

**Inflectional morphology and compounding in English: A single
route, associative memory based account**

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Abstract

Native English speakers include irregular plurals in English compounds (e.g., *mice chaser*) more frequently than regular plurals (e.g., **rats chaser*) (Gordon, 1985). This dissociation in inflectional morphology has been argued to stem from an internal and innate morphological constraint as it is thought that the input to which English speaking children are exposed is insufficient to signal that regular plurals are prohibited in compounds but irregulars might be allowed (Marcus, Brinkmann, Clahsen, Weise & Pinker, 1995). In addition, this dissociation in English compounds has been invoked to support the idea that regular and irregular morphology are mediated by separate cognitive systems (Pinker, 1999). It is argued in this thesis however, that the constraint on English compounds can be derived from the general frequencies and patterns in which the two types of plural (regular and irregular) and the possessive morpheme occur in the input. In English both plurality (on regular nouns) and possession are denoted by a [-s] morpheme. It is argued that the constraint on the use of plurals in English compounds occurs because of competition between these two identical morphemes. Regular plurals are excluded before a second noun because the pattern *-noun-[-s] morpheme- noun-* is reserved for marking possession in English. Irregular plurals do not end in the [-s] morpheme and as such do not compete with the possessive marker and consequently may be optionally included in compounds. Interestingly, plurals are allowed in compounds in other languages where this competitive relationship does not exist (e.g. Dutch (Schreuder, Neijt, van der Weide & Baayen, 1998) and French (Murphy, 2000)). As well as not being in competition with the possessive structure irregular plurals also occur relatively infrequently in the input compared to regular plurals. This imbalance between the frequency of regular and irregular plurals in compounds also affects the way the two types of plural are treated in compounds. Thus there is no need for an innate mechanism to explain the treatment of plurals in English compounds. There is enough evidence available in the input to constrain the formation of compound words in English.

Chapter 1.

1. 1 Introduction

The treatment of plural morphemes in English noun-noun compounds is significant because it provides a test case for competing theories of language acquisition and representation. Even when the first noun in a compound refers to plural items, adult native speakers frequently use the singular form (Murphy, 2000). Sometimes they will use the irregular plural form (i.e., a plural that does not end in the morpheme [-s]) but very rarely are regular plurals used as the first noun in a compound. This apparent dissociation between regular and irregular plurals (i.e. that irregular plurals are included before a second noun but regular plurals are almost never included before a second noun) is thought to be due to innate morphological constraints. Such constraints predict that all items of regular and irregular morphology should be treated differently by language users. An alternative view is put forward in this thesis that argues that the way in which regular and irregular plurals are treated in compounds is constrained by the different patterns and frequencies in which the two types of morphology appear in the linguistic input.

Classical models assume that human cognition includes the capacity to use stored mental rules to process input from the environment (Fodor & Pylyshyn, 1988). Implicit in Chomsky's (1959) idea, that children use some innate, language specific mechanism to uncover the underlying rules of their native language, for instance, is the notion that there are rules there to be discovered. Others, such as Rumelhart and McClelland (1986), while agreeing that it may be possible to describe language in rule-like terms, argue that there

might not actually be any rules available for the child to represent. Rumelhart and McClelland and many other connectionist modellers have been able to simulate rule like behaviour in artificial neural networks that have no specific knowledge of the rules of grammar. The connectionist view is that general associative memory processes are used to learn language. These processes are guided by the fact that language appears in highly regular patterns (Saffran, 2001) and the way learning proceeds is influenced by the frequency with which linguistic items appear in the input during the acquisition process.

The debate over whether or not language is mediated by a series of rules has been frequently investigated in the field of inflectional morphology. In English, the majority of inflectional morphemes occur as suffixes on the end of words. For instance, the past tense of the majority of English verbs (known as regular verbs) is formed by adding [-ed] to the stem (e.g. walk + [ed] = walked). Similarly the plural of many English nouns (known as regular nouns) is formed by adding [-s] to the stem e.g. cat + [-s] = cats. However, English also has both verbs (e.g. *see/saw*) and nouns (e.g. *mouse/mice*), known as irregulars, which are not produced by adding [-ed] (to verb stems) or [-s] (to noun stems). While no one past tense “rule” can account for all irregular verbs in English, attempts have been made to develop sub-groups of irregular verbs which appear to adhere to the same rule e.g. the “rule” {“i -> ^” in the pattern CC_ng) can account for the past tenses of *string*, *fling*, *cling*. However, this rule does not explain the past tense of *bring* or *spring* and incorrectly excludes *stick* and *spin* (from Pinker and Prince, 1992). Of the 7 frequently occurring irregular nouns in English it might be argued that *tooth – teeth*, *foot – feet* and *goose-geese* conform to one “rule” and *man-men* and *woman-women* conform to a second “rule”. However, it is not

possible to characterise the other 2 frequently used irregular plurals i.e. *mouse-mice* or *child-children* using either of these rules. If all language is mediated by rules, why is it impossible to find a set of rules to explain all items of English inflectional morphology?

The inability to develop a full set of rules to explain all items of English inflectional morphology is not an issue for those who propose that associative memory systems (in which the past tenses of verbs and the plurals of nouns are stored with their stems in the lexicon) drive language acquisition. It does, however, present a problem for classical theorists who argue that all morphology is mediated by rules and only the stems of regular items of morphology are stored in the lexicon. Pinker (1991, 1994, 1999) and others (e.g., Marcus, Brinkmann, Clahsen, Wiese & Pinker, 1995) have developed a hybrid theory, hereafter referred to as the dual mechanism model, that attempts to unite the classic symbolic view of language with associative memory based accounts of language processing. The dual mechanism model proposes that items of regular inflectional morphology are rule governed but less systematic features of language such as irregular verbs and nouns are learned and represented using associative memory systems. Thus, irregulars are learned on a case by case basis. However, they are not simply learned as separate examples by rote memory systems and stored as unique, isolated items. Instead items which share phonetic similarity (e.g. *sing/ sang/ sung: ring/ rang/ rung*) appear to have overlapping representations (Chandler, 1993). Marcus et al suggested that only the stems of regular verbs and nouns are stored in the lexicon as the “rule is applied” (i.e. the past tense [-ed] and the plural [-s] morpheme are added) at a post lexical stage in word formation. Conversely, all irregular past tense verbs

and irregular plural nouns are learned and stored (with their stems) in the lexicon by associative memory systems and a high strength of association exists between sub-groups of irregulars (e.g. *blow, grow, throw*).

Whether due to rule based, innate constraints or to constraints derived from the patterns in the linguistic input, the evidence consistently indicates that regular and irregular morphological items are treated differently by language users. Marcus et al, (1995), for example, cite 21 instances in which regulars and irregulars behave differently. For instance, in lexical decision tasks, participants are influenced by word frequency when retrieving irregulars but not regulars (Prasada, Pinker & Snyder, 1990). Similarity has also been shown to influence the processing of irregular but not regular items of morphology (Bybee & Moder, 1983). For instance participants inflected the nonce verb *spling* (i.e similar to the irregular verb *fling*) as *splung* more often than they inflected *sp|iv* as *sp|uv*. Regular and irregular plural nouns are also treated differently when they are followed by a second noun (i.e. they are used as the first element in a compound). In a series of experiments (e.g., Gordon, 1985) participants have included irregular plurals in compounds (e.g. *mice chaser*) more frequently than they have included regular plurals (e.g. **rats chaser*). This happens, according to the dual mechanism model, because only the singular stems of regular nouns are stored in the lexicon and thus the plural form is never available to be included within compound words (Marcus et al). Conversely, irregular plurals are available in the lexicon to be included within compound words.

An alternative explanation, is one based on a purely associative system whereby differences in the way regular and irregular items are treated arises from an input based constraint. The input constrains compound production because the

two types of morphology appear at different type and token frequencies and in different patterns in English. Such an alternative, associative explanation had not been systematically and fully explored. An explanation of this sort may explain the treatment of both regular and irregular plurals in compounds (Murphy, 2000). The associative explanation put forward here is based on the fact that the [-s] suffix on English nouns is used to convey both plurality and possession. Token frequency counts of a sample of the CHILDES (Child Language Data Exchange System) corpora (McWhinney & Snow, 1985) have shown (Hayes, Murphy, Davey, Smith & Peters, 2002) that the plural [-s] morpheme is rarely followed by a second noun. Importantly, the reverse pattern is found with the possessive [-'s] morpheme since it is always followed by a second noun. Therefore, it might be that a noun rarely follows the regular plural [-s] morpheme (i.e. patterns such as **rat[s] chaser* do not occur) in English because the pattern *noun – morpheme [-s]- noun* is reserved for marking possession (such as *rat's tail*). Interestingly, in other languages that do not have this competition between the plural and possessive morpheme such as Dutch (Schreuder, Neijt, van der Weide & Baayen, 1998) and French (Murphy, 2000), regular plurals are allowed within compounds. Irregular plurals may, however, appear in English compounds as they are not formed by the addition of the plural [-s] morpheme. Thus, irregulars do not compete with the possessive structure and as such may be followed by a second noun in a compound. This idea that the different uses of the [-s] morpheme acts as an input driven constraint on how regular and irregular morphology is treated in compounds is explored here using experimental studies and connectionist models. Other factors which might also provide external constraints on the treatment of plurals in compounds such as the difference in the

frequency in which regular and irregular plurals occur in the input; the fact that the regular plural [-s] only occurs at the end of a word in English and the treatment of compounds by language users of different levels of proficiency are also considered.

1.2 Compounds

A compound is made up of two or more words concatenated to form another word. For instance, '*pan*' and '*cake*' produced together form the compound '*pancake*'. The experiments (e.g., Gordon, 1985; Murphy, 2000), conducted to investigate how regular and irregular plurals are treated in compounds, have tested synthetic compounds. These are compounds in which the words making up the compound have a head-complement relationship (e.g. *taxi driver* where *taxi* describes what kind of vehicle the driver is driving). More importantly, the second noun (the head noun) (e.g., *driver*, *maker*, *teacher*) is a deverbal noun (i.e., a noun derived from a verb). Root compounds are compounds made up of nouns where the nouns have a modifier head relationship (e.g., *blackboard* where *black* modifies or describes what kind of *board* it is) and the head noun is not a deverbal noun. Clarke, Hecht and Mulford (1986) showed that while very young children produce root compounds (e.g., *skycar* (1;6) *airplane*, *coffee-churn* (2;0)) they rarely use synthetic compounds before age three. Furthermore, when children start to use synthetic compounds they make more errors than they do with root compounds. Thus, Clark et al concluded that children find synthetic compounds more difficult to produce than root compounds. Furthermore, Lardiere (1995a) reports that when adults include regular plurals in compounds it tends to be in root rather than in synthetic compounds. Thus the distinction between the two types of compound appears to

have a degree of psychological validity (Murphy, 2000). Root and synthetic compounds appear to be treated differently by both adults and children but to date the conclusions regarding plurality in compounds has been made solely on the basis of synthetic compounds.

1.3 Evidence for the putative dissociation between regular and irregular plurals in English compounds

When asked to produce synthetic compounds made up of two nouns in which the non-head noun (first noun) is a plural, English speaking children (Gordon, 1985; Oetting and Rice, 1993; Nicoladis, 2000; van der Lely and Christian, 2000); native German speaking children (Clahsen, Marcus and Bartke, 1993); native English speaking teenagers (van der Lely and Christian, 2000); and native English speaking adults (Lardiere and Schwartz 1997; Murphy, 2000; Buck-Gengler, Menn and Healy, 2001) have all been more ready to include irregular than regular plurals in compounds. Accordingly, in the literature, it has become generally accepted that regular plurals are omitted but irregular plurals “easily appear inside compounds” (Marcus et al, 1995, p 208).

Thus it seems that the dissociation between the treatment of regular and irregular plurals in compounds is robust. The interesting issue is whether this dissociation is mediated by innate or input driven constraints.

1.4 Innate constraint based explanations of the putative dissociation between regular and irregular plurals in compounds

1.4.1 Level ordering model

Gordon (1985) was the first to point out that it was surprising that children included irregular plurals in compounds in experimental studies when

they never hear them (i.e., they hear *'toothbrush'* never *'teeth brush'* and *'mouse-trap'* never *'mice-trap'*) in natural child directed speech. Thus, Gordon (1985) argued that if compounds with plurals (of either type) do not occur frequently enough in the input to signal when and what type of plurals go in compounds then an innate morphological constraint must mediate compound production.

One such innate constraint that has been proposed to explain the dissociation between regular and irregular plurals in compounds arises from a theory that orders morphological processes on a hierarchy of levels (Kiparsky, 1982). According to Kiparsky's level ordering model, morphology is generated at three hierarchical stages. At level 1, irregular inflections and primary affixes (e.g., -ian, -ous, -ion) are applied. At level 2 derivational affixes (-er, -ism, -ness) and nominal compounding are generated and finally regular inflection (e.g., -ed, -s) is applied at level 3. Morphological application proceeds through these three levels in a serial fashion such that morphology generated at a later level may not be incorporated in morphology applied at a previous stage. As regular plurals (level 3) are applied after nominal compounding (level 2), regular plurals inside compounds (e.g., **rats-eater*) should never occur. However, irregular plurals are applied at level 1, before nominal compounding (level 2), and may therefore appear in compounds (e.g., *mice-eater*). Thus the level ordering model makes the very strong, testable prediction that not one regular plural should ever occur within a compound (Lardiere, 1995a) but irregular plurals may be optionally included. The level ordering model's account of the treatment of plural morphology in compounds has been tested on several different populations. Native adult English speakers (Lardiere and Schwartz, 1997; Murphy, 2000) and

children (Gordon, 1985) have been tested. To investigate whether the same innate constraints apply in other languages, German children were also tested (Clahsen et al, 1993). Further investigations were carried out to see if innate constraints on compounding applied to English second language learners (ESL) (Lardiere 1995a; Murphy, 2000) and had an effect on compound processing by bilingual children (Nicoladis, 2000). Specific language impairment (SLI) children have also been seen as a good test case for the level ordering model as it has been argued that this group lack the ability to apply morphological rules and thus putatively store regular morphology with irregular morphology at level 1 (van der Lely and Christian, 2000). Thus contrary to normally developing children, SLI children should include both regular and irregular plurals in compounds (which are produced at level 2).

1.4.1.1 Tests of the Level ordering model's account of compounding with native English speaking children

In the first compound production study carried out, Gordon (1985) examined the claims made by the level-ordering model regarding compounding. Gordon tested 33 children between the ages of 3 and 6 years of age. The children were shown 4 examples of an item (either as real items or as a toys) and asked to produce the plural form. To elicit a compound the experimenter asked "*what do you call someone who eats X*" (where X was the plural which the child had previously supplied). The children omitted regular plurals from 98% of compounds. Conversely they included irregular plurals in 90% of compounds produced. Gordon argues that these results strongly support the idea that level ordering, as opposed to evidence from the input, constrains word formation by

children because although the children never hear irregular plurals in compounds, they still include them in compounds if prompted.

1.4.1.2 Tests of the Level ordering model with native German speaking children

If, as Gordon (1985) suggested, the constraint on morphological processing is innate, i.e., children do not develop this grammatical system from evidence in the input, then this aspect of morphological processing must be “hard wired” in the human brain and it should be applied regardless of the language being learned. Thus Clahsen et al (1993) attempted to replicate Gordon’s findings using German children. The English regular plural [-s] suffix is sometimes described as being the default plural ending as it is applied unless there is an irregular plural associated with that stem in the lexicon (Marcus, 1996). Clahsen et al characterise the German plural as being a system in which each individual language user applies a default ending to a noun (usually the [-s] or the [-(e)n] suffix) to make it plural, unless use of this default is blocked by one of the other 7 plural suffixes being associated with that stem. Clahsen et al identified the plural ending which they argued that each child used as the default by recording which suffix the child used when making overregularisation errors. They claimed that the majority of children used the [-s] plural suffix as the default plural ending but that some children used the [-(e)n] suffix as the default. Clahsen et al predicted that if German and English children were governed by the same innate constraint on plural usage in compounds then German children should omit the plural ending they use as the default just as English children omitted the regular plural [-s] default from the compounds they produced in Gordon’s experiment. Clahsen et al adapted Gordon’s methodology by asking

their participants (aged 3-6 years old) to produce the compounds using a range of deverbal nouns as the head element (this represented a methodological shift from Gordon who used *eater* as the head noun in all the compounds he tested). As they predicted, Clahsen et al found that the children did not omit all plurals from compounds. Instead, German children only omitted the plural ending which Clahsen et al had identified as being their default plural inflection. Clahsen et al argued that the German children displayed exactly the same behaviour as the English children who omitted the default plural [-s] ending. Thus it was claimed that Clahsen et al's findings were in line with Gordon's results and as such provided evidence for the idea that despite differences between the plural systems in English and German, children are subject to the same grammatical constraints in producing plurals in compounds in both languages.

However, other experimental evidence suggests that Clahsen et al (1993) were oversimplifying the situation when they argued that each German speaker uses one of the plural endings as their default. Closer inspection of Clahsen et al's data found that 19 out of 30 (63%) of the children made overregularisation errors on more than one plural ending (Clahsen et al predicted that the children who overregularised more than one plural suffix would omit both defaults from compounds). Furthermore Gawlitzek-Maiwald (1994) asked 33 German children (aged between 3 and 6 years of age) and 10 adults to provide the plural of a series of nonce words (i.e. words that were not associated with any of the German plural endings). She found that rather than using one default, her participants applied plural endings to the nonce words depending on the gender marker and final phoneme of the stem (auslaut). This evidence contradicts the viewpoint that the German plural system is completely irregular and provides no

clear indicators to dictate which nouns will take which plural ending (Weise, 1988; Clahsen, 1992). Gawlitzek-Maiwald's experimental evidence and her analysis of German grammar together with connectionist modelling (Hahn and Nakisa, 2000) have shown that the German plural system is in fact highly predictable. Thus the evidence points to the fact that German speakers do not have one default plural ending but rather apply a plural ending to a noun new to them depending on the gender and the auslaut (final sound) of the noun.

Furthermore Gawlitzek-Maiwald suggested that the non-[-s] plural endings that are included within compounds (i.e. the plurals which Clahsen et al argued are similar to English irregular plurals) are actually linking morphemes rather than true plurals. Given these questions concerning Clahsen et al's findings it seems erroneous to compare the treatment of plurals in English and German compounds and as such the conclusion that Clahsen et al replicated Gordon (1985) is questionable.

1.4.1.3 Tests of the level ordering model's account of compounding with children with language disorders

Specific language impairment (SLI) is a heterogeneous disorder of language in children who have no other apparent cognitive, social or neurological deficit which could account for their behaviour (Menyuk, 1964). Children with SLI are of interest to researchers who study how morphology is represented and processed because it has been proposed that children with SLI are not able to compute the rules needed to produce regular morphology (van der Lely and Ullman, 1996). Thus, they store both regular and irregular forms in the lexicon. In terms of the Level Ordering model this means that for these people both regular and irregular plurals will be stored at the same level (level 1). Thus, both

types of plural are available to be included in compounds which are produced at level 2. Clahsen, Rothweiler, Woest and Marcus, (1992) investigating the spontaneous use of noun compounds in German SLI children found that, unlike normally developing German children, SLI children failed to delete [-en], the highest frequency plural ending (and here regarded as the default German plural) from nearly half of the compounds they produced. Bartke (1998), using an elicitation task based on Gordon's (1985) methodology, found that German SLI children made numerous errors forming the correct plural which made interpretation of the way they treated plurals in compounds difficult. Despite these confounds, Bartke concluded that German SLI children displayed a general tendency to include more non-default than default plurals in compounds. However, the difference was less pronounced than in normally developing children. The motivation for van der Lely and Christian's (2000) study was to investigate whether English SLI participants would, like German children, show evidence that they stored both regular and irregular plurals at level 1 and thus produced compounds containing both types of plural. van de Lely and Christian used an exact replication of Gordon's methodology. The young people (aged between 10;4 to 18) tested were asked to produce the plural of various items and then to elicit the compound they were asked "*What do you call someone who eats X*" (where X was the plural that the child had supplied). As controls, van der Lely and Christian also tested 36 normally developing children ranging in age from 6 years to 18 years old. van der Lely et al found that the normally developing controls reliably included more irregular than regular plurals in compounds (in fact they included hardly any regular plurals). The SLI children did not show this dissociation as they included over 35% of regular plurals and

20% of irregular plurals in the compounds they produced. van der Lely and Christian argued that had this difference in treatment of regular morphology (by SLI children compared to normal children) been due to processing deficits (i.e., if the production of inflections required a level of processing capacity not available to these children (Joanisse & Seidenberg, 1998; Leonard, 1998;)) then participants would have not been able to process the plural [-s] inflection. Had the difference been due to a lack of processing capacity, then a pattern similar to that displayed by normal language users in which no regular plurals are included in compounds would have been found. This was not the case. Thus van der Lely and Christian rule out phonemic processing deficits as an explanation for the deviation from normal behaviour shown by their SLI participants and conclude that English SLI children produce regular plurals in compounds because of deficits to their morphological processing system. However, Leonard (1998), in an extensive review of the literature, points out that SLI children learning more highly inflected languages than English, such as Italian, can produce regular morphology. Leonard concluded that SLI children, across a whole range of languages, actually show a similar pattern of language development to that displayed by normally developing children learning that language. The defining characteristic of SLI children, however, is a protracted rate of language development. In van der Lely and Christian's study the children did not appear to systematically include or omit either type of plural from the compounds they produced (they included regular plurals in compounds more or less at chance). If these children, as Leonard suggests, are developmentally delayed in learning to use morphology, it may be that they do not use plurals in compounds, in the same way as their normally developing age-matched peers, because they are yet

to master the use of morphology in compounds. Recent evidence from Murphy, Messer, Dockrell and Farr (in preparation) suggests that had van der Lely and Christian used younger controls they may have found more similarities between SLI and normally developing children. Murphy et al found that normally developing children aged 4 and 5 years behaved more like the SLI children tested by van der Lely and Christian (who included 35% of regulars and 20% of irregulars in compounds) in that they included 15% of regulars and 28% of irregular plurals in compounds.¹ Thus lack of proficiency rather than a breakdown in an innate processing system may be responsible for the performance differences seen between SLI and normal controls.

