 11-44.
- Blenkhorn, P. (1986). The RCEVH Project on Micro-Computer Systems and Computer Assisted Learning. The British Journal of Visual Impairment, 4 (3), 101-103.
- Bowler, D., Okamoto, T. and Pothier, B. (1996). Internet Access for the Visually Impaired. BSc Project, Worcester Polytechnic Institute: MA.  
On-line at - <http://ee.wpi.edu/~bdp/iqp>  
Summarised in: Bowler, D., Okamoto, T. and Pothier, B. (1996) Screen Reader Access and the Internet: Some Technical Solutions. Ability, 18, 16-18. Special Issue: World Wide Web: Design for Accessibility. British Computer Society Disability Group.
- Boyd, L.H., Boyd, W.L. and Vanderheiden, G.C. (1990). The Graphical User Interface: Crisis, Danger, and Opportunity. Journal of Visual Impairment and Blindness, 84 (12), 496-502.

- Braun, N. and Dörner, R. (1998). Using Sonic Hyperlinks in Web-TV. In Proceedings of the International Conference on Auditory Display, ICAD'98.  
On-line proceedings only at - <http://www.ewic.org.uk/>
- Bregman, A.S. (1990). Auditory Scene Analysis: The Perceptual Organization of Sound. Cambridge, MA: MIT Press.
- Brewster, S.A. (1997). Navigating Telephone-Based Interfaces with Earcons. In H. Thimbleby, B. O'Connell, and P. Thomas (Eds.) People and Computers XII, Proceedings of the British Computer Society HCI Group Annual Conference, HCI'97, (pp. 39-56). London: Springer.
- Brewster, S.A., Wright, P.C. and Edwards, A.D.N. (1994). A Detailed Investigation into the Effectiveness of Earcons. In G. Kramer (Ed.) Auditory Display (pp. 471-498). Reading, MA: Addison-Wesley.
- Brouwer-Janse, M.D., Suri, J.F., Yawitz, M., de Vries, G., Fozard, J.L. and Coleman, R. (1997). User Interfaces for Young and Old. Interactions, IV (2), 34-46.
- Bruce, I., McKennell, A., and Walker, E. (1991). Blind and Partially Sighted Adults in Britain: the RNIB Survey, Vol 1. London: HMSO.
- Buckingham Shum, S. (1996). The Missing Link: Hypermedia Usability Research & The Web. ACM SIGCHI Bulletin, 28 (4), 68-75.
- Bush, V. (1945). As We May Think. Atlantic Monthly, 176, 101-108.
- Cahill, H., Linehan, C., McCarthy, J., Bormans, G. and Engelen, J. (1996). Blind and Partially Sighted Students' Access to Mathematics and Computer Technology in Ireland and Belgium. Journal of Visual Impairment and Blindness, 90 (2), 105-114.
- Card, S., Moran, T., and Newell, A. (1983). The Psychology of Human-Computer Interaction. Hillsdale, New Jersey: Lawrence Erlbaum.
- Carroll, J.M. (Ed.). (1995). Scenario-Based Design: Envisioning Work and Technology in System Development. New York: John Wiley & Sons.
- Carroll, J.M. and Carrithers, C. (1984). Training Wheels in a User Interface. Communications of the ACM, 27 (8), 800-806.
- Carruthers, S., Humphreys, A. and Sandhu, J. (1993). The Market for R.T. in Europe: A Demographic Study of Need. In: E. Ballabio, I. Placencia-Porrero, and R. Puig de la Bellacasa (Eds.) Rehabilitation Technology: Strategies for the European Union (pp. 158-163). Amsterdam: IOS Press.
- Catenazzi, N., Aedo, I., Díaz, P. and Sommaruga, L. (1997). The Evaluation of Electronic Book Guidelines From Two Practical Experiences. Journal of Educational Multimedia and Hypermedia, 6 (1), 91-114.
- Chen, C. and Rada, R. (1996) Interacting with Hypertext: A Meta-Analysis of Experimental Studies. Human-Computer Interaction 11 (2), 125-156.

- Cherry, J.M. and Jackson, S-R. (1989). Online Help: Effects of Content and Writing Style on User Performance and Attitudes. IEEE Transactions on Professional Communication, 32 (4), 294-299.
- Christie, B. and Gardiner, M.M. (1990). Evaluation of the Human-Computer Interface. In J.R. Wilson and E.N. Corlett (Eds.) Evaluation of Human Work: A Practical Ergonomics Methodology (pp. 271-320). London: Taylor & Francis Ltd.
- Clunies-Ross, L. (1997). Where Have All the Children Gone? An Analysis of New Statistical Data on Visual Impairment Amongst Children in England, Scotland and Wales. The British Journal of Visual Impairment, 15 (2), 48-53.
- Cobb, R. (1997). Study Skills. In H. Mason and S. McCall (Eds.) Visual Impairment: Access to Education for Children and Young People (pp. 179-186). London: David Fulton.
- Cohen, J. (1993). "Kirk Here:" Using Genre Sounds to Monitor Background Activity. In Adjunct Proceedings of the ACM Conference on Human Factors in Computing Systems InterChi'93. 63-64.
- Conklin, J. (1987). Hypertext: An Introduction and Survey. Computer 20 (9), 17-41.
- Cookson, J., Rasmussen, L. and Stockton, G. (1997). Talking Books: Towards a Digital Model. In Proceedings of the Annual International Conference on Technology and Persons with Disabilities, CSUN'97.  
On-line paper only at - [http://www.dinf.org/csun\\_97/csun97\\_032.htm](http://www.dinf.org/csun_97/csun97_032.htm)
- Cress, C.J., and French, G.J. (1994). The Relationship between Cognitive Load Measurements and Estimates of Computer Input Control Skills. Assistive Technology, 6(1), 54-66.
- Cress, C.J. and Goltz, C.C. (1989a). Cognitive Factors Affecting Accessibility of Computers and Electronic Devices. Proceedings of the 12<sup>th</sup> Annual Rehabilitation Engineering and Assistive Technology Conference, RESNA'89. 11-12.
- Cress, C. J., and Goltz, C.C. (1989b). Tips for Selecting and Evaluating Software. In Proceedings of the Closing the Gap Conference. 13-17.
- Cress, C.J. and Tew, J.P. (1990). Cognitive Skills Associated with the Operation of Various Computer Interfaces. Proceedings of the 13th Annual Rehabilitation Engineering and Assistive Technology Conference, RESNA'90. 26-27.
- Cunningham, D.J., Duffy, T.M. and Knuth, R.A. (1993). The Textbook of the Future. In C. McKnight, and A. Dillon, and J. Richardson (Eds.) Hypertext: A Psychological Perspective (pp. 19-51). London: Ellis Horwood.
- Daly-Jones, O., Bevan, N. and Thomas, C. (1997). Handbook of User-Centred Design. Teddington, England: National Physical Laboratory.
- Davis, N. (1998). The Great Dictators. Ability, 23, p. 14. British Computer Society Disability Group.

- Degen, L., Mander, R. and Salomon, G. (1992). Working with Audio: Integrating Personal Tape Recorders and Desktop Computers. Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'92. 413-418.
- Deshler, D.D. and Graham, S. (1980). Tape Recording Educational Materials for Secondary Handicapped Students. Teaching Exceptional Children, Winter, 52-54.
- Desurvire, H.W. (1994). Faster, Cheaper!! Are Usability Inspection Methods as Effective as Empirical Testing? In J. Nielsen and R.L. Mack (Eds.) Usability Inspection Methods (pp. 173-202). New York: John Wiley and Sons.
- Desurvire, H., Lawrence, D. and Atwood, M. (1991). Empiricism Versus Judgement: Comparing User Interface Evaluation Methods on a New Telephone-Based Interface. ACM SIGCHI Bulletin, 23 (4), 58-59.
- De Vendra, D. P. (1998). Features and Benefits for the Interface of the Next Generation Digital Talking Book. In Proceedings of the Annual International Conference on Technology and Persons with Disabilities, CSUN '98.  
Online paper only at - [http://www.dinf.org/csun\\_98/csun98\\_115.htm](http://www.dinf.org/csun_98/csun98_115.htm)
- De Witt, J. and Hakkinen, M. (1998). Surfing the Web with pwWebSpeak™. In Proceedings of the Annual International Conference on Technology and Persons with Disabilities, CSUN '98.  
Online paper only at - [http://www.dinf.org/csun\\_98/csun98\\_159.htm](http://www.dinf.org/csun_98/csun98_159.htm)
- DigiBook (1995). The First DigiBook Newsletter, October.  
On-line at - <http://www.esat.kuleuven.ac.be/teo/Resproj/DIGIBOOK/newsletter1.htm>
- Dillon, A. (1990). Designing the Human-Computer Interface to Hypermedia Applications. In D.H. Jonassen and H. Mandl (Eds.) Designing Hypermedia for Learning (pp. 185-195). Berlin: Springer-Verlag.
- Dillon, A., McKnight, C. and Richardson, J. (1993). Space - The Final Chapter *or* Why Physical Representations are not Semantic Intentions. In C. McKnight, A. Dillon, and J. Richardson, (Eds.) Hypertext: A Psychological Perspective (pp.169-191). London: Ellis Horwood.
- Dix, A., Finlay, J., Abowd, G. and Beale, R. (1993). Human-Computer Interaction. Hemel Hempstead, England: Prentice-Hall International (UK) Ltd.
- Douglas, G. and Gamble, A. (1994). Future Developments in Computer-Aided Teaching of Visually Impaired Children. The British Journal of Visual Impairment, 12 (3), 96-100.
- Dumas, J.S. and Redish, J.C. (1994). A Practical Guide to Usability Testing. Norwood, NJ: Ablex.
- Edman, P.K. (1992). Tactile Graphics. New York: American Foundation for the Blind.
- Edwards, A.D.N. (1987) Adapting User Interfaces for Visually Disabled Users. Unpublished PhD Thesis, Open University, UK.

- Edwards, A.D.N. (1989). Soundtrack: An Auditory Interface for Blind Users. Human-Computer Interaction, 4 (1), 45-66.
- Edwards, A.D.N. (1991). Speech Synthesis: Technology for Disabled People. London: Chapman.
- Edwards, A.D.N. (1992). Redundancy and Adaptability. In A.D.N. Edwards and S.Holland (Eds.) Multimedia Interface Design in Education (pp. 145-155). Berlin: Springer-Verlag.
- Edwards, A.D.N. (1995a). Computers and People with Disabilities. In A.D.N. Edwards, (Ed.) Extra-Ordinary Human-Computer Interaction: Interfaces for Users with Disabilities (pp. 21-43). Cambridge Series on Human-Computer Interaction, Vol 7. Cambridge: Cambridge University Press.
- Edwards, A.D.N. (1995b). Outspoken Software for Blind Users. In A.D.N. Edwards (Ed.) Extra-Ordinary Human-Computer Interaction: Interfaces for Users with Disabilities (pp. 59-82). Cambridge Series on Human-Computer Interaction, Vol 7. Cambridge: Cambridge University Press.
- Edwards, D.M. and Hardman, L. (1989). Lost in Hyperspace: Cognitive Mapping and Navigation in a Hypertext Environment. In R. McAleese (Ed.) Hypertext: Theory into Practice (pp. 105-125). Oxford: Intellect Ltd.
- Edwards, W.K., Mynatt, E.D. and Stockton, K. (1995). Access to Graphical User Interfaces. Interactions, 11 (1), 54-67.
- Egan, D.E., Remde, J.R., Landauer, T.K., Lochbaum, C.C. and Gomez, L.M. (1989). Acquiring Information in Books and SuperBooks. Machine Mediated Learning, 3, 259-277.
- Elkerton, J. (1988). Online Aiding for Human-Computer Interfaces. In M. Helander (Ed.) Handbook of Human-Computer Interaction (pp. 345-364). Amsterdam: Elsevier Science.
- Elm, W. and Woods, D. (1985). Getting Lost: A Case Study in Interface Design. Proceedings of the Human Factors Society 29<sup>th</sup> Annual Meeting. 927-931.
- Engelen, J., Evenepoel, P. and Wesley, T. (1998). Surmounting the Copyright Hurdle: The SEDODEL Project. In I. Placencia-Porero and E. Ballabio (Eds.) Improving the Quality of Life for the European Citizen (pp. 20-25). Amsterdam: IOS Press.
- Ericsson, K.A. and Simon, H.A. (1985). Verbal Reports as Data. Psychological Review, 87, 215-251.
- Ess, C. (1991). The Pedagogy of Computing: Hypermedia in the Classroom. In Proceedings of the ACM Conference on Hypertext, Hypertext'91. 277-289.
- European Blind Union (1996). Reaching Forward to the 21st Century: User Requirements for the Next Generation of Talking Books. London: Royal National Institute for the Blind.

- Evans, J., Rooney, C., Ashwood, F., Dattani, N. and Wormald, R. (1996). Blindness and Partial Sight in England and Wales: April 1990 - March 1991. Health Trends, 28 (1), 5-12.
- Fanstone, J. (1995). Mobility and Blindness: A Campus Audio-Tactile Map System. The Skill Journal, 53, 21-23.
- Fernström, M. and Bannon, L. (1997). Explorations in Sonic Browsing. In H. Thimbleby, B.O'Connell, and P.Thomas (Eds.) People and Computers XII, Proceedings of the British Computer Society HCI Group Annual Conference, HCI'97. (pp. 117-131). London: Springer.
- Fetton, E. (1994). No Room for Complacency: Issues in Training Teachers to Meet the Needs of Visually Impaired Children. The British Journal of Visual Impairment, 12 (2), 50-53.
- Fine, B. (1997). Never Assume Limitation. Ability, 21, 14-16. British Computer Society Disability Group.
- Fischer, P.M. and Mandl, H. (1990). Towards a Psychophysics of Hypermedia. In D.H. Jonassen and H. Mandl (Eds.) Designing Hypermedia for Learning (pp. xix-xxv). Berlin: Springer-Verlag.
- Foulke, E. (1982). Reading Braille. In W. Schiff and E. Foulke (Eds.) Tactual Perception: A Sourcebook (pp. 168-208). Cambridge: Cambridge University Press.
- Free, L., Graziani, P., Lauder, R., Majoe, D., Morley, S. and Petrie, H. (1995). ACCESS Report D 4.1.2: Final Report on User Needs, Vol 1. London: ACCESS Consortium.
- Free, L., Majoe, D., McNally, P., Morley, S. and Petrie, H. (1995). ACCESS Report D.3.2.1: Report on the Design of Non-Visual Aspects of the Unified ACCESS Interfaces. London: ACCESS Consortium.
- Friedlander, C. (1987). Future Technology for Talking Books. The British Journal of Visual Impairment, 5 (3), 89-91.
- Gardner, H. (1985) The Mind's New Science: A History of the Cognitive Revolution. New York: Basic Books.
- Gates, W. (1997). Why Helping People with Disabilities Helps Everybody. Ability, 22, 8-9. British Computer Society Disability Group.
- Gaver, W.W. (1989). The SonicFinder: An Interface That Uses Auditory Icons. Human-Computer Interaction, 4, 67-94.
- Gaver, W.W. (1991). Technology Affordances. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'91. 79-84.
- Gaver, W.W. (1994). Using and Creating Auditory Icons. In G. Kramer (Ed.) Auditory Display (pp. 417-446). Reading, MA: Addison-Wesley.

