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Temporal Requirements and the Human Computer Interface: Not just an Afterthought

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ABSTRACT

Time plays an intrinsic part in the human computer interface. We argue that temporal issues must be recognised as fundamental to the interface, not relegated to the status of quality requirements. If we treat time as being relevant only to quality we run the risk of identifying related requirements too late in the RE process for them to be properly incorporated. We recognise that it is neither practical nor desirable to impose strict temporal requirements on the performance of every system, and we focus our discussion on systems where the satisfaction of such requirements cannot be guaranteed, such as Web-based applications where some delays are inevitable. Using the Web browser as an example we illustrate that early consideration of temporal issues allows for the identification of additional non-temporal functional requirements before it is too late.

Keywords: Temporal Requirements, Time, World Wide Web, Web-based Applications, Human-Computer Interface

1 Introduction

This paper addresses the way in which temporal issues are considered when defining requirements, and demonstrates that earlier consideration of these issues may give rise to additional functional requirements. These additional requirements may be overlooked if we ignore temporal issues until after functional requirements have been identified. Temporal requirements are generally deemed to be non-functional or quality requirements[Chung et al 95, Franch 98], except with regard to those systems where time is critical (for example, where the timing of computations is critical to correct performance and/or safety) and there is evidence that, outside the area of hard real time systems, consideration of performance and response issues is lacking. [Lubars et al 93]. We suggest that by considering temporal issues relating to the human-computer interface at an early stage in the requirements process, it is possible to identify functional requirements for features which will assist the user to better exploit the utility of the system. Although detailed analysis of some quality requirements may be achieved only through the design process [Vanwelkenhuysen 96], we argue that we must consider temporal issues alongside functional requirements in order that requirements related to such issues may be properly incorporated.

We illustrate the implications of early consideration of temporal issues when defining requirements, using the Web Browser as an example. Networked and distributed systems, and particularly Web-based applications pose particular difficulties with regard to temporal performance. For example when using the World Wide Web, delays in accessing information can be caused by communications failure, network loading or processor overheads [Johnson 95].
In the rest of this paper we:

- explain the significance of temporal issues in interaction in more detail, providing a number of examples of how this may impact upon requirements for the human-computer interface (section 2)
- present a more detailed description of temporal issues and the requirements which flow from them in the case of our example system, the Web browser (section 3)
- explain how this impacts upon the way in which we should identify temporal requirements for the human-computer interface (section 4)
- discuss the generalisability of the claims made, and identify directions for future work (section 4)

1.1 Definition of Terms

For the purposes of this paper 'temporal issues' are defined as including both specific temporal requirements (for example, the system shall respond to action X within Y seconds), and the more general notion of timeliness, which refers to the ability of a system to act or respond 'in good time'. We use the term system to refer to both systems and applications

2 Time and Interaction

Time plays a fundamental part in interaction between the user and system, and temporal properties of interaction should strongly influence interface requirements. The system's potential for supporting different user strategies (or goal trajectories), and the system's demand on user memory are significantly affected by timing, particularly system or user delay [Parker 97]. For example if the rate of interaction is too slow the user's execution/evaluation loop is broken [Dix 94a]. This can lead to the user forgetting what must be done before the task is completed. The user generally expects feedback, informing him of what has happened, but with at a very slow level of interaction it may be that nothing has yet happened. Thus, once a response finally arrives, the user must recall the appropriate context, which he may have difficulty doing. The relationship between time and interaction is of particular importance in multimedia applications, networked or distributed systems, and use of the World Wide Web. A small pilot study [Byrne & Picking 97] surveyed and analysed the issues which Web users regard to be of central importance. The results indicated that users consider temporal issues to be intrinsic to usability. Below, we consider the ways in which time impacts upon interaction in more detail.