1.4.1.4 Tests of the level ordering model's account of compounding with adult English native speakers, adult and child English second language learners and bilingual children

While the data presented by Gordon (1985), Clahsen et al (1993) and van der Lely and Christian (2000) appears to support the level ordering model's account of compounding, a number of difficulties with this model have been raised by Lardiere (1995a). Lardiere and Schwartz (1997) using picture stimuli only (in the standard Gordon experiment verbal questioning as well as visual stimuli had been used) tested 12 adult native English speakers.

However, Nicoladis (2000) found that monolingual children (aged between 3 and 4 years of age) included regular plurals in as few as 2.5 % of compounds produced. They included irregular plurals in 65% of compounds produced. Nicoladis adopted a different methodology to Murphy et al which may explain the differences in the results they found. The effect of methodology on the results of compound production experiments is discussed in detail in Chapter 2.

They found that no regular nouns and only 4.8% of irregular nouns were produced in the plural form in compounds. Using verbal questioning only, Murphy (2000) also found that native English speaking adults omitted regular plurals from 98% of compounds. They included irregular plurals in 28% of compounds produced. It is interesting that irregulars were omitted from compounds much more frequently by Lardiere and Schwartz's and Murphy's adult native English speakers than they were by the native English speaking children tested by Gordon. Furthermore, Lardiere and Schwartz and Murphy obtained very different rates for the inclusion of irregular plurals. The differing rate at which irregular plurals have been included in all the various compounding studies conducted to date and the role that language proficiency and methodological factors might play in causing this variability in results is considered in detail in Chapter 2. However, despite the fact that Lardiere and Schwartz and Murphy's results (for irregular plurals at least) differ from Gordon's, they do not contradict the predictions of the level-ordering model. No regular plurals were included in compounds and the model allows for irregulars to be included optionally. However, Lardiere (1995a) also tested Spanish and Chinese, English Second Language learners (ESL) and found that they only omitted possible regular plurals from compounds roughly at chance. They included irregular plurals in 78% of compounds produced. Similarly, Murphy testing French speaking ESL school children (mean age 12;4 years) found that they included regular plurals in 15% of compounds produced and irregulars in 25% of the compounds produced. Commenting on Lardiere's results, Marcus (1995b) argues that as both the Spanish and Chinese participants omitted significantly more regulars than irregulars from compounds, averaged across

participants, the results support the level-ordering model. However, the level ordering model makes a very strong testable prediction that regular plurals should never be produced inside compounds because of a morphologically innate constraint. If the level ordering model is correct then no regular plurals should be included in compounds by any group of language users (Lardiere, 1995b). Thus both Lardiere and Murphy present results that question the level ordering model's account of plural inclusion in compounds. Nicoladis (2000) tested bilingual children (aged 3 and 4 years) and found that they included regular plurals in compounds in 15% of cases. This evidence together with Lardiere and Murphy's results indicate that knowing a second language affects the production of regular plurals in non-head position. Again it seems that lack of proficiency in English may affect the rate at which plurals of both kinds are included in compounds. This is hard to explain if an innate constraint is responsible for morphology, regardless of language but not if it rests on exposure to English. Lardiere also lists a series of root compounds in which regular plurals are included in both English (e.g. *drinks cabinet*) and German (e.g. *Bilder-buch* (*picture-book*)) compounds. Furthermore, Lardiere presents examples in which other items of regular morphology such as the comparative (*longer lasting effects*) and the superlative (*lowest priced items*) appear before a noun in English. As items of regular inflection they would be applied at level 3, i.e., too late to be included in nominal compounding which takes place at level 2. Thus level ordering has been discredited over recent years and is no longer seen as a serious explanation for the dissociation between regular and irregular plurals in compounds (For English; Senghas, Kim, Pinker & Collins, 1991; Murphy, 2000;

Buck-Gengler et al, 2001; Haskell, MacDonald & Seidenberg (in press): For German; Gawlitzek-Maiwald, 1994).

1.4.2 Dual mechanism model

Another explanation for the dissociation between regular and irregular plurals in compounds (that is driven by internal factors rather than the input) stems from a position that irregular plurals are represented and processed differently from regulars (Pinker and Prince, 1988; 1992, Pinker, 1999). Pinker argues that while some specific features of language need to be learned, children are born with a system which actively seeks out rules which are represented symbolically. Pinker and Prince's dual mechanism theory proposes dissociated systems in which the processing of regular morphology is mediated by classic symbolic rules of grammar (e.g., the plural of regular English nouns is formed by attaching the inflectional morpheme [-s] to the stem [N] (e.g., rat + [s] = rats)). Conversely, irregulars are stored as memorised pairs of words (*mouse-mice*) in the mental lexicon. A great deal of evidence has been put forward to support the dual mechanism model. For instance, the fact that children make overregularisation errors such as *buyed* instead of *bought* or *holded* instead of *held* is cited as evidence of immature language users using the wrong system from two distinct language systems (Pinker, 1999). Furthermore, Pinker claims that a double dissociation exists between the language produced by people with Williams Syndrome who, it is argued, have difficulties with irregulars but are freely able to use regular morphology and the language produced by people with specific language impairment (SLI) who show the opposite pattern. The putative dissociation between the treatment of regular and irregular plurals in compounds is also cited as evidence for the dual mechanism model. In terms of how the dual

mechanism model might impact upon compounding, Marcus et al (1995) have argued that as compounds are the product of joining together two stems from the mental lexicon to form one word, irregular plurals may be used in compounds because they are stored, already inflected, as lexical items. However, regular forms may not be included in compounds because they are products of the application of a rule that takes place outside the lexicon, “online” and at a later stage than compounding in the word formation process. Thus like the level ordering model, the dual mechanism model also makes the prediction that regular plurals should never occur within compounds but irregulars may be included optionally.

1.4.2.1 Experimental testing of the dual mechanism model’s explanation of plural inclusion in compounds

Oetting and Rice (1993) tested the predictions of the dual mechanism model by asking SLI children (mean age 5 years) to complete a compound production task. In the first stage of the experiment they sought to establish whether SLI children could produce regular plurals outside of compounds. They found that contrary to van der Lely and Ullman (1996)’s prediction that SLI children would not be able to produce regular morphology, the SLI children tested (similar to the control groups tested) were able to produce regular plurals (i.e., demonstrate rule-like behaviour). In the second stage of their experiment, using Gordon’s methodology they encouraged the children to use the plural in a compound by asking “*What do you call my puppet if he eats X*” (where X was the plural form that the child had supplied). All children tested, in both SLI and control groups, omitted over 90% of regular plurals from compounds and included 60 % of irregulars. Interestingly, the SLI children were more accurate

with frequently pluralised nouns (e.g. *hat*) than they were with nouns that are used infrequently in the plural form (e.g. *belt*). According to the dual mechanism model once a rule is learned usage should be independent of frequency effects. Oetting and Rice argue that this may be because frequency effects may appear whenever a child is faced with a difficult linguistic task (Winitz, Sanders & Kort, 1981). Several other authors have found that SLI children are affected by frequency in producing regular morphology (Ullman & Gopnik, 1994, 1999; van der Lely and Ullman, 1996,1998). Again this seems to imply that application of rule like behaviour depends on the proficiency of the language user, a concept not allowed for by the dual mechanism model (as it was also not allowed for in the level ordering model). A discrepancy is evident between the number of regular plurals omitted by SLI children in Oetting and Rice's study (92%) and the number omitted in van der Lely's study (65%). This difference cannot be explained by age as van der Lely's children, who omitted fewer regulars, were actually older than the participants tested by Oetting and Rice. However, van der Lely and Christian's participants were all children (described as G-SLI children) who demonstrate a persisting grammatical impairment in the production and comprehension of language. These children do not, however, have problems with articulation or phonology, do not demonstrate pragmatic social impairment and do not display non-verbal cognitive deficits. van der Lely and Christian point out that two of Oetting and Rice's participants included regular plurals in 28% of compounds produced. Thus van der lely and Christian argue that their participants and Oetting and Rice's two participants (who showed a similar pattern of results) are representative of a particular sub-group of SLI children who cannot process regular morphology. It might be, however, that these

children, because of the very specific nature of their linguistic deficits, are actually more severely developmentally delayed than other SLI children such as the majority of the children included in Oetting and Rice's study.

While, Oetting and Rice's (1993) data support the dual mechanism's prediction that regular plurals will be omitted from compounds more frequently than irregular plurals, the study does raise concerns about the dual mechanism model's explanation of compounding because the model cannot account for the frequency effects found with regular morphology. Other doubts have also been raised concerning the dual mechanism model's explanation of compounding. Firstly, it has been pointed out that regular plurals do occur in natural language before other nouns. Haskell et al (in press) found that in 6% of occasions in which regular plurals appeared, in their corpus analysis, they were followed by a second noun. Pinker (1999, p181) lists 25 examples, such as "*singles bar*" and "*publications catalogue*" where regular plurals occur inside compounds. Secondly Lardiere (1995a) and Murphy (2000) found that ESL participants included regular plurals in compounds. The SLI children tested by van der Lely and Christian also included regular plurals in over 35% of compounds. Thus proficiency both in terms of learning a second language or possessing a neurological based difficulty in learning language seems to affect the rate of plurals included in compounds. Furthermore, regular plurals do occur inside compounds in languages other than English such as Dutch (Screuder, Neijt, van der Weide, and Baayen) (1998), and Spanish (Lardiere, 1995). Any explanation (such as the level ordering or dual mechanism model) which is so categorical at prohibiting the inclusion of regular plurals in compounds has a problem accounting for all aspects of the data.

1.5 Input based constraint explanations of compounding

As indicated above there are difficulties with the proposals that explain the dissociation between regular and irregular plurals in compounds being due to some form of internally driven, innate morphological constraint. However, the fact remains that while children may hear enough compounds without regular plurals to learn that they should not be produced in compounds, it is doubtful whether they hear enough irregular plurals inside compounds to learn that they may be optionally included within these structures. Murphy (2000) and Haskell et al (in press) have suggested that children may learn that regular and irregular plurals are treated differently in compounds from more general properties of language that are frequently exemplified in the input to which they are exposed.

1.5.1 General differences between regular and irregular plurals in English

The morphological rules governing the regular plural in English have important phonological components that do not simply involve adding an affix to a stem. There are three regular plural allomorphs in English. The [-s] allomorph is used with stems ending in a non-strident voiceless consonant (e.g. top + s = tops /tops/). The [-z] allomorph is used with stems ending in a non-strident vowel or a voiced consonant (e.g. pin + s = pins /pinz/). The [-iz] allomorph is used with stems ending in a strident consonant (e.g. hiss + es = hisses /hisiz/). In order to apply the appropriate form the language user must be aware of the alternative allomorphs and how they are used. Berko (1958) found that normally developing children were able to apply the [-s] and [-z] allomorph relatively easily to nonce stems but they had difficulties using the [-iz] plural allomorph. Joannise and Seidenberg (1998) argue that to be able to learn the cues to apply the correct phonetic form of the morpheme, language users need to be proficient in

categorising the point at which one phoneme begins and another ends (the delay in developing this ability may explain why children with SLI have difficulty processing regular morphology). Forming the correct regular plural allomorph may require a non-trivial amount of processing effort. Thus, producing the regular plural may in fact require more processing effort than that required to form the irregular plural, since all irregular plurals in English are formed by changing a vowel rather than adding a correctly pronounced phoneme (Stemberger, 1995). This difference in processing may influence language users to include the singular form of the regular plural more frequently than they include the singular form of irregulars in all parts of language including compound words. Furthermore, as illustrated in Table 1.1 four of the frequently occurring English irregular plurals occur more frequently in the plural than the singular form. This may also influence language users to use irregular nouns in their plural forms more frequently than they use plural regular nouns in all language use including compound word formation.

However, despite the factors that might influence English speakers to include irregular plurals more frequently than regular plurals, the fact remains that the type frequency of regular plurals is much higher than that for irregular plurals (there are only 7 frequently used irregular plurals in English). Regular plurals make up 98% of noun types and 97% of noun tokens (Marcus, 1995a). Thus 98% of all nouns in English add an [-s] allomorph to make their plural. And 97% of all plural usage in English involves the processing of the [-s] allomorph at the end of the noun.

Table 1.1 Frequency of use of regular and irregular nouns in the singular and plural forms

<i>Irregular noun</i>	<i>Frequency in singular</i>	<i>Frequency in plural</i>
goose	485	394
mouse	1856	1021
tooth	637	4499*
foot	7249	13346*
man	58860	37104
woman	22008	38240*
children	23669	45731*

*Used in the plural more frequently than the singular form

Source British National Corpus. Frequencies shown represent the frequency in which these items appear in the corpus, which comprises 100,106,008 words. 77.81% of the corpus is made up of written English.

1.5.2 Difficulties with processing regular plurals in the middle of words

Murphy (2000) suggests that one reason children learn to omit regular plurals from English compounds stems from the fact that the plural [-s] morpheme consistently goes at the end rather than in the middle of words. When given the option of including a regular plural in the middle of a word (e.g., to produce **rats eater*), children omit it (and produce *rat eater*) because the plural [-s] morpheme is never found internal to a word. Were they to include the [-s] internal to a compound, the children would be violating an overwhelming pattern found in the input. Irregular plurals do not end in the [-s] morpheme and thus may be included in the middle of compounds.

1.5.3 Constraint satisfaction model

Haskell et al (in press) argue that the use of nouns, like the use of all linguistic structures is governed by a series of constraints (Allen and Seidenberg, 1999; Seidenberg and Macdonald, 1999). They argue that the constraints applicable to nouns govern such things as what nouns mean, what they sound like and in what contexts they may appear. Addressing the issue of compounding, they argue that two input driven constraints linked to noun usage actually drive the dissociation between regular and irregular plurals in compounds. Firstly in English, adjectives that precede nouns are not marked for plurality. Evidence from corpus analysis has also shown that nouns that precede other nouns do not tend to be marked for plurality. When nouns that precede nouns are marked for plurality, Haskell et al conclude that it is to convey that the plural means different types of an item not just multiple copies of the item. So for instance in Pinker's example "*publications catalogue*", *publications* refers to several different publications and not just to multiple copies of the same publication. This first constraint that Haskell et al refer to as the semantic constraint works alongside another constraint which they call the phonetic constraint. The phonetic constraint refers to the fact that while many different sounding words may precede a noun, words sounding like regular plurals rarely do. This is obviously critical to the treatment of regular plurals in noun-noun compounds. Thus, the influence of the semantic and the phonetic constraints working in tandem leads to very few plurals that end in [-s] appearing before a noun. When the item is plural but does not sound like a regular plural, only the semantic (and not the phonetic constraint) is invoked and under these circumstances some plurals that do not end in [-s] (i.e. irregular plurals) may be produced before a second noun.

Table 1.2. Prediction of modifier acceptability by semantic and phonetic factors

<i>Type</i>	<i>Example</i>	<i>Semantically plural?</i>	<i>Phonetically plural?</i>	<i>Acceptability</i>
Singular nouns not ending in phonetic [-s]	rat, tooth	no	no	acceptable
Irregular plural	mice	yes	no	marginal
Bifurcate pluralia tanta	scissors	no	yes	marginal
Singular nouns ending in phonetic [-s]*	lens	no	yes	marginal
Possessives*	cat's	no	yes	marginal
Voicing change	knives	yes	yes	not acceptable
Regular plural	rats	yes	yes	not acceptable

*Predictions following from Haskell et al's model but not tested on language users by them.

Table 1.2 shows Haskell et al's (in press) prediction of how various items should be treated before a second noun, if Haskell et al's model is correct and compounding is governed by the co-influence of the semantic and the phonetic constraints on nouns. According to Haskell et al's constraint satisfaction model, singular nouns being neither semantically nor phonetically plural, may appear in compounds (e.g. *rat catcher*). Irregular plurals are semantically plural without being phonetically plural and thus they may appear optionally within compounds

(*mice catcher*). Bifurcate pluralia tanta items such as “*scissors*”, “*pants*” and “*binoculars*” which although being phonetically plural are considered semantically singular (Bock, Eberhard, Cutting and Schriefers; 2001) should also appear optionally within compounds. Pinker (1999) considered these items to be irregular plurals and argued that they could be used (optionally) as the first element of a compound. Haskell et al tested this prediction by asking participants to rate “how good” compounds including bifurcate pluralia tanta sounded compared to compounds that contained semantically similar singular and plural nouns. Haskell et al found that pluralia tanta nouns were more acceptable than regulars but not as acceptable as irregulars (thus disconfirming Pinker’s assumption that they would pattern with irregulars).

Singular/mass nouns ending in phonetic [-s] such as *lens* or *news* that sound like regular plurals (items such as *blouse*, *house*, *nurse* while ending in the phoneme [-s] are not confused with regular plurals in the same way according to Haskell et al because they make their plural by the addition of the [-iz] allomorph) would be marginally acceptable before a second noun because they are affected by the phonetic but not the semantic constraint.

Voicing change plurals (where the unvoiced final consonant /f/ in the singular becomes the voiced /v/ in the plural e.g. *knife* → *knives*) are also irregular plurals according to Marcus (1995). As irregulars, voicing change plurals may be used as the first element of a compound. In terms of Haskell et al’s (in press) constraint satisfaction model these items are both semantically and phonetically plural and thus they should pattern with regular plurals and be omitted from compounds. Haskell et al (in press), using their acceptability rating paradigm found that voicing change plurals patterned with irregular rather than

regular plurals (thus confirming Marcus' view that voicing change plurals pattern with irregulars). Interestingly, Senghas et al (1993), using a similar methodology to Haskell et al, found no significant difference between the acceptability of voicing change plurals and regular plurals inside compounds. Furthermore, voicing change plurals were rated as being significantly less acceptable than irregular plurals in similar compounds. Thus while the evidence is mixed, there is some evidence that voicing change plurals which are subject to both the phonetic and the semantic constraint, do not appear in front of a second noun. Regular plurals are obviously subject to both the phonetic and the semantic constraint and this is why they do not appear before a second noun.

A pattern seems to be emerging in which items that do not violate either the phonetic constraint or the semantic constraint are permitted as the first element in compounds (i.e. singular nouns). Items that violate one of the constraints, either the semantic constraint (irregular plurals) or the phonetic constraint (*pluralia tanta*), are allowed optionally within compounds. Items that violate both constraints (regular plurals, voicing change plurals) are not included in compounds.

Haskell et al argue that the phonetic and semantic constraints are learnt from general properties of plurals and pre-nominal modifiers that children experience in the input they receive. Children may not hear items such as *mice-chaser* but they hear many noun-noun compounds that do not include plurals such as *toy box* or *cookie jar*. They also hear many plurals in other contexts and learn quickly how plurals should behave in general language. Thus they learn that in contrast to the way the presence of more than one item is usually indicated in language, the presence of more than one of something is not

indicated before a second noun. They also hear many phrases in which pre-nominal modifiers (i.e. adjectives), that do not sound like regular plurals, precede nouns e.g. *big box*, or *green jar*. These patterns drive learning that items that do not sound like regular plurals tend to appear before a noun. The idea behind Haskell et al's constraint satisfaction model is that children use all the items they have heard to judge whether new items they experience are grammatical or not. This process has been modelled using connectionist models (Allen & Seidenberg, 1999). In Allen and Seidenberg's model the weights on connections between neurons represent "probabilistic constraints". Every neuron is involved in processing every input. If an input is consistent with items that the network has been trained on it will be more acceptable (produce a lower error) than items that have not been experienced before. Items that are similar to things previously experienced move weights in the direction of features that do appear in the input and away from features that do not appear in the input. Thus, in the case of compounds, items that do not contain plurals (i.e. the vast amount heard) would move weights towards plurals being omitted from compounds and away from plurals being included in compounds. Similarly, experiencing many items that do not sound like regular plurals appearing before a noun would drive weights towards words sounding like regular plurals being omitted before a noun and away from words sounding like regular plurals being included before a noun.

The constraint satisfaction model is an important development in compound research as for the first time it shows how input driven constraints might drive learning about compound formation. However, the constraint satisfaction model cannot account for all aspects of English synthetic compounding. A crucial element in the compounding puzzle is possessive nouns.

Singular possessive nouns are clearly not plurals (they do not violate the semantic constraint when appearing in front of a second noun). However, singular possessive nouns sound like regular plurals, violating Haskell et al's phonetic constraint. Their model would predict, therefore, that we should not find possessive nouns before other nouns but clearly we do. Frequency counts of a sample of the CHILDES corpora (McWhinney & Snow, 1985) have shown (Hayes et al, 2002) that possessive nouns are always followed by a second noun. Haskell et al's phonetic constraint is unable to account for items like *possessive noun-noun*, a frequently occurring pattern in English. The main research question investigated in this thesis is whether the co-influence of the possessive and plural morphological systems is a viable explanation for why regular and irregular plural morphology is dissociated in English compounds.

Additionally, as Murphy (2000) suggests, the fact that [-s] is the most frequent plural ending in English (there are only 7 irregular plurals in common usage in English) and the fact that it is used as a suffix to mark plurality and possession on nouns and agreement in verbs (third person singular) means that it is strongly associated with word ending. This factor is also investigated in the research reported here. Other input driven constraints such as the relative frequency in which the two types of plural occur in the input and the way English speakers of different proficiency levels treat plurals in compounds are also considered.