- Gaver, W.W. and Smith, R.B. (1990). Auditory Icons in Large-Scale Collaborative Environments. In Proceedings of the IFIP Conference on Human-Computer Interaction, INTERACT'90. 735-740.
- Good, M.D., Whiteside, J.A., Wixon, D.R. and Jones, S.J. (1984). Building a User-Derived Interface. Communications of the ACM, 27 (10), 1032-1043.
- Gould, J.D. (1988). How to Design Usable Systems. In M. Helander (Ed.) Handbook of Human-Computer Interaction (pp. 757-789). Amsterdam: Elsevier Science.
- Gould, J.D., Conti, J. and Hovanyecz, T. (1983). Composing Letters with a Simulated Listening Typewriter. Communications of the ACM, 26 (4), 295-308.
- Gould, J.D. and Lewis, C. (1985). Designing for Usability: Key Principles and What Designers Think. Communications of the ACM, 28 (3), 300-311.
- Gray, K. and McDonald, M. (Eds.) (1993). Access Technology: A Guide to Educational Technology Resources for Visually Impaired Users 1993/4 Edition. London: Royal National Institute for the Blind.
- Gray, W.D. and Salzman, M.C. (1998) Damaged Merchandise? A Review of Experiments That Compare Usability Methods. Human-Computer Interaction, 13 (3), 203-261.
- Graziani, P. and Vaspöri, T. (1998). Experience with Hybrid Books for Blind People in Italy and Hungary. In A.D.N. Edwards, A. Arató and W. Zagler (Eds.) Computers and Assistive Technology, Proceedings of ICCHP'98 (pp. 91-95). Vienna: Austrian Computer Society.
- Griffiths, J. (1994). Towards a New Generation of Talking Books. In Proceedings of the International Expert Meeting on Library Services to the Visually Handicapped, (pp. 27-35). Madrid: ONCE.
- GUIB Project Final Report (1995). Textual and Graphical User Interfaces for Blind People. London: Royal National Institute for the Blind.
- GVU WWW User Surveys - [http://www.cc.gatech.edu/gvu/user\\_surveys/](http://www.cc.gatech.edu/gvu/user_surveys/)
- Hadjadj, D., Bouzidi, A., and Burger, D. (1998). An Internet Browser for Visually Handicapped Users: Principles and Methods. In A.D.N. Edwards, A. Arató, and W. Zagler (Eds.) Computers and Assistive Technology, Proceedings of ICCHP'98 (pp. 170-178). Vienna: Austrian Computer Society.
- Hakkinen, M. and De Witt, J. (1996). pwWebSpeak: User Interface Design of an Accessible Web Browser - White Paper. Trenton, NJ: The Productivity Works.
- Hammond, N. and Allison, L. (1989). Extending Hypertext for Learning: An Investigation of Access and Guidance Tools. In A. Sutcliffe and L. Macaulay (Eds.) People and Computers V, Proceedings of the British Computer Society HCI Group Annual Conference, HCI'89 (pp. 293-304). Cambridge: Cambridge University Press.
- Handel, S. (1989). Listening: An Introduction to the Perception of Auditory Events. Cambridge, MA: MIT Press.

- Hannemann, J. and Thüring, M. (1995). What Matters in Developing Interfaces for Hyper Document Presentation? In W. Schuler, J. Hannemann and N. Streitz (Eds.) Designing User Interfaces for Hypermedia (pp. 29-42). Berlin: Springer-Verlag.
- Hansson, K., Sönnebo, L. and Lindholm, J. (1994). Digital Talking Books - a Report from a Practical, Ongoing Project. In W.L. Zagler, G. Busby, and R.R. Wagner (Eds.) Computers and Assistive Technology. Proceedings of ICCHP'98 (pp. 262-268). Vienna: Austrian Computer Society.
- Hardman, L. (1995). Experiences in Authoring Hypermedia: Creating Better Presentations. In W. Schuler, J. Hannemann and N. Streitz (Eds.) Designing User Interfaces for Hypermedia (pp. 18-28). Berlin: Springer-Verlag.
- Hardman, L. and Sharratt, B.S. (1990). User-Centred Hypertext Design: The Application of HCI Design Principles and Guidelines. In R. McAleese and C. Green (Eds.) Hypertext: State of the Art (pp. 252-259). Oxford: Intellect Ltd.
- HARMONY Project Final Report (1997). The Art of Providing Access to Electronic Documents. Leuven, Belgium: The HARMONY Consortium.
- Harris, P. (1986). Designing and Reporting Experiments. Milton Keynes: Open University Press.
- Hawley, A., Jefferys, S., Ross, M., Spencer, S. and Tobin, M.J., (1987). Electronic Publishing and Visually Handicapped Learners. The New Beacon, LXXI (844), 253-255.
- Henderson, R., Podd, J., Smith, M. and Varela-Alvarez (1995). An Examination of Four User-Based Software Evaluation Methods. Interacting with Computers, 7 (4), 412-432.
- Hendry, D.G., Carey, T.T. and TeWinkel, S.T. (1990). A Study of Measures for Research in Hypertext Navigation. In Proceedings of the IFIP Conference on Human-Computer Interaction, INTERACT'90. 101-106.
- Henter Joyce JAWS for Windows Screenreader Home Page - <http://www.hj.com/JFW/JFW.html>
- Hermisdorf, D. (1998). WebAdapter: A Prototype of a WWW Browser with New Special Needs Adaptations. In W.L. Zagler, G. Busby, and R.R. Wagner (Eds.) Computers and Assistive Technology. Proceedings of ICCHP'98 (pp. 151-160). Vienna: Austrian Computer Society.
- Herrstrom, D.S. and Massey, D.G. (1989). Hypertext in Context. In Barrett, E. (Ed.) The Society of Text: Hypertext, Hypermedia, and the Social Construction of Information (pp. 45-58). Cambridge, MA: The MIT Press.
- Hewett, T.T. (1986). The Role of Iterative Evaluation in Designing Systems for Usability. In M.D. Harrison and A.F. Monk (Eds.) People and Computers: Designing for Usability. Proceedings of the British Computer Society HCI Group Annual Conference, HCI'86, (pp. 196-214). Cambridge: Cambridge University Press.

- Hewitt, J. (1998). Current Developments in Low-Budget Speech Recognition Systems. In W.L. Zagler, G. Busby, and R.R. Wagner (Eds.) Computers and Assistive Technology, Proceedings of ICCHP'98 (pp. 474-483). Vienna: Austrian Computer Society.
- Hill, E. and Tobin, M.J. (1992). Microcomputers in Education: Their Use by Blind and Partially Sighted Learners. Computer Education, 70, 30-31.
- Hiser Group (1995). Designing With Users: The Key to Success. Melbourne: The Hiser Group.
- Hollins, M. (1989). Understanding Blindness: An Integrative Approach. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Holtzblatt, K. and Jones, S. (1993). Contextual Inquiry: A Participatory Technique for System Design. In S. Schuler and A. Namioka (Eds.) Participatory Design: Principles and Practices (pp. 177-210). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Hudson, D. (1996a). The Internet: A DOS and Windows Perspective (Part I of II). Access Review, 1 (2), 15-19.
- Hudson, D. (1996b). The Internet: A DOS and Windows Perspective (Part II of II). Access Review, 1 (3), 14-17.
- Ina, S. (1996). Presentation of Images for the Blind. ACM SIGCAPH Newsletter, 56, 10-16.
- Instone, K. (1997). Usability Heuristics for the Web. Web Review 10/10/97 (an on-line magazine) at - <http://webreview.com/97/10/10/usability/sidebar.html>
- Instone, K., Teasley, B.M. and Leventhal, M. (1993). Empirically-Based Re-Design of a Hypertext Encyclopedia. In Proceedings of ACM Conference on Human Factors in Computing Systems, INTERCHI'93. 500-506.
- ISO DIS 9241-11 (1994). Draft International Standard. Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs) - Part 11: Guidance on Usability. London: British Standards Institution.
- James, F. (1998). Lessons from Developing Audio HTML Interfaces. In Proceedings of the Third International ACM Conference on Assistive Technologies, ASSETS '98. 27-34.
- Jeffries, R. (1994). Usability Problem Reports: Helping Evaluators Communicate Effectively with Developers. In J. Nielsen and R.L. Mack (Eds.) Usability Inspection Methods (pp. 273-294). New York: John Wiley and Sons.
- Jeffries, R., Miller, J.R., Wharton, C. and Uyeda, K.M. (1991). User Interface Evaluation in the Real World: A Comparison of Four Techniques. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'91. 119-124.
- Jonassen, D.H. and Grabinger, R.S. (1990). Problems and Issues in Designing Hypertext/Hypermedia for Learning. In D.H. Jonassen and H. Mandl (Eds.) Designing Hypermedia for Learning (pp. 3-25). Berlin: Springer-Verlag.

- Jones, S. and Hewitt, J. (1997). Heuristic Evaluation of Web Site Usability: Experiences from Two Case Studies. In P. Thomas and D. Withers (Eds.) Conference Companion to Proceedings of the British Computer Society HCI Group Annual Conference HCI'97. 23-25.
- Karat, J. (1988). Software Evaluation Methods. In M. Helander (Ed.) Handbook of Human-Computer Interaction (pp. 891-903). Amsterdam: Elsevier Science.
- Karat, C.M., Campbell, R. and Fiegel, T. (1992). Comparison of Empirical Testing and Walkthrough Methods in User Interface Evaluation. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'92. 397-404.
- Karshmer, A.I., Brawner, P. and Reiswig, G. (1994). An Experimental Sound-Based Hierarchical Menu Navigation System for Visually Handicapped Use of Graphical User Interfaces. In Proceedings of the First Annual ACM Conference on Assistive Technologies, ASSETS'94. 123-128.
- Katholieke Universiteit Leuven (1997a). DigiBook: On the Future of Talking and Hybrid Books for Reading Impaired Persons. Final Report. Leuven, Belgium: KUL.
- Katholieke Universiteit Leuven (1997b). HARMONY: The Art of Providing Access to Electronic Documents. Final Report. Leuven, Belgium: KUL.
- Kelly, J.F. (1984). An Iterative Design Methodology for User-Friendly Natural Language Office Information Applications. ACM Transactions on Office Information Systems, 2 (1) 26-41.
- Kelway, P. (1993). The Paperless Newspaper. The British Journal of Visual Impairment 11 (2), 63-64.
- Kennedy, J.M. (1993). Drawing and the Blind: Pictures to Touch. New Haven: Yale University Press.
- Kennel, A. (1996). AudioGraf: A Diagram-Reader for the Blind. In Proceedings of the Second Annual ACM Conference on Assistive Technologies, ASSETS'96. 51-56.
- Kennel, A., Perrochon, L. and Darvishi, A. (1996). WAB: W3-Access for Blind and Visually Impaired Computer Users. In D. Burger (Ed.) New Technologies in the Education of the Visually Handicapped, Vol 237. (pp. 297-303). Montrouge, France: Colloque INSERM/John Libbey Eurotext.
- Kerscher, G. and Hansson, K. (1998). DAISY Consortium - Developing the Next Generation of Digital Talking Books (TDB). In Proceedings of the Annual International Conference on Technology for Persons with Disabilities, CSUN'98.  
Online only at - [http://www.dinf.org/csun\\_98/csun98\\_065.htm](http://www.dinf.org/csun_98/csun98_065.htm)
- Kirwan, B. and Ainsworth, L.K. (Eds.) (1992) A Guide to Task Analysis. London: Taylor and Francis Ltd.
- Kobayashi, M. and Schmandt, C. (1997). Dynamic Soundscape: Mapping Time to Space for Audio Browsing. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'97. 194-201.

- Kochanek, D. (1992). A Hypertext System for the Blind Newspaper Reader. In W. Zagler (Ed.) Proceedings of the 3rd International Conference on Computers for Handicapped People, ICCHP'92 (pp. 285-293). Vienna: Oldernbourg.
- Kopocek, I. (1998). The Architecture of the Blind User Oriented Hypertext AUDIS. In A.D.N. Edwards, A. Arató, and W. Zagler (Eds.) Computers and Assistive Technology, Proceedings of ICCHP'98 (pp. 215-223). Vienna: Austrian Computer Society.
- Kramer, G. (1994). An Introduction to Auditory Display. In G. Kramer (Ed.) Auditory Display: Sonification, Audification and Auditory Interfaces (pp. 1-77). Reading MA: Addison-Wesley.
- Krell, M. and Cubranic, D. (1996). V-Lynx: Bringing the World Wide Web to Sight-Impaired Users. In Proceedings of The Second Annual ACM Conference on Assistive Technologies, ASSETS'96. 23-26.
- Kurze, M., Petrie, H., Morley, S., Deconninck, F., and Strothotte, T. (1995). New Approaches for Accessing Different Classes of Graphics by Blind People. In I. Placencia-Porrero and R. Puig de la Bellacasa (Eds.) The European Context for Assistive Technology (pp. 268-271). Amsterdam: IOS Press.
- Labyrinth Data AB, Sweden - <http://www.labyrinthen.se/>
- Landauer, T.K. (1996). The Trouble with Computers: Usefulness, Usability and Productivity. Cambridge, MA: MIT Press.
- Landauer, T., Egan, D., Remde, J., Lesk, M., Lochbaum, C. and Ketchum, D. (1993). Enhancing the Usability of Text Through Computer Delivery and Formative Evaluation: The SuperBook Project. In C. McKnight, A. Dillon and J. Richardson, (Eds.) Hypertext: A Psychological Perspective (pp.71-136). London: Ellis Horwood.
- Landow, G. (1990). Popular Fallacies About Hypertext. In D.H. Jonassen and H. Mandl (Eds.) Designing Hypermedia for Learning (pp. 39-59). Berlin: Springer-Verlag.
- Larsen, S. and Jorgensen, N. (1989). Talking Books for Pre-School Children. Journal of Visual Impairment and Blindness, 83 (2), 118-119.
- Laux, L.F, McNally, P.R., Paciello, M.G. and Vanderheiden, G.C. (1996). Designing the World Wide Web for People with Disabilities: A User Centered Approach. In Proceedings of the Second Annual ACM Conference on Assistive Technologies, ASSETS'96. 94-101.
- Lazzaro, J.J. (1993). Adaptive Technologies for Learning and Work Environments. Chicago: American Library Association.
- Lazzaro, J.J. (1995). An Electronic Bill of Rights: Adapting PCs for Disabilities. Reading, MA: Addison Wesley.
- Leggett, J.J., Schnase, J.L. and Kacmar, C.J. (1990). Hypertext for Learning. In D.H. Jonassen and H. Mandl (Eds.) Designing Hypermedia for Learning (pp. 27-37). Berlin: Springer-Verlag.