2.1 Two-Timing

Dix [Dix 87] has suggested that there may be no relation between the user's appreciation of time and the actual execution times of internal machine events. The traditional notion that increased computational power is all that is required to improve temporal qualities of interaction is questioned, and indeed in a further paper [Dix94b] it is noted that hardware insufficiencies have largely been overcome by advances in technology, only to for us to be faced with similar temporal difficulties as a result of the increase in networking and its associated delays. Temporal issues are too entwined with usability for us to dismiss them on the assumption that technological advances will in themselves solve the problem. The fact that, in the user's view, the hardware hurdle has been overcome simply to be replaced by a network hurdle causing similar problems, emphasises the point that the user experience should be separated from hardware issues. As we demonstrate below, it is possible to reduce the disruption to the user which is caused by our inability to eliminate delays, but this will occur only if we consider the user's experience at the interface rather than expecting the problem itself to be designed away.

In a technique referred to as 'two-timing', the temporal behaviour experienced by the user, at the interface, is viewed separately from the actual temporal behaviour of system computation [Dix 87]. This encourages us to think in terms of the realities faced by the user, rather than hoping that we can achieve 'quality' requirements once the system is under development. If we consider the user's experience at the interface in isolation we are forced to acknowledge the inadequacies present at the interface, and are able to consider what functional requirements might be included to help resolve the difficulties caused. It is imperative we do this in tandem with the definition of other functional requirements if we are to ensure that these additional requirements are incorporated.

2.2 Pace and Rhythm

Pace has been argued to have an important bearing on the user's experience of interaction [Dix 92]. This is a temporal quality which is quite different to speed of response, the temporal property most often encountered in computer science. During interaction, channels of communication between the user and the computer are used not at a constant rate, but intermittently. Consequently, bandwidth, which assumes continuous transmission, is not necessarily an appropriate measure of communication. For example, when analysing the rate at which two individuals exchange emails, the pace of their interaction could be defined as the rate at which individual mail messages are produced. This would give us a somewhat different insight into the temporal properties of that relationship than if we were to consider bandwidth, which assumes continuous transmission, and could therefore tell us only about the average transmission of messages over a given period. Pace, the measure of the rate at which individual communications occur through a channel, is proposed as a primary property. This is an important issue with regard to interaction, which is both measurable and quantifiable, and may therefore provide a useful way of relating the pace, or potential pace, of the channels to the tasks the user must carry out.

Related to the notion of pace is the question of what time-scales humans can comfortably work to. It has been suggested [Dix 96a] that our experience of whether timings are good or bad are affected by a combination of psycho-motor abilities and external stimuli. Rhythms are easier to deal with than occasional delays and it would seem that prediction is easier if we are dealing with regular time intervals. This means that regularity may be more relevant to the user's experience than absolute response time intervals. Thus a slower but consistent interface may be more effective than a generally fast but inconsistent one.

As we noted in the introduction to section two, a very slow pace of interaction can result in the user's execution/evaluation loop being broken. An alternative scenario to delayed feedback is that a response fails to arrive at all, requiring the user to both recognise that it has failed to arrive and take appropriate action. Feedback is often delayed in open and cooperative systems. This obviously causes pace to slow and the user must therefore devise strategies to overcome the difficulties outlined. In order to provide alternatives these strategies must be identified and considered early on in the requirements process. We must not only identify current user solutions for dealing with such problems, in order that new support strategies do not interfere with those (possibly subconscious) strategies currently in use, but also introduce new support systems to assist the user in overcoming these problems. If we are to do this effectively these issues must be considered when functional requirements are being defined.

2.3 Granularity of Time

Temporal issues affect interaction at a number of different levels of granularity. At the fine-grained level we encounter issues such as status-status mappings (see below, 2.3.1), and the need for synchronisation of different multimedia modalities to ensure that audio and video channels perform in harmony. At the coarser-grained levels we may, for example, be concerned with the rate of turnaround of messages over a period of hours, days or weeks (see below 2.3.2). Somewhere in between these two levels of

granularity is the level at which the system makes demands on user memory. The recorded tolerance for response from command-line interfaces is 5 seconds [Shneiderman 84], after which the user's short term memory begins to decay, and consequently longer delays place extra demands on the user's memory, and affect the process of interaction. We raise the issue of granularity of time to illustrate that, when we consider the way in which temporal issues impact upon interaction, it is necessary to consider time scales which have not traditionally been seen as relevant to system requirements.