1.6 Summary

This first introductory chapter has presented the general framework within which this research project is set. There can be no dispute that participants in a series of experiments included more irregular plurals in compounds than

regular plurals. However, while in some studies irregular plurals patterned with regular plurals and were omitted from compounds, in other investigations irregulars have been included in these structures. It was thought that proficiency of participants might be responsible for the different rates of inclusion of irregular plurals. However, the experimental work carried out has adopted a variety of methodologies and to rule out factors such as presentation and response modality being responsible for the inconsistency in the treatment of irregular plurals in the various studies an experiment was conducted. This first experiment (described in Chapter 2) was carried out to investigate whether manipulating presentation and response mode would affect the number of regular and irregular plurals included in compounds. This was seen as an important first step to ensure that the dissociation between regular and irregular plurals in compounds was not simply an artefact of a particular set of methodological factors. Thus this programme of research sought firstly to establish the role that methodological issues play in compound word formation. Having investigated this methodological issue then the key issue of whether this dissociation was due to innate or input driven constraints could be considered. Evidence has been put forward here which calls into question the level ordering model and the dual mechanism model which both propose an innate constraint on including regular plurals in compounds. However, this still leaves a learnability problem in that children will include irregular plurals in compounds even though they never hear them in the linguistic input they receive. An alternative account is put forward that proposes that the apparent dissociation between regular and irregular plurals in compounds may arise from more general patterns of language input. For instance that the regular plural [-s] only occurs at the end rather than in the

middle of words such as compounds. Also the possessive [-s] morpheme is always followed by a noun but the plural [-s] morpheme is rarely followed by a noun. Furthermore the two types of plural appear in different frequencies in the input and English speakers of different proficiency levels seem to produce different forms of compounds. Thus a second study testing adult native speakers (described in Chapter 3) was carried out to investigate these input driven factors and also to consider innate constraints on compounding in the same experiment. The purpose of this study was to present language users with a range of compounds containing non-head nouns ending in different morphemes and phonemes to measure how various factors influenced processing speed. For instance, if the input driven constraint of competition between possessives and regular plurals applies then possessives should be processed more quickly than regular plurals. If an internal constraint mediates morphology in compounds then regular and irregular morphology should be processed at different speeds.

As it was hypothesised that the treatment of plurals in English compounds is driven by a single route associative memory mechanism then it was also considered appropriate to investigate these issues using connectionist models. Chapter 4 outlines how connectionist models have successfully modelled other phenomena previously thought to be mediated by dual mechanisms. Models that have successfully learnt sequential mappings are also reviewed in Chapter 4. Chapters 5, 6 and 7 describe 4 connectionist models that were developed as part of this research programme. These models investigate whether consistent patterns in the input, for instance that the regular plural [-s] only occurs at the end rather than in the middle of words such as compounds or that the possessive [-s] morpheme is always followed by a noun but the plural [-s]

morpheme is rarely followed by a noun, provide enough evidence to drive learning about how plurals should be treated in compounds.

Chapter 2.

2.1 Introduction

As demonstrated in Chapter 1, compound words with irregular plural nouns in non-head position (e.g., *mice-eater*) have been produced more frequently than compounds with regular plural nouns in non-head position (e.g., *rats-eater*) in all of the compound production studies carried out to date with native English speakers (Gordon, 1985; Oetting and Rice, 1993; Lardiere and Schwartz, 1997; Murphy, 2000; Nicoladis, 2000; van der Lely and Christian, 2000).

It has been claimed that this dissociation is due to innate morphological constraints such as those proposed by the level ordering model (Kiparsky, 1982) or the dual mechanism model (Pinker and Prince, 1988; 1992, Pinker, 1999). Both the level ordering model and the dual mechanism model predict that regular plurals should not occur in the non-head position of a compound. Irregular plurals, on the other hand, are licensed by both the dual mechanism and the level ordering models to appear optionally within compounds.

Table 2.1 presents a summary of the compound production studies carried out with native English speakers to date, including a breakdown of the percentage of regular and irregular plurals produced within compounds in these studies.

Table 2.1. Percentage of plurals (of either type) included in compounds in previous compounding studies with native English speakers

<i>Study</i>	<i>Participants X age (n participants/ items)</i>	<i>Number included</i>		<i>Presentation modality</i>	<i>Response modality</i>
		<i>Regular plurals (%)</i>	<i>Correct irregular plurals (%)</i>		
Native English speaking children with normal language development					
Gordon (1985)	4;6 (33/16)	2	90	Pictorial and aural	Oral
Oetting & Rice (1993)	5;0 (19/14)	2	59	Pictorial and aural	Oral
Nicoladis (2000)	3;0-4;0 (25/16)	2.5	65	Pictorial and aural	Oral
van der Lely & Christian (2000)	5;2-6;8 (12/18)	6.6	61.6	Pictorial and aural	Oral
	6;9-7;10 (12/18)	1.6	55		
	14;0-17;4 (12/18)	0	28.3		
Native English speaking adults					
Lardiere & Schwartz (1997)	Adults (12/16)	0	4.8	Pictorial	Oral
Murphy (2000)	Adults (12/16)	1.7	28	aural	Written

It is clear from Table 2.1 that the omission of regular plurals from compounds is a robust experimental finding and that irregular plurals may or may not be included in compounds. Thus the studies carried out to date would seem to provide support for both the dual mechanism and the level ordering account of compounding.

In some accounts of the dual mechanism model, however, the prediction is made that in any language all examples of regular morphology should be processed in one way and all examples of irregular morphology should be treated in another manner. Pinker & Prince (1992) state that

“it is an extremely strong prediction that in any language one should find that phenomena in either of these two clusters (i.e., regular and irregular morphology) should be found exclusively in association with one another, never in association with a phenomenon from the other cluster” (p.246).

However, such a clear distinction between the way the two types of morphology were treated is not apparent from the studies in Table 2.1. In fact, the pattern of results across the studies is far from uniform. While regulars were almost always omitted from compounds, it is not true to say that irregulars were always included in compounds. In some of the studies some irregular plurals patterned with regular plurals and were omitted from compounds. Other irregulars, however, have been included in compounds.

Only in the earliest compounding study carried out by Gordon in 1985 was there complete uniformity in that the 3-5 year old children tested included 98% of regular nouns in compounds in the singular form and 90% of irregular nouns in compounds in the plural form. At the other extreme, while Lardiere and Schwartz (1997) also found that their participants included all regular nouns in their singular form, unlike Gordon, their adult native English speakers also included irregular nouns in the singular form in 95% of compounds produced. Between the two extremes, age of participants seems to be an important factor in whether the compounds produced included irregular plurals or not. It would seem from Table 2.1 that as native speakers mature and become more proficient in the use of their native language, they include fewer irregular plurals in compounds. For instance, from a study of 3 and 4-year-old native English speaking children, Nicoladis (2000) reports that the correct irregular plural was included in 65% of cases in which the children were required to produce compounds using irregular nouns. The 5 year olds with normally developing language ability in Oetting and Rice's study included irregular plurals in about 60% of compounds produced. The 5 to 6 years olds with normally developing language ability in the study carried out by van der Lely and Christian (2000) knew the correct irregular plural in an average of 78% of cases but they only included it in an average of 61.6 % of compounds produced. The older children (6-10 year olds) tested by van der Lely and Christian demonstrated that they knew the correct

irregular plural in an average of 73% of cases but only included it in an average of 55% of compounds produced. van der Lely and Christian's teenaged participants (aged 14-17;4) were able to name all the correct irregular plurals but they only included irregular plurals in 28.3% of compounds produced. Similarly, the 15 adult native speakers included in Murphy's (2000) study produced irregular plurals in non-head position in 28% of compounds produced. Thus it appears that there may be a developmental trend to exclude irregulars as native English speakers get older.

In Gordon's level-ordering based explanation of the compounding phenomenon he makes the point very strongly that adults hardly ever produce compounds containing irregular plurals which is borne out in these experiments with adults. In fact, the lack of irregular plurals in compounds (e.g., *'toothbrush'* never *'teeth brush'* and *'mouse-trap'* never *'mice-trap'*) forms the centre of Gordon's argument that an innate language process such as level-ordering must mediate compound production in children because they could not learn that irregular plurals (and not regular plurals) are licensed in compounds from the input they receive. Irregular plurals are licensed by the level ordering model to appear optionally within compounds but what Gordon fails to explain is why children "take up the option" to include irregulars in compounds but adults do not. Similarly, the dual mechanism model argues that irregular plurals may appear optionally within compounds but fails to explain why children seem more likely to select the irregular plural from the

lexicon but conversely why adults seem more likely to select the singular form. The level ordering and dual mechanism models have put forward an explanation for the dissociation between the treatment of regular and irregular plurals in compounds but have yet to explain the variation in the way irregular plurals seem to be treated by adults and children in compounds.

However, before concluding that there is a developmental element to the inclusion of plural morphology in compounds it was thought necessary to investigate whether something as relatively straightforward as methodological factors might be causing the differences seen in the various studies. Direct comparisons can be made between all of the studies that tested child participants. Oetting and Rice (1993) and van der Lely and Christian (2000) replicated exactly the methodology adopted by Gordon (1985) in his original experiment. Thus they all showed the children they tested visual stimuli and then asked the child “*what could we call someone who eats X*” (where X was the plural already supplied by the child). In all these studies the child heard the noun used in the plural form before being asked to supply a compound using that noun. Thus the child may have been primed to use the noun in the plural form. Nicoladis (2000) tested root compounds and adopted a slightly different methodology. She showed pictures and asked the children to find a name for the compounds depicted. To test an item such as “*flower chairs*” she would say “*here are some flowers*” (and show a picture of some flowers) then she would show

a picture of some chairs and say “*here are some chairs*” then she would show chairs patterned with flowers and ask “*What could we call these?*” Thus, while Nicoladis did not use the non-head noun in the plural form in the compound elicitation prompt (i.e. she did not say “*what could we call these chairs pattered with flowers?*”) she did supply the plural before asking the child to produce the compound. This means that in all the compound studies testing children the plural was supplied to them before they were asked to form the compound. In every study in which children were tested, participants were required to supply their answers verbally.

It may be impractical, however, to make direct comparisons between the results of the investigations carried out by Lardiere and Schwartz (1997), Murphy (2000) and van der Lely and Christian (2000) on teenagers and adults. The type of questioning stimuli used to elicit compounds was similar in all three studies but the mode of presentation of the stimuli and the mode in which participants were required to respond were not consistent. Lardiere and Schwartz, Murphy and van der Lely and Christian all based their methodologies on Gordon (1985). van der Lely and Christian followed Gordon’s methodology exactly. Their participants were required to produce the plural before the compounding task and during the compounding task the plural, they had supplied, was repeated back to them. They recorded verbal responses. Murphy used aural only rather than pictorial and aural stimuli. Specifically, Murphy read out a list of questions such as “*what do you call a cat that*

watches mice". Thus Murphy mentioned the noun in the plural form before asking her participants to use that noun in a compound. Murphy also elicited written rather than spoken responses. Lardiere and Schwartz presented a series of pictures showing cartoon characters performing particular tasks and asked their participants to make up names for the characters depicted. For instance a character was shown painting its toes and the target compound was *toe/toes painter*. Thus Lardiere and Schwartz employed pictorial stimuli and recorded verbal responses and as such used the same modalities as Gordon. Crucially, however, they did not elicit the plural form in advance and they did not repeat the plural form back to the participant. These methodological differences could be exerting their own influence in dictating the kinds of compounds participants produce. Lardiere and Schwartz's participants never heard the plural used and were required to retrieve the name of the picture from their own mental representation. Conversely, in Murphy's and van der Lely's study, participants were provided with a plural and required to hold it in memory while a question was asked to facilitate the production of a compound word. Interestingly, Murphy and van der Lely and Christian report quite different results in terms of number of irregulars included in compounds than Lardiere and Schwartz in that both Murphy's and van der Lely and Christian's participants included 28% of irregulars in compounds but Lardiere and Schwartz's only included 4.8% of irregulars in compounds. Some research has indicated that if participants are able to make use of

information provided by the experimenter than the surface features of that information may be just as likely, if not more likely, to be encoded than the semantics of that same information (Morris, Bransford & Franks, 1977; Jacoby, 1983; Blaxton, 1989; Roediger, Weldon & Challis, 1989, Weldon, 1991). As Murphy and van der Lely and Christian provided the plural form in their questions, there may have been a tendency for their participants to encode the sound of that plural and use it in the production of the compound rather than retrieving their own solution to how that plural should be employed in the target compound. This may have been the case particularly for very infrequently used plurals where the participant was less sure of the correct form to use in a compound. Evidence that it is easier to produce an irregular plural than an irregular singular, when primed with an irregular plural, comes from a study by Buck-Gengler et al (2001). Buck-Gengler et al asked adult native English speakers to read (i.e. participants were supplied with the plural) sentences of the form “a jar containing COOKIES is a _____” and then supply the compound which would fill the blank. Sentences including both regular and irregular primes were tested and reaction time and whether the participant supplied a plural or a singular noun in the compound produced was recorded. They found that the longest reaction times were recorded by participants who responded with an irregular singular having been presented with an irregular plural (i.e. produced *mouse bowl* when the stimulus was “*a bowl containing mice is a _____*”). Reaction

times were more or less identical from participants who produced irregular plurals in response to a plural sentence (i.e. produced *mice bowl* when the stimulus was “*a bowl containing mice is a _____*”) or produced either singular or plural regular nouns in response to a plural sentence (i.e. produced *rat bowl* or *rats bowl* when the stimulus was “*a bowl containing rats is a _____*”). Buck Gengler et al argue that it takes longer to produce a singular irregular noun in a compound, when the stimulus is plural, because extra time is needed to inhibit the just primed plural and produce a singular noun instead.

With respect to response mode there is evidence from previous research that participants respond differently on tasks depending on the modality in which they are required to supply a response. Providing written responses to lexical access tasks may require different processing systems than those implicated in producing spoken responses to the same task (Bonin, Fayol and Gombert, 1998).

Hence, an experiment was conducted which, as well as testing a larger number of mature native speakers than in previous compounding experiments, also compares presentation and response modalities within a single study. By comparing both presentation and response modalities it should be possible to unravel whether and which methodological factors are responsible for the inconsistencies in the proportion of irregular plurals included in compounds in the various teenager/adult compounding studies. If, having controlled for modality, it still emerges that adult

participants include very few irregular plurals within compounds then it will provide more information about whether the distinction between the way regular and irregular plurals are treated in compounds dissipates with maturity.

Another factor which needs to be examined is the exact nature of the irregular plurals being tested. In previous compounding experiments the irregular plurals tested have included [-en] irregular plurals (e.g., child-children) and vowel-change irregular plurals (e.g., foot-feet) but the influence of voicing change plurals (e.g., wolf-wolves) in a compound production test has not been investigated. van der Lely and Christian (2000) did include knives as one of their test nouns but they included it as a regular noun based on the work of Senghas et al (1993). Senghas et al found no significant difference between the acceptability of voicing change plurals and regular plurals inside compounds but did find that voicing change plurals were significantly less acceptable than irregular plurals in similar compounds. Marcus (1995a), however, using Quirk, Greenbaum, Leech and Svartik (1985) as his source treats voicing change plurals as irregulars. Haskell et al (in press) using an acceptability rating paradigm found that voicing change plurals patterned with irregular rather than regular plurals. Thus in the present experiment voicing change nouns were included to determine whether participants treated them in a similar manner to regular or to irregular plurals or otherwise.

To summarise, an experiment was carried out to compare the number of both irregular and regular plurals that would be included in compounds by mature native English speakers when both the presentation and response modality were manipulated. Type of plural (i.e., regular, voicing change or irregular) was also manipulated.

2. 2 Method

2.2.1 Design

The experimental design is summarised in Table 2.2. This experiment was a mixed design with one within subjects factor; type of noun (regular, voicing change, irregular) and two between groups factors: mode of presentation (visual or aural) and mode of response (oral or written). The dependent variable was the number of plural nouns of each type which participants included in their compounds. Twenty participants were shown pictorial stimuli and of these, 10 were asked to produce compounds orally and 10 in writing. The remaining twenty participants had the stimuli read out to them and of these, 10 were asked to produce compounds orally and 10 in writing.

Table 2.2 Experimental design

	Presentation		
	<i>Pictorial</i>	<i>Aural</i>	
Response	<i>Oral</i>	n = 10 participants	n = 10 participants
	<i>Written</i>	n = 10 participants	n = 10 participants

2.2.2 Participants

40 undergraduate students in the Department of Psychology at the University of Hertfordshire took part in the study in exchange for course credit. All were native English speakers and had been educated in the UK continuously between the ages of 5 to 18 years. Twenty-eight participants were aged between 18-24 years; eleven were aged between 25-44 years and one participant was aged between 45-60 years. Thirty-nine participants were female and one participant was male.

2.2.3 Stimuli

Four mass nouns (*rice, water, glass and grass*), were used to train participants and familiarise them with the task. The test stimuli consisted of 10 regular plural nouns, 3 voicing change plural nouns and 7 irregular plural nouns (1 [-en] plural and 6 vowel change plurals). The 10 regular plural nouns were matched against the 3 voicing change and the 7 irregular plural nouns for semantic similarity.

Appendix A.1 shows the full list of test stimuli used. Frequency counts per thousand for each of the nouns (Kucera & Francis, 1967) is shown in Appendix A.2.

For pictorial presentation, both the training and test nouns were represented by black and white line drawings of plural items. The pictures measured 15cms wide by 13cms long and were mounted on sheets of A4 sized white laminated card. The pictures were piloted to ensure that they elicited the intended response. Examples of the pictures can be seen in Appendix A.3.

2.2.4 Procedure

Participants were tested individually in an experimental cubicle at the University of Hertfordshire. A preliminary briefing took place during which participants were told that the experiment would involve putting two separate words together to form a new word. They were informed that they would be asked to make up compound words that described someone performing a particular task. The experimenter gave the participants two examples *“So for example, you could call someone who drinks wine a “wine drinker” and you could call someone who cuts grass a “grass cutter”.*

In the visual conditions, participants were shown picture representations of 4 training nouns and asked to produce a compound in response to the experimenter’s questions. For example, the experimenter showed a picture of rice and asked *“What do you call someone who boils this?”* and the participants were to respond *“A rice*

boiler". In the aural conditions the experimenter asked the participants "*What do you call someone who boils rice*" and again participants were to respond "*A rice boiler*". On the rare occasion that a participant did not produce the appropriate compound, the experimenter provided further examples until the participant understood the form of compound that was required.

Once the participants had completed the training session they moved on to the test questions that were delivered in exactly the same way. Participants in the oral response conditions were asked to speak clearly into the tape recorder. Participants in the written response conditions were asked to write their responses on the response sheet they had been provided with. The order of the 20 test items was randomised for each participant.

2.3 Results

Firstly, to analyse whether voicing change plurals patterned with regular or irregular plurals in this experiment or in some other way, a one way analysis of variance was carried out. There was a reliable difference between the type of noun being tested and the number of plural nouns included in compounds, subjects $F(2, 117) = 107.69, p < .00005$; items $F(2,17) = 37.89, p < .00005$.

A planned comparison revealed that there was a reliable difference between the way participants treated voicing change and irregular plurals, subjects $t(39) = 10.52, p < .00005$; items $t(6.48)^1 = 6.16, p < .0010$ in the compounding task but no reliable difference between the way voicing change and regular plurals were treated, subjects $t(39) = -1.30, p > .05$; items $t(11) = -1.44, p > .05$. Thus in all subsequent analyses the data for regular and voicing change plurals were collapsed together (and the group is referred to as regulars) and compared with the data for irregular plurals. As the combined group of regular and voicing change plurals consisted of 13 items and there were only 7 irregular plurals, percentages were calculated and included in all subsequent analyses.

Table 2.3 provides an indication of the extent of pluralisation in compounds as it shows the mean percentage of regular compounds in which singulars were included and the mean percentage of regular compounds in which plurals were included. The same information is provided for irregular compounds.

Two separate t tests (paired samples for the subjects analysis and independent samples for the items analysis) showed that a higher mean percentage of singular nouns were included in regular compounds compared with irregular compounds, subjects $t(39) = 9.23, p < .0010$; items $t(18) = 9.03, p < .0010$.

¹Degrees of freedom corrected due to significant Levene's test.

Two further paired samples t tests showed that there was a reliable difference between the rate at which regular plurals were included in the singular or plural form in compounds, subjects $t(39) = -47.40, p < .00005$; items $t(12) = -210.46, p = .00005$ but no reliable difference between the rate at which irregulars were included in the singular or plural form in compounds, subjects $t < 1$; items $t < 1$.

Table 2.3. Mean percentage of plural and singular nouns in regular and irregular compounds (standard deviations are shown in brackets).

<i>Noun</i>	<i>Singular</i> %	<i>Plural</i> %
Regulars	98.65 (6.25)	1.35 (6.25)
Irregulars	53.93 (27.16)	46.07 (27.16)

The focus of the study was to determine whether there were differences in the number of regular and irregular plurals included in compounds and whether different presentation and response modalities affected the rates of inclusion of these items. The mean percentage rates of inclusion (with their standard deviations) of regular and irregular plurals are shown in Table 2.4.

Table 2.4 Mean percentage (with their standard deviations) of regular and irregular plurals included in compounds for the 13 regular and 7 irregular plurals in the 4 conditions tested (i.e., pictorial presentation with written responses, pictorial presentation with oral responses, aural presentation with written responses and aural presentation with oral responses).

	<i>Pictorial stimuli</i>		<i>aural stimuli</i>		<i>Overall mean for response modalities</i>	
	Regular Plurals	Irregular plurals	Regular plurals	Irregular plurals	Regular plurals	Irregular plurals
Written responses	0.77 (2.43)	30 (28.13)	3.85 (12.16)	48.57 (29.50)	2.31 (8.68)	39.29 (29.63)
Oral responses	0 (0)	40 (16.21)	0.77 (2.43)	65.71 (22.53)	0.39 (1.7)	52.86 (23.22)
Overall Mean for presentation modalities	0.39 (1.7)	35 (22.93)	2.31 (8.68)	57.14 (27.03)		

A repeated measures, multivariate Analysis of Variance with one within subjects factor: noun type (measured at two levels: regular plurals and irregular plurals) and two between subjects factors: presentation modality (measured at two levels: visual and aural) and response modality (measured at two levels: written and oral) was carried out. A repeated measures, multivariate Analysis of Variance with two within items factors: presentation modality (measured at two levels; visual and aural) and response modality (measured at two levels: written and oral) and one

between items factor: noun type (measured at two levels regular plurals and irregular plurals) was also conducted. This revealed a reliable effect of noun type, subjects $F(1,36) = 149.06, p < .00005, \eta^2 = 1.00$; items $F(1,18) = 79.99, p < .00005, \eta^2 = .816$. This effect interacted with both presentation modality, $F(1,36) = 7.94, p < .05, \eta^2 = .783$; items $F(1,18) = 33.55, p < .00005, \eta^2 = .651$ and response modality, subjects $F(1,36) = 4.76, p < .05, \eta^2 = .565$; items $F(1,18) = 14.36, p < .00005, \eta^2 = .444$. There was no reliable three-way interaction between noun type, presentation mode and response mode, $F < 1$ in either the subjects or the items analysis.