- Leventhal, L.M., Teasley, B.M., Instone, K., Rohlman, D.S. and Farhat, J. (1993). Sleuthing in HyperHolmes™: an Evaluation of Using Hypertext Vs. a Book to Answer Questions. Behaviour & Information Technology, 12 (3), 149-164.
- Lewis, J.R. (1995). IBM Computer Usability Satisfaction Questionnaires: Psychometric Evaluation and Instructions for Use. International Journal of Human-Computer Interaction, 7 (1), 57-78.
- Lim, K.Y. and Long, J.B. (1995). The MUSE Method for Usability Engineering. Cambridge: Cambridge University Press.  
The MUSE website is at - <http://www.ergohci.ucl.ac.uk/research/muse.html>
- Lindgaard, G. (1994). Usability Testing and System Evaluation: A Guide for Designing Useful Computer Systems. London: Chapman & Hall.
- Lock, P. (1998). Ending Discrimination and Promoting Equal Opportunities for People with Visual Impairment and Additional Disabilities. The British Journal of Visual Impairment, 16 (1) 11-13.
- Lodge, J. (Ed.) (1994). Access Technology (1995 ed.). London: Royal National Institute for the Blind.
- Luxton, K. (1990). Training Students in Adaptive Computer Technology. Journal of Visual Impairment and Blindness, 84, 523-525.
- Mack, C.G., Koenig, A.J. and Ashcroft, S.C. (1990). Microcomputers and Access Technology in Programs for Teachers of Visually Impaired Students. Journal of Visual Impairment and Blindness, 84, 526-529.
- Mack, R.L. and Nielsen, J. (1994). Executive Summary. In J. Nielsen and R.L. Mack (Eds.) Usability Inspection Methods (pp. 1-23). New York: John Wiley and Sons.
- Mansur, D.L., Blattner, M.M. and Joy, K.I. (1985). Sound-Graphs: A Numerical Data Analysis Method for the Blind. Journal of Medical Systems, 9, 163-174.
- Marchionini, G. (1990). Evaluating Hypermedia-Based Learning. In D.H. Jonassen and H. Mandl (Eds.) Designing Hypermedia for Learning (pp. 355-373). Berlin: Springer-Verlag.
- Marchionini, G. and Crane, G. (1994). Evaluating Hypermedia and Learning: Methods and Results from the Perseus Project. ACM Transactions on Information Systems, 12 (1), 5-34.
- Martin, J., Meltzer, H., and Elliot, D. (1988). The Prevalence of Disability Among Adults. OPCS Surveys of Disability in Great Britain. Report 1. London: HMSO.
- Mason, H. (1997). Common Eye Defects and Their Educational Implications. In H. Mason and S. McCall (Eds.) Visual Impairment: Access to Education for Children and Young People (pp. 38-50). London: David Fulton Publishers.
- Mason, H. and Arter, C. (1997). The Preparation of Raised Diagrams. In H. Mason and S. McCall (Eds.) Visual Impairment: Access to Education for Children and Young People (pp. 171-178). London: David Fulton Publishers.

- Mayes, T., Kibby, M.R. and Anderson, T. (1990). Signposts for Conceptual Orientation: Some Requirements for Learning From Hypertext. In R. McAleese and C. Green (Eds.) Hypertext: State of the Art (pp. 121-129). Oxford: Intellect Ltd.
- McAleese, R. (1989). Navigation and Browsing in Hypertext. In R. McAleese (Ed.) Hypertext: Theory into Practice (pp. 6-45). Oxford: Intellect Ltd.
- McCall, S. (1997). The Development of Literacy Through Touch. In H. Mason and S. McCall (Eds.) Visual Impairment: Access to Education for Children and Young People (pp. 149-158). London: David Fulton Publishers.
- McClelland, I. (1990). Product Assessment and User Trials. In J.R. Wilson and E.N. Corlett (Eds.) Evaluation of Human Work: A Practical Ergonomics Methodology. (pp. 218-247). London: Taylor and Francis.
- McGraw, K.L. (1997). Defining and Designing the Performance-Centered Interface: Moving Beyond the User-Centered Interface. ACM Interactions, IV (2), 19-26.
- McLachlan, N. (1997). Access to Newspapers and Journals for Visually Impaired People. Ariadne, Issue 10, July.  
Web Magazine, article at - <http://www.ariadne.ac.uk/issue10/tnauk/>
- McNally, P., Morley, S., O'Neill, A-M. and Petrie, H. (1996a). Report on the Functionality of the Demonstrator Hypermedia Application (D 3.3.2). London: ACCESS Consortium.
- McNally, P., Morley, S., O'Neill, A-M. and Petrie, H. (1996b). Report on the Functionality of the On-Line Help System for the Demonstrator Hypermedia Application (D 3.3.3). London: ACCESS Consortium.
- Mereu, S.W. and Kazman, R. (1996). Audio Enhanced 3D Interfaces for Visually Impaired Users. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'96. 72-78.
- Microsoft (1997). Microsoft Windows Guidelines for Accessible Software Design. WA, Microsoft Corp.
- Monk, A., Wright, P., Haber, J., and Davenport, L. (1993). Improving your Human-Computer Interface: A Practical Approach. Hemel Hempstead, Hertfordshire: Prentice Hall International (UK).
- Moore, B.C.J. (1989). An Introduction to the Psychology of Hearing (3<sup>rd</sup> ed.). London: Academic Press.
- Moran, T.P. and Carroll, J. M (Eds.) (1994). Design Rationale: Concepts, Techniques, and Use. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Morley, S. (1995). Window Concepts: An Introductory Guide for Blind and Visually Disabled Users. Peterborough: Royal National Institute for the Blind.
- Morley, S. (1996). The Microsoft Accessibility Conference, Part 1. The New Beacon, 80 (946), 4-9.

- Morley, S. (1997a). Usability Evaluation of the DAISY Playback Software. Report from the Sensory Disabilities Research Unit, University of Hertfordshire, submitted to the DAISY Consortium.
- Morley, S. (1997b). Windows 95 Explained: A Guide for Blind and Visually Impaired Users. Peterborough: Royal National Institute for the Blind.
- Morley, S. (1998). Digital Talking Books on a PC: A Usability Evaluation of the Prototype DAISY Playback Software. In Proceedings of the Third International ACM Conference on Assistive Technologies, ASSETS '98. 157-164.
- Morley, S., Petrie, H., O'Neill, A-M. and McNally, P. (1998a). Auditory Navigation in Hyperspace: Design and Evaluation of a Non-Visual Hypermedia System for Blind Users. Behaviour and Information Technology, 18 (1), 18-26. First published in: Proceedings of the Third International ACM Conference on Assistive Technologies, ASSETS '98. 100-107.
- Morley, S., Petrie, H., O'Neill, A-M. and McNally, P. (1998b). The Use of Non-Speech Sounds in a Hypermedia Interface for Blind Users. In A.D.N. Edwards, A. Arató and W. Zagler (Eds.) Computers and Assistive Technology, Proceedings of ICCHP'98 (pp. 205-214). Vienna: Austrian Computer Society.
- Mosier, J.N. and Smith, S.L. (1986) Application of Guidelines for Designing User Interface Software. Behaviour and Information Technology, 5 (1), 39-46.
- Murnion, S. (1996a). A Guide to Internet Access for Visually Impaired People. Birmingham: Research Centre for the Education of the Visually Impaired.
- Murnion, S. (1996b). The Internet. It Sounds Great But... Centre Software Newsletter, Number 40, June 1996, 3-5. Birmingham: Research Centre for the Education of the Visually Handicapped.
- Mynatt, E.D. (1994). Designing with Auditory Icons. In Proceedings of the Second International Conference on Auditory Display, ICAD'94. 109-119.
- Mynatt, E.D. and Weber, G. (1994). Nonvisual Presentation of Graphical User Interfaces: Contrasting Two Approaches. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'94. 166-172.
- Nelson, T. (1965). Suggestions for an On-Line Braille Display. Proceedings of the Society for Information Display, Autumn 1965. Personal Communication 1998.
- Nelson, T. (1981). Literary Machines. Self Published.
- Newell, A.F. (1995). Extra-Ordinary Human-Computer Interaction. In A.D.N. Edwards, (Ed.) Extra-Ordinary Human-Computer Interaction: Interfaces for Users with Disabilities (pp. 3-18). Cambridge Series on Human-Computer Interaction, Vol 7. Cambridge: Cambridge University Press.
- Newell, A.F. and Cairns, A.Y. (1993). Designing for Extraordinary Users. Ergonomics in Design, 1 (4), 10-16. Reprinted in Interfaces (1997), 35, 4-5.

- Nielsen, J. (1989). The Matters That Really Matter for Hypertext Usability. In Proceedings of the ACM Conference on Hypertext, Hypertext'89. 239-248.
- Nielsen, J. (1990a). Hypertext and Hypermedia. London: Academic Press.
- Nielsen, J. (1990b). Evaluating Hypertext Usability. In D.H. Jonassen and H. Mandl (Eds.) Designing Hypermedia for Learning (pp. 147-168). Berlin: Springer-Verlag.
- Nielsen, J. (1992). Finding Usability Problems Through Heuristic Evaluation. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'92. 373-380.
- Nielsen, J. (1993). Usability Engineering. Boston: Academic Press.
- Nielsen, J. (1994a). Enhancing the Explanatory Power of Usability Heuristics. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'94. 152-158.
- Nielsen, J. (1994b). Estimating the Number of Subjects Needed for a Think-Aloud Test. International Journal of Human-Computer Studies, 41 (3), 385-397.
- Nielsen, J. (1994c). Guerilla HCI: Using Discount Usability Engineering to Penetrate the Intimidation Barrier. In R.G. Bias and D.J. Mayhew (Eds.) Cost-Justifying Usability (pp. 245-272). Boston: Academic Press.
- Nielsen, J. (1994d). Heuristic Evaluation. In J. Nielsen, and R.L. Mack (Eds.) Usability Inspection Methods (pp. 25-62). New York: John Wiley and Sons.
- Nielsen, J. (1995). Multimedia and Hypertext: The Internet and Beyond. London: Academic Press.
- Nielsen, J., and Landauer, T.K. (1993). A Mathematical Model of the Finding of Usability Problems. In Proceedings of the ACM Conference on Human Factors in Computing Systems, INTERCHI'93. 206-213.
- Nielsen, J. and Levy, J. (1994). Measuring Usability: Preference vs. Performance. Communications of the ACM, 37 (4), 67-75.
- Nielsen, J. and Lyngbæk, U. (1990). Two Field Studies of Hypermedia Usability. In R. McAleese and C. Green (Eds.) Hypertext: State of the Art (pp. 64-72). Oxford: Intellect Ltd.
- Nielsen, J. and Mack R.L. (Eds.) (1994). Usability Inspection Methods. New York: John Wiley & Sons.
- NISO (National Information Standards Organisation - <http://www.niso.org/>)
- Norman, D.A. (1988). The Design of Everyday Things. London: The MIT Press.
- Olson, G.M. and Moran, T.P. (Eds.) (1998). Special Issue on Experimental Comparisons of Usability Evaluation Methods. Human-Computer Interaction, 13 (3).

- Oogane, T. and Asakawa, C. (1998). An Interactive Method for Accessing Tables in HTML. In Proceedings of The Third International ACM Conference on Assistive Technologies, ASSETS '98. 126-128.
- Oppenheim, A.N. (1992). Questionnaire Design, Interviewing and Attitude Measurement (new edition). London: Pinter Publishers.
- Orne, M.T. (1962). On the Social Psychology of the Psychological Experiment: With Particular Reference to Demand Characteristics and their Implications. American Psychologist, 17, 776-783.
- Othman, E. and Levanto, M. (1996). Pictures for Listening. Visual Art for the Visually Handicapped. In D. Burger (Ed.) New Technologies in the Education of the Visually Handicapped, Vol 237 (pp. 109-118). Montrouge, France: Colloque INSERM/John Libbey Eurotext.
- Parkin, A.J. and Aldrich, F.K. (1989). Improving Learning from Audiotape: A Technique that Works! The British Journal of Visual Impairment, VII (2), 58-60.
- Patterson, R.D. (1982). Guidelines for Auditory Warning Systems on Civil Aircraft. London: Civil Aviation Authority
- Peli, E., Fine, E.M. and Labianca, A.T. (1996). Evaluating Visual Information Provided by Audio Description. Journal of Visual Impairment and Blindness, 90 (5) 378-385.
- Perkins, B. (1995). Integrating Hypermedia and Assistive Technology: An Overview of Possibilities. Information Technology and Disabilities 2 (2).  
On-line journal, see - <http://www.rit.edu/~easi/itd/itdv02n2/perkins.html>
- Perlman, G., Egan, D.E., Ehrlich, K., Marchionini, G., Nielsen, J. and Shneiderman, B. (1990). Evaluating Hypermedia Systems. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'90. 387-390.
- Petrie, H. (1997). User-Centred Design and Evaluation of Adaptive and Assistive Technology for Disabled and Elderly Users. it + ti - Informationstechnik und Technische Informatik, 39 (2), 7-12.
- Petrie, H. and Gill, J. (1993). Current Research on Access to Graphical User Interfaces for Visually Disabled Computer Users. European Journal of Special Needs, 8 (2), 153-157.
- Petrie, H. and Morley, S. (1998). The Use of Non-Speech Sounds in Non-Visual Interfaces to the MS-Windows GUI for Blind Computer Users. In Proceedings of the Fifth International Conference on Auditory Display, ICAD'98.  
On-line proceedings only at - <http://ewic.org.uk/ewic/>
- Petrie, H., Morley, S., McNally, P., Graziani, P. and Emiliani, P-L. (1996). Access to Hypermedia Systems for Blind Students. In D. Burger (Ed.) New Technologies in the Education of the Visually Handicapped, Vol 237, (pp. 223-227). Montrouge: Colloque INSERM/John Libbey Eurotext.

- Petrie, H., Morley, S., O'Neill, A-M., McNally, P., Lauder, R., Graziani, P., Palchetti, E. and Burzagli, L. (1997). Final Internal Report on Evaluation of the Demonstrator Hypermedia Application, On-Line Help and Training Module (M.3.5.2). London: ACCESS Consortium.
- Petrie, H., Morley, S. and Weber, G. (1995). Tactile-Based Direct Manipulation in GUIs for Blind Users. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'95. 428-429.
- Petrie, H., Morley, S., Weber, G. and Kochanek, D. (1995). Access to Graphical User Interfaces for Blind People: Appropriate Concepts and Techniques for Training. In Proceedings of the Annual International Conference on Technology and Persons with Disabilities, CSUN'95. Available from the Sensory Disabilities Research Unit.
- Petrie, H., Strothotte, T., Weber, G. and Deconinck, F. (1995). The Design and Evaluation of Rehabilitative Computer Technology for Blind People: The Need for a Multi-Disciplinary Approach. In E. Ballabio, I. Placencia-Porrero, and R. Puig de la Bellacasa (Eds.) Rehabilitation Technology: Strategies for the E.U. (pp. 220-224). Amsterdam: IOS Press.
- Pettitt, B., Sharpe, K. and Cooper, S. (1996). AUDETEL: Enhancing Television for Visually Impaired People. The British Journal of Visual Impairment, 14 (2), 48-52.
- Pikow, J.E. and Kehoe, C.M. (1996). Emerging Trends in the WWW User Population. Communications of the ACM, 39 (6), 106-108.
- Plextor Co. Ltd, Japan - <http://www.plextor.com/about.htm#JAPAN>
- Polson, P.G., Lewis, C., Rieman, J. and Wharton, C. (1992). Cognitive Walkthroughs: A Method for Theory-Based Evaluation of User Interfaces. International Journal of Man-Machine Studies, 36 (5), 741-773.
- Portigal, S. and Carey, T. (1994). Auralization of Document Structure. In Proceedings of the Second International Conference on Auditory Display, ICAD'92, 45-53.
- Preece, J. (Ed.) (1993a). A Guide to Usability: Human Factors in Computing. Wokingham: Addison-Wesley.
- Preece, J. (1993b). Hypermedia, Multimedia and Human Factors. In C. Latcham, J. Williamson and L. Henderson-Lancett (Eds.) Interactive Multimedia: Practice and Promise (pp. 135-150). London: Kogan Page.
- Pring, L. and Rusted, J. (1985). Pictures for the Blind: An Investigation of the Influence of Pictures on Recall of Text by Blind Children. British Journal of Developmental Psychology, 3, 41-45.
- Print Access Project (1993). An Investigation into Making Daily Newspapers Accessible to Print-Disabled People. Boston, MA: WGBH Educational Foundation.
- Productivity Works Web Site - <http://www.prodworks.com/>
- Project Gutenberg Home Page - <http://promo.net/pg/>

- Raffray, M. (1995). Audio Description - The First European Conference. New Beacon, 937, 10-13.
- Raman, T.V. (1994). Audio Systems for Technical Readings. Unpublished PhD Thesis, Cornell University, NY.
- Raman, T.V. (1996). Emacspeak - A Speech Interface. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'96. 66-71.
- Ramstein, C., Martial, O., Dufresne, A., Carignan, M., Chassé, P. and Mabilieu, P. (1996). Touching and Hearing GUI's: Design Issues for the PC-Access System. In Proceedings of the Second Annual ACM Conference on Assistive Technologies, ASSETS'96. 2-9.
- RCEVH Centre Software Catalogue (1996). Birmingham: The Research Centre for the Education of the Visually Handicapped.
- ReadOut Web Pages at the Open University - <http://met.open.ac.uk/readout/>
- Recording for the Blind and Dyslexic Web Site - <http://www.rfbd.org/>
- Redish, J.C. (1989). Reading to Learn to Do. IEEE Transactions on Professional Communication, 32 (4), 289-293.
- Reeves, T. (1993). Research Support for IMM: Existing Foundations and New Directions. In C. Latcham, J. Williamson and L. Henderson-Lancett (Eds.) Interactive Multimedia: Practice and Promise (pp. 79-97). London: Kogan Page.
- Resele, P. and Resele, W. (1994). NewsReader - A Comfortable Digital Newspaper and Bookreading System. In W.L. Zagler, G. Busby, and R.R. Wagner (Eds.) Computers for Handicapped Persons. Proceedings of ICCHP'94 (pp. 255-261). Berlin: Springer-Verlag.
- Rieman, J. (1996). A Field Study of Exploratory Learning Strategies. ACM Transactions on Computer-Human Interaction, 3 (3), 189-218.
- Rigas, D.I. and Alty, J.L. (1997). The Use of Music in a Graphical Interface for the Visually Impaired. In Proceedings of the IFIP Conference on Human-Computer Interaction, INTERACT'97, (pp 228-235). London: Chapman & Hall.
- Roesler, A.W. and McLellan, S.G. (1995). What Help do Users Need? Taxonomies for On-Line Information Needs & Access Methods. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'95. 437-441.
- Romiszowski, A.J. (1993). Developing Interactive Multimedia Courseware and Networks: Some Current Issues. In C. Latcham, J. Williamson and J. Henderson-Lancett (Eds.) Interactive Multimedia: Practice and Promise (pp. 57-79). London: Kogan Page.
- Rose, D. (1996). The Internet: Made for Blind People. New Beacon, 80 (944), 4-7.
- Rosenthal, R. (1967). Covert Communication in the Psychological Experiment. Psychological Bulletin, 67, 356-367.