2.3.1 Status-Status Mappings

Status is defined as those things in an interface which have a constantly available value [Dix 96b]. Examples include screen contents or mouse position. Status-status mappings are constraints or functional dependencies between the status of different components within a system, such as the relationship between a document and the screen image of it within a word processor package, or the way in which an icon being dragged across the screen follows the mouse movement. These mappings can be identified during the specification stage, and thus highlight potential temporal problems in the interface. The early identification of such potential anomalies, and reference to them in the requirements documentation should assist in eliminating them.

2.3.2 Long Term Interaction

Long-term interaction, where the rate of turnaround of individual messages may take hours, days or weeks, poses problems which are different from those found in higher pace interaction. People must remember that they have to do things, that other people should do things, and why things happen when they do [Dix et al 98]. A recurrent pattern of activity is identified - request, receipt, response, release (the four R's). To illustrate: someone sends you a message requiring your action (request), you receive the message (receipt), you perform some necessary action (response) and then file or dispose of things used in the process (release). The user may have difficulty in recalling the context of a delayed response, may forget to act themselves if they cannot react instantly to a request or, if an expected external response is not forthcoming, the whole interactive process may break down. This poses questions as to how the user may be assisted with coping strategies, particularly when automating a functioning paper-based system. If we identify the triggers for these different activities, and the areas where delays are likely to occur, we may be able to minimise the disruption caused by incorporating functional requirements which support alternative strategies.

2.4 Summary

In can be seen, therefore that temporal issues affect requirements for the human computer interface in a number of different ways. Temporal properties such as pace and rhythm may have a greater bearing on the user's interactive experience than simply speed of response and therefore it is apparent that the temporal challenges in interaction may be quite different to those in other areas of computer science. If we recognise that temporal issues are not only of relevance to non-functional requirements, we may be able to reduce the impact of delays by assisting alternative strategies. This is of particular relevance where delays arise in areas which may be out of the control of the system owner, such as networked systems and particularly where the World Wide Web is used. Although we may be unable to eradicate such

difficulties, we are able to minimise the disruption they cause through the introduction of further functional requirements. If we are to provide solutions to the problems that the user experiences at the interface, arising from these temporal issues, then we must begin to give temporal issues higher priority than they are currently afforded in the requirements process. This is not to say that we should always try to incorporate strict temporal requirements, but that we must consider whether there are functional requirements which might arise in order for the user to be supported where delays and temporal inconsistencies are experienced.

3 Temporal Issues in The Human-Computer Interface of a Web browser

Temporal issues have a significant impact on the usability of Web-based applications. This is particularly important with regard to the dependability of systems used in e-commerce, where users will simply turn away if they experience delays when they attempt to use the services provided. If we fail to consider the user's experience in this kind of system, we are unlikely to build systems which are successful, either in terms of usability, or from a business viewpoint. It is however, important to note that, since Web-based applications rely on the use of open networks, their performance is not under the application owner's control. As delays may be caused by circumstances outside their control, it is meaningless to specify arbitrary temporal requirements (e.g. a web page should be fully loaded by a Web browser within 10 seconds of a user requesting the URL). With the best will in the world, there is currently no possibility that an application may be developed which could be shown to reliably meet that requirement. An alternative is to define requirements for system functionality which will allow users to deal with the inevitable delays.

3.1 Defining Requirements for the Interface to a Web Browser

There are two main sources for the requirements which we have defined. The first is the literature relating to human computer action, and these ideas are presented in section 3.1.1. The second source is a study of compensatory actions taken by users presented with delays when accessing information on the World Wide Web [McManus 97] and these are discussed in section 3.1.2. A summary of proposed requirements is presented in section 3.2. We consider the requirements in general terms rather than with reference to a specific Web browser. Where we are aware of the existence of similar functionality in a particular browser it is noted, but our intention is to focus on the more general requirements for Web browsers which may be extrapolated for use in specific applications.