Thus both the modality in which the stimuli were presented and the modality in which participants responded affected the number of plurals included in compounds. Figure 2.1 shows the mean percentage number of plurals of both types that were included in compounds when presentation modality was manipulated. From Figure 2.1 it is evident that more irregular plurals were included in compounds when the stimuli were presented aurally (57.14%) than when they were presented visually (35%). A planned comparison revealed that this difference was reliable, subjects $t(38) = -2.86, p < .05$; items $t(6) = -4.70, p < .05$. Figure 2.1 also illustrates that more regular plurals were included in compounds when stimuli were presented aurally (2.3%) than when they were presented visually (0.38%). A

planned comparison revealed that this difference was not reliable, subjects $t < 1$;

items $t(12) = 1.00, p > .05$.

Figure 2.1 Interaction between noun type and presentation modality

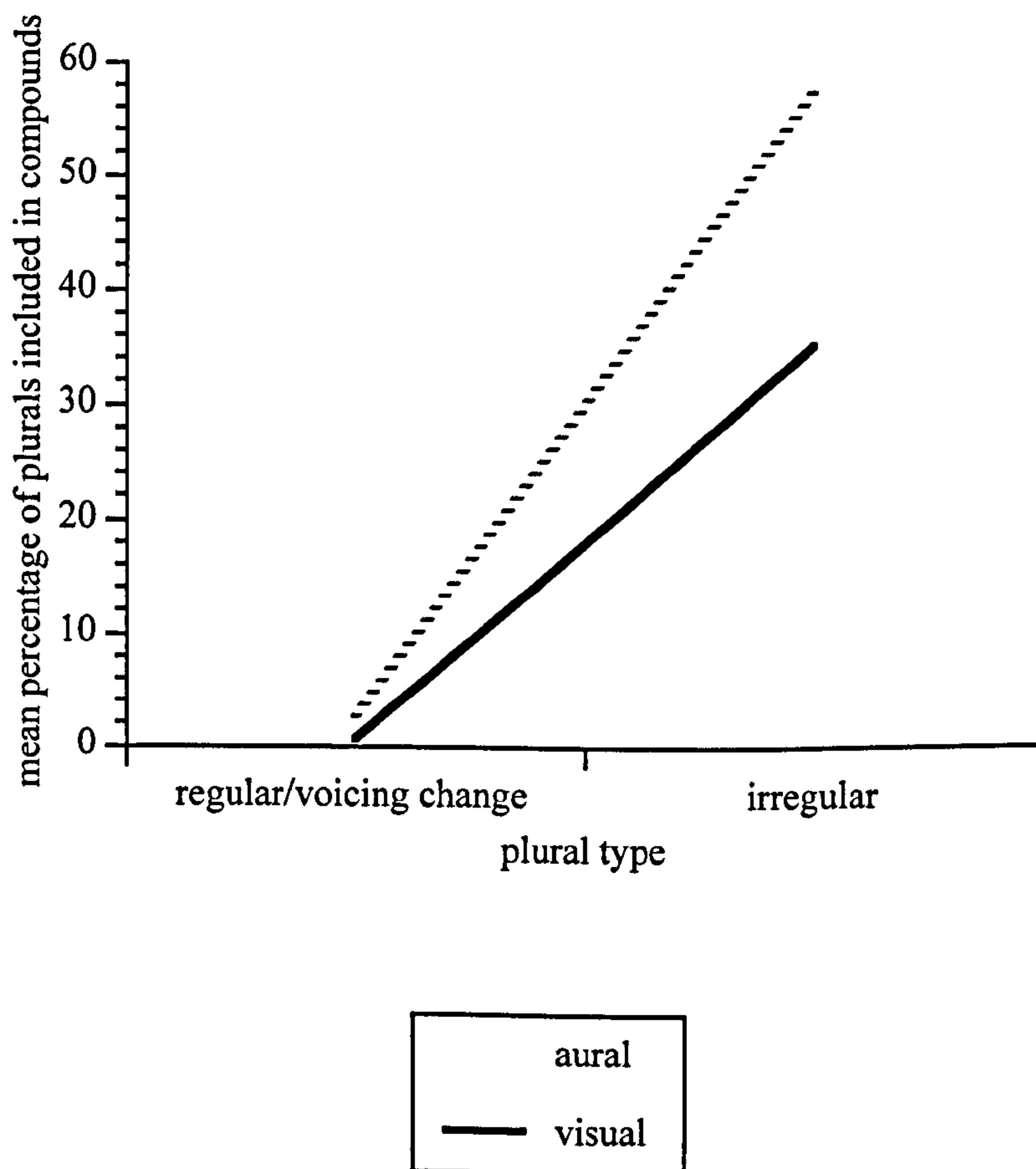
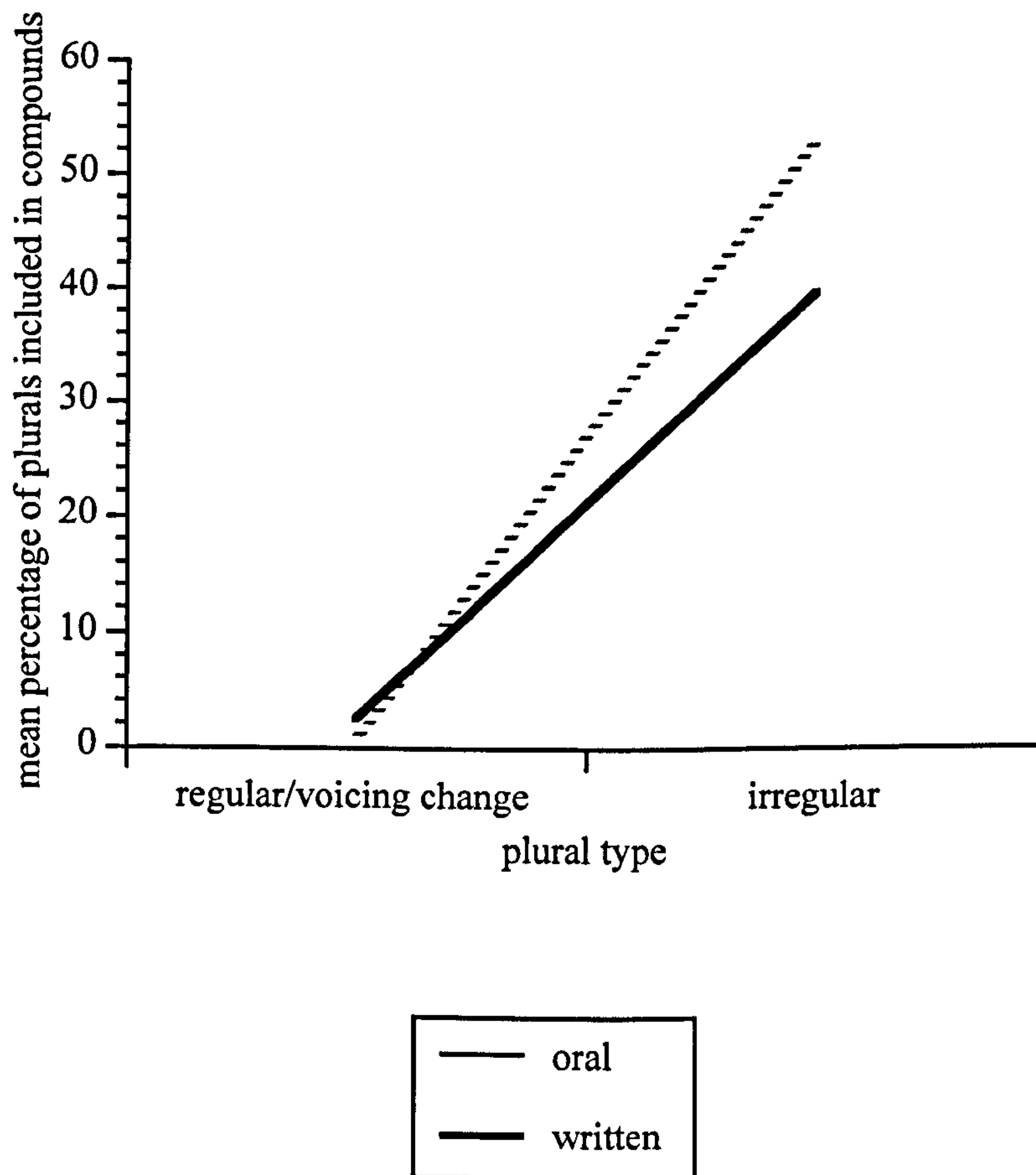


Figure 2.2 shows the mean percentage number of plurals of both types that were included in compounds when response modality was manipulated. From Figure 2.2 it is evident that more irregular plurals were included in compounds when participants responded orally (52.8%) than when they responded in writing

(39.29%). More regular plurals were included in compounds when participants responded in writing (2.3%) than when they responded aurally (0.38%). Planned comparisons revealed that the difference in responding to irregulars in the different modalities was not reliable, subjects $t(38) = -1.69, p > .05$; items $t < 1$ and neither was the difference in responding to regulars in the different modalities, subjects $t < 1$; items $t(6) = -2.32, p > .05$. However, the differential between the percentage of regulars and the percentage of irregulars included in compounds in the oral response modality was greater (52.42%) than the differential between the percentage of regulars and percentage of irregulars included in compounds in the written response modality (36.99 %). A planned comparison revealed that the difference between these two percentages was just reliable , subjects $t(38) = -2.02, p = .05$.

Figure 2.2 Interaction between noun Type and response modality



2.4 Discussion

The present study tested a larger number of mature native speakers than in previous compounding experiments and also for the first time compared presentation and response modalities within a single study. In this study, regardless of

presentation or response modality adopted, a much higher percentage of irregular plurals were included in compounds than was the case for regular plurals. This behavioural dissociation between the treatment of regular and irregular plural morphology in compounds has been reported in all previous compounding experiments testing native speakers (Gordon, 1985; Oetting and Rice, 1993; Lardiere and Schwartz 1997; Murphy, 2000, Nicoladis, 2000; van der Lely and Christian, 2000).

Manipulating presentation or response modality had no effect on the number of regular plurals included in compounds. Varying presentation modality did, however, affect the inclusion of irregular plurals in compounds. More irregular plurals were included in compounds in the oral presentation mode where participants were given the irregular plural than in the visual presentation modality where participants never heard the plural used and were required to retrieve the name of the picture from their own mental representation. These findings would seem to support previous research which has indicated that if, in performing a task, participants are able to make use of information provided by the experimenter then the surface features of that information are likely to be used by the participant (Morris et al, 1977; Jacoby, 1983; Blaxton, 1989; Roediger et al, 1989, Weldon, 1991). This effect may explain the fact that Murphy (2000), using oral presentation, found that participants included 28% of irregulars in compounds and van der Lely and Christian

who used a combination of oral and visual presentation also found that irregular plurals were included in 28% of compounds produced. However, Lardiere and Schwartz (1997) who used visual presentation found that only 4.8% of irregulars were included in compounds. Thus methodological differences may at least in part explain the fact that irregular plurals have been treated differently in the various studies carried out on adult participants. The results of a study by Murphy et al (in preparation) testing children similar in age to those tested by Gordon (i.e. between 4 and 7 years of age) are interesting in this regard. The children tested by Murphy et al were shown visual stimuli of plural items and asked to produce the plural. Then they were asked "*what do you call someone who eats these*" i.e., the plural supplied by the child was not repeated back to them. In these circumstances, Murphy et al found that children included irregular plurals (across all age groups) in only 34% of compounds produced and regulars in 10 % of compounds. Interestingly the younger children aged 4 (n=4) included regular plurals in 15% of compounds and irregulars in 28% of compounds. Children aged 5 (n=10) included regular plurals in 15% of compounds and irregulars in 30% of compounds. Children aged 6 (n=21) included regular plurals in 8% of compounds and irregulars in 36% of compounds. Thus, if priming is controlled for, the dissociation between regular and irregular plurals in compounds even in children may be reduced. Evidence from the van der Lely and Christian (2000) study shows that it is not possible, however, to conclude that

priming alone is responsible for the difference in the rate at which irregular plurals have been included by children and adults in the various compounding studies. van der Lely and Christian used exactly the same methodology as Gordon but found that their teenage participants included fewer irregular plurals in compounds (increased maturity may simply lead participants to be less susceptible to priming) than the children tested by Gordon. Furthermore, van der Lely and Christian tested children as well as teenagers as controls for their SLI children and found that they included more irregular plurals between 5-6 years of age (61.6%) than they did at 7 years of age (55%) and in turn more irregulars than the teenagers included (28%).

Even controlling for priming effects the fact remains that mature adult English speakers seem to include fewer irregular plurals in compounds than younger English speakers. The pattern of responding in which irregulars are included in compounds and regulars are omitted from compounds is strongest in children. To date, however, all the evidence about how children treat plurals in compounds comes from experimental studies. The only data about how frequently children include plurals in compounds in spontaneous speech has been collected by Nicoladis (1999) who recorded the compounds produced by a three year old English/French bilingual child. The only irregular noun included in a compound by this child was included in the plural form. However, he also included regular plurals in compounds roughly at chance and thus showed evidence of a lack of competence in using plurals in

compounds. Nicoladis (2000) has shown that knowing a second language affects the rate at which children include plurals in compounds. Thus the evidence from this child is of limited use and as naturalistic observation data from monolingual children are not available, it is impossible to make conclusions concerning how frequently children include plurals in compounds in spontaneous speech. As for adult native speakers, Haskell et al (in press) have conducted frequency counts of the parsed Treebank Brown Corpus (University of Pennsylvania, Philadelphia, PA) of adult language. This has shown that regular plurals are very rarely used before a second noun (in 2% of cases in which nouns precede other nouns). Conversely, irregulars are produced as plurals in 12% of cases in which nouns precede another nouns. Both regular and irregular nouns were produced as plurals (rather than singulars) at more or less the same rate (30% for regulars, 35% for irregulars) when they preceded items other than nouns. Frequency counts of the Wells data from the CHILDES Corpora (Mac Whinney and Snow, 1985) have shown that out of 70 regular plurals found in the Wells corpus in no case was a regular plural followed by another noun (Hayes et al, 2002). Similarly, a second noun never followed the 6 irregular plurals found. 24% of the 281 singular nouns were followed by a second noun. Thus plurals in naturalistic speech were not included before a noun and hence the classic dissociation between the treatment of regular and irregular plurals in compounds was not evident

in these samples of spontaneous speech by adults analysed by Haskell et al or Hayes et al.

There is only experimental data to suggest how frequently children include regular and irregular plurals in compounds. From this it seems that children do include many more irregular than regular plurals in compounds. For adults both the evidence from experimentally produced (regardless of presentation or response modality) and spontaneously produced compounds suggests that they include very few of either type of plural in compounds.

Both the level ordering model and the dual mechanism model have yet to explain this apparent developmental aspect to the inclusion of irregular plurals in compounds. In fact the optional nature of irregulars in compounds does somewhat render the dual mechanism model unfalsifiable in terms of its relevance to compounding. In experiments, if adults, like children, take up the option of including irregulars in compounds, they manifest the characteristic dissociation predicted by the dual mechanism model. If, however, adults do not include irregulars then there is effectively no dissociation between regulars and irregulars in compounds: yet proponents of the dual mechanism model still argue that this lack of dissociation is licensed by the dual mechanism model.

An explanation based on the frequency of occurrence of items and the patterns in which regular and irregular plurals occur in the linguistic input might,

however, explain both the treatment of regular and irregular plurals in compounds (Murphy, 2000). Looking first at regular plurals, adult English speaking participants seem to omit regular plurals from compounds, regardless of the manner in which the stimulus is presented or the modality in which they are asked to supply responses. This robust experimental finding may be due to the fact that regular morphology is governed by a rule based system. However, it might equally be due to the fact that regular plurals are far more frequent in the English language than irregular plurals. Regular plurals make up 98% of noun types and 97% of noun tokens (Marcus, 1995a). Thus 98% of all nouns in English add an [-s] sound to make their plural. And 97% of all plural usage in English involves the processing of the [-s] sound at the end of a noun. Thus, adult English speakers will have had a great deal of practice in using the regular plural morpheme at the end of words and thus never in the middle of words (such as compounds). Certainly, frequency counts of a sample of the Wells corpus of child directed speech (Hayes et al, 2002) have shown that the regular plural affix is never included in the middle of words in English. Furthermore, as discussed in Chapter 1, competition between the possessive and the plural morpheme may explain why regular plurals are omitted before a second noun. Varying presentation modality did, however, affect the inclusion of irregular plurals in compounds. Again it may be that irregular plurals are affected by changes in modality in a way that regulars are not because unlike regulars they are not mediated

by an “automatically” applied rule. However, it may be that the token frequency of individual irregular plurals influences the way they are treated in compounds.

Irregular plurals have a much lower type frequency than regulars and while some irregulars are phonologically similar, e.g., *mouse-mice/louse-lice; tooth-teeth/foot-feet/goose-geese; man-men/woman-women*, there is no one dominant phonological pattern occurring in one particular place in the irregular plurals. Also as irregulars are not formed by the addition of the plural [-s] morpheme they also do not compete with the possessive structure and therefore they may be followed by the second noun.

Research manipulating the token frequency of regular and irregular plurals might provide a clue as to why all regulars are treated the same in compounds but irregulars manifest greater variability regarding plural marking in compounds. Ellis and Schmidt (1998) required participants to learn a miniature artificial language (MAL). The regular plural prefix used in this MAL had an overwhelmingly higher token frequency than the individual irregular plural patterns used, although some of the irregulars had very high individual token frequencies (as is the case with the plurals in English (Marcus, 1995a)). Ellis and Schmidt showed that in the very earliest stages of language learning both regular and irregular morphology were subject to token frequency effects. With increased exposure to a language, however, token frequency effects on the regular plurals disappeared due to the power law of

practice. The power law of practice states that the amount of improvement shown in the processing of particular items decreases as a function of increasing exposure to those items (Anderson, 1982). Thus as performance approaches asymptote on very frequently encountered items it is difficult to influence performance by introducing extraneous variables such as changing presentation modality. Thus in both the MAL and in English the regular plural affix develops “high lexical strength” (cf. Bybee, 1995) and becomes invulnerable to contextual effects.

It might be argued therefore, that well-practiced language users (i.e., adult native speakers) learn that the high token frequency regular plural affix [-s] goes at the end of words and the sequence noun *-morpheme [-s] – noun-* is reserved for marking possession rather than plurality (in almost every case). High token frequency irregulars may also have accrued enough “lexical strength” (cf. Bybee, 1995) to withstand the influence of extraneous variables such as the modality in which the word is presented. Thus like regulars, regardless of context, they also are excluded from appearing in the middle of words such as compounds. The regular plural affix has a considerably higher token frequency than even the highest token frequency irregular plural, however, it may be that the two pattern together due to the semantic link of plurality i.e., that any plural noun (regardless of token frequency) conveys the concept of “more than oneness”. Lower token frequency irregulars plurals, however, may not have enough “lexical strength” (cf. Bybee,

1995) to withstand these external influences and thus in some contexts language users may be “tempted” to include them in the middle of words such as compounds.

Certainly, in this experiment, when participants were given the plural form, it seems that they were “tempted” to repeat the plural form in more than half of the compounds produced using irregular plurals. Where they had to identify a picture from their own mental representations they were less tempted (in 37% of cases) to include the plural form of the irregular. Indeed, in this experiment, participants included the lowest token frequency irregular plural nouns in compounds twice as often as those with the highest token frequencies ($t(2) = -4.44, p < .05$). The two irregular plurals with the lowest token frequency “mice” and “geese” (token frequency 9 and 3 per thousand respectively (Kucera & Francis, 1967)) were included in an average of 25% of compounds. Conversely the high frequency irregulars, “men”, “women” and “children” (token frequency 752, 184 and 346 per thousand respectively (Kucera & Francis, 1967)) were only included in an average of 11% of compounds. The difference between the results of the present study (i.e., that 57% of orally presented irregular compounds contained plurals) and those reported by Murphy (2000) (where 28% of orally presented irregular compounds contained plurals) may be partly explained by the items that were tested. Murphy did not test the low frequency item ‘geese’ which was the most frequently included item in this experiment (included in 28% of opportunities).

The difference between the number of irregular plurals included by children and adults in compounds may result from the fact that children have processed fewer plurals than adults. The children tested in the various compounding experiments may have sufficient experience with regular plurals to learn that the [-s] morpheme goes at the end rather than in the middle of words. Furthermore, they may also have learned that the pattern noun - *morpheme* [-s] – noun - is reserved for marking possession. However, they will have experienced far fewer of any one irregular plural pattern and hence the frequency effect will not have “kicked in”. Thus they tend to include all irregulars in compounds. The SLI children, tested by van der Lely and Christian (2000) who evidence suggests are developmentally delayed in mastering the use of plurals in compounds included regulars as well as irregular plurals in compounds. Correspondingly, the French ESL participants tested by Murphy (2000), and the Spanish ESL participants tested by Lardiere (1995a), who included a large number of regular plurals in compounds, may not have had enough experience with English regular plurals to learn that they always go at the end rather than in the middle of words. Furthermore, abetted by the fact that possession is not marked with the same morpheme as plurality in their native languages, (i.e., in Spanish Mother’s house is “*la casa del mama*” and in French it is “*la maison de ma mere*”), they may also have yet to master the competitive relationship between the plural and the possessive morpheme in English.