- Rothberg, M. and Wlodkowski, T. (1998). Multimedia: Making it Accessible to Blind Users. In Proceedings of the Annual International Conference on Technology for Persons with Disabilities, CSUN'98.  
Online paper only at - [http://www.dinf.org/csun\\_98/csun98\\_047.htm](http://www.dinf.org/csun_98/csun98_047.htm)
- Rowley, D.E. and Rhoades, D.G. (1992). The Cognitive Jogthrough: A Fast-Paced User Interface Evaluation Procedure. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'92. 389-395.
- Rowley, J. and Slack, F. (1997). The Evaluation of Interface Design on CDROMS. Online & CDROM Review 21 (1), 3-14.
- Roy, D.K. and Schmandt, C. (1996). NewsComm: A Hand-Held Interface for Interactive Access to Structured Audio. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'96. 173-180.
- Sawhney, N., Balcom, D. and Smith, I. (1996). HyperCafe: Narrative and Aesthetic Properties of Hypervideo. In Proceedings of the Seventh ACM Conference on Hypertext, Hypertext'96. 1-10.
- Schuler, S. and Namioka, A. (Eds.) (1993). Participatory Design: Principles and Practices. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Senge, J.C. and Dote-Kwan, J. (1995). Information Accessibility in Alternative Formats in Postsecondary Education. Journal of Visual Impairment and Blindness, 89 (2), 120-128.
- Sevigny, R.J. and VanDyke Scourfield, J. (1997). The Disability Community in Brief: A Statistical Profile. Washington DC: National Council on Disability.
- Shackel, B. (1986). Ergonomics in Design for Usability. In M.D. Harrison and A.F. Monk (Eds.) People and Computers: Designing for Usability, Proceedings of the British Computer Society HCI Group Annual Conference, HCI'86, (pp. 44-64). Cambridge: Cambridge University Press.
- Shackel, B. (1991). Usability - Context, Framework, Definition, Design and Evaluation. In B. Shackel and S. Richardson (Eds.) Human Factors for Informatics Usability (pp. 21-37). Cambridge: Cambridge University Press.
- Shneiderman, B. (1992). Designing the User Interface: Strategies for Effective Human-Computer Interaction (2<sup>nd</sup> ed.). Reading, MA: Addison-Wesley.
- Shneiderman, B., Alavi, M., Norman, K. and Borkowski, E.Y. (1995). Windows of Opportunity in Electronic Classrooms. Communications of the ACM, 38 (11), 19-24.
- Shneiderman, B., Brethauer, D., Plaisant, C. and Potter, R. (1989). Evaluating Three Museum Installations of a Hypertext System. Journal of the American Society for Information Science, 40 (3), 172-182.
- Sikora, C.A. and Roberts, L.A. (1997). Defining a Family of Feedback Signals for Multimedia Communication Devices. In Proceedings of the IFIP Conference on Human-Computer Interaction, INTERACT'97 (pp. 373-380). London: Chapman & Hall.

- Snodgrass, J.G., Levy-Burger, G. and Haydon, M. (1985) Human Experimental Psychology. New York: Oxford University Press.
- Söderberg, A. (1996). Digital Textbooks: A Useful Aid for People with Disabilities. In D.Burger (Ed.) New Technologies in the Education of the Visually Handicapped. Vol 237 (pp. 229-234). Montrouge, France: Colloque INSERM/John Libbey Eurotext.
- Stephanidis, C., Savidis, A. & Akoumianakis, D. (1995). Tools for User Interfaces for All. In I. Placencia-Porrero and R. Puig de la Bellacasa (Eds.) The European Context for Assistive Technology (pp. 167-170). Amsterdam: IOS Press.
- Stevens, R.D. (1996) Principles for the Design of Auditory Interfaces to Present Complex Information to Blind People. Unpublished DPhil Thesis, University of York, UK.
- Stevens, R.D. and Edwards, A.D.N. (1996). An Approach to the Evaluation of Assistive Technology. In Proceedings of the Second Annual ACM Conference on Assistive Technologies, ASSETS'96. 64-71.
- Stevens, R.D., Edwards, A.D.N. & Harling, P.A. (1997). Access to Mathematics for Visually Disabled Students Through Multimodal Interaction. Human-Computer Interaction, 12 (1), 47-92.
- Stifelman, L.J., Arons, B., Schmandt, C. and Hulteen, E.A. (1993). VoiceNotes: A Speech Interface for a Hand-Held Voice Notetaker. In Proceedings of the ACM Conference on Human Factors in Computing Systems, InterChi'93. 179-186.
- SUMI website - <http://www.ucc.ie/hfrg/questionnaires/sumi/>
- Taylor, M.E. (1991). Talking Hypertext: An Alternative to Print for Visually Impaired Students. Report Number 157, November. Milton Keynes: Centre for Information Technology in Education.
- Texas Education Agency (1997). Accessibility of Information in Electronic Textbooks for Students Who Are Blind or Visually Impaired. Austin, TX: Texas Education Agency.
- Thatcher, J. (1993). The Problems and Challenges of the Graphical User Interface. Baltimore, MD: National Federation of the Blind.
- Thatcher, J. (1994). Screen Reader/2: Access to OS/2 and the Graphical User Interface. In Proceedings of the First Annual ACM Conference on Assistive Technologies, ASSETS'94. 39-47.
- Tisne, A., Oriola, B., Vigouroux, N. and Truillet, P. (1998). A Reading System for Digital Recorded Speech. In Proceedings of the Annual International Conference on Technology for Persons with Disabilities, CSUN'98.  
Online paper only at - [http://www.dinf.org/csun\\_98/csun98\\_094.htm](http://www.dinf.org/csun_98/csun98_094.htm)
- Tobin, M.J. (1993). The Educational Implications of Visual Impairment. In A.R. Fielder, A.B. Best and M.C.O. Bax (Eds.) The Management of Visual Impairment in Childhood (pp. 143-149). London: MacKeith Press.

- Tobin, M., Bozic, N., Douglas, G. and Greaney, J. (1996). How Non-Visual Modalities Can Help the Young Visually Impaired Child to Succeed in Visual and Other Tasks. The British Journal of Visual Impairment. 14(1), 11-17.
- TRACE Center Home Page - <http://www.trace.wisc.edu/>
- Trewin, S. (1996). A Study of Input Device Manipulation Difficulties. In Proceedings of the Second Annual ACM Conference on Assistive Technologies, ASSETS'96. 15-22.
- Trewin, S. and Pain, H. (1998). A Model of Keyboard Configuration Requirements. In Proceedings of the Third International ACM Conference on Assistive Technologies, ASSETS'98. 173-181.
- Truillet, P., Vigouroux, N. and Oriola, B. (1998). A Friendly Document Reader by Use of Multimodality. In Proceedings of the Annual International Conference on Technology for Persons with Disabilities, CSUN'98.  
Online paper only at - [http://www.dinf.org/csun\\_98/csun98\\_095.htm](http://www.dinf.org/csun_98/csun98_095.htm)
- U.S. Census Bureau (1997). Disability Statistics. Compiled by J. McNeil.  
On-Line at - <http://www.census.gov/population/www/pop-profile/disabil.html>
- U.S. Department of Education (1996). Getting America's Students Ready for the 21<sup>st</sup> Century: Meeting the Technology Literacy Challenge. Washington, D.C: US DoE.  
Online report at - <http://www.ed.gov/Technology/Plan/NatTechPlan/>
- Vanderheiden, G.C. (1989). NonVisual Alternative Display Techniques for Output from Graphics-Based Computers. Journal of Visual Impairment and Blindness, 83, 383-390.
- Vanderheiden, G.C. (1990). Thirty-Something Million: Should They Be Exceptions? Human Factors 32 (4), 383-396.
- Vanderheiden, G.C., Chisholm, W. and Ewers, N. (1996). Design of HTML Pages to Increase their Accessibility to Users with Disabilities: Strategies for Today and Tomorrow. ACM SIGLINK Newsletter, Special Issue on Hypermedia for People with Disabilities, V (1), 9-20.
- Van Someren, M.W., Barnard, Y.F. and Sandberg, J.A.C. (1994). The Think Aloud Method: A Practical Guide to Modelling Cognitive Processes. London: Academic Press.
- Vincent, T. (1994). Distance Teaching and Visually Impaired Students: An Electronic Environment for Learning. In N. Paine (Ed.) All Our Learning Futures: The Role of Technology in Education (pp. 155-167). Glasgow: SCET.
- Vincent, T. and Taylor, M. (1995). Access to Books for Visually Impaired Learners - An Investigation into the Use of Compact Disc Technology (CD-ROM). In N. Heap, R. Thomas, G. Einon, R. Mason and H. MacKay (Eds.) Information Technology and Society (pp. 224-236). London: Sage Publications Ltd.
- Virzi, R.A. (1992). Refining the Test Phase of Usability Evaluation: How Many Subjects is Enough? Human Factors, 34 (4), 457-468.

- Virzi, R.A., Sokolov, J.L. and Karis, D. (1996). Usability Problem Identification Using Both Low- and High-Fidelity Prototypes. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'96. 236-243.
- Visuaide Web Site - <http://www.visuaide.com/>
- Waddell, L. (Ed.) (1998). Access Technology: A Guide to Educational Technology Resources for Visually Impaired Users, 1998/99 Edition. London: Royal National Institute for the Blind.
- Walker, W., Tobin, M. and McKennell, A. (1992). Blind and Partially Sighted Children in Britain: the RNIB Survey, Vol 2. London: HMSO.
- Warren, D. (1978). Perception by the Blind. In E.C. Carterette and M.P. Friedman (Eds.) Handbook of Perception, Vol X. Perceptual Ecology (pp. 65-90). New York: Academic Press.
- Web Accessibility Initiative Home Page - <http://www.w3.org/WAI/>
- Weber, G., Petrie, H., Kochanek, D. and Morley, S. (1994). Training Blind People in the Use of Graphical User Interfaces. In W.L. Zagler, G. Busby, and R.R. Wagner (Eds.) Computers for Handicapped Persons, Proceedings of ICCHP'94, (pp. 25-31). Berlin: Springer-Verlag.
- Weber, G., Petrie, H. & Morley, S. (1994). Input Devices for Blind Users. In Ancillary Proceedings of the British Computer Society HCI Group Annual Conference, HCI'94, (no page numbers included).
- Whiteside, J., Bennett, J. and Hotzblatt, K. (1988). Usability Engineering: Our Experience and Evolution. In M. Helander (Ed.) Handbook of Human-Computer Interaction (pp. 791-817). Amsterdam: Elsevier Science.
- Whittaker, S., Hyland, P. and Wiley, M. (1994). Filochat: Handwritten Notes Provide Access to Recorded Conversations. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'94. 271-277.
- Widenbeck, S., Zila, P.L. and McConnell, D.S. (1995). End-User Training: An Empirical Study Comparing On-Line Practice Methods. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'95. 74-81.
- Wild, G. and Hinton, R. (1996). An Evaluated Study of the Use of Tactile Diagrams on Open University Science Courses. The British Journal of Visual Impairment, 14 (1), 5-9.
- Wilson, J. and Rosenberg, D. (1988). Rapid Prototyping for User Interface Design. In M. Helander (Ed.) Handbook of Human-Computer Interaction (pp. 859-875). Amsterdam: Elsevier Science.
- Wolffe, K. (1998). Preparing People with Visual Impairments for Work. Journal of Visual Impairment and Blindness News Service, 92 (2), 110-113.
- Wood, L.E. (1997). Semi-Structured Interviewing for User-Centered Design. Interactions IV (2), 48-61.

- Woodhead, N. (1991). Hypertext & Hypermedia: Theory and Applications. Wokingham, England: Addison-Wesley.
- WHO: World Health Organisation. (1980). International Classification of Impairments, Disabilities and Handicaps: A Manual of Classification Relating to the Consequences of Diseases. Geneva: WHO.
- WHO: World Health Organisation (1997). Press Office Factsheet, No 142, Feb 1997.
- World Wide Web Consortium (W3C) Home Page - <http://www.w3.org/>
- Wright, P. (1990). Hypertexts as an Interface for Learners: Some Human Factors Issues. In D.H. Jonassen and H. Mandl (Eds.) Designing Hypermedia for Learning (pp.169-184). Berlin: Springer-Verlag.
- Wright, P. (1991). Cognitive Overheads and Prostheses: Some Issues in Evaluating Hypertexts. In Proceedings of The ACM Conference on Hypertext, Hypertext'91. 1-12.
- Wright, P. and Likorish, A. (1990). An Empirical Comparison of Two Navigation Systems for Two Hypertexts. In R. McAleese and C. Green (Eds.) Hypertext: State of the Art. (pp. 84-93). Oxford: Intellect Ltd.
- Wright, P.C. and Monk, A.F. (1989). Evaluation for Design. In A. Sutcliffe and L. Macaulay (Eds.) People and Computers V, Proceedings of the British Computer Society HCI Group Annual Conference HCI'89, (pp. 345-358). Cambridge: Cambridge University Press.
- Wright, P.C. and Monk, A.F. (1991). A Cost-Effective Evaluation Method for Use by Designers. International Journal of Man-Machine Studies, 35 (6), 891-912.
- Yankelovich, N., Levow, G-A. and Marx, M. (1995). Designing SpeechActs: Issues in Speech User Interfaces. In Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI'95. 369-376.
- Zajicek, M., Powell, C. and Reeves, C. (1998). A Web Navigation Tool for the Blind. In Proceedings of the Third International ACM Conference on Assistive Technologies, ASSETS'98. 204-206.
- Zajicek, M., Powell, C., Reeves, C. and Griffiths, J. (1998). Web Browsing for the Visually Impaired. In A.D.N. Edwards, A. Arató, and W. Zagler (Eds.). Computers and Assistive Technology, Proceedings of ICCHP'98, (pp. 161-169). Vienna: Austrian Computer Society.