3.1.1 Sources of Requirements in the Literature

We noted above that rhythms may be easier to deal with than occasional delays, and so regularity may be of more relevance to the user's experience of time than actual response time [Dix 96a]. In order to provide the user with a sense of rhythm the variability of response time must be reduced, this is discussed further in [Roast 98]. Whilst it is clear that we would be unable to consistently meet some notional temporal requirement, for example that a page is always loaded within ten seconds, we can provide a sense of rhythm by ensuring that perhaps a dialogue is always commenced within this time, providing a range of alternative strategies in which the user might

engage. In order to do this we must define functional requirements which ensure that these strategies are provided *{requirement 1}*. (In the remainder of this sub-section proposals are linked to the corresponding numbered requirement in section 3.2 using the format *{requirement n}*).

If the pace of interaction of web-based systems is too slow, the user's execution-evaluation loop will be broken, interrupting the interactive process. It has been noted that browser design suggests exploratory interaction with rapid feedback, whereby information is sought in an unstructured manner, following links and 'browsing'. The unpredictable delays experienced by users encourage more speculative and goal directed interaction [Roast 95] with users simply trying to find a particular piece of information as quickly as possible.

When using a Web browser the user is often presented with 'bizarre', apparently unpredictable temporal behaviour. This may be exacerbated by a lack of understanding of underlying network architectures. Interfaces often attempt to hide underlying system architectures and computations, but it may be that in the case of WWW Browsers, this decreases rather than enhances usability. For example, two buttons which have the same appearance may lead to variously, a cached or remote page, which may take very different times to load. This could be overcome by allowing the buttons to be distinguished [Roast 95], a functional requirement exposed only via consideration of the user's experience of temporal issues at the interface. *{requirement 4}*

Johnson [Johnson 95] identifies a number of temporal issues that arise in interaction. One of these has particular relevance for networked or distributed systems: how may we provide users with an adequate representation of the flow of information from remote sites? This is a challenge which appears to have been taken on board in the Web browser Netscape, which give a user some indication of the rate of progress. However, the fact that this information relates to the file currently under transfer renders this information meaningless to the user. The provision of information such as "45% of 117k" is insufficient for a user who is unaware of how many other files must be transferred. A more useful indication would be one which estimates how long it will take to transfer all files required to fully display the page. This is an issue which, if it is to be resolved, must be considered early on in system development, and incorporated into the requirements documentation. *{requirement 1}*

A second area in which temporal challenges of interaction have been identified is that of multimedia systems [Johnson 95]. Technological limitations, and particularly problems with speed of retrieval from remote sites, cause multimedia bottlenecks. This can have a considerable effect on the presentation of real-time media such as audio and video output. Real-time multimedia modalities are obviously tightly interwoven, but it is suggested that as well as considering technological solutions (increasing processor speeds, shortening transfer times etc.) we should consider ways in which the user may exercise more power over the bottleneck, by choosing for example, to sacrifice some video quality, in order to gain enhanced sound quality, or vice versa. Consequently the user could indicate a preference for a particular perceptual modality. Thus two further issues identified are:

- how can designers represent the changing priorities that might be assigned to different modalities during interaction?
- how can these priorities be adequately related to the changing demands of particular user tasks?