The role that individual irregular plurals play in the compounding task in general needs to be considered further. For instance, there is already considerable evidence to show that “*feet*” and “*teeth*” are frequently included in the plural form (in 26% and 21% respectively of opportunities in this experiment). The inclusion of ‘feet’ and ‘teeth’ is perhaps due to a semantic effect that they are treated like some kind of collective noun (Lardiere, 1997, Murphy 2000). Other research (Seidenberg, Haskell and MacDonald, 1999) has suggested that the sound of an item may affect its inclusion in compounds. According to Seidenberg et al, irregular plurals are only included when they do not sound like regular plurals. Hence, “*feet*” would be included but items such as “*mice*” and “*geese*” would be omitted. Certainly, in this experiment voicing change plurals (e.g., “*wolf*”, “*wolves*”), described by some as irregulars (Marcus, 1995), which end in an allomorph of the plural [-s] morpheme and involve a voicing change to the final consonant of the stem, were treated like regular plurals. However, “*geese*” and “*mice*” which Seidenberg argued would also be omitted from compounds because they “sound” like regulars were the most frequently included irregular plurals in this experiment. However, while these results provide mixed support for Seidenberg et al’s ideas the point is that not all irregular plurals are treated the same in the compounding task.

Thus, further research is required to investigate the role that token frequency, semantics and phonetics might play in how a particular irregular is treated in a

compound. These factors need to be systematically tested in a cross-sectional study (perhaps using a language which includes more irregular plurals than English) to provide an indication of how items with different token frequencies, semantics and phonetics are treated by different age groups.

In conclusion, work carried out by Murphy and Ellis (in preparation) has shown that when the frequency differences between regular and irregular morphology are matched then the differences between them are eliminated. Thus it may be that the behavioural dissociation between the treatment of regular and irregular plurals in compounds is simply mediated by the frequency of the two types of morphology in the English language. In other words, the compounding phenomenon, rather than being the result of the differences in output of two separate mechanisms, is due to the fact that the token frequency of the regular plural morpheme is far more frequent than the token frequency of any one irregular plural. This frequency factor may work alongside the fact that regular plurals are omitted from compounds because the pattern - *noun* - [-s] *morpheme* - *noun* - is reserved for marking possession to ensure that regular plurals are never included in English compounds. Irregulars are not formed by the addition of the [-s] morpheme and thus do not compete with the possessive construction and as such may be included in compounds. The evidence reported here is in line with the notion that input driven rather than innate constraints drive the dissociation between regular and irregulars.

Chapter 3

3.1 Introduction

3.1.1 Background

Much of the previous work conducted on the treatment of plural morphology in compounds has concluded that regular and irregular plurals are treated differently in these structures because the two types of morphology are mediated by separate cognitive systems. However, from the work reported in Chapter 2 it seems that the considerable difference in the frequency with which the two types of morphology occur in the input is more likely to result in the dissociation in the way the two types of morphology are treated in English compounds. Irregular plurals have a low type frequency in English. In Chapter 2 it was argued that relative to the regular plural, language users encounter irregular plurals infrequently and rarely before a second noun. Thus they can be very unsure whether to include them in the singular or the plural form in a compound. Regular plurals are very frequent in the input. Language users learn quickly to add an [-s] to the stem to make the vast majority of plurals in English. They also quickly learn to omit the [-s] morpheme when a second noun follows the regular plural. Comparing the very frequent, highly consistent regular plurals with the low type frequency irregular nouns that seem to be arbitrarily formed as singulars or plurals in compounds seems to be an erroneous route for future compounding research to take. The remainder of the research reported in this thesis focuses on the more interesting issue concerning the factors which dictate why the plural [-s] morpheme is omitted from compounds. It will be argued that the

regular plural [-s] morpheme is omitted from compounds because language users learn that the pattern *-noun- [-s] morpheme-noun* - is reserved for marking possession rather than plurality. Learning about competition between the plural and the possessive morpheme may well proceed using the constraint satisfaction model proposed by Haskell et al (in press). The competition between the plural and the possessive [-s] morpheme may serve to enhance Haskell et al's model as it provides an explanation for why the semantic constraint on the use of plurals before second nouns develops in English but not in other languages. Furthermore as Murphy (2000) pointed out, language users may omit the regular plural [-s] from the middle of words such as compounds because it is so closely associated with word-finality.

The advantage of this associative memory-based probabilistic account of compounding is that it allows for some regular plurals to be included in compounds in some circumstances. There is evidence, for instance, of regular plurals being included in compounds for semantic reasons such as in Pinker's (1999) examples *publications catalogue* or *drinks trolley*. Also, less proficient language users such as very young native speakers (Murphy et al, in preparation), English second language learners (Lardiere, 1995; Murphy, 2000) and SLI children (van der Lely and Christian, 2000) have been found to include a relatively high number of regular plurals in compounds. Thus rather than the inclusion of plurals in compounds being mediated by a "black and white" rule, the evidence points to a continuum based system. Along this continuum, some language users are more likely than others to use plurals in some circumstances. Importantly, no structures are prohibited. Haskell et al (in press) found evidence for a continuum of this sort testing adult native

English speakers. They found that participants rated singular nouns in compounds (e.g. *toe examination* or *tooth examination*) as sounding most acceptable to them. Compounds that included irregular plurals (e.g. *teeth examination*) were rated as being less acceptable but more preferable to compounds which included regular plurals (e.g. *toes examination*). Haskell et al obtained their results using a questionnaire-based preference task in which participants had the opportunity to read both forms of a compound (i.e. they had to choose between compounds which included a plural non-head noun or compounds which included a singular non-head noun) and decide which they preferred. Senghas et al (1991) found similar results also using a questionnaire-based paradigm. To date, however, a participant's ability to process compounds including different linguistic features that they see or hear "on-line" has not been tested. In the following experiment native adult English speakers were asked to process "noun-noun" compounds as part of an on-line lexical decision (LD) task. The advantage of an "on-line task" over a questionnaire-based preference paradigm, is that it is possible to collect reaction time and thus obtain a measure of the relative degree to which some structures are more easily processed than others. The advantage of processing studies over production studies is that it is possible to measure how participants respond to structures that they might in fact never produce and never encounter in natural language. Reaction time data is frequently collected in lexical decision tasks because it offers an indication of the amount of processing that is required before a participant is able to confirm that a word is a real word i.e. is present in their lexicon, or is a non-word, i.e. is not present in their lexicon. While the dual mechanism model makes the prediction that only

irregular plurals are stored in the lexicon, the associative explanation put forward here and Haskell et al's constraint satisfaction model hypothesise that both types of plural are represented in the same way. Thus a timed LD task should provide interesting indicators of how much processing and or "searching" needs to be carried out in order to manipulate different types of morphology in compounds. Furthermore, there is considerable evidence that the frequency of items in the input affects how quickly they are accessed in a LD task. If the [-s] phoneme is frequently associated with word finality it may take longer to confirm that items where the [-s] phoneme occurs in the middle of words (such as compounds) are real words. Compounds where the non-head noun ends in a phoneme other than [-s] should be identified more quickly as real words because these structures are more frequent in the input.

In this experiment reaction times and error rates were recorded for six different categories of words in the same within subjects design. The types of compounds¹ tested were ones in which the first noun was either (1) a regular plural noun (2) a possessive noun (3) an irregular plural noun (4) a comparative or a superlative (i.e. regular, non-plural morphemes which do not end in [-s] (included as a control for possessives)) (5) a singular/mass noun which ends in phonetic [-s] (6) a singular/mass noun which ends in a phoneme other than [-s].

¹ The stimuli in this experiment are described as being compounds. However where a possessive noun or a comparative or superlative was used as the first element in a compound these are not truly compounds as defined by linguists. In this associative account, the interest was in two word combinations rather than strict compounds and as such these items were included in the experiment.

The inclusion of these various items tested the single route associative explanation of compounding. This design enabled the investigation of whether possessive nouns followed by a second noun are processed more quickly than compounds containing plural nouns, an important prediction of this alternative explanation of compounding.

Also, if as Murphy (2000) suggested, plural [-s] is omitted from the middle of words like compounds because it is associated with word finality, then compounds in which the first noun ends in [-s] (of any kind) should be processed more slowly than compounds that do not include a first noun ending in [-s]. More specifically, singular/mass non-head nouns ending in the [-s] phoneme should be processed more slowly than singular/mass non-head nouns ending in another phoneme.

Further hypotheses were investigated to test the dual mechanism model's explanation of compounding. Pinker (1991) stated that:

“because it categorically distinguishes regular from irregular forms, the rule-association hybrid predicts that the two processes should be dissociated from virtually every point of view.....[including] reaction time ” (p 253).

However, the dual mechanism model makes no directional prediction as to which type of morphology might be processed more quickly. Beck (1997) asked native speakers to supply the past tense of a series of base form regular and irregular verbs. Beck found that both low and high frequency regulars were produced more quickly than both low and high frequency irregulars. By collecting reaction times in the present experiment it was possible to test the speed at which the two types of

morphology were processed within compounds in a lexical decision task. Secondly, and more specifically, it was predicted that compounds containing irregular plurals and compounds containing regular plurals would be processed at different speeds. Thirdly, it might be expected that items of regular morphology (i.e., regular plurals, possessive nouns and comparatives and superlatives) that, according to the dual mechanism model are all produced by the same system, would be processed at similar speeds. A list of the specific hypothesis that were tested is shown in section 3.1.2 together with the predictions stemming from the frequency explanation, the dual mechanism model and the constraint satisfaction model.

3.1.2 Hypothesis and predictions of the frequency explanation, the dual mechanism model and the constraint satisfaction model

1. All types of non-head nouns ending in [-s] will take longer to process than all types of non-head nouns not ending in [-s].

Groups compared: All types of non-head nouns ending in [-s] (regular plurals, possessive nouns, singular/mass nouns ending in phoneme [-s]) and all types of non-head noun not ending in [-s] (irregular plurals, comparatives and superlatives, singular/mass nouns ending in phonemes other than [-s]).

Predictions

- **Frequency based explanation** – If [-s] is associated with word finality then words that do not end in [-s] should be processed more quickly in the middle of words such as compounds. Not all items ending in [-s] will be processed at the same speed. More frequent items will be processed more quickly than less frequent items.
- **Dual mechanism model** – No prediction.
- **Constraint satisfaction model** - Words ending in [-s] are more likely to sound like regular plurals and as such are more likely to be subject to the phonetic constraint and should therefore take longer to process than words that do not end in [-s].

2. Not all items ending in [-s] will be processed at the same speed. In particular possessive nouns should be processed more quickly than regular plurals

Groups compared: Regular plurals, possessive nouns and singular/mass nouns ending in phoneme [-s].

Predictions

- **Frequency based explanation** – Possessive nouns should be processed more quickly than regular plurals because they occur more frequently before a second noun. The rate at which singular/mass nouns ending in phonetic [-s] are processed depends on their individual frequency in the input.
 - **Dual mechanism model** – No prediction.
 - **Constraint satisfaction model** - Regular plurals should take the longest to process because they are subject to both the phonetic and the semantic constraint. The phonetic constraint implies that reaction time to process possessive nouns and singular/mass nouns ending in phonetic [-s] should be related to their similarity to regular plurals.
3. **Singular/mass nouns ending in phoneme [-s] will be processed more quickly than singular/mass nouns ending in other phonemes.**

Groups compared: Singular/mass nouns ending in phonetic [-s] and singular/mass nouns ending in other phonemes.

Predictions

- **Frequency based explanation** – If [-s] is associated with word finality then words ending in [-s] may be difficult to process in the middle of words such as compounds. Nouns that do not end in an [-s] may be processed more quickly in the middle of words.
 - **Dual mechanism model** - No prediction.
 - **Constraint satisfaction model** – Singular/mass nouns ending in [-s] should be processed more slowly because they are more likely to sound like regular plural and as such are subject to the phonetic constraint.
4. **Regular morphology will be processed at different speeds than irregular morphology**

Groups compared: All regular morphology (i.e., regular plurals, possessive nouns, comparatives and superlatives) and irregular plurals.

Predictions

- **Frequency based explanation** – All items of regular morphology tested have a higher type frequency than irregular plurals and should therefore be processed more quickly. However, individual high token frequency irregulars may be processed quickly.
- **Dual mechanism model** – No directional prediction. However, there should be a difference between the two types of morphology. However, implied in the dual mechanism model is the idea that the stored irregulars have to be searched through before the default rule is applied. Thus it is implied that irregulars should be processed more quickly than regulars. Also regulars are prohibited from occurring in the middle of compounds and encountering something that is not possible may lead participants to process regulars more slowly than irregulars.
- **Constraint satisfaction model** - Regular plurals should take longer to process than irregular plurals because they are influenced by both the semantic and the phonetic constraint (irregulars are only influenced by the semantic constraint). Possessives should be processed at a similar rate to irregular plurals as both are only influenced by one constraint (the phonetic and semantic

constraint respectively). Comparatives and superlatives should be processed faster than irregular plurals because they are not subject to either type of constraint.

5. Regular and irregular plurals will be processed at different speeds.

Groups compared: Regular and irregular plurals.

Predictions

- **Frequency based explanation** – Regular plurals have higher type frequency so should be processed more quickly than irregulars as a group. However, individual high token frequency irregulars may be processed quickly.
- **Dual mechanism model** - No prediction. However, there should be a difference between the two types of morphology. Implied in the dual mechanism model is the idea that the stored irregulars have to be searched through before the default rule is applied. Thus it is implied that irregulars should be processed more quickly than regulars. Also regulars are prohibited from occurring in the middle of compounds and encountering something that is not possible may lead participants to process regulars more slowly than irregulars
- **Constraint satisfaction model** - Regulars should be processed more slowly than irregulars because they are subject to both the semantic and phonetic constraint. Irregulars are only subject to the semantic constraint

6. All types of regular morphology will be processed at the same speed

Groups compared: Regular plurals, possessives, comparatives and superlatives

Predictions

- **Frequency based explanation** – Regular plurals will take longer to process than possessives or comparatives and superlatives because they occur less frequently before a noun in the input
- **Dual mechanism model** - All items of regular morphology are formed using the same rule based mechanism so all items should be processed at the same rate
- **Constraint satisfaction model** - Regular plurals should be processed the slowest because they are subject to both the phonetic and semantic constraint. Possessives, because they are subject to the phonetic constraint only, should be processed more slowly than comparatives and superlatives that are not subject to either constraint

3.1.3 Summary of predictions

The order in which the Frequency based account the dual mechanism account and the constraint satisfaction model would predict that the word groups would be processed is shown in Table 3.1

Table 3.1. Predicted order in which the word groups should be processed according to the frequency based account the dual mechanism account and the constraint satisfaction model

Model	Prediction
Frequency based account	1= singular nouns not ending in [-s] 1= comparatives/ superlatives 3. possessives 4= regular plurals 4= singular nouns ending in [-s], 6. irregular plurals
Dual mechanism account	1= comparatives/superlatives 1= possessives 1= regular plurals 4. irregular plurals. (Singular nouns not ending in [-s], Singular nouns ending in [-s] no prediction)
Constraint satisfaction model	1= singular nouns not ending in [-s], 1= comparatives/superlatives, 3= possessives 3= singular nouns ending in [-s] 3= irregular plurals 6. regular plurals

Note- predicted fastest group shown first

3.1.3 Modality effects

In the production experiment reported in Chapter 2 it was found that the modality in which items are presented affects the type of morphology that is included in compounds. The inclusion of irregular plurals is particularly linked to the context in which items are presented to participants. This data has contributed to the growing evidence that, due to the low type frequency of irregular nouns in the input, participants produce either the singular or plural form of an irregular noun before a second noun more or less at chance. This seems to happen because language users have no firm template of how to treat irregular plurals in compounds. Thus in this first “on-line” processing experiment, the stimuli were presented both aurally and visually to see if the modality in which items were presented would also affect how compounds containing different types of morphology are processed.

3.2 Method

3.2.1 Design

In a mixed design, type of word was the one within subjects factor tested at 6 levels (regular plural, possessive, comparative/superlative, irregular plural, singular or mass nouns ending in phonetic [-s], singular or mass nouns ending in phoneme other than [-s]). Two between subjects factors, modality and presentation order were tested. Half the participants were required to process visual stimuli; the other half processed aural stimuli. Within each presentation condition, half the participants were presented with the stimuli in one random order and half were presented with it in a second random order. The dependent variables were reaction time and accuracy (measured in terms of number of items correctly categorised as words or non words).

3.2.2 Participants

44 undergraduate students in the Department of Psychology at the University of Hertfordshire took part in the study in exchange for course credit. All were native English speakers and had been educated in the UK continuously between the ages of 5 to 18 years. The average age was 21.5 years. 41 participants were female and three were male.

3.2.3 Materials and stimuli

The first noun in each compound was taken from one of six groups. These were: - (1) regular plural nouns (2) possessive nouns (3) comparative/superlatives (4) irregular plural nouns (5) singular/mass nouns ending in phonetic [-s] (6) singular/mass nouns ending in a phoneme other than [-s]. A one way analysis of

variance found that there was no difference in frequency between the non-head nouns used in the various groups of items. The second noun in each compound was a deverbal noun, i.e., a noun that is derived from a verb (e.g., *walker, chaser*). A one way analysis of variance found that there was no difference in frequency between the head nouns used in the various groups of items. Table 3.2 shows examples of each type of compound tested (A full list of stimuli is shown in Appendix B.1). In the visual condition, the apostrophe was omitted from all the possessive nouns thus making it impossible to distinguish between the plural and possessive solely on the basis of punctuation. Each compound was preceded by a contextualizing sentence which pilot work had confirmed would lead the first noun in the compound (e.g., *rats* in **rats eater*) to be interpreted appropriately (as either possessive or plural). In the pilot study 10 participants were read a list of 50 randomised sentences such as *I feed four cats, a Burmese, a Siamese and two lovely old Persians, I enjoy being a cats feeder* (example of plural sentence) or *Last week, I left my purse in a London taxi, luckily, I managed to signal to the *taxi driver* (example of possessive sentence) and asked, in the case of these examples, how many cats and how many taxis were implied? All participants were over 80% accurate on the test.

To ensure uniform treatment of all stimuli, contextualising sentences also preceded the first noun even where they were not taken from the plural or possessive groups (see Table 3.2. for examples of sentences). For every compound made up of real words, a dummy compound was also constructed made up of 2 non-words (see Appendix B.2). In the visual condition, sentences and compounds appeared centred on the computer screen in 48pt type. Stimuli were presented on an Apple imac

computer using Psyscope software (Cohen, MacWinney, Flatt & Povost, 1993). In the aural condition, the compounds were recorded into the Psyscope package and participants heard the stimuli played to them through headphones. Response times were recorded by the Psyscope software.

Table 3.2 Examples of stimuli tested

Group	Example of context sentence	Examples of compounds
(1) Possessive nouns (n=20)	Last week, I left my purse in a London taxi. Luckily, I managed to signal to the	taxis driver
(2) Regular plural nouns (n=26)	I feed four cats, a Burmese, a Siamese and two lovely old Persians. I enjoy being a	cats feeder
(3) Irregular plural nouns (n=9)	Women always get lowly jobs. In the nursery rhyme the farmer's wife is nothing more than a	mice chaser
(4) Comparatives or superlatives (n=8)	Greg is very modest. He was amazed to hear that his song is still the record company's	biggest seller
(5) singular/mass nouns ending in phoneme [-s] (n=24)	We'll have a larger lawn and mowing the grass will take longer. I'm thinking of employing a	grass cutter
(6) singular/mass nouns ending in a phoneme other than [-s] (n=22)	Stephen is so skilled at mixing cocktails that the hotel want him to work permanently as a	drink server

3.2.4 Procedure

Participants were tested individually in an experimental cubicle at the University of Hertfordshire. A preliminary briefing took place during which participants were told that they would be expected to categorise a series of compounds as being made up of real words or non-words. It was also explained that compounds should be categorised as real if they were made up of 2 real English words even if they were 2 words that the participant would never use together. Furthermore, words should be categorised as quickly as possible.

3.2.4.1 Visual condition

At the beginning of each trial a contextualizing sentence appeared on screen. Participants were required to read the sentence out loud. When they had finished reading the sentence, they pressed the space bar causing an asterix to appear on screen. When they were ready to proceed they pressed the space bar again and the compound appeared. Reaction times were recorded from the moment the participant pressed the space bar for the second time and caused the compound to appear. Participants pressed 1 of 2 clearly marked keys on the keyboard corresponding to whether they thought the compound was a real item or not. Participants were given 6 practice trials before moving on to the 256 test trials. Each participant took approximately 45 minutes to complete the experiment.

3.2.4.2 Aural condition

At the beginning of each trial participants heard a contextualizing sentence followed by a buzzer and then the compound word. Reaction times were recorded from the moment the buzzer sound ended. Participants pressed 1 of 2 clearly marked keys on the keyboard corresponding to whether they thought the compound was a real item or not. Participants were given 6 practice trials before moving on to the 218 test trials. Each participant took approximately 45 minutes to complete the experiment.

3.3 Results

Both error data and reaction time data were collected. Half the participants were tested with visual stimuli and half were tested with aural stimuli. In each modality, half the participants were tested with the stimuli presented in one order and the other half were tested with stimuli presented in a different order.

3.3.1 Error data

Participants in both modalities were over 93% accurate in performing the task. Individual items which individual participants categorised wrongly as real words or non-words were omitted from the analysis. A within subjects analysis using a repeated measures, multivariate Analysis of Variance was carried out. This within subjects analysis of variance had one within subjects factor: word type (measured at six levels, regular plurals, possessives, comparatives/superlatives, irregular plurals, singular/mass nouns ending in [-s] and singular/mass nouns ending in phoneme other than [-s]) and two between subjects factors: presentation modality (measured at two levels visual and aural) and presentation order measured at two levels (order 1 and order 2). A within items analysis was also carried out using a multivariate Analysis of Variance. The within items Analysis of Variance had two within items factors presentation modality (measured at two levels visual and aural) and presentation order measured at two levels (order 1 and order 2) and one between items factor word type (measured at six levels, regular plurals, possessives, comparatives/superlatives, irregular plurals, singular/mass nouns ending in

[-s] and singular/mass nouns ending in phoneme other than [-s]).

The ANOVA revealed a main effect of modality, subjects $F(1,40) = 10.90$, $p < .05$, eta squared = .214; items $F(1,102) = 15.00$, $p < .00005$, eta squared = .970.