## Appendices

**1.1 DAHNI-1: Participant Characteristics Questionnaire**

Participant number: \_\_\_\_\_

Date: \_\_\_\_\_

What is your level of vision? \_\_\_\_\_

How long have you been blind/partially sighted? \_\_\_\_\_

1) age: \_\_\_\_\_

2) sex: M/F

3) courses: \_\_\_\_\_

4) Do you read Braille? Y/N

5) For how long? \_\_\_\_\_

6) Have you used an electronic Braille display? Y/N

7) Are you a touch-typist? Y/N

8) For how long? \_\_\_\_\_

9) Activities on computer: \_\_\_\_\_

10) What software are you using for these tasks? \_\_\_\_\_

11) What screenreaders do you use? \_\_\_\_\_

12) Output: (speech synth or Braille, and makes): \_\_\_\_\_

13) What devices have you used for input? (eg joystick, touchtablet, voice) (and how long?)  
\_\_\_\_\_

14) Experience with Windows? Yes / only heard of / No experience

15) What did you use to access it? \_\_\_\_\_

16) Experience with Internet? Yes / only heard of / No experience

17) What did you use to access it? \_\_\_\_\_

18) Experience with CD-ROMS? Yes / only heard of / No experience

19) What did you use to access it? \_\_\_\_\_

## 1.2 DAHNI-1: Evaluation Tasks

Now you are familiar with all of the input devices we would like to take them one at a time and see how you get along with each. We would also like to see if anything about the hypermedia system itself is easy or hard to understand, so please feel free to make any comments as you progress through.

<b>Task 1.</b>	<b>Commands Required</b>
Let's see if we are at home	<b>HOME</b>
In this node, is a reference to the Queen. Please select this link to the Queen.	<b>SP&gt;&gt; (Speak Right) SELECT</b>
Now we're in the Queen node. Continue reading and when you hear the link to Westminster Abbey, please select it.	<b>SP&gt;&gt; SELECT</b>
Now we're in the Abbey node. Would you read through the units in this node.	<b>SP&gt;&gt; SP&gt;&gt;</b>
Q: What was the last link? Q: What year does the chair date from?	<b>REPEAT or &lt;&lt;SP (Speak Left) REPEAT or &lt;&lt;SP</b>
We're now interested in hearing more from the Queen node that we just heard. Can you go back to this node please?	<b>BACK or HOME</b>
Read the node until you hear the link to the City of London and select it.	<b>SP&gt;&gt;, SP&gt;&gt;, SELECT</b>
Q: What are the main industries in the City?	<b>REPEAT</b>
Could you take us right back to the beginning?	<b>HOME</b>
<b>Task 2.</b>	<b>Commands Required</b>
Let's check we are at home.	<b>HOME</b>
In this node is a link to the Houses of Parliament. Read through and select it.	<b>SP&gt;&gt; SP&gt;&gt; SELECT</b>
Now we are in the Houses of Parliament node please read through the first two units and tell me the links.	<b>SP&gt;&gt; SP&gt;&gt;</b>
Go to the first unit of this node and select the link to the chimes of Big Ben.	<b>&lt;&lt;SP SELECT</b>
Let's hear the chimes of Big Ben. We are going to leave the Big Ben node now and go back to the previous node. [ <i>back to HoP</i> ]	<b>SP&gt;&gt; BACK</b>

Skim through the node because we have already heard the first two units, until you reach the third unit and select the link to the Tower of London. <i>[may have to tell S how to skim]</i>	<b>SP&gt;&gt;</b> <b>SP&gt;&gt;</b> <b>SP&gt;&gt;</b> <b>SELECT</b>
Can you read through the Tower node.	<b>SP&gt;&gt;</b>
Q: How many Ravens live in the Tower? Q: What was the link?	<b>REPEAT</b> or <b>TOP</b> or <b>SP&gt;&gt;</b>
Select the Beefeater link and hear that node.	<b>SELECT, SP&gt;&gt;</b>
Let's go home now.	<b>HOME</b>
<b>Task 3</b>	<b>Commands Required</b>
Let's check we are at Home.	<b>HOME</b>
In this node there's a link to the City of London in the third unit, please read through and select it. You may skim past the first two units.	<b>SP&gt;&gt;</b> <b>SP&gt;&gt;</b> <b>SP&gt;&gt;</b> <b>SELECT</b>
Let's hear the City of London node.	<b>SP&gt;&gt;</b>
Try and see if there are any more units in this node. <i>[dead-end sound]</i>	<b>SP&gt;&gt;</b>
You can only go back to the previous node. <i>[If S chooses Home instead, ask why]</i>	<b>BACK</b>
We are back in the Home node can you read through until you come to the Houses of Parliament, and select it?	<b>SP&gt;&gt;</b> <b>SP&gt;&gt;</b> <b>SELECT</b>
Can you read through and select the link to the Queen.	<b>SP&gt;&gt;</b> <b>SP&gt;&gt;, SELECT</b>
Q: What month was the Queen born? Q: What was the link?	<b>REPEAT</b> or <b>SP&lt;&lt; then SP&gt;&gt;</b>
Follow the link to the Abbey.	<b>SELECT, SP&gt;&gt;</b>
Read through the first unit. Q: What was the link? We've already been here, so we won't follow it but can you confirm the heading of this node.	<b>SP&gt;&gt;</b>  <b>TOP</b> or <b>&lt;&lt;SP</b>
Let's go back Home.	<b>HOME</b>

**1.3 DAHNI-1: Evaluation Questionnaire**

**Include comments throughout, by each question.**

	Low	High
<b><u>Overall impression of the system</u></b>		
(Think of general use, not of specific devices.)		
1) How easy is this system to use?	1	2 3 4 5
2) How easy was it to learn?	1	2 3 4 5
3) How interesting and enjoyable was this system to use?	1	2 3 4 5
4) How useful was the layout of commands on the workspace?	1	2 3 4 5
5) How easy was it to identify the links, (in their change of voice)?	1	2 3 4 5
6) Could you rate these as other methods of identifying links?		
a) beep before the word	1	2 3 4 5
b) beep both before and after the word	1	2 3 4 5
c) a tone played while the word is spoken	1	2 3 4 5
d) Can you think of any other ways of identifying a link?		
7) Rate how important it is to know which type of node a link goes to (eg text, audio, picture)	1	2 3 4 5
8) How useful was the dead-end sound, which told you that you could not go any further?	1	2 3 4 5
9) How much did you like the sound itself?	1	2 3 4 5
10) What other sounds might you prefer?		
11) How easy did you find it to listen to all the information in only one voice (except the one digitised node)	1	2 3 4 5
11a) Rate the speed of the speech output.	1	2 3 4 5
12) How important would you rate having a different voice to read the commands, (different from the nodes)?	1	2 3 4 5

- 13) How easy did you find it to listen to the digitised node?  
(eg: Memorability, entertainment, broke the monotony, more pleasant.) 1 2 3 4 5
- 14) How useful would you rate the use of sound effects in the system? 1 2 3 4 5
- 15) How useful would you rate the use of the tactile picture? 1 2 3 4 5
- 16) How would you rate the quality of the tactile picture?  
(eg too detailed, too small...) 1 2 3 4 5
- 17) How much did the description of the picture enable you to 'see' the Beefeater?  
(eg too detailed, not enough detail) 1 2 3 4 5

**Input Devices.**

***Joystick***

- 1) How easy was it to learn how to use the JS? 1 2 3 4 5
- 2) How easy was it to read in the system using JS? 1 2 3 4 5
- 3) How easy was it for you to follow links using JS? 1 2 3 4 5
- 4) How easy was it to find the commands with JS? 1 2 3 4 5
- 5) How easy was it to select commands using the Thumb button? 1 2 3 4 5

***Keyboard***

- 1) How easy was it to learn how to use the KB? 1 2 3 4 5
- 2) How easy was it to read using KB? 1 2 3 4 5
- 3) How easy was it for you to follow links using KB? 1 2 3 4 5
- 4) How easy was it to find the commands using KB? 1 2 3 4 5
- 5) How easy was it to select commands using <Enter>? If not, what would you prefer? 1 2 3 4 5
- 6) What do you think of having shortcut keys?
- 7) What do you think about having the spacebar to return you to centrepoin when moving around the commands on the workspace?

**Touchtablet**

- |  |           |
|--|-----------|
| 1) How easy was it to learn how to use the TT?                     | 1 2 3 4 5 |
| 2) How easy was it to read in the system using TT?                 | 1 2 3 4 5 |
| 3) How easy was it for you to follow links using TT?               | 1 2 3 4 5 |
| 4) How easy was it to find the commands on the workspace using TT? | 1 2 3 4 5 |
| 5) How easy was selecting commands? (double clicks)                | 1 2 3 4 5 |
| 6) How important was it to have both single and double clicking?   | 1 2 3 4 5 |
| 7) What alternative would you prefer?                              |           |
| 8) How useful would you rate the different overlays?               |           |
| a) large, with Braille text  | 1 2 3 4 5 |
| b) small with Braille initials                                     | 1 2 3 4 5 |
| c) small with symbols  | 1 2 3 4 5 |
| d) large with symbols  | 1 2 3 4 5 |
| 9) What is your order of preference of the three input devices?    |           |

## 1.4 DAHNI-2: Content of The London Hypermedia Module

---

### TEXT NODES

---

#### <heading> A Tour Around London - Past and Present (HOME NODE)

<para 1> London was originally called, Londinium, when it was created by the Romans. It became a city on the North bank of the \LINK{<**Thames**>,<Thames:1:(1,25)>}, built around two hills, Cornhill, and Ludhill. It was a natural port, since it was the most convenient gateway to the continent. It was also good for keeping a firm grasp, on the Southern half of England.

<para 2> The roads built by the Romans, soon radiated out from Londinium, and straddled the country. Perhaps as early as one hundred AD, the engineering of the Great Roman Wall of London, began. A wooden bridge was built across the Thames, and for hundreds of years, this was the only bridge London possessed. To this day, we are still reminded of the Roman influence, since part of the wall, still stands in the small area known as the \LINK{<**City**>,<col:1:(1,29)>} of London.

<para 3> The Romans left Britain, in four hundred and ten, AD, to be succeeded by the Saxons, followed by the Danes. Then the Normans arrived, who started building \LINK{<**Westminster**>,<West-abbey:1:(1,28)>} Abbey, in the Norman style even before they had won the Norman conquest, in 1066.

<para 4> Edward the Confessor, was King between, 1042 and 1066, and made London the official capital of England. Since that time, London has been the home of the Royal Family, and also of British politics in the \LINK{<**Houses**>,<houses:1:(1,35)>} of Parliament.

<para 5> A famous landmark in London, is Buckingham Palace, which is the main home of the \LINK{<**Queen**>,<Queen:1:(1,20)>}.

<para 6> London is not all about Royalty, and historical landmarks. London also has a wealth of theatres, museums, galleries and concert halls for those interested in \LINK{<**cultural**>,<Cultacts:1:(1,40)>} activities. In addition, London houses some of the most famous shops in the world, for example Harrods, and famous markets, such as Portabello Road, and Camden markets.

---

#### <heading> Changing The Guard.

<para 1> Since 1660, the Household Division, has protected the sovereign. Today, public guard duties happen in four places around London. The changing of the guard, at Buckingham Palace, is a very popular \LINK{<**ceremony**>,<CG-pic:1>} for tourists to watch. At 11am, the old guard march up The Mall, to Buckingham Palace, where they are relieved by the new guard .

<para 2> As the guard is changed, the wind \LINK{<**band**>,<Band-cg:2>} plays marches, for around half an hour. Then the palace keys, are symbolically handed over to the new guard, by the captain.

---

---

## <heading> The City of London.

<para 1> The City of London, was devastated by The \LINK{<Great >,<great-fire:3>} Fire of London, and by the bombing of the blitz, in World War two.

<para 2> Surprisingly, however, plenty of the City's oldest traditions, and buildings survived. For example, \LINK{<Saint>,<Paul:1:(1,30)>} Paul's Cathedral, miraculously escaped damage, on both occasions.

<para 3> The City has always been the centre of commerce, since the tradesmen set up their institutions, and guilds, which still reside there today. Today, the City of London is a concentrated area of business and finance, and is one of the main centres of \LINK{<trading >,<AudCoL:2>} in the world.

---

## <heading> Concert Halls in London.

<para 1> The London Symphony orchestra, is in residence at the Barbican, although other top orchestras, including the Royal Philharmonic, also perform there. For the chance to take part in a great British tradition, visit the Royal Albert Hall, during the summer Promenade Concert Season, famous for the last night of the \LINK{<Proms>,<proms:3>}.

<para 2> The main venue for opera in London, is the Royal Opera House, in Covent Garden, where beautiful ballets are performed, by the world-famous, Royal \LINK{<Ballet>,<Audio-Beauty:2>}

<para 3> Visitors are also offered many opportunities, to see live performances, by famous rock, and pop bands. Earl's Court recently hosted the largest ever indoor gig, when \LINK{<Oasis>,<Oasis:2>} played there.

---

## <heading> Cultural Activities in London.

<para 1> London is famous for its diversity of cultural activities, including \LINK {<theatres>,<Theatres:1:(1,17)>}. With so many theatres, we are offered a wide range of plays, shows and comedy.

<para 2> London has many large \LINK{< galleries>,<Galleries:1:(1,652)>}, which house famous art works, and often hold special exhibitions. London also has many museums, ranging from the large ones, such as the Natural History and Science museums, and small ones, such as the Freud museum.

<para 3> There is also a tremendous diversity, of musical entertainment available in London, with performances of every sort, in the \LINK{<Concert >,<Conhalls:1:(1,34)>} Halls.

<para 4> Traditional cockney music hall songs still survive, due to the vibrant characters called pearley kings and queens. These people are true \LINK{<cockneys >,<Aud-cockney:1>} because they are born in an area of London, within the sound of Bow bells.

---

## <heading> London's Galleries

<para 1> London houses some of the most prestigious art galleries, in the world, including the National Gallery. This resides, on the North side of Trafalgar Square, and was founded, in 1824. It holds well over 2000 paintings, including those of Cezanne, and, \LINK{< Leonardo>,<vinc-pic:1>} da Vinci.

<para 2> The famous works of Constable, and \LINK{<Goya, >,<Goy-pic:1>} are also on display at the National Gallery.

<para 3>The Tate Gallery, opened in, 1897, and is one of the most important galleries, in London, housing two national collections in one: British art from the 16th century to around 1900, and international modern art from the Impressionists. The gallery has the fortune to house the Turner collection, and other famous artists including Van Gogh, Picasso, and \LINK{<Monet>,<Monet-pic:1>}.  
-----

### <heading> The Houses of Parliament.

<para 1> This gothic \LINK{<building >,<picture-houses:1>} of pinnacles and towers, is a wonderful example of British architecture. The Houses of Parliament, are the seat of British government, and consist of, the House of Commons, and the House of Lords. In the month of October, the Queen officially opens the new parliamentary year, in a ceremony called, the State Opening of Parliament.

<para 2> At one end of of the Houses of Parliament, stands the clock tower, affectionately known as Big Ben. This is in fact, the name of the 13 tonne Bell, inside the tower. The clock went into operation, in 1859, and before the increase in motor cars in London, the \LINK{<chimes >,<audio-big-ben:2>} of Big Ben, could be heard across London. It was sounded during the war, to indicate that England was still free.