This could be translated into a requirement which allows the user to sacrifice a particular modality on a page by page basis, without having to make permanent changes to the operation of the browser, as is currently the case for Internet Explorer. If delays are being experienced, a dialogue initiated by the browser, offering the user this, or other choices, would support the user in formulating the most appropriate strategy for his current needs.*{requirement 2}*

The impact of retrieval delays on the value of information retrieved from remote sources has been considered in [Johnson 97]. The author presents the results of a study which showed that the provision of information (such as the indication of the quality of an image shown via a thumbnail) at the interface meant that the user was better able to assess whether the cost of retrieving the information (in terms of the delay experienced), outweighed the value of that information. Consequently we make two further suggestions for the Web browser: Firstly, where possible, we should indicate the size of the file or page that links lead to (this information might be displayed when the mouse is moved over the link). Secondly, if the Browser were to initially render all images as thumbnails, providing the user with the option of displaying the full image on request, the user would have greater control over the time spent in retrieving images, and could thus choose to view only those which are of value to him.*{requirements 5 & 6}*

Shneiderman [Shneiderman 87] argues that there are so many variables at play that it is impossible to define a single acceptable response rate. This conflicts with the suggestion in [Newman 97] that we need to define critical parameters for performance. Bearing in mind that short term memory decays after a few seconds, and that the acceptable response time for command line interfaces has been found to be 5 seconds, perhaps the imposition of a response rate (response does not necessarily imply full page loading) of this time would provide a starting point. In order to both provide the user with a sense of rhythm, and avoid the breaking of the execution-evaluation loop, we propose that within 5 seconds of the user requesting a particular URL, information is provided within the interface, estimating the time which it will take to fully load the page at current rates of transfer *{requirement 1}*. However, given the varying expectations of different categories of users, and the disparities in performance of the systems being used it would seem sensible to allow the user to define the response time with the 5 seconds being used as a default.

In order to provide the user with greater control over the interface, and create a sense of rhythm which is adjustable to both the particular user and the system he is using, we also propose that the user is able to define a maximum acceptable loading time for Web pages *{requirement 2}*. If this cannot be satisfied then the browser should commence a dialogue, offering choices to the user as to how he wishes to proceed. For example the user may simply wish to record the URL so that he is able to remind himself that he wishes to return to the page, *{requirement 3}* or alternatively he may decide that the page is of sufficient value that he is prepared to wait for longer than usual in order to view it. The options that we feel should be provided, based on both

the discussion in this section, and the study presented in the next section, are presented below in section 3.2.

3.1.2 Compensatory Actions Taken by Users

A study has shown that users will engage in a variety of compensatory actions in order to overcome difficulties presented by delays in accessing the WWW [McManus 97]. These actions are of relevance to browser requirements, because they offer the opportunity to provide support for such strategies and minimise disruption experienced by the user when inevitable delays occur. Where we have identified requirements which would support such strategies, the requirement is referred to as in section 3.1.1 above.

Users take compensatory actions under two sets of circumstances:
(1) The user has knowledge of the page location that he would like to reach and is trying to reach it as efficiently as possible. This is often combined with knowledge of the hardware and/or browser being used. The positive compensatory actions in these circumstances were:

- multi-threading (This can cause disorientation if the threads are similar, and cannot overcome the problem of slow network access) *{requirement 2}*
- downloading pages to the local machine to look at later. (Users often found that graphics were not saved) *{requirement 2}*
- expanding the cache, allowing for quicker access to pages viewed earlier in the session. As users can only remember 7 +/-2 chunks of information in the short term memory this allowed for forward and backward navigation without needing to revisit remote sites
- deactivating automatic image loading. This can be problematic if the author has not provided text alternatives. *{requirement 5}*

(2) Users do not know what information they are seeking, but wish to minimise the time spent in locating it. This resulted in the following actions:

- Using a site or author who the user feels has some credibility, following their links and maintaining contact with that site. However, user's views and understanding are not necessarily the same as those of the author
- avoiding sites which contain a large amount of graphics or which use frames
- using search engines
- use of personal information feedback or agents
- use of FTP instead

Not all of these compensatory actions can be supported by the Web-browser but they provide some insight into ways in which browsers may provide some support for the user in overcoming system delay. This support may be simply to provide the user with alternatives if delays are experienced, such as to open the page in a new window, or to save the URL in a location which will remind the user that he wished to view the page. Where a user strategy is currently problematic, such as the difficulties users have experienced with the saving of graphics, the browser could support the user by ensuring that he is able to save all of the relevant files. These are functional requirements which are only exposed by the consideration of non-functional requirements.