There was no reliable interaction between word type and modality for items, $F(5,102) = 1.05$, $p > .05$ but a marginally reliable interaction between word type and modality for subjects was found $F(5,36) = 2.56$, $p = .0430^1$. No reliable main effect of order was found for subjects, $F < 1$ but this effect was marginally reliable for items, $F(1,102) = 3.94$, $p = .0500^2$. A reliable interaction between word type and order was not found, subjects $F < 1$; items $F < 1$. The three-way interaction between word type, modality and order was also not reliable, subjects $F < 1$; items $F < 1$.

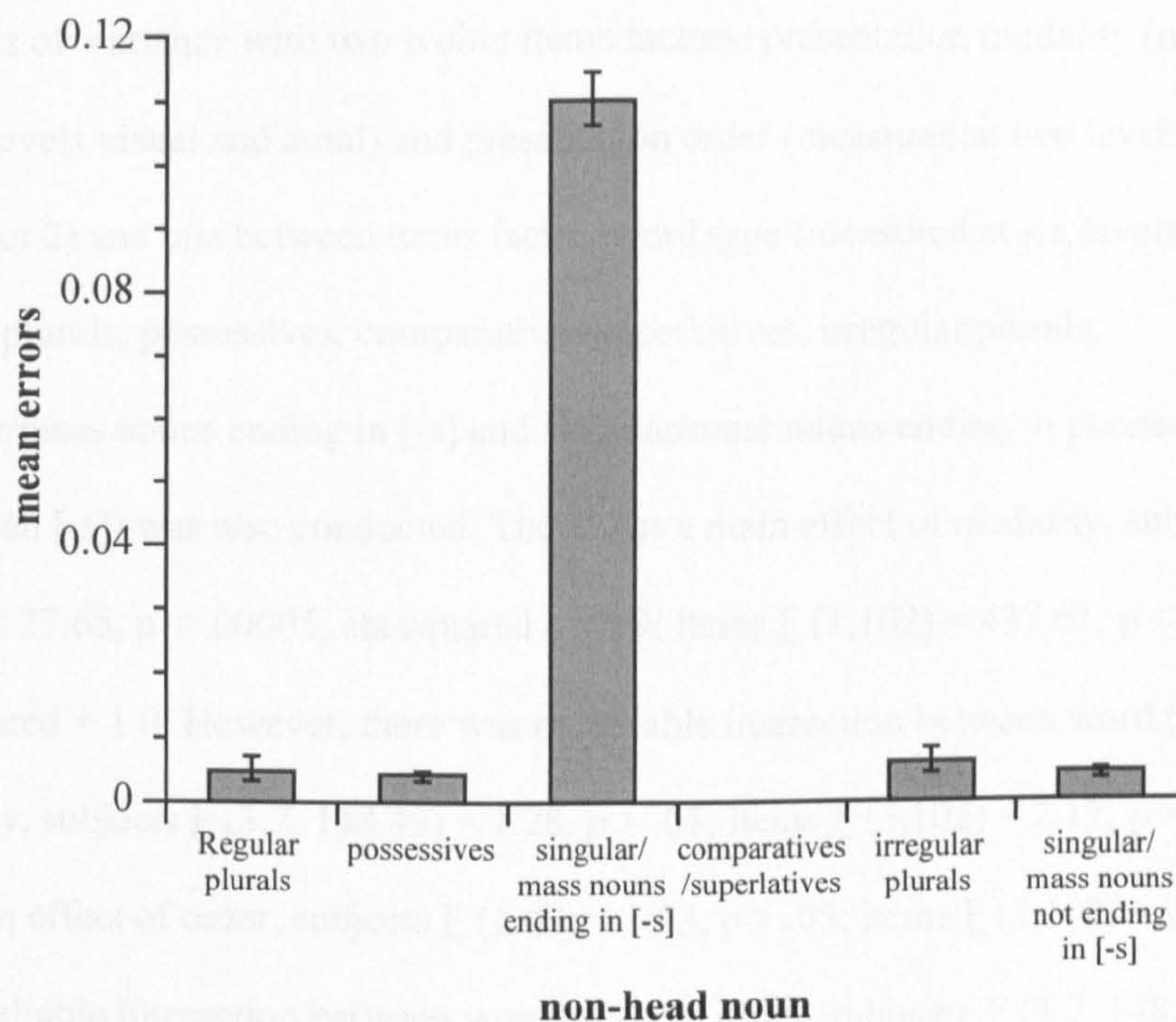
However, there was a main effect of word type, subjects $F(5, 36) = 18.82$, $p < .00005$, eta squared = .723; items $F(5,102) = 2.58$, $p < .05$, eta squared = .778.

Figure 3.1 shows the percentage of errors made to each type of word. A planned comparison found that more errors were made in response to non-head nouns that were singular/mass nouns ending in phoneme [-s] than to all other types of words combined, subjects $t(43) = 8.571$, $p < .00005$; items $F(1,107) = 13.84$, $p < .00005$. None of the other differences between groups were found to be reliably different.

¹ There was an interaction between modality and word type in the within-subjects analysis. However, in both the modalities the majority of errors were made in response to singular/mass nouns ending in phoneme [-s]. Although the pattern of errors for the other word types was different between the two modalities, error rates for these word types were so low that the interaction was not analysed further.

²The main effect of order was marginally reliable in the items analysis. Again, however, in both orders the majority of errors were made in response to singular/mass nouns ending in phoneme [-s]. Although the pattern of word errors for the other word types was different in the two orders, the error rates for these word types was very low.

Figure 3.1. Proportion of errors for different groups of words



3.3.2. Reaction time data

3.3.2.1 Analysis of Variance

A repeated measures, multivariate Analysis of Variance with one within subjects factor: word type (measured at six levels, regular plurals, possessives, comparatives/superlatives, irregular plurals, singular/mass nouns ending in [-s] and singular/mass nouns ending in phoneme other than [-s]) and two between subjects factors: presentation modality (measured at two levels visual and aural) and presentation order (measured at two levels order 1 and order 2) was carried out.

Mauchly's test of sphericity was found to be significant and thus the F values shown are subject to Greenhouse-Geisser corrections. A repeated measures multivariate Analysis of Variance with two within items factors: presentation modality (measured at two levels visual and aural) and presentation order (measured at two levels order 1 and order 2) and one between items factor: word type (measured at six levels, regular plurals, possessives, comparatives/superlatives, irregular plurals, singular/mass nouns ending in [-s] and singular/mass nouns ending in phoneme other than [-s]) was also conducted. There was a main effect of modality, subjects $F(1,40) = 27.65, p < .00005, \eta^2 = .999$; items $F(1,102) = 437.61, p < .00005, \eta^2 = 1.0$. However, there was no reliable interaction between word type and modality, subjects $F(3.7, 148.49) = 1.28, p > .05$; items $F(5,102) = 2.17, p > .05$. No main effect of order, subjects $F(1,40) = 1.33, p > .05$; items $F(1,102) = 2.73, p > .05$ or reliable interaction between word type and order, subjects, $F(3.7, 148.49) = 1.41, p > .05$; items $F < 1$ was found. The three-way interaction between word type, modality and order was also not found to be reliable, subjects, $F < 1$; items $F(5,102) = 1.96, p > .05$. There was a main effect of word type, subjects $F(3.7, 148.49) = 11.34, p < .00005, \eta^2 = 1.0$; items $F(5,102) = 2.96, p < .05, \eta^2 = .839$.

3.3.2.1 Planned comparisons between different word groups

As there was no effect of order in either the subject or the item analysis, data from both orders of presentation were collapsed together in all subsequent analyses. There was a main effect of modality. Participants in the aural condition processed the stimuli more quickly than participants in the visual condition. However, there

was no interaction between word type and modality. Thus data for the two presentation modalities were also collapsed together in all subsequent analyses. The means and standard deviations of reaction times to process the six categories of words tested in both orders and both modalities are shown in Table 3.3. Figure 3.3 shows a box plot of the distribution of reaction times to word groups tested.

The Frequency based account predicted that the groups would be processed in the following order (predicted fastest group shown first):- 1= Singular nouns not ending in [-s], 1= Comparatives/superlatives, 3. Possessives, 4= Regular plurals, 4= Singular nouns ending in [-s], 6. Irregular plurals. Follow-up polynomial contrasts indicated a significant linear effect in the direction predicted by the frequency based account, $F(1, 40) = 83.01, p = .00005, \eta^2 = .675$.

Table 3.3 Mean reaction times

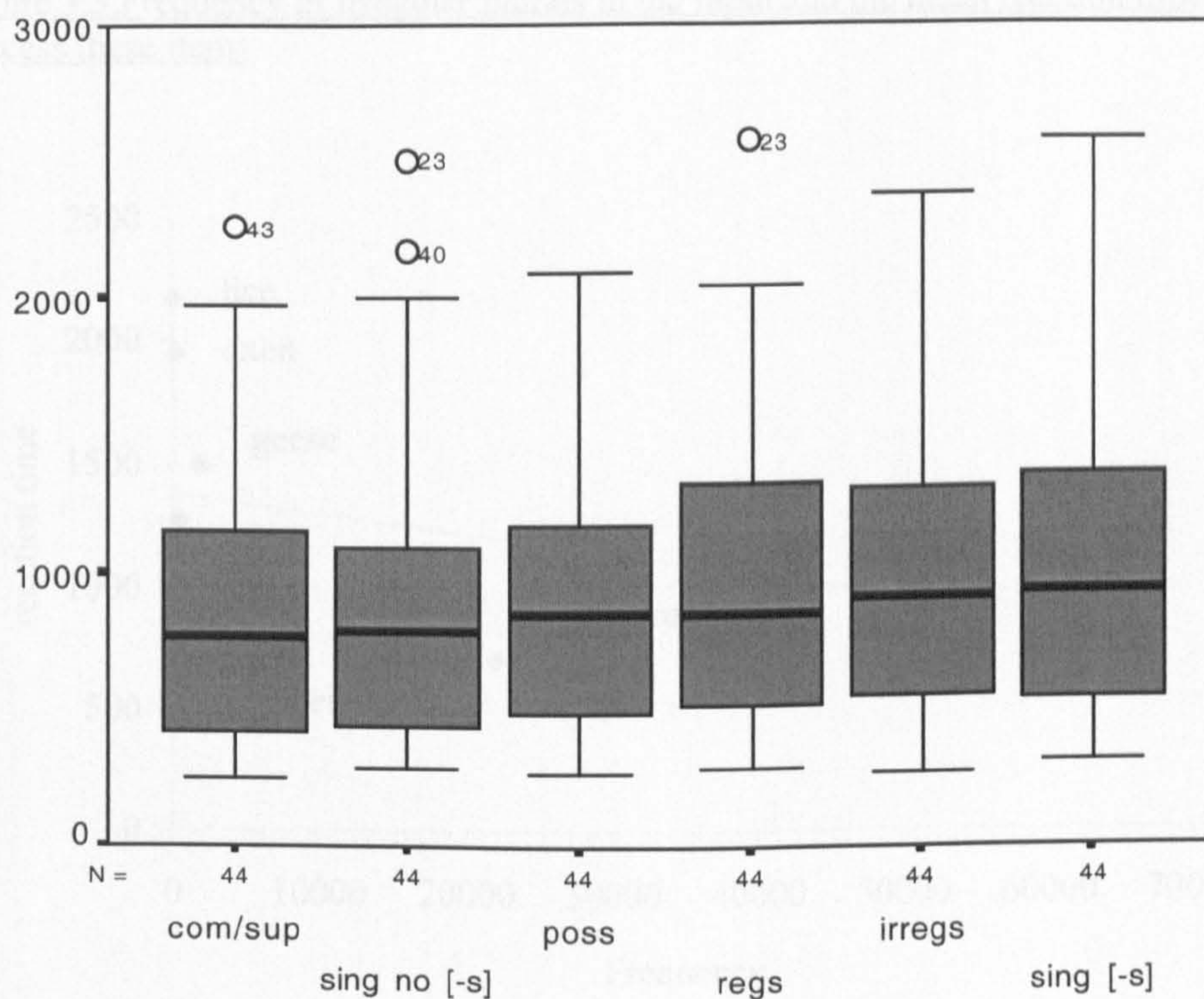
	\bar{x} reaction time in milliseconds (standard deviation in brackets)
Comparatives/superlatives	860 (490)
Singular nouns ending in other phonemes	881 (527)
Possessives	909 (508)
Regular plurals	970 (544)
Irregular plurals	1018 (534)
Singular nouns ending in [-s]	1021 (559)
All groups containing regular morphology	913 (501)

The dual mechanism model predicted that the groups of regular morphology would be processed at a different speed to irregular plurals. A planned comparison found a reliable difference between the time taken to process all regular morphology collapsed together (comparatives/superlatives, possessives, regular plurals) and irregular plurals, subjects $t(43) = 5.40, p < .00005$; items $t(61) = -2.33, p < .05$. However there was no reliable difference between the time taken to process regular and irregular plurals, subjects $t(43) = -1.81, p = .0700$; items $t(33) = -1.65, p > .05$. Furthermore, the dual mechanism predicted that there would be no difference in the time taken to process different types of regular morphology. However follow-up polynomial contrasts indicated that rather than comparatives/ superlatives possessives and regular plurals being processed in similar times a significant linear effect was found between these three groups of regular morphology, $F(1, 40) = 11.07, p = .0020, \eta^2 = .217$.

The Constraint satisfaction model predicted that the groups would be processed in the following order (predicted fastest group shown first):- 1= Singular nouns not ending in [-s], 1= Comparatives/superlatives, 3= Possessives, 3= Singular nouns ending in [-s], 3= Irregular plurals, 6 regular plurals. Follow-up polynomial contrasts indicated a significant linear effect in the direction predicted by the constraint satisfaction model $F(1, 40) = 21.27, p = .00005, \eta^2 = .347$. However further polynomial contrasts indicated that rather than possessives, irregular plurals and singular nouns ending in [-s] being processed in similar times (as predicted by the constraint satisfaction model) a significant linear effect was

found between these three groups of regular morphology, $F(1, 43) = 14.80$, $p = .00005$, eta squared = .270.

Figure 3.2. Distribution of reaction times for word types tested



3.3.2.3 Frequency of individual items

While it is evident, at a descriptive level, from Figure 3.7 that the high type frequency regular plurals are responded to more quickly than the low type frequency irregular plurals, the frequency explanation predicted that the token frequency of individual irregular plurals would influence the amount of time it took to process them in the LD test. From Figure 3.10 it is evident that at a descriptive level higher token frequency irregular plurals were responded to more quickly than lower token

frequency irregular plurals. While the graph indicates that there may be a slight negative correlation between frequency and reaction time a Pearson's correlation test did not find this relationship to be reliable.

Figure 3.3. Frequency of irregular plurals in the input and the mean reaction time to process these items

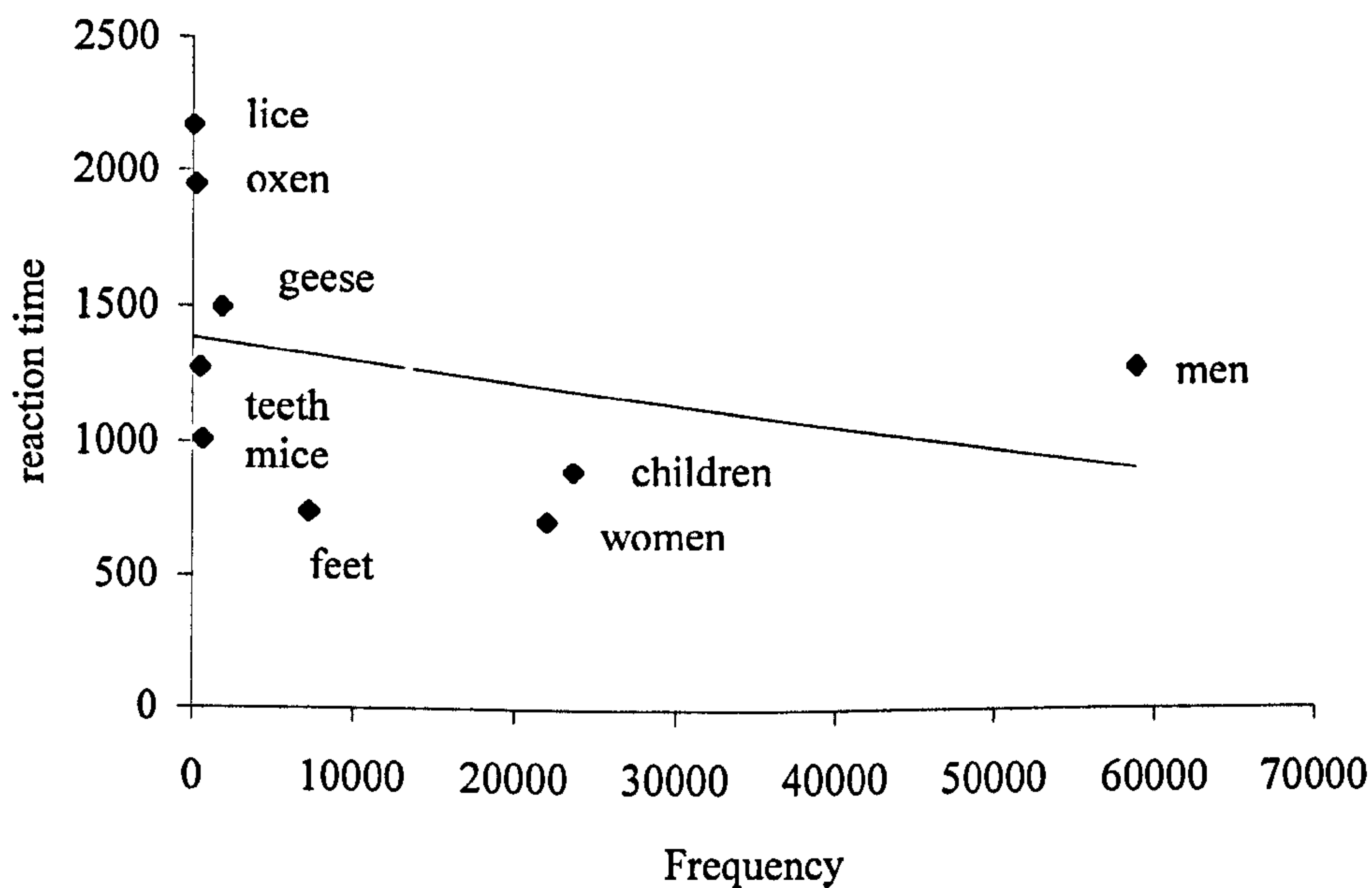
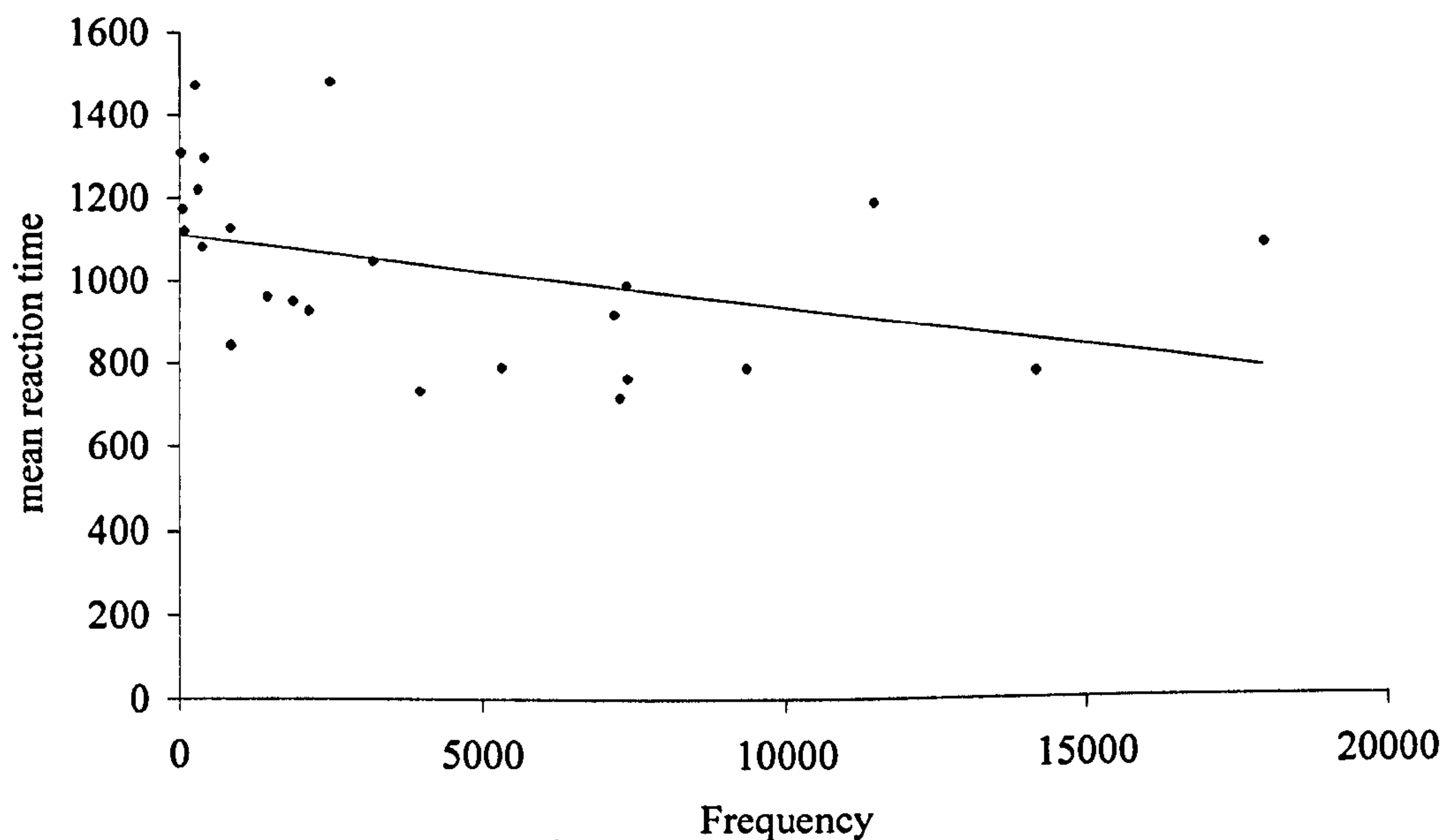


Figure 3.4. Frequency of singular or mass non-head nouns ending in [-s] and mean reaction time to process these items



The frequency explanation differs from the constraint satisfaction model in that it predicts that the individual frequency of a singular or mass noun ending in [-s] will be influenced by the token frequency of that item rather than how much like a regular plural it sounds. From Figure 3.11 it is evident that high token frequency nouns ending in [-s] tend to be processed more quickly than lower token frequency nouns ending in [-s]. The graph indicates that there is a slight negative correlation between frequency and reaction time to process an item. However a Pearson's correlation did not find this relationship to be reliable.