<para 3> The most famous plot, against the government and monarchy, is that of Guy Fawkes, and his six Catholic conspirators. They were caught, planning to blow up James the first, and both Houses, on November 5th, 1605. This day is still commemorated, with fireworks, & by the burning of a Guy Fawkes effigy on bonfires. The story has been immortalised, in a children's \LINK{<rhyme >,<AudGuy :1>}.  
-----

### <heading> St. Paul's Cathedral.

<para 1> The cathedral we can visit today, was the fifth cathedral, built on the same site, dedicated to London's patron saint. It was designed and built, by the architect, Sir Christopher Wren, who lived from, 1632 until 1723. It still greatly enhances the city skyline. Wren began restoration work, on the Old St. Paul's, but sadly, only ten days later, his work turned to dust, due to the \LINK{<Great >,<great-fire:3>} Fire of London. Then, Wren transformed his ideas, to a grand scale.

<para 2> Visitors can now climb up, 259 spiral steps, to the famous dome, where the Whispering Gallery, is situated. Due to the spectacular acoustic structure, of the dome, a whisper on one side of the huge circular wall, is carried a second later, to the other side, 107 feet away. Of course, identifying your whisper, from the multitude of everyone else's, can be difficult.

<para 3> St Paul's is well-loved, because it is a church for all Londoners, as opposed to the royal role, that \LINK{<Westminster >,<West-abbey:1:(1,28)>} Abbey, tends to hold. However, St. Paul's did hold the services, for the Queen's Silver Jubilee, in 1977, and the Royal marriage, of Prince Charles and Lady Diana Spencer, in 1981.  
-----

### <heading> Poet's Corner.

<para 1> In one corner in Westminster Abbey, many famous people have been honoured, for their contribution to English society, not just poets. Some of the famous poets, that have been

buried here, include, Chaucer, and Dryden. Other poets that have memorials dedicated to them, include, Wordsworth, \LINK{<**Shakespeare**, >,<Aud-hamlet:2>}, Austen, Eliot, and Shelley, among others. Some famous scientists have memorials here. Sir Isaac Newton, James Watt, and Michael Faraday, are among these scientists. There is only one painter remembered here, a Godfrey Kneller, whose dying words were, By God, I will not be buried in Westminster. And he wasn't.

---

<heading> **The Queen.**

<para 1> Queen Elizabeth the second, was born on April 21st, 1926, and she married Phillip Mountbatten, on November 20th, 1947, at Westminster Abbey. In 1952, she succeeded the throne, from George the sixth, and was \LINK{<**crowned** >,<Aud-coron:2>} Queen.

<para 2> Her interests include, horse racing, and dogs. The Queen's jockey, wears her racing colours, purple with gold braid, and scarlet sleeves, with a black velvet cap, with gold fringe. The Queen's Labradors, live at Sandringham, while her five Corgis, often travel with her. She also has three, Dorgis, the result of breeding her Corgis, with Princess Margaret's Dachshunds.

<para 3> The Queen and her family, provide a continual calendar of Royal \LINK{<**events** >,<Royal-events:1:(1,23)>} in the forms of ceremony, formal display, and often, glittering glamour.

<para 4> One of the Queen's official duties includes the \LINK{<**State** >,<State-open:1:(1,38)>} Opening of Parliament.

---

<heading> **Royal Events.**

<para 1> The changing of the Queen's house-guards, is one of the traditions from the days of sovereign protection. This duty is called the \LINK{<**changing** >,<Chngeguard:1:(1,29)>} of the guard.

<para 2> On major royal birthdays, there is a gun salute, and on the Queen's official birthday, which is not her real birthday, we witness the \LINK{<**Trooping**>,<Trooping:1:(1,28)>} of the colour.

<para 3> Members of the Royal family, often attend gala charity events, which might include, cinema screenings, variety performances, concerts, and \LINK{<**ballet** >,<Audio-Beauty:2>} performances.

<para 4> Another tradition still maintained, isThe Ceremony of Keys, at the Tower of London. In this ceremony, as every night, for 7 hundred years, the gates of the Sovereign's fortress have been solemnly locked. Despite the fact that, the Queen does not live at the \LINK{<**Tower** >,<Twer:1:(1,30)>} of London, the tradition lives on.

---

<heading> **State Opening of Parliament.**

<para 1> This marks the start of the new parliamentary year. At 11am, the Queen, processes along, The Mall, towards the \LINK{<**Houses** >,<houses:1:(1,35)>}of Parliament. She continues in procession, to the Throne, in the Lord's Chamber and, after the ceremony of summoning the Commons, she reads the Queen's speech, outlining the government's programme, for the coming session.

---

---

### <heading> The River Thames.

<para 1> The growth of London flourished, because it was strategically situated, on the River Thames, which is the major entry point from the sea. Ports grew up along the Thames, taking \LINK{<imports >,<imports:2>}, from all around the world. Ships set off to trade, explore, fight, and to govern. Nowadays, many of the docks have been converted, into offices and housing developments, and although the river is still used, for some commercial transport, river cruises and ferries are a common sight.

<para 2> Famous bridges, over the Thames include, London Bridge, which was London's first stone bridge. It was built in 1176, and stood for 600 years. The heads of traitors were displayed here when they removed from The \LINK{<Tower>,<Twer:1:(1,31)>} of London.

---

### <heading> Theatres in London.

<para 1> Of the, one hundred or so, legitimate theatres in the capital, half are officially, West End, while the remainder go under the blanket title of, fringe. The Royal \LINK{<Shakespeare >,<Aud-hamlet:2>} Company, and the Royal National Theatre Company, perform at London's two main arts complexes, the Barbican Centre, and the Royal National Theatre.

<para 2> London also hosts daily performances of musicals, and the hit-musical \LINK{<Cats>,<Audio-Cats:2>}, by Andrew Lloyd Webber, is the longest-running musical in the world.

---

### <heading> Trooping The Colour.

<para 1> Trooping the Colour, originates from the need to show the regimental colour, flag, to the army, so that they would recognise it, on the battlefield. Now, it is a tradition we witness, on the Queen's official birthday, in June. The Queen, assumes the role of both sovereign, and Colonel-in-Chief of the seven regiments, of the Household Division.

<para 2> At 11am, she arrives in a carriage procession, at Horseguard's Parade, where the birthday parade is performed. Then she returns to Buckingham palace, where she appears on the balcony, with other members of the Royal family, for the R.A.F. fly past, at 1pm.

---

### <heading> The Tower of London.

<para 1> The building of the Tower of London was started by William the first, the Conqueror, who was King from, 1066 until 1087. The Tower was completed, by Edward the first, who was King from, 1272 until 1307. The Tower was designed for the protection of the \LINK{<Monarch >,<Queen:1:(1,20)>} and the protection of the docks, which held the country's main source of wealth. It also had the double role of being both a palace and a prison.

<para 2> Henry the Eighth, was the last monarch to live at the Tower, and now it merely houses the Crown Jewels, which are guarded by the, 42 Yeomen, better known as \LINK{<Beefeaters >,<Beefpic:2>}. Beefeaters, are ex-servicemen, and have been guarding the Tower, since Henry the seventh, appointed them, in 1485. One of their duties, is to make life comfortable for the eight ravens, who live in the Tower. This is an important duty, since legend has it, that if the ravens desert the Tower, the kingdom will fall.

---

### <heading> Westminster Abbey.

<para 1> Westminster Abbey is at the core of British history. The Normans started to build it even before they conquered England, at the Norman conquest, of 1066. The Abbey is full of

spectacular medieval architecture, and monuments. Nearly all of Britain's monarchs, including the present \LINK{<Queen, >,<Queen:1:(1,20)>} have been crowned, married, and buried here.

<para 2> The Abbey is still a place of worship, and offers the public a glimpse of the Abbey, in its full majesty, accompanied by singing from the \LINK{<choristers, >,<Audchoir:2>}, and organ music, from the organ that Henry Purcell once played.

<para 3> Behind the alter stands the \LINK{<Coronation >,<Aud-coron:2>}, chair, dating from 1300, and encases the Stone of Skoon. Originally from Scotland, Edward the first brought it to England, and the stone has been returned to Scotland in recent months.

<para 4> Other interesting pieces of British history, can seen around the Abbey. For instance, the Tomb of the Unknown Warrior, the Rose Window, the Chapel of Edward the Confessor, and \LINK{<Poets >,<PCorner:1:(1,24)>} Corner.

<para 5> Opposite Westminster Abbey are the, \LINK{<Houses >,<houses:1:(1,35)>} of Parliament. These are on the south side of Parliament Square.

---

## PICTURE NODES

---

<heading> **A picture of a Beefeater.**

<desc> This picture shows a Beefeater, who is standing proudly, and is facing towards the camera. He is a mature man, about sixty years old, and has a full grey beard, and moustache. The Beefeater is dressed in the traditional uniform, of a resplendent navy and red, Tudor outfit. This consists of a hat, which is about 15 centimetres high, and the sides of the hat go out, so that the top of the hat, is a little wider than the base of the hat, where it meets the larger round rim. On the front of the Beefeater's hat, there is a navy rosette, with red edging. The Beefeater wears a navy tunic, with red braid trimming, and has two silver buttons, on his left shoulder. On the front of the tunic, is a red Crown, and beneath this, is E2R, both symbolising the Beefeater's loyalty, to Her Majesty the Queen. Around the middle of his tunic, is a belt which has a large silver buckle. The Beefeater holds this belt with his right hand. Finally, the Beefeater wears thick navy leather gloves, for the purpose of handling the Royal ravens, if necessary.

<heading> **A photograph of the changing of the guard, at Buckingham Palace.**

<desc> This photograph shows the daily changing of the Foot Guard, at Buckingham Palace. In the centre of the photo, are two troops of Guards, marching through the gates and playing brass instruments. The guards are all dressed in the distinctive Foot Guard livery, of red jackets, with a white belt, and black trousers. They are all wearing the famous black busby, a large tall cylindrical hat, originally made of black bearskin. The large stone gateposts to the Palace, are decorated on the sides, with a stone crown, and the Royal crest, and the black iron gates are decorated with gold.

<heading> **A painting, called The Duke of Wellington, by Goya.**

<desc> This painting, shows the upper body, of the Duke of Wellington, in full military dress. He is in his forties, and has short brown hair, and is clean shaven. He wears a scarlet red jacket, decorated with gold braid and buttons. Underneath his jacket, is a high-necked white shirt. He

wears several medals around his neck, and has two ornate badges pinned to his chest. He wears a red sash, which rests on his right shoulder and falls across his chest, down to his left hip.

---

**<heading> A painting, entitled, The Virgin and child, by Da Vinci.**

**<desc>** This is a painting, of the Virgin Mary with the baby Jesus, and Saint Anne with her young 3 year old son, John the Baptist. Mary is in the centre of the picture, with Saint Anne sitting behind her, looking over Mary's shoulder. Mary is holding the baby Jesus, who reaches out for the young John the Baptist, who is standing next to his mother.

---

**<heading> A Photograph of the houses of Parliament.**

**<desc>** This is a photograph, of the Houses of Parliament, and Westminster Bridge, taken from across the River Thames. In the foreground of the photograph, the river is busy, with several passenger boats, ferrying tourists and commuters, along the river. The Victoria Tower, is on the left-hand side of the picture, and the tower housing the bell Big Ben, is on the right-hand side. The building is ornate, with hundreds of pinnacles, and spires. The stone is dark grey with pollution, and this photo was taken before the building was recently restored, to its former dark golden colour. There are four large clock faces, one on each side of the tower.

---

**<heading> An Impressionist painting by Monet.**

**<desc>** This is a painting, in the impressionist style, using short brush strokes. It shows four ladies in large crinoline dresses, and bonnets, in pale yellow and cream. They are outside, in the dappled sunlight, under trees, on a warm summer afternoon. The lady at the front of the picture is sitting under a tree, holding a bunch of flowers on her lap. Another lady is holding onto a branch on the tree, and is gently running around the tree. The other two ladies are watching the activity.

---

## MUSIC NODES

---

**<heading> Audio clip of a church choir.**

Westminster Abbey choir, Lift up Thine Eyes.

**<heading> Children singing the Guy Fawkes Rhyme:**

Remember the 5th of November..

**<heading> Audio clip of The Waltz, from Tchaikovsky's The Sleeping Beauty.**

**<heading> Audio clip of big ben chiming:.**  
noon chimes.

**<heading> Audio clip of MacCavity from Cats.**

**<heading> An Audio clip of the band music played at changing of the guard.**

**<heading> Audio clip of Oasis playing, Don't Look Back in Anger.**

**<heading> An audio clip from the last night of the proms.**

---

**DIGITISED AUDIO NODES**

---

**<heading> The Great Fire of London,**  
with fire crackling and bell tolling

**<heading> Audio clip about the history of  
trading in London,** with office sounds

**<heading> An audio clip about imports into  
London,** with water babbling sounds

**<heading> An Audio clip about the coronation,**  
with happy bells ringing and crowd cheering

**<heading> Audio clip of a cockney Londoner.**  
Talking about music halls etc

**<heading> An audio clip from Shakespeare's play, Hamlet:**  
Richard Burton, To Be or Not To Be speech

### 1.5 DAHNI-2: Participant Characteristics Questionnaire

1. Participant Number: \_\_\_\_\_

2. Gender: M / F (please ring)

3. Age: \_\_\_\_\_

4. Level of Vision: Partially Sighted / Blind (please ring)

5. "How many years have you used a computer?" \_\_\_\_\_ (please fill in)

6. "Of the following activities, which do you use your computer for?"  
(Please tick those undertaken)

"word processing: \_\_\_\_\_  
spreadsheets: \_\_\_\_\_  
email: \_\_\_\_\_  
WWW: \_\_\_\_\_  
CD-ROMS:" \_\_\_\_\_

7. "In the last 6 months, how often have you used the WWW?" (Please ring )

never / 10-20 times / 20-50 times / over 50 times

8. "In the last 6 months, how often have you used CD-ROMS?" (Please ring)

never / 10-20 times / 20-50 times / over 50 times

9. "What software have you used to access the WWW / CD-ROMS?"

10. "What problems have you found with using the WWW / CD-ROMS?"

11. "Of the following input and output devices for a computer, which have you used before, and how often?" (Please ring)

**Input:**

**Keyboard:** never / not very often / quite often / all the time

**Joystick:** never / not very often / quite often / all the time

**Touchtablet:** never / not very often / quite often / all the time

**Output:**

**Speech:** never / not very often / quite often / all the time

**Braille:** never / not very often / quite often / all the time

12. "Do you have any problems with using any of these devices?"

## 1.6 DAHNI-2: Evaluation Tasks

**Tasks A and B. Instructions:** "Now, we are going to try and find some interesting pieces of information in the hypermedia".

### **Task A: Guided Task with KB / JS**

1. Make sure that you are at Home(*time stamp*)

2. *Home.*

Read into the second unit.

Q: Approximately what year did the Romans start building the Great Roman Wall of London?  
(*answer=100AD*)

Select the link to the City of London.

3. *City of London*

In the City of London node there is a link to the Great Fire of London.

Can you select it please?

4. *Great Fire of London.*

Listen to the audio clip and listen for how many wooden houses were burnt during the fire.

(*answer=13,000*)

5. Now, I want you to go to completely different area of the hypermedia. What do you think is the best thing to do? (*commands=Home or Back*)

Can you do this please?

6. *Home*

From this node, go off to cultural activities to find out about the art galleries in London.

7. *Cultural Activities to Galleries.*

In the Tate gallery is a picture by Monet, can you go and listen to the description of one of his pictures?

8. Can you return to the cultural activities node because now we are going to hear what is on in the concert halls.(*commands=Back, Back*)

9. *Cultural Activities*

The Last Night of the Proms are held in one of London's concert halls, can you take us there?