3.2 Summary of Requirements Identified

Based on the discussion and survey in section 3.1 above, we propose the following requirements of relevance to the user's temporal experience when using the Web.

1. That the user is provided with an estimate of the time which it will take to load the full page, based on total file size and current rate of transfer. This should occur within 5 seconds of the user requesting a particular URL. The time scale should be user definable with 5 seconds used as a default value

2. That the user should be able to define a maximum acceptable loading time (default value, 10 seconds) for pages to be fully displayed. If this cannot be satisfied an information box should be provided offering the choice of:
   continuing to wait for the page to load
   abandoning the request
   loading the page into a new window
   saving the page to a local disk for later viewing
   disabling automatic image loading, or sacrificing audio transfer *(for this page only)*

3. A list of sites which the user wishes to view but has been unable to reach ('return-to's'), similar in style to bookmarks, should be incorporated in order to allow such pages to be remembered and filed

4. The location of a site (i.e. remote or cached) should be indicated through the use of distinguishable buttons

5. Indication of file and page size should be provided to allow the user to decide whether he wishes to view the image or linked URL

6. Where possible, indications of image quality should be provided using thumbnail images.

These are all functional requirements for the interface, not simply quality issues. However, we have only discovered these requirements through careful consideration of what is generally though to be a non-functional requirement, namely timeliness. This illustrates that the definition of requirements for the human-computer interface requires serious consideration of temporal issues if an effective interface is to be provided.

4 Conclusions

The approach which we have taken to considering temporal issues relating to the human-computer interface has led to the identification of some previously unrecognised (non-temporal) functional requirements. The additional requirements we have defined relate both to system functionality and the interface itself. These requirements were defined only because we considered the experience of the user at the interface, separately to issues relating to system performance. Temporal performance cannot be guaranteed for our example system, the Web browser, due to

the variety of factors which may contribute to delays, but we have identified a number of requirements which allow us to minimise the disruption that delays cause. Many of these requirements contain no reference to time, and we must recognise that requirements relating to temporal issues may encompass matters other than response time.

The rise in use of the World Wide Web, and particularly the anticipated rise in the use of e-commerce, are dependant on interfaces which support the (often inexperienced) user. We argue that the issues we identify in this paper are relevant to the determination of requirements relating to the human-computer interface in any networked or distributed system where temporal performance cannot be guaranteed. It is unclear at this stage whether these findings can be applied to other types of system. Further research is also needed to assess whether this approach yields similar results in relation to other non-functional requirements. What is clear is that where temporal performance cannot be guaranteed, temporal issues affecting the interface must be considered alongside functional requirements. If we continue to treat time as merely a non-functional requirement we are in danger of identifying functional requirements too late in the requirements process for them to be properly incorporated.

The objective of the RE process is to specify a successful system, and there is a corresponding need for the requirements engineer to be aware of the possible causes of failure, and to use techniques which will help avoid failure. Therefore we must look to those factors which contribute to the success of a system [Macaulay 96]. Successful systems combine both utility and usability, and we believe that the approach that we suggest to defining interface requirements can lead to enhanced usability achieved through the inclusion of additional functionality.

References

Byrne, A. and Picking, R. (1997) Is Time Out to be the Big Issue? Presented at *Time and the Web, Staffordshire University 19 June 1997.*
Available at: http://www.soc.staffs.ac.uk/seminars/web97/papers/picking.html

Chung,C., Nixon,B.A. & Yu,E. (1995) Using Non-Functional Requirements to Systematically Support Change. In *Proceedings of the Second IEEE International Symposium on Requirements Engineering*, York, England, March 27-29 1995. IEEE Press

Dix, A.J. (1987) The Myth of the infinitely Fast Machine. In *People and Computers III* Diaper and Winder (Eds.) CUP

Dix, A.J. (1992) Pace and Interaction. In *People and Computers VII.* Monk, Diaper and Harrison (Eds) CUP