3.4 Discussion

The focus of this experiment was to consider first the comparisons that were made to test the associative explanation of compounding. Possessive nouns were easier to process than plural nouns in the middle of compounds even though they share exactly the same final phoneme and are allegedly both delivered by a rule. Participants seem to find it easier to interpret an internal [-s] in a compound as a possessive rather than a plural. Furthermore, it took longer to process compounds in which the first noun ended in [-s] of all types than compounds which did not include a first noun ending in [-s]. More specifically participants found singular/mass non-head nouns ending in [-s] harder to process than singular/ mass nouns ending in other phonemes. Thus, native English speakers found it relatively more difficult to process [-s] in the middle of a word.

Consider next the comparisons that tested the dual mechanism model's explanation of compounding. Unlike previous compound production studies, where there has been a reliable difference in the treatment of regular and irregular plurals, in this experiment no reliable difference was found between the time taken to process regular plurals and the time taken to process irregular plurals in compounds. However it took less time to process all types of regular morphology collapsed together than it took to process irregular plurals (the only type of irregular morphology tested). Interestingly, reaction times to both types of plural were longer than reaction times to non- plural morphology (comparatives/superlatives and possessives). Adult language users take longer to process either type of plural in the middle of compounds. However, contrary to the predictions of the dual mechanism

model, adults seem to have no difficulty processing other items of regular morphology such as possessives and comparatives and superlatives (i.e. items that are allegedly produced at a post lexical stage) within compounds (cf. Marcus et al, 1995).

Many researchers (Gordon 1985; Oetting and Rice, 1993; Clahsen, et al, 1995; Lardiere and Schwartz 1997; Murphy, 2000; Nicoladis, 2000; van der Lely and Christian, 2000) have been able to demonstrate that irregular plurals are included in compounds more frequently than regular plurals. The consistency of the evidence suggests that there must be some constraint on how the two types of plural are treated in compound production. The lexical decision task reported here sought to identify the origin of this constraint using a design in which participants processed compounds which contained, in some cases, structures which they may never have encountered before. However, unlike previous studies, no dissociation between regular and irregular plurals was found in this experiment. This finding questions Pinker & Prince's (1992) assertion that

“ it is an extremely strong prediction that in any language one should find that phenomena in either of these two clusters (i.e. regular and irregular morphology) should be found exclusively in association with one another, never in association with a phenomenon from the other cluster” (p.246).

A dissociation was found between the time taken to process all items of regular morphology collapsed together (regular plurals, possessives nouns and comparatives /superlatives) and irregular plurals. However, it was items of regular morphology that according to the dual mechanism model are produced at a post

lexical stage and therefore cannot be included in compounds that were processed more quickly than irregular plurals which Marcus et al (1995) claimed should appear easily within compounds. Also according to the level ordering model, as items of regular inflection, regular plurals, possessives nouns and comparatives /superlatives are applied at level 3, i.e., too late to be included in nominal compounding which takes place at level 2. Thus the results of this lexical decision study pose serious questions of the view that the treatment of plurals in compounds is driven by an innate morphological constraint.

Haskell et al (in press) also implies that due to the co-influence of their semantic and phonetic constraints regular plurals, which are influenced by both constraints, should be less preferred in compounds than irregular plurals that are only influenced by the semantic constraint. Thus the failure to obtain a reliable difference between processing time for regular and irregular plurals in this experiment also questions the idea that the interplay between the two types of constraints is an explanation for the dissociation between the two types of plural in compounds. The constraint satisfaction model does not explain why there is a putative semantic constraint on plurals but not on other types of morphology (such as possessive nouns or comparatives or superlatives) occurring before nouns. As such the constraint satisfaction model does not speak to the issue of why other regular morphemes occur before a noun but regular plurals do not occur in this position.

If frequency of occurrence of items in the input is influencing the treatment of plurals in compounds then the results are as predicted. It is not surprising that

when forced to process plurals in compounds that native speakers process regular morphology (i.e., items that have high type frequency in English) faster than irregular morphology (i.e., items that have low type frequency in English). Thus, items of regular morphology such as possessive nouns and comparatives and superlatives which occur more frequently before a second noun are processed more quickly in compounds than either type of plural. The dissociation seems to be between items (comparatives/superlatives and possessives) that frequently precede a noun in general language and items that rarely occur before other nouns (i.e., plurals of either type) and not between regular and irregular morphology.

It took longer for native speakers in this experiment to process compounds in which the non-head noun ended in the phoneme [-s] (i.e., items from the possessive, regular plural or Singular/mass non-head nouns ending in [-s] groups) rather than in any other phoneme (i.e., comparatives/superlatives or singular/mass non-head nouns ending in phonemes other than [-s] groups). This would seem to indicate that there is something special about [-s]. The [-s] phoneme as Murphy (2000) suggests may be associated with word ending and as such English speakers find it difficult to process in the middle of words such as compounds. Singular/mass non-head nouns ending in [-s] were also processed more slowly than singular/mass non-head nouns ending in other phonemes.

In the lexical decision task, the mean response time to process compounds including regular plurals was longer than the mean response time to process possessive nouns. This data supports Haskell et al's constraint satisfaction model that predicts that regular plurals should be difficult to process in compounds since

they are affected by both the semantic and the phonetic constraint. Compounds containing possessive nouns are only affected by the phonetic constraint and thus they should be easier to process. If competition between the possessive and plural and also the frequency of items is responsible however then this data is also as might be expected. Possessives are preferred in compounds over plurals because they occur more frequently in these noun-noun structures.

Further evidence of the role of frequency in compound production comes from the way singular nouns ending in phonetic [-s] were treated in the lexical decision task. While compounds with non-head nouns ending in phonetic [-s] were matched for frequency as a group with the other word groups tested, some items were far more frequent than others¹. Some items such as *cuss* (\bar{x} rt = 1338 msecs, frequency in the input = 16), and *dross* (\bar{x} rt = 1280 msecs, frequency in the input = 47), are used very infrequently in the input and these items took longer to process.²

¹ A similar range of frequencies within other groups of words tested may have contributed to the fact that several of the within items planned comparisons were not reliable. The within items analyses of the difference between reaction time to process regular plurals and possessives, all non-head nouns ending in [-s] and all non-head nouns not ending in [-s], regular and irregular plurals, regular plurals and comparatives/superlatives and plurals and other types of morphology all failed to find reliable differences. For several word groups such as irregular plurals and comparatives and superlatives the limited range of examples available meant that it was not possible to find words similar in frequency to use in this category. Furthermore the requirement to match frequencies between groups also limited the choice of words available.

² All frequency counts are taken from the British National Corpus, (Oxford University, 1996). Frequencies shown represent the frequency in which these items appear in the corpus, which comprises 100,106,008 words. 77.81% of the corpus is made up of written English.

Conversely, very frequent non-head nouns ending in [-s] i.e. *gas* (\bar{x} rt = 696 msec, frequency in the input = 7252), *grass* (\bar{x} rt = 736 msec, frequency in the input = 3970), *cross* (\bar{x} rt = 755 msec, frequency in the input = 7382), *glass* (\bar{x} rt = 755 msec, frequency in the input = 9358) *news* (\bar{x} rt = 791 msec, frequency in the input = 14174), and *bus* (\bar{x} rt = 796 msec, frequency in the input = 5307) were processed very quickly (\bar{x} rt for these 6 items = 755 msec). Thus frequency plays an important role in how quickly items ending in phonetic [-s] are responded to in compounds.

The phonetic constraint would predict that singular/mass nouns ending in phonetic [-s] would be dispreferred in compounds if they sound like regular plurals. Haskell et al argue that only singular/mass nouns that could be regular plurals such as *news* are directly affected by the phonetic constraint (*Blouse* for instance while ending in [-s] is not directly affected because it makes its plural by the addition of the [-iz] allomorph). However in this experiment *news* (\bar{x} rt = 791 msec) which was the only singular/mass noun ending in [-s] tested here, which could be a regular plural by Haskell et al's definition, was responded to the fifth fastest of all 24 singular/mass nouns ending in [-s] tested. Thus *news* was processed faster than the average item ending in phonetic [-s] (\bar{x} rt = 1021 msec) although apart from *news* these items are not argued to be affected by the phonetic constraint. Furthermore *news* was processed more quickly than the average time it took to process singular/mass nouns not ending in [-s] (\bar{x} rt = 881 msec) which are not affected by

either the semantic or the phonetic constraint. Thus the phonetic constraint does not explain the treatment of singular/mass nouns ending in [-s] in this experiment.

In fact the data presented here only provides limited support for the constraint satisfaction model. There is support of the semantic constraint in that both types of plural are processed slowly in compounds. However, it might be expected that regular plurals, which are influenced by both constraints, would be the slowest to process. This was not the case. There was no reliable difference between the time taken to process both types of plural. At a descriptive level, irregulars (items that are only influenced by the semantic constraint), were processed even more slowly than regular plurals (items that are influenced by both constraints). Furthermore, there is only mixed support for the phonetic constraint. Items that do not end in [-s] are processed more quickly than items that do end in [-s] a finding that is in accord with the idea of the phonetic constraint. Also in line with the predictions of the constraint satisfaction model, possessive [-s] is processed more quickly than plural [-s] (because the plural [-s] is affected by both constraints and the possessive by only 1 constraint). However, the phonetic constraint predicts that the mass noun *news* which sounds like a regular plural would be processed more slowly than singular/mass nouns not ending in [-s] which are not affected by either constraint. However this was not the case.

The results of this experiment support the idea that (type or token) frequency of items in the input in conjunction with the competition between the plural and possessive morpheme constrains the processing and production of plurals in English compounds. This input-based explanation for compounding, driven by the dual role

of the [-s] morpheme in English, relies on specific and key information present in English. Regular plurals are far more type frequent in the English language than irregular plurals. Thus, adult English speakers will have had a great deal of practice in using the regular plural morpheme at the end of words. They will also have a great deal of practice using possessive nouns followed by other nouns. However, they will have rarely experienced the plural [-s] morpheme followed by a second noun. Irregular plurals follow the same template as regular plurals and like regular plurals they are processed slowly in compounds.

These ideas were supported by a further study which compared Chinese native speakers against English native speakers on the lexical decision task described above (Murphy and Hayes, 2002). The Chinese participants, even though they were highly proficient speakers of English, were not able to dissociate possessive morphology from regular plural morphology on this task. It would seem that language users need a certain level of exposure to English before they are able to compute the relative probabilities of the different co-occurrence relationships between nouns, regular plurals or possessive morphemes.

Thus there is no need for an innate mechanism to explain the treatment of plurals in English compounds. There is enough evidence available in the input to constrain the formation of compound words in English.

Chapter 4

4.1 Introduction

The dual mechanism, level ordering and constraint satisfaction models, referred to in earlier chapters, are examples of theoretical models that posit mechanisms to explain how inflectional morphology might be processed. Predictions of these theoretical models have been tested using human participants and computational models. One type of computational modelling architecture that has been frequently used to test theoretical models is connectionist modelling. Connectionist models are interesting not only because they possess observable behaviours, but also because all learning can be driven by exposure to the statistical regularities in the training data. Models of this kind are truly single route systems, and many cognitive processes that have been initially explained by dual mechanisms, involving both symbolic and associative learning, have been successfully simulated using connectionist models based on single route associative memory architectures. It is also a characteristic of connectionist models that, depending on their architecture, they can learn both static and sequential patterns. This ability to learn sequential patterns is a feature that is particularly relevant for the issues explored in this thesis. Both types of model, implementations in relation to the dual and single route mechanisms, and in relation to how morphological constraints, such as those that govern compound production in English, might be learnt, are discussed. This Chapter ends with a description of a model that has addressed some of the issues which are thought to constrain compound formation in English and a consideration of how

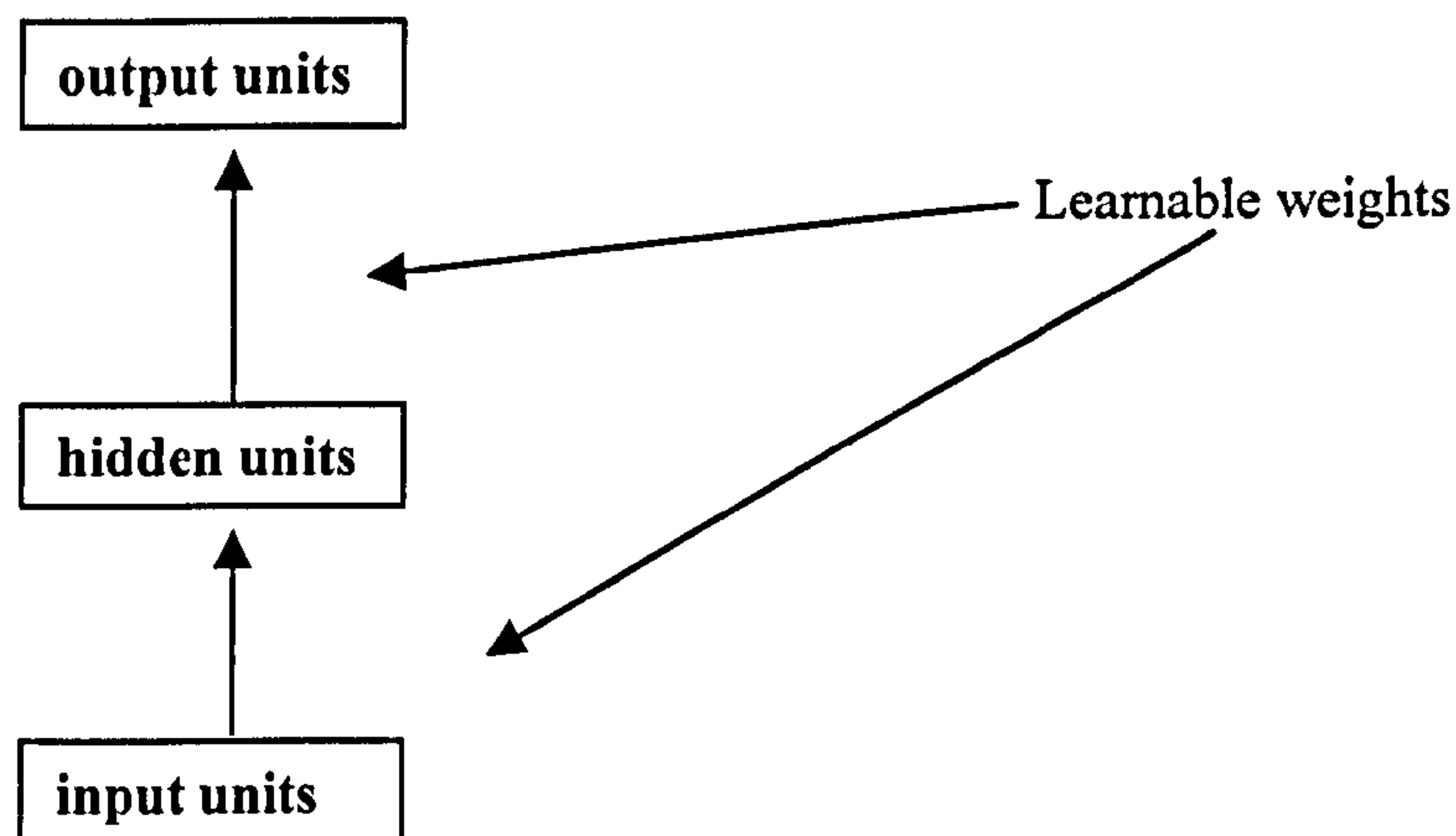
connectionist models might be used to further investigate these and other constraints on compounding in English.

4.2 Static and sequential models

4.2.1 Static models

Static models learn that a particular input should be paired with a particular output. For instance static models of the English past tense can learn to output the “*ed*” suffix when a regular verb is input, but not to output it when an irregular verb is presented. In a static model, weights of the connections in the network are randomised at the start of training. When an input is first presented to the network, an erroneous pattern of activity is produced at the output. This output is compared to a teacher signal which specifies the correct output for the current input. The discrepancy between the actual output from the network and the teacher signal is used as the error signal for the learning algorithm. Thus, over the period of training, the learning algorithm in a successful model builds a set of connections that will be able to pair the correct output with each input. Figure 4.1 shows a typical architecture of a static model. During training, similar input patterns become represented in a similar form in the hidden layers thus facilitating the network’s ability to generate the correct output for any input, including previously unseen items.

Figure 4.1 Typical architecture of a static connectionist model



Models using a static architecture were not employed in this thesis.

However, a number of models of this type have been influential in demonstrating that both verbal and nominal morphology in English can be learnt using single route architectures. As such static models have been able to offer alternative explanations for many lines of evidence put forward in support of a dual route model of morphology in English. Examples of static models that have provided this evidence are described in Section 4.4 of this chapter.

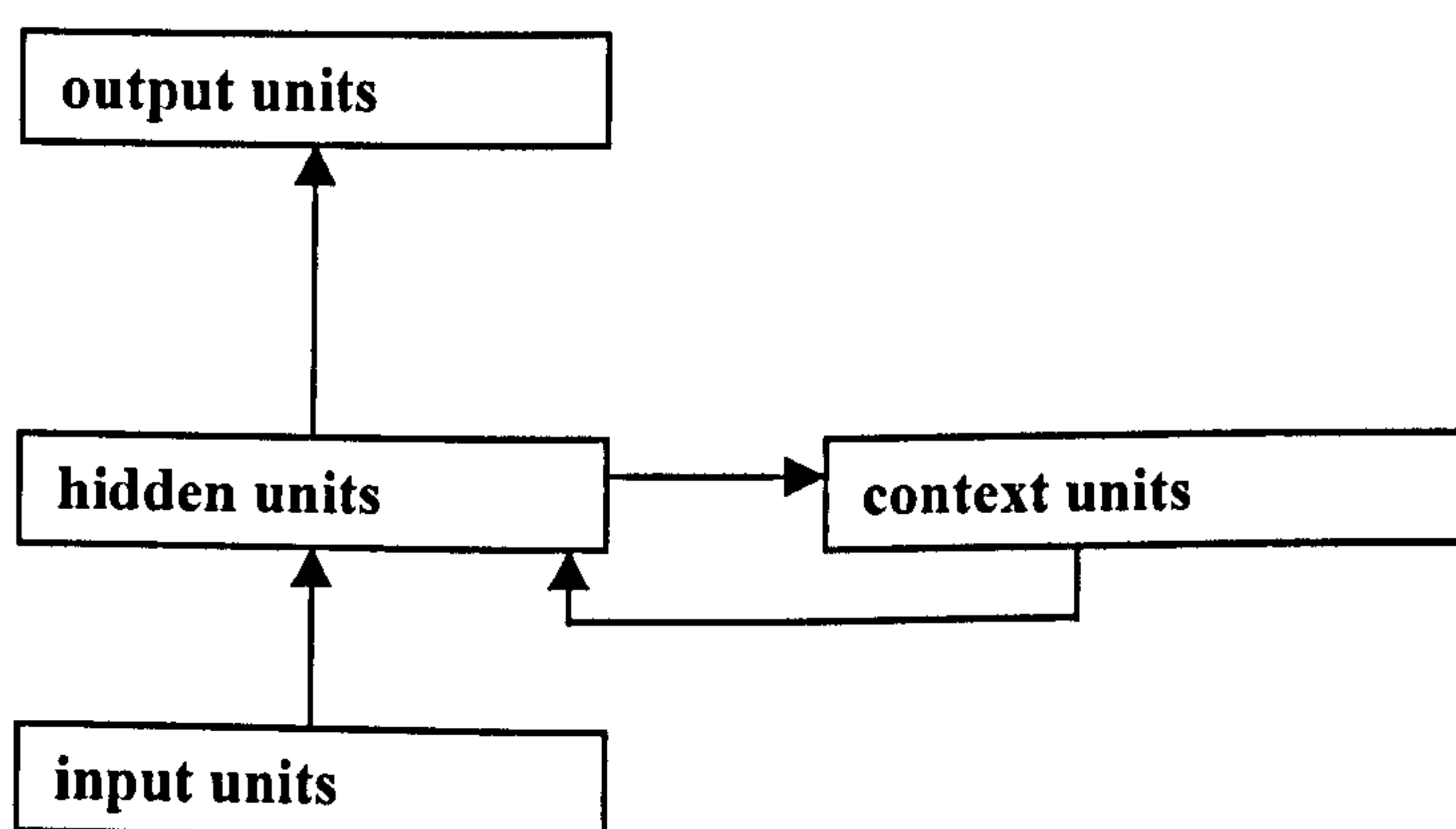
4.2.2 Sequential models

Many researchers have sought to investigate how the sequential processing of language might be represented in a neural network (i.e. a mechanism based on parallel computation). One approach has been to represent time implicitly through its effects on processing rather than explicitly in the architecture of a model.

Elman's (1990) simple recurrent network (SRN) uses recurrent links (as first suggested by Jordan, 1986) between the hidden units and context units that store representations of prior internal states (i.e. memory stores). As the context

units link back to the hidden units, at any point in time the state of the hidden units at the previous time step are used as additional input. A typical architecture for a SRN is shown in Figure 4.2. The hidden units output to the output units but also to the context units from where this output is fed back into the hidden layers as additional input.

Figure 4.2. Typical architecture of a sequential connectionist model



If the treatment of plural morphology in compounds is constrained by the patterns in which nouns and different types of morpheme [-s] appear in the input, then sequential neural network models, which have been very successful at uncovering syntactic structure from simple exposure to language, would seem to be an ideal architecture to explore this issue. Two types of sequential models have been used to investigate syntax.

The first type of model attempts to complete the more difficult task of discovering the grammatical type (and function) of each word token (e.g. Elman 1990). The input to this first type of model is a representation of word tokens and

the output is the word token that the network predicts is likely to follow that particular input. A successful network is able to learn that word tokens of particular grammatical types are able to follow tokens of some grammatical types but not others. The disadvantage of this approach is that it uses small lexicons and can only test fragments of grammar. However, models of this kind are able to simulate data collected from human participants on grammatical ratings (Christiansen, 1999; Christiansen and Chater, 1999), complex grammatical structure (MacDonald and Christiansen, 1999) and sentence comprehension (Tabor, Juliano and Tanenhaus, 1997). This type of model is reviewed in detail in Chapters 5 and 6 of this thesis as the models described in those chapters use this design to investigate whether morphology as well as syntax can emerge from simple exposure to language.

The second type of model involves training a network on sentences in which grammatical type is used as the input and the network outputs a prediction of the grammatical type that the next item is likely to come from (e.g. Hanson & Kegl, 1987; Howells, 1988). To test performance, the network is required to assign the appropriate grammatical type to the next word. The advantage of models such as these is that they can be used with large corpora of natural language as the network does not have to remember individual word tokens but rather in which order the various grammatical types in the input must appear to form “grammatical sentences.” The model described in Chapter 7 of this thesis adopts a methodology of this kind.

4.3 Implications of connectionist modelling in relation to a dual or single route mechanism

A series of connectionist models that have been able to learn items of inflectional morphology are described below. In each of these models any learning that takes place is driven by exposure to patterns and frequencies recoverable from the input. As such, these models raise questions for the viewpoint that inflectional morphology is mediated by a dual mechanism involving both symbolic and associative learning.

4.3.1 The role of input frequency in learning by single route models

4.3.1.1 Learning majority default systems

Inflectional systems such as English past tense, where regular (default) morphology has a much higher type frequency than irregular morphology are referred to as majority default systems. Rumelhart and McClelland (1986a), who were the first to develop a neural network able to demonstrate that a single mechanism might be sufficient to learn an aspect of morphology, used a static connectionist model and modelled the English past tense (a majority default system). Rumelhart and McClelland were able to model the three stages that children demonstrate, to some degree or other, in acquiring the past tense of some English verbs (Bowerman, 1982; Brown, 1988; Marcus, Pinker, Ullman, Hollander, Rosen and Xu, 1992). In the first stage, children only use a few past tense verbs and these tend to be mainly high frequency irregular verbs on which they make few errors. In the second stage children begin to use many past tenses, the majority of which are regular verbs. At this stage children appear to have learned rules which guide their behaviour, in that they make overregularizations on irregular verbs which they could use correctly at stage one (e.g., using 'buyed')

instead of '*bought*' as the past tense of the verb *to 'buy'*). This, it is argued, must be due to rule learning because the children never hear these overregularisations in the input they receive. At stage three they stop making overregularization errors and are able to use the correct form of irregular and regular verbs. This has been described as the U-shaped profile of learning. By altering the balance between the frequency of regular and irregular verbs in the input to their model, at various stages of learning, Rumelhart and McClelland demonstrated evidence of these three stages of learning in their model. Initially the network was trained on eight highly frequent irregular verbs and 2 regular verbs and the net showed performance similar to children at stage 1. The training set was then changed to 420 medium frequency verbs (80% of which were regular verbs) and initially the network showed evidence of overregularising irregular verbs but of being able to produce the correct past tense for regular verbs (i.e., similar to stage 2 of child behaviour). Later in training, the network made few errors in forming the correct past tense of the 420 verbs (stage 3 behaviour). Furthermore when the network was tested on 86 unseen low frequency verbs (80% regular), it demonstrated an ability to generalise to these new forms.

The Rumelhart and McClelland (1986a) model has received much criticism (e.g. Pinker & Prince, 1988) mainly because the increase in training from 10 to 420 verbs is not representative of the exposure to the 2 types of verb that children receive. However, Plunkett and Marchman (1991) addressed this issue and successfully modelled the U shaped profile using a training set in which the size of the vocabulary was held constant at 500 verbs. Plunkett and Marchman trained a network with an architecture similar to that shown in Figure 4.1 using an artificial lexicon of verb stems and past tenses. The artificial verbs

mimicked the phonological patterns found in English verbs. Importantly, Plunkett and Marchman (1991) found that their network could learn irregular past tenses if the type and token ratios approximated those in English. In a later simulation, Plunkett and Marchman (1993) gradually increased the training set from 20-500 verbs. From the results of this simulation, Plunkett and Marchman concluded that a critical mass of exposure to verbs is needed before the change from rote learning (memory) to system building (rule like behaviour) can occur (Marchman & Bates, 1994; Plunkett and Marchman, 1996), indicating that exposure to the linguistic input plays a critical role in acquiring morphology. MacWhinney and Leinbach (1986) and Cottrell and Plunkett (1991) also produced successful models of past tense acquisition, having addressed the criticisms levelled at the Rumelhart and McClelland model.

An aspect of the success of the Rumelhart and McClelland (1986) model was that it was able to demonstrate (regardless of whether the frequencies represented were realistic or not) that the frequency of the two types of morphology had a direct effect upon learning about regular and irregular morphology in English. This is the very factor that it has been suggested here, drives the dissociation between the treatment of regular and irregular plurals in compounds. However, Prasada and Pinker (1993) have argued that the fact that connectionist models rely so heavily on the balance of frequency between regular and irregular morphology, is actually a disadvantage of this approach to language learning.

4.3.1.2 Learning minority default systems

Prasada and Pinker (1993) argue that Rumelhart and McClelland were only able to demonstrate generalisation in models of the English past tense because of the particular frequency make-up of the English verbs. The default past tense ending (i.e. the regular [-ed] ending) has (by far) the highest type frequency in the input but many regular verbs have low individual token frequencies. Irregular verbs have a low type frequency but many individual verbs have high token frequencies (e.g., *go-went*, *see-saw*). Prasada and Pinker argue that this distribution pattern allows the networks to construct a system in which irregulars are represented as a series of phonological sub-categories and all other verbs are mediated by a large default category. Thus, an inflectional system such as the German or Arabic plural system which has a default ending which has both low type frequency and low token frequency could not be modelled. Furthermore, Marcus, et al (1995) have argued that the German plural system is quite arbitrary in that while there are some patterns of gender and phonology which dictate which plural ending is applied to nouns, there are long lists of exceptions to each pattern. However, a series of connectionist models with different architectures developed by Hahn and Nakisa (2000) were able to predict approximately 80% of German plural forms. Thus, they demonstrated that neural net models were able to learn the underlying structure of German plurals. Both single route and dual route computational models were tested and interestingly it was found that dual route models did not show superior performance. By actually building and testing a dual route model, Hahn and Nakisa were able to demonstrate the process that a dual route system would have to undergo in order to produce the correct plural ending. Firstly, any noun selected was “looked up”

in the associative memory system to see if the plural form was stored. If the item was not found (various thresholds of activation of the associative memory store were tested before the rule was applied), the rule would be adopted and the default ending was applied. The argument had been that single route models would not be able to cope with a minority default because they work by learning the small number of irregulars and applying the rule to the vast majority of other items. Thus, in the case of a minority default there would be too many items to have to learn and store in an associative mechanism. By instantiating a dual route model, Hahn and Nakisa demonstrated that as dual route models also have a pattern-associator facility, they are just as dependent as single route models on the balance between the frequency of regular and irregular plurals in the input. The rule is only applied once the item has not been found in associative memory, so the pattern associator element of a dual mechanism model, also has to store a large number of examples where a minority default situation exists. Plunkett and Nakisa (1997) have also successfully simulated learning of the Arabic minority plural system and Daugherty and Hare (1993) and Hare, Elman and Daugherty (1995) have modelled old English verbs which also have a minority default (i.e. only 17% of items have regular past tenses).

4.3.1.3 Learning when the type frequency of the irregular category is very low

A further criticism of connectionist models of morphological acquisition centres around Marcus' (1995a) claim that while it was possible to model the acquisition of the past tense of verbs it would not be possible to model the acquisition of the plurals of English nouns. This was because the success of the connectionist models that simulated learning of the past tense was driven by the fact that there were sufficient numbers of irregular verbs to stop items being

overregularised at an unrealistic rate. However, Marcus claimed that there may not be a sufficient critical mass of irregular nouns to stop all nouns being regularised by a connectionist model. Like the past tense, English regular plurals involve the addition of a suffix and like many irregular verbs, several irregular plurals are formed by changing the internal vowel in the stem (e.g., *goose* becomes *geese*). Brown (1973), Marcus and Marchman, Plunkett and Goodman (1997) have reported similar time courses for the acquisition of both types of morphology, and evidence that the U shaped curve of development occurs in both types of morphology. However, as Marcus points out, there are also differences. While there are approximately 100 commonly used irregular verbs (e.g., *go-went, see-saw*), there are only seven frequently used irregular plurals in English (*man –men, woman- women, child-children, tooth-teeth, foot-feet, mouse-mice, geese-goose*). However, Marchman et al (1997) showed that irregular plurals are frequently exemplified in children's early lexicons. This high token frequency of irregular plurals stops these items being dominated by the far more type frequent regular plurals. Plunkett and Juola (1999) have in fact developed a model of English past tense and plural morphology using a single mechanism connectionist network. Plunkett and Juola's model showed a similar developmental profile as children, in that nouns were learned more quickly than verbs and early performance was characterised by few errors but later performance saw the development of the U-shaped profile for both nouns and verbs.

4.3.2 Models addressing the behavioural evidence for a dual route model

Thus connectionist models have been able to learn static patterns of both verbal and nominal inflectional morphology when the default is both the majority

or the minority category. They have also been able to learn to produce the correct morphology when the irregular category is very small. These models have all been used to argue for a single route mechanism of inflectional morphology. Other models (examples of which are described below) have addressed some of the behavioural evidence put forward by supporters of the dual mechanism model.

4.3.2.1 The effects of frequency on irregular (but not regular) morphology

One of the most frequently cited lines of evidence for the dual mechanism model is that irregular morphology (because it is stored with the stem in the lexicon) is subject to frequency effects but regular morphology is not (Pinker, 1991). Daugherty and Seidenberg (1994) have demonstrated that neural nets can also account for this phenomenon. Regular, “rule governed” words have phonetic patterns that are very frequent in the input. In other words, regular verbs have lots of “neighbours” that are similar in sound. However, irregulars have far fewer phonetic neighbours. Thus, performance on irregulars depends far more on how often the language learner is exposed to these items (than is the case for regulars) because the correct past tense cannot be learned from a large number of similar examples.

4.3.2.2 Evidence that brain injured patients are impaired on the production of either regular or irregular inflections

Joanisse and Seidenberg (1999) addressed the evidence that some brain injured patients seem to be impaired on producing regular morphology, and others seem to be impaired on producing irregular past tenses. This, it is argued, provides evidence for the fact that the two types of morphology are mediated by

two separate areas of the brain. Joanisse and Seidenberg showed that damage to either phonological information or semantic information within a single route model can simulate these types of impairments.

Thus single route static models have been able to simulate the development of both verbal (Rumelhart and McClelland, 1986a; Plunkett and Marchman, 1991) and nominal morphology (Plunkett and Juola, 1999) in English and have been able to find alternative explanations for many lines of evidence put forward in support of a dual route model of morphology in English (e.g. Daugherty and Seidenberg, 1994; Joanisse and Seidenberg, 1999).

4.4 Connectionist explanations of language learning

4.4.1 Introduction

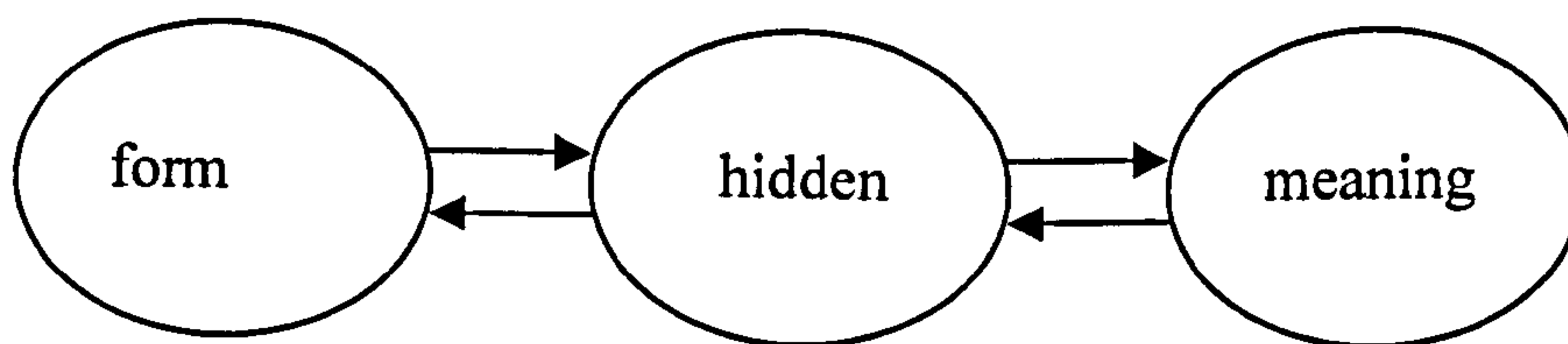
Connectionist models are also able to suggest mechanisms by which language learners might acquire particular linguistic functions by exposure to the linguistic input. The dual mechanism model or the level-ordering model do not need to propose learning mechanisms because they argue that linguistic constraints are innate. However, if a connectionist model without built in constraints is able to offer an explanation of how learning might proceed then the assumption that this knowledge is innate is weakened.

4.4.2 Probabilistic learning of language

Seidenberg and McDonald (1999) posit a mechanism by which they argue language learners might acquire linguistic constraints such as those that govern the treatment of plurals in compounds (Haskell et al, in press). Seidenberg and McDonald built upon the findings of sequential models, where grammatical learning emerges from exposure to language, to develop a

probabilistic approach to language acquisition and processing. They posit that knowing a language is not equated with knowing a grammar. Instead, they argue that knowledge of language develops as children attempt to speak (production) and understand (comprehension) the speech they hear. To test these ideas, Allan and Seidenberg (1999) developed a connectionist model that was trained on two tasks. The first was to compute the semantics of a series of words (comprehension) the second was to compute a series of words (production) having been given semantic patterns. The network was then presented with a series of test sentences and was required to identify whether these test sentences were grammatical or not (i.e. did the test sentences conform to the grammar that the network had been exposed to during training). The architecture of the model is shown in Figure 4.3.

Figure 4.3. Architecture of Allan & Seidenberg's 1999 model



The training set consisted of 20 examples of 10 types of sentences (i.e. sentences with different grammatical structures) from a vocabulary of 97 words. Each word was represented locally in the network. This meant that every individual word was encoded using a coding that was independent of the coding used for all other items. The semantics of each word were represented as the state of a space made up of 297 units. During training when the network was required

to perform the comprehension task the units representing each word in the sentence were activated in sequence. The task of the network was to compute the correct semantic representation of each word in the sequence. On the production task the model was required to produce the correct localist code for each word in the sentence having been given the semantics of the words in that sentence. The network was trained by interleaving form to meaning and meaning to form tasks. Thus, the network was simply trained on exposure to examples and weights became adjusted towards structures to which the network had been exposed and weights became adjusted away from structures that had not been exemplified in the input. During the test phase, words making up a sentence were supplied to the network and the semantics of these words would be activated (via the form to meaning connections, see Figure 4.3.). This semantic pattern would then be translated back into words (via the meaning to form connections, see Figure 4.3) and if the form of the translated sentences were unlike the patterns of words (sentences) used in the training set then a large error would be produced. However, if the translated sentences were similar in form to sentences in the training set then a lower error would be produced.

Allan and Seidenberg's (1999) model was successful at learning which structures were grammatical (i.e., similar to sentences seen previously) and led Haskell et al (in press) to conclude that the treatment of plural morphology in compounds might be learnt in a similar manner. Haskell et al did not build a network to describe how the treatment of plurals in compounds is learnt but argued that weights would be adjusted towards plurals being omitted from compounds and away from plurals being included in compounds. Thus plurals would become less likely to be included in compounds but could be in certain

circumstances (if that item had been included in the plural form frequently in the input) and particularly early in training (before the weights settled down). The significance of this model is that it counters the argument that children cannot learn to include irregular plurals in compounds (which they did in Gordon's (1985) experiment) from the input they receive because they do not hear adults including plurals of either type in compounds. Haskell et al, applying this probabilistic learning viewpoint to compounding, argue that in the vast majority of instances children will have heard plurals used when plural semantics are required and thus will have developed a language system based on this fact. They will experience far fewer examples of where plurals are omitted (i.e. in compounds) but gradually they will learn this exception to the general way that plurals are treated in English.

4.4.3 Connectionist model investigating factors affecting the treatment of plurals in compounds

Although they discuss how a connectionist model of the treatment of plural morphology in compounds using probabilistic constraints might be developed, Haskell et al (in press) do not build such a model. Instead they build a connectionist model to investigate whether the phonological structure of a word indicates whether this item is permissible before a second noun. This is to investigate their hypothesis that due to a phonetic constraint words that sound like regular plurals do not appear before a second noun. They hypothesised that adjectives (i.e. words that may occur before a second noun) have a particular phonetic structure (in particular they tend not to sound like regular plurals) that is not present in words from other syntactic categories. The network consisted of 26 input units that encoded phonetic features. The hidden layer had 20 units and the

output layer had one unit, adjective or not. The frequency with which an item was presented to the network was representative of its frequency in the Brown Corpus produced by the Penn Treebank project (University of Pennsylvania, Philadelphia, PA). The training set was presented for 50 iterations. Over 3 test runs the network on average was able to correctly identify 75% of the adjectives it was trained on as being from this syntactic category and 84% of items as being from other categories i.e. not adjectives. On testing with novel input, the network classed 70 % of previously unseen adjectives correctly and 79% of non-adjectives correctly. Thus Haskell et al concluded that phonetics play a significant role in learning syntactic categories (Kelly(1992); Morgan (1996)).

4.5 How connectionist models might be used to investigate the factors that constrain compound production in English

A range of connectionist models has been productive in finding explanations for various aspects of language learning. In particular a number of models have cast doubt on the dual mechanism model. To date the treatment of plural morphology in compounds has not been investigated to any great extent using connectionist models. In their modelling, Haskell et al (in press) investigated whether the phonological structure of a word indicated whether this item is permissible before a second noun; an issue that is relevant to their probabilistic constraint based explanation of the treatment of plurals in compounds. However, they did not consider the fact that in English some nouns (as well as adjectives) frequently precede other nouns. Furthermore these nouns that mark possession have a very different phonetic structure from adjectives because they always end in the phoneme [-s] (and as such sound like regular plurals). Similarly to Elman, (1990) the models explored in the rest of this thesis

will use sequential architectures. In Chapter 5 the role of [-s] as a predictor of word finality is investigated using a connectionist model. In Chapters 6 and 7 the competition between these nouns which end in the possessive [-s] morpheme and nouns that end in the plural [-s] morpheme and the role this competitive relationship plays in constraining the production of plurals in English compounds are investigated using a series of connectionist models.

Chapter 5

5.1.Introduction

5.1.1.Background

The lexical decision study described in Chapter 3 provided support for an associative explanation of compounding and also raised doubts about the dual mechanism model's account of compound production. This associative explanation therefore merits further investigation. As illustrated in Chapter 4, neural network modelling has been frequently used as a research tool to investigate other associative accounts of language acquisition. Several neural net models have successfully simulated the putative dissociation between regular and irregular inflection for both verbal morphology (Daugherty & Seidenberg, 1994) and plural morphology (Plunkett & Juola, 1999) using a single learning mechanism and no explicit rules. Furthermore, as well as being able to learn mappings from input to output, connectionist models have also been able to learn sequential mappings (Elman 1990). Thus it is predicted that a single route associative memory system could learn that the inclusion or omission of the regular plural morpheme [-s] is influenced by where that [-s] morpheme occurs in a sequence of language input. Four networks were developed. The first of these models is described here. Models 2 and 3 are described in Chapter 6 and model 4 is described in Chapter 7.

5.1.2 [-s] as a predictor of word finality

The first connectionist model in this programme of work investigated the idea in Murphy (2000) that the regular plural morpheme is omitted from the end of the first element of a compound, because it is strongly related to word finality in English. This model sought to identify any role that [-s] acting as a morpheme or as a phoneme might play as a predictor of word finality in child directed speech. It was predicted that a connectionist model could learn that [-s] is associated with the end of words in English simply by being trained on child directed speech. In English the plural [-s] morpheme, the possessive [-s] morpheme, and the third person singular [-s] agreement marker morpheme on verbs, all occur at the end of words. Thus the morpheme [-s] is a perfect predictor of word finality. Furthermore a number of frequently occurring English words e.g. “*bus*”, “*gas*”, “*grass*”, “*glass*,” “*news*” also end in the phoneme [-s]. A child learning the English language is therefore exposed to many examples of [-s] occurring at the end of words. A connectionist model was developed to investigate whether it is possible to use the distribution of [-s] in child directed speech to predict where word ending boundaries might occur. The study was based on Elman (1990) who trained a simple recurrent network to discover word boundaries from a concatenated stream of letters. This network is a replication of Elman (1990) but was necessary as Elman did not report data concerning the role of individual letters such as [-s] in predicting word endings. Elman was interested in exploring ways in which the sequential language process might be represented in a neural network. The approach adopted was to represent time implicitly through its effects on processing rather than explicitly in the architecture of his model. Elman’s simple recurrent network (SRN) uses

recurrent links (as first suggested by Jordan, 1986) between the hidden units and context units, which copy the output of the hidden units and feed this back into the hidden units with the next input. Elman used this architecture to see if a network could discover the notion of "word." He was interested in whether the concept of words emerge from learning sequential patterns of letters in which word boundaries were not marked. The sequence of letters was formed from a lexicon of 15 words using a sentence generation tool. Two hundred sentences, varying in length from 4 to 9 words were created. The sentences were then concatenated to form a string of 1270 words. The words were then broken down into the 4963 letters from which they were constructed. Each letter of the alphabet was given a separate 5 bit code, so there were 26, 5