10. *Concert Halls*

Can find out what sort of songs are sung at the Last Night of the Proms?

11. Can you listen to the audio clip?

12. Press control H for Home. (*time stamp*) *End of task*

### **Task B: Free Task**

Let's go home. *Home stamp*

What was your most favourite node? Why?

Can you take us there? *Home stamp*

**1.7 DAHNI-2: Evaluation Questionnaire & Separate Investigations**  
**Include comments throughout.**

**Tutorial**

- |  |           |
|--|-----------|
| 1. Did you use the tutorial again during the last week?<br>Why?          | Y/N       |
| 2. Why did you use the tutorial rather than the help system? (if approp) |           |
| 3. Can you rate how useful do you think the Tutorial is for new users?   | 1 2 3 4 5 |
| 4. Rate how useful <u>you</u> found the tutorial?                        | 1 2 3 4 5 |
| 5. Do you have any comments on how to improve the tutorial?              |           |

**Input Devices**

- |  |                         |
|--|-------------------------|
| 6. What device did you use the most?<br>Why?   | KB JS TT                |
| 7. Rate how easy the Keyboard was to use?  | 1 2 3 4 5               |
| 8. Rate how much you liked using the arrow keys?   | 1 2 3 4 5               |
| 9. Rate how much you liked using the short-cut keys?   | 1 2 3 4 5               |
| 10. Which did you use the most to execute commands,<br>arrow keys or short-cuts?             | Arrow/ same / Shortcuts |
| 11. Rate how easy was the Joystick to use?   | 1 2 3 4 5               |
| 12. Rate how much you liked using the Joystick?<br>What did you like or dislike about it?    | 1 2 3 4 5               |
| 13. Rate how easy the Touchtablet was to use?  | 1 2 3 4 5               |
| 14. Rate how much you liked using the Touchtablet?<br>What did you like or dislike about it? | 1 2 3 4 5               |

**Speech Output**

- |   |  |
|---|--|
| 15. Rate how much you liked the synthetic voice | 1 2 3 4 5  |
| 16. What do you like about it?                  |  |
| 17. What do you dislike about it?               |  |
| 18. How useful was the Change Voice command?    | 1 2 3 4 5  |
| 19. How often did you use it?                   | never / not often / quite often / lots of the time |
| 20. Did you prefer the male or female voice?    | M ?/ F   |
| 21. How useful was the Change Rate command?     | 1 2 3 4 5  |



### 1.7.1 Memorability of Headings Investigation

Instructions: Can you think about the London Hypermedia again? We want to know how easy or hard it is to remember headings in a hypermedia system. So, I'm going to read out a list of headings of nodes from the hypermedia about London. Some of these are real headings and some of them are made up. All I want you to tell me is which ones you recognise and which ones you don't.

Heading	Yes	No	?
St. Paul's Cathedral			
Cultural Activities in London			
An audio clip of Macbeth			
Westminster Abbey			
Famous pubs in London			
An audio clip of Blur playing at the Hippodrome.			
A picture by Picasso			
The River Thames			
Prince Charles			
Royal Events			

### 1.7.2 Non-Speech Sounds Questions

When you first started, how useful did you find the sounds?  
(ie: commands, centre-point, dead-end sounds) 1 2 3 4 5

Now you are more experienced, how useful do you find the sounds?  
(ie: commands, centre-point, dead-end sounds) 1 2 3 4 5

3) Any comments on usefulness:

4) Were any of the sounds ever irritating, and why?

(don't prompt P, but tick any responses that match from this list, and write others below:)

- distracting from what was happening
- not necessary any more
- too long
- too loud
- slowed the feedback down / others:

5) Which sounds do you find the most useful now?

6) Which sounds do you find the least useful now?

7) Any ideas for improvements / changes to sounds in the system?

### 1.7.3 Sound Memorability Investigation

"Now, I'm going to play you some sounds, to see whether they are good sounds for using in the hypermedia system. For each sound can you tell me what command or event the sound went with.

If you can't think of the command immediately, I will give you a list to remind you of which commands had sounds. Then maybe you will remember which command the sound went with.

After each sound, I will ask you to rate how easy the sound was to remember as being associated with the command. We'll use the same scale as before: 1=hard, 5=easy"

<b>Sound Played</b>	<b>(Event / Object)</b>	<b>knew</b> √	<b>used list</b>	<b>didn't knowX</b>	<b>How easy to remember?</b> <b>1=hard,</b> <b>5=easy</b> <b>and</b> <b>comments</b>
<b>Read.wav</b> <i>Paper shuffling</i>	Read right and left				
<b>DeadEnd.wav</b> <i>Plonk</i>	- End of node - Dead-end on workspace - Command not working	.....	.....	.....	
<b>Centre.wav</b> <i>Pop</i>	Centre-Point				
<b>Home.wav</b> <i>Transporter</i>	Home				
<b>Heading.wav</b> <i>Fanfare, Ta-Da</i>	Arriving at Heading				
<b>Back.wav</b> <i>Upwards shooting</i> <i>Play with Forwards so can compare</i>	Back				
<b>Forward.wav</b> <i>Downwards shooting</i>	Forwards				
<b>Link.wav</b> <i>Ding before word in another voice</i>	Link				
<b>Headcmd.wav</b> <i>Shwoosh</i>	The Heading Command				

### 1.7.4 Memorability of Information from Different Media Investigation

How much did you like the nodes containing real human voices with sound effects?  
(Eg: Hamlet, Fire of London, Imports, Trading in London)

1 2 3 4 5

Why?

2) Would you prefer the commands in a real human voice, or would synthetic speech be OK?

real / ? / synth

Why?

-----

"We want to try to find out how useful it is to have audio clips and picture descriptions in a hypermedia system.

I would like to know which of the audio clips and picture descriptions you remember hearing, and whether there was anything interesting in them that you remember.

I want you to know that this isn't a test of your ability: we just want to know how useful audio clips can be."

Topic	visited √ / X	What P remembers:
Audio clip of what happened at the Great Fire of London		
Audio clip about trading in the City of London		
Audio clip from a Shakespeare play		
Audio clip of a Cockney Londoner talking about his work		
Audio clip about imports into London		
Description of the photo of the Houses of Parliament		
Description of the Impressionist painting by Monet		
Description of the photo of the Changing of the Guard		

### 1.7.5 Evaluation of Hypermedia Questionnaire

1. Overall, how much of the time did you know where you were in the hypermedia?

Very Rarely	Rarely	Sometimes	Often	Very Often
1	2	3	4	5

2. Overall, did you ever feel lost in the hypermedia about London?

N/Y/Sometimes

3. How concerned would you be about feeling lost in the hypermedia?

Not At All	Not Very	Moderately	Quite	Very Concerned
1	2	3	4	5

4. What would you do, if anything, to stop feeling lost in the London hypermedia?

5. Why would you do this?

6. How much of the time did you know where you were within a node?

Very Rarely	Rarely	Sometimes	Often	Very Often
1	2	3	4	5

7. Did you ever feel lost in a node?

N/Y/Sometimes

8. How bothered would you be about feeling lost within a node?

Not At All	Not Very	Moderately	Quite	Very Concerned
1	2	3	4	5

9. What would you do, if anything, to stop feeling lost in a node?

10. Why would you do this?

11. If you are reading for an essay would you prefer this material to be in hypermedia, electronic text print or a combination? & Why? HM/ET/Print

12. If you are reading for leisure, would you prefer this material to be in hypermedia, electronic text, print or a combination? & Why? HM/ET/Print

13. What do you prefer about hypermedia?

14. What do you prefer about electronic text?

15. What do you prefer about print?

16. During the last weeks you were expected to find specific pieces of information in the hypermedia about London. (NAVIGATION) How easy was that?

Very Hard	Hard	Moderately	Easy	Very Easy
1	2	3	4	5

17. What made it difficult/easy?

18. Are there any things that you wanted to do in the hypermedia, but were unable to do? (commands or functions).

**1.8 DAHNI-2: Separate Investigations - Raw Data**

**1.8.1 Memorability Of Information From Picture and Audio Nodes: Raw Data**

P	Details Recalled		Total Recall PP	Low / Mod / High
	Picture Nodes	Audio Nodes		
1	0	1	1	Low
2	4	0	4	Low
3	1	3	4	Low
4	3	5	8	High
5	9	9	18	High
6	4	2	6	Mod
7	4	4	8	High
8	0	7	7	Mod
9	1	5	6	Mod
	Mean PP (sd) 2.89 (2.85) range 0-9	Mean PP (sd) 4.00 (2.88) range 0-9	Mean: 6.89 (4.73) n=9 or 5.5 (2.40) n = 8: without P5	

## 1.8.2 Memorability of Headings: Raw Data

Heading Type	Heading	Correct Answer Given by Ps:	Incorrect Answer Given by Ps:	Ps who were Unsure:
<b>TRUE</b>	St. Paul's Cathedral	1, 3, 4, 5, 6, 8, 9 (Total = 7)	2, 7 (Total = 2)	
	Cultural Activities in London	1, 2, 3, 4, 5, 6, 7, 8, 9 (Total = 9)		
	Westminster Abbey	1, 2, 3, 4, 5, 6, 7, 8, 9 (Total = 9)		
	The River Thames	1, 2, 4, 5, 6, 7, 8, 9 (Total = 8)	3 (Total = 1)	
	Royal Events	1, 3, 4, 5, 7, 8, 9 (Total = 7)	6 (Total = 1)	2 (Total = 1)
<b>Total True</b>		<b>40/90 = 44.4%</b>	<b>4/90 = 4.4%</b>	<b>1/90 = 1.1%</b>
<b>FALSE</b>	An audio clip of Macbeth	2, 3, 4, 5, 6, 8 (Total = 6)	7, 9 (Total = 2)	1 (Total = 1)
	Famous pubs in London	1, 2, 3, 4, 5, 6, 7, 8, 9 (Total = 9)		
	An audio clip of Blur playing at the Hippodrome.	1, 4, 5, 6, 7, 8, 9 (Total = 7)	3 (Total = 1)	2 (Total = 1)
	A picture by Picasso	2, 3, 4, 6, 7 (Total = 5)	8 (Total = 1)	1, 5, 9 (Total = 3)
	Prince Charles	1, 2, 4, 5, 6, 7, 8, 9 (Total = 8)		3 (Total = 1)
<b>Total False</b>		<b>35/90 = 83.4%</b>	<b>4/90 = 8.8%</b>	<b>6/90 = 7.8%</b>

**1.8.3 Identification and Memorability of Non-Speech Sounds: Raw Data**

Sound Referent	P1.	P2.	P3.	P4.	P5.	P6.	P7.	P8.	P9.	No of Ps:
Read L/R	✓	✓	✓	✓	✓	✓	✓	✓	✓	9/9
Dead-End	✓	✓	✓	✓	✓	✓	✓	✓	✓	9/9
Centrepoint	✓	✓	? Dead-end?	✓	✓	✓	✓	? a bug?	✓	7/9
Home	✓	✓	X	✓	✓	✓	✓	✓	✓	8/9
Heading	✓ Select	✓ Select	✓ Select	✓	✓ Select	? only in Home	✓	✓ Select	✓	3/9 5/9 select
Back	✓ said Home 1st	? used overlay	✓	✓	✓	✓	✓	?	✓	7/9
Forward	? with hints	? used overlay	X	✓	✓	✓	✓	?	✓	5/9
Link	✓	✓	✓ sub-headg	✓ Dead-End?	✓	✓	✓	✓	✓	8/9
Heading Command	-	-	-	-	-	-	-	-	-	0/9
Totals per P	7/9	6/9	5/9	8/9	8/9	7/9	8/9	5/9	8/9	

**KEY:** ? means half remembered, needed prompting, or made small error; X = completely wrong; ✓ = with another command means their 1<sup>st</sup> guess was wrong, but 2<sup>nd</sup> guess was right; used overlay = they had to refer to the overlay before correctly naming the referent

Memorability Rating	P1.	P2.	P3.	P4.	P5.	P6.	P7.	P8.	P9.	av of cmd*	N	SD
Read L/R	5	5	5	5	5	5	5	5	5	5.00	9	0.00
Dead-End	5	5	5	5	5	4	5	5	5	4.89	9	0.33
Centrepoint	5	3	2	5	5	4	5	4.88 <sup>a</sup>	5	4.32	9	1.11
Home	4	5	2	5	5	5	5	3	5	4.33	9	1.12
Heading	5	5	4	5	4	4	5	3	5	4.44	9	0.73
Back	4	2	3	4	5	4	5	3	5	3.89	9	1.05
Forward	3	2	2	4	4	4	5	3	5	3.56	9	1.13
Link	5	5	3	5	4	5	5	5	5	4.67	9	0.71
Heading Command	-	-	-	-	-	-	-	-	-	-	0	-
* Mean per P	4.5 n=8	4.0 n=8	3.25 n=8	4.75 n=8	4.63 n=8	4.38 n=8	5.0 n=8	3.86 n=7	5.0 n=8			

**KEY**

<sup>a</sup> Missing value replaced by mean of sound for purposes of statistical analysis  
 \* Means do not include those who did not know the sound.

## **1.9 DAISY Playback Software: Visual Help System V1.0**

### **General Information**

The DAISY Playback Program allows you to access and read Talking Books produced in the new and revolutionary DAISY Digital Talking Book format. DAISY books contains structured digital audio recordings of human narrators, reading out the text from the original material. The Talking Book recordings are organised in a way close to the printed original to give the DAISY user much the same accessibility to the Talking Book as a reader of a printed book has.

The DAISY access software runs on IBM compatible PC:s with multimedia capabilities, i.e. sound card and CD-ROM drive. The CD-ROM medium is today the most command means of distribution of DAISY books, since it is widely available and cost effective.

Please note that a Pentium class PC is needed if you wish to make use of the "Time compression" features in the system. Time compression is used in the "High speed" and "Turbo speed" speech styles. If the PC is not powerful enough to provide time compression, the speech output may be garbled and the program will be slow in responding to keyboard commands. If this should happen, please avoid the two highest speed settings.

Below, you will find brief descriptions of all keyboard-activated commands that may be used to control the DAISY Talking Book playback software. Even though most of the commands may also be initiated by using the mouse, we would like to recommend using the keyboard as much as possible. This document does not deal with any mouse-driven program operation.

### **1. Commands for navigating the Table of Contents**

#### **Next section:**

**<Control> and <Down arrow> or  
<Control> and <Num Pad 2>.**

Moves the reading position to the next section that can be found on the same hierarchical level as the current section, according to the book's Table of Contents. For example, if you are on section 1, you will move to section 2, and if you are on section 1.1, you will move to section 1.2.

#### **Previous section:**

**<Control> and <Up arrow> or  
<Control> and <Num pad 8>.**

Moves the reading position to the previous section that belongs to the same hierarchical level as the current section, according to the book's Table of Contents. For example, if the current section is 2, you will be moved to section 1, and if you are in section 1.2, you will be moved to section 1.1.

#### **Level up:**

**<Control> and <Left arrow> or  
<Control> and <Num pad 4>.**

Moves the reading position to the previous section belonging to the nearest higher level in the book's Table of Contents. For example, if you are on section 1.5, you will be moved to section 1.

#### **Level down:**

**<Control> and <Right arrow> or  
<Control> and <Num pad 6>.**

Moves your reading position to a section that belongs to the nearest lower level in the book's Table of Contents. If there is no section on a lower level, this command instead moves to the next section, regardless of its hierarchical level. For example, if you are on chapter 1 and this section has sub-sections, the command will take you to section 1.1.

**First section:**

**<Control> and <Home> or  
<Control> and <Num pad 7>.**

Moves the reading position directly to the first section that can be found on the same level as the current section. For example, if you are in section 1.7, you will be taken to section 1.1.

**Last section:**

**<Control> and <End> or  
<Control> and <Num pad 1>.**

Moves your reading position straight to the last section that can be found on the same level as the current section. For example, if you were on section 3 and the book had 14 main sections, you would be moved directly to section 14 by this command.

**Jump forward:**

**<Control> and <PgDn> or  
<Control> and <Num Pad 3>.**

Moves the reading position 15 sections forward in the book's Table of Contents.

**Jump back:**

**<Control> and <PgUp> or  
<Control> and <Num pad 9>**

Moves the current position 15 sections backward in the book's Table of Contents.

**Section information:**

**letter <I> or <Num pad 5>.**

The first key press announces the heading for the current section. Another key press reads the title for the section on the nearest level above the current one, if the current section is a sub-section of another section.

**Current position:**

**Letter <C> key or <Control> and <Num pad 5>**

This command announces the section number for the current section. The section number is not taken from the actual contents of the book, but is calculated by the system. Use this command if the headings of the book are not numbered. The section number identifies a section hierarchically by a series of numbers, separated by the word "point", for example "Section one point two".

---

**2. Reading commands**

---

**Start/stop:**

**<Space bar> or <Num pad 0>.**

Starts continuous playback of phrases beginning with the phrase at the current reading position. If the system is in play mode, the command stops continuous playback and mutes the speech. The reading position is moved to the phrase that is playing when the stop command is given.

**Next phrase:**

**<Right arrow>, <Num pad 6> or <Num pad plus>.**

Moves the reading position to the beginning of the next phrase in the book.

**Previous phrase:**

**<Left arrow>, <Num pad 4> or <Num pad minus>.**

Moves the reading position to beginning of previous phrase.

**Next group:**

**<Down arrow> or <Num pad 2>.**

Moves the reading position to the beginning of the first phrase in a new phrase group, as defined by the book's producer. If no groups exist in the section, the playback position will instead be moved 10 phrases forward.

**Previous group:****<Up arrow> or <Num pad 8>.**

Moves the reading position to the first phrase in the previous phrase groups. If no groups have been defined, the command will simply move 10 phrases backwards.

**Next page:****<PgDn> or <Num pad 3>.**

Moves the playback position to the first phrase belonging to the next page.

**Previous page:****<PgUp> or <Num pad 9>.**

Moves the reading position to the first phrase belonging to the previous page.

**Last phrase:****<End> or <Num pad 1>.**

Moves the reading position directly to the last phrase in the current section.

**First phrase:****<Home> or <Num pad 7>.**

Moves the reading position to the first phrase in the current section.

**3. Searching and marking commands**

---

**Find String:****letter <F>.**

This command opens a dialogue box where you can enter a string of characters to search for in the book's Table of Contents. Type in the string letters, numbers and punctuation symbols you want to search for and press the <Enter> key to start the search. Cancel the search operation by pressing the <Escape> key.

The last entered character can be erased by hitting the <Backspace> key.

The string that has been typed in can be spelled out by using the <Alt> and <R> key combination.

The search feature does not distinguish lower from upper case letters.

The system will look for an occurrence of your search string in the headings of your book's Table of Contents. The search starts from the heading coming after the current section. If the search pattern is found in a section's heading, that section becomes the current section. If the search string can not be found, the current section remains.

**Search next:****letter <V>.**

Continues searching for a new occurrence of the current search string, starting from the next section heading. If no more matches of the search string can be made, the current position remains.

**Search previous:****letter <R>.**

Searches backwards in the Table of Contents for an earlier occurrence of the current search string. The search starts at the previous section heading. If the search string can not be found, the current reading position is not changed.

**Set bookmark:****<Control> and number keys <1> to <9>**

(the number keys above the letter keys).

Places the specified bookmark number at the current playback position.

**Goto bookmark:****Number keys <0> to <9> (above the letter keys).**

Moves the playback position to the phrase where the specified bookmark number have been set.

**Goto page:****Letter <G>**

This command opens a dialog box in which you can enter the page number you want to move to. Use the number keys above the top row, above the letter keys. Press <Enter> to search for the specified page, or press <Escape> to cancel the operation. If the specified page exists in the book, you will be moved to the first phrase on that page. If the specified page can not be found, an error message will be announced.

**Page information:****Letter <P>**

Announces the current page number as a string of digits. The page number is calculated from information that has been provided by the talking book producer, and may or may not exactly match the page numbering used in the original, printed book.

**4. Voice control commands**

---

**Mute speech:****<Enter> or <Num pad Enter> or <Escape>.**

Immediately stops any ongoing speech, whether it is book text or messages from the system. The command also stops playback if the system is in continuous play mode.

**Low speed:****letter <L>.**

Selects the "slow" playback speech style, which introduces slightly longer pauses in the speech than those originally recorded.

**Standard speed:****letter <S>.**

Sets the playback speech style to "standard", which means that all the pauses will be as they were originally recorded. No time compression is used in this speech style.

**Brisk speed:****letter <B>.**

Activates the "brisk" speech style, where the pauses are shortened in comparison with the original. No pitch change or time compression is used in this speech style.

**High speed:****letter <H>.**

Selects the "Fast" speech style. This style compresses pauses extensively and also introduces some extra "time compression".

**Turbo speed:****Letter <T>.**

The "turbo" speech style gives maximum compression of pauses and also uses quite heavy time compression. The result is a very fast playback speed.

**5. Other commands**

---

**Audio help:****<F1>**

Activates the audio help mode, where short help information about all the system's keyboard commands can be read as a normal DAISY Talking Book. Press the <Escape> key to leave the Audio Help mode and return to normal book reading mode.

**Visual help:****<SHIFT> and <F1>**

Shows brief help texts that describe each command that is accessible from the keyboard. Press the <Escape> key to leave the help page and return to the Playback Program.

**Open Book :****Letter <O>.**

Enters book and book drive selection mode. Use the arrow keys to select a book from the current drive. Use <Control> and arrow keys to change book drive, or press the letter key that corresponds to the drive. Press <Enter> to open the selected book and return to normal book reading mode. Press <Escape> to cancel the book selection and return to book reading.

**Quit program :****Letter <Q>.**

A message will ask you to confirm the operation. Press the <Y> key to exit the DAISY software. Any other key cancels the operation.

**1.10 DAISY Playback Software: Participant Characteristics Questionnaire**

**P. No:** \_\_\_\_\_

**Name:** \_\_\_\_\_

**Region:** \_\_\_\_\_

**Gender:** M / F

**Age:** \_\_\_\_\_

**RNIB Talking Book Member:** Yes / No

**Occupation:** Employed, Student, Retired, Unemployed

**Sight:** Sighted, Reg Blind, Reg P/S, B not reg, PS not reg

**Do you read:** Ordinary Print, Large Print, Braille

**Do you have any other difficulty which affects using the Player, and if so, what?**

**Reading Habits and Use of Other Audio and Multi-Media Equipment**

Before we talk about the CD-based talking book player I would first like to ask some general questions about other hi-fi and audio equipment that you have and use. Ask Qs 1-3 in sequence for each item, then move to next item.

	<b>Responses</b>	<b>Tape</b>	<b>CD</b>	<b>PC</b>
<b>1. Do you own / have access to:</b>	Yes No			
<b>2. How often do you use it?</b>	Every day ~ 3-5 days a week ~ 1-2 days a week ~ 1'ce a month Never No Response (NR)			
<b>3. How easy / difficult would you rate it to use (for playing CD books)?</b>	Very easy Easy Manageable Difficult ** Very Difficult** N/A NR			

**\*\* 4. Why do you find (x) difficult to use? List reasons below.**

**Tape** \_\_\_\_\_

**CD** \_\_\_\_\_

**PC** \_\_\_\_\_

**5. How many years have you been listening to Recorded Books?**

This 1st	< 1 yr	1-4 yrs	5-9 yrs	10+ yrs
8	1	2	3	4

**6. Do you use Recorded Books for any of the following:**

Magazines/Newspapers Study Leisure Work

**7. Do you use printed / Braille text in conjunction with the audio books?**

**Yes / No**

**Why?** \_\_\_\_\_  
 \_\_\_\_\_

**8. Have you used any other recorded books, other than RNIB Talking Books?**

Which, and what did you like/dislike about them?

\_\_\_\_\_

## 1.11 DAISY Playback Software: Generic Evaluation Tasks

**Book Title:** \_\_\_\_\_

*These are the sorts of tasks Ps should complete, but they will depend on the structure of the book. Meaningful tasks for each book should be based on these, leaving P fairly free to read what they want in the book(s).*

*Complete one of these Task sheets for every title P wishes to assess. Make notes on performance, methods chosen, problems or mistakes, and why problem arose.*

**Please could you insert the disc and open the book**

[insert disk, in SW press 'o' to get Open D.Box, then change to D: by pressing 'd' or use Ctrl+arrows. Press 'Enter' to accept.]

**Let's read the first part of the disc, to hear the publishing details and what the book contains to get a feeling for the book.**

[play]

**Could you try the different speech rates, and see which you prefer. You can put it back to the one you like best for the rest of the tasks.**

[L, S, B, H, T]

**Let's jump around through the ToC and see what information is in this book. Feel free to change the levels while you do this, if you'd like to explore the sub-sections.**

[Use Ctrl up and down or 8, 2 to jump between heading of one level, and Ctrl left and right or 4 and 6 to change level. Make notes on what P chooses to do, and how much they found out]

**Can you get to Section 1 in the ToC, and then put a numbered bookmark (1) there, so we can get back to it later on?**

[navigate to Section 1 heading, press Ctrl + 1 (not numpad) to make bookmark1]

**Can you show me how to read through phrases and groups of phrases from here.**

[play, pressing:

- right arrow to skip through phrases (or numpad 6/+, or 4/-) and
- down /up arrow to skip through groups of phrases (or numpad 2 and 8)]

**Can you find out what page we are now on?**

['p' reads page number]

**There's something interesting about X on page N, can you jump there?**

[press 'g' for Goto, and type number, press Enter, to jump to the page]

**Can you find out the heading and parent heading of this section - using the Section Information command?**

['i' (numpad5) announces heading, 'i' again announces major heading if a sub-section]

**Now, find out exactly where we are in this section we are, using the Current Position command.**

[ 'c', or Ctrl+numpad5, announces number of section and sub-sections, eg Section one, point two, point three]

**Can you skip to the next page?**

[3 or PageDn for Next Page]

**What topic are you interested in reading in this book? Let's do a find task and see if we can find anything on that.**

[ 'f' for Find, type in string, press Enter]

**Shall we see if there are any other instances?**

[ 'v' for search next]

**Can you jump to the first section in this section?**

[Ctrl+Home, or numpad7]

**Now can you return to the bookmark we just made, number 1 - can you remember where it was?**

[press 1 to jump to bookmark 1]

**Can you read for a little way, and then show me how to jump to the last phrase in this group of phrases please.**

[1 or End]

**Now can you return to the beginning of the disc**

[navigate either ToC or while reading, using Ctrl+Left arrow/4 to go up levels, then , Ctrl+up arrow/8 to skip between sub-levels]

**Let's quit the program, and we'll re-start it later if we need to.**

[press 'q' and then 'y' for Yes]

### 1.12 DAISY Playback Software: Evaluation Questionnaire

Now, I need to ask you for your opinions of different aspects of the Playback Software. We're going to use a 5-point rating scale, where the higher the number, the more you like it.

• Overall, how easy to learn did you find the player? 1 2 3 4 5

• Overall, how easy to use did you find the player? 1 2 3 4 5

• Overall, how easy to remember were the commands? 1 2 3 4 5

• Overall, how much did you like using the player? 1 2 3 4 5

• How useful was the numpad for commands? 1 2 3 4 5

• How useful were the shortcuts, like Home, End, PgUp? 1 2 3 4 5

• Did you prefer one or the other, or either? Shortcuts / Either / Numpad

• How useful was it that the system goes to the last location when you insert a new disc? 1 2 3 4 5

• What did you particularly like about the Player?

• How easy to use did you find the following commands, and how useful were they? Why, & what would you prefer? 1-5 scale.

Command	Ease of Use	Usefulness	Good Points, Problems, Preferences
Open Book	12345	(12345)	
Play/Stop	12345	12345	
Mute	12345	12345	
Goto Page	12345	12345	
Set Bkmk	12345	12345	
Goto Bkmk	12345	12345	
Search	12345	12345	
Search Next/Prev	12345	12345	
Changing Levels	12345	12345	
Skipping Sections	12345	12345	
Current Position	12345	12345	

Section Info	12345	12345	
Audio Help	12345	12345	
Visual Help	12345	12345	
Speeds	12345	12345	
Skipping Phrases	12345	12345	
First/Last Phrase	12345	12345	
Skipping Groups	12345	12345	
Skipping Pages	12345	12345	
First/Last Section	12345	12345	
Jump 15 Sections	12345	12345	

• How useful would you find a new command which gave you time information: eg 'T' told you total time, time passed and time remaining.

1 2 3 4 5

• You can only set up to 9 bookmarks. How useful would you find it to be able to set as many bookmarks as you wish, using eg: Ctrl 1 2, Enter?

1 2 3 4 5

• How useful would you find a command that told you the highest number of bookmarks set?  
"There are 7 bookmarks set".

1 2 3 4 5

• When you were navigating through the sections and sub-sections of the book, how easy was that, and what made it easy / difficult?

1 2 3 4 5

• How easy was it to find out how many levels there are in the book, and where these sub-sections are?

1 2 3 4 5

• How useful would you find the following?

a) a command 'Overview' which would describe the organisation of the whole book, tell you the number of sub-sections, and which chapters had which sub-sections.

1 2 3 4 5

b) a command 'Overview' which would describe the organisation of the current section, tell you where there were sub-sections etc - included in 'Section Info' command?

1 2 3 4 5

c) When I'm reading or skipping through headings, a sound could tell me if there were any sub-sections below a heading. Like the dot dot dot on some menu items in computer programs. 1 2 3 4 5

d) When I'm reading, or skipping, it would be good to hear what level a heading is, (using different sounds) so that I can tell if its a sub-heading, or a main heading. Then I know what level of indexing to use to find something. I would also hear these sounds if I was using other reading commands too. 1 2 3 4 5

e) The 'Location Info' command - tells you the section number, it could also tell you how many sections there are, eg: "Section 4.5 of 9". 1 2 3 4 5

• Did you ever get lost when reading or skipping - what happened?

• What would you do if / when you got lost?

• How useful would a 'Start of Book' command be which took you immediately to the beginning / End? 1 2 3 4 5

• How useful were the Help Systems?	Audio Help	1 2 3 4 5
	Visual Help	1 2 3 4 5

• Would you continue to use the player for leisure reading, and why (not)?

• Would you continue to use the player for study or work, and why (not)?

If no to both these questions:

• What do you prefer about Braille / Audio / Standard electronic text?

• Would you want to use a print / Braille copy of some or all of the book while you were reading? Yes / No  
Why?

• Any other problems we haven't brought up? & Is there anything the player doesn't do which you'd like it to?

**Titles Used**

Which of the following titles have you already used? What did you like or dislike about using them - for example, were they easy or difficult to get around - rather than being boring or uninteresting!

	<b>Liked / Disliked / Problems</b>
<b><u>Leisure Reading</u></b>	
Gunner Milligan	
<b><u>Study / Text Books</u></b>	
5 Lectures on Psycho-Analysis	
The Facts about Alcohol, Aggression and Adolescence	
The Venice and Turin Tour Guide	
<b><u>Cookery</u></b>	
Real Good Food	
<b><u>Periodical</u></b>	
New Beacon (synthetic voice)	
<b><u>Religious</u></b>	
The Four Gospels	
<b><u>Complicated Books</u></b>	
Robin Hood - the man behind the myth	