Dix, A.J. (1994a). Que Sera Sera - The Problem of Future Perfect in Open and Cooperative Systems. In *People and Computers IX.* Draper and Weir (Eds) CUP

Dix, A.J. (1994b) Seven Years On, The Myth Continues. University of Huddersfield Research Report RR9405

Dix, A.J. (1996a) Natural Time. Position Paper for *CHI 96 Basic Research Symposium, April 1996, Vancouver, BC.*
Available at: http://www.soc.staffs.ac.uk/~cmtajd/papers/natural/natural.html

Dix, A.J. (1996b) Temporal Aspects of Usability. Delays and temporal Incoherence Due to Mediated Status-Status Mappings. In *SIGCHI Bulletin, Vol 28 No 3, April 1996*
Available at: http://www1.acm.org:82/sigs/sigchi/bulletin/1996.2/Alan-Dix.html

Dix, A.J., Ramduny, D. and Wilkinson, J. (1998) Interaction in the Large. In *Interacting With Computers, Special Issue on Temporal Aspects of Usability* (in press)

Franch, X. (1998) Systematic Formulation of Non-Functional Characteristics of Software. In *Proceedings of the Third International Conference on Requirements Engineering*, Colorado Springs, Colorado, April 6-10 1998. IEEE Press

Johnson, C. (1995) Time and the Web: Representing and reasoning About Temporal Properties of Interaction With Distributed Systems. In *People And Computers X: HCI'95,* M. Kirby and A. Dix (Eds) pp39-50. Cambridge University Press

Johnson, C. (1997) What's the Web Worth? The Impact of Retrieval Delays on the Value of Distributed Information. Presented at 'Time and the Web' Staffordshire University, 19th June 1997.
Available at: http://www.soc.staffs.ac.uk/seminars/web97/papers/

Lubars, Potts, C. and Richter. (1993) A Review of the State of Practice in Requirements Modelling. In *Proceedings IEEE Int Symposium on Requirements Engineering, RE93, pp 2-14.* IEEE Press 1993

Macaulay, L. (1996) Requirements for Engineering Techniques. In *Proceedings of the Second International Conference on Requirements Engineering*, Colorado Springs, Colorado, April 15-18 1996. IEEE Press

McManus, B. (1997) Compensatory Actions for Time Delays. Presented at 'Time and the Web' Staffordshire University, 19th June 1997.
Available at: http://www.soc.staffs.ac.uk/seminars/web97/papers/

Newman, W. (1997) The Use of Critical Parameters in the Design of Web-based Interactive Systems. Presented at 'Time and the Web' Staffordshire University, 19th June 1997.
Available at: http://www.soc.staffs.ac.uk/seminars/web97/papers

Parker, H. (1997) The User's Experience of Time During Interaction. Technical Report CRC-97-1, Computing Research Centre, School of Computing and Management Sciences, Sheffield Hallam University, 1997. Available online at: http://homepages.shu.ac.uk/%7Ecmscrr/PAPERS/crc-97-1.ps.

Roast, C. (1995) Modelling Temporal Requirements for Interactive Behaviour In Proceedings of the International Symposium on Human Factors in Telecommunications '95. Available on-line at: http://homepages.shu.ac.uk/%7Ecmscrr/PAPERS/hft95.pdf.

Roast, C. (1998) Designing For delay in Interactive Information Retrieval. In *Interacting With Computers* 10 (1998) 87-104

Shneiderman, B. (1984) Response Time and Display Rate in Human Performance with Computers. In *ACM Computing Surveys, Vol 16, No 3, pp 265-285, September 1984*

Shneiderman, B. (1987) Response Time and Display Rate. In *Designing the User Interface: Strategies for effective Human Computer Interaction*, Addison-Wesley 1987

Vanwelkenhuysen, J.(1996) Quality Requirements in Customer-Centred Software Development. In *Proceedings of the Second International Conference on Requirements Engineering*, Colorado Springs, Colorado, April 15-18 1996. IEEE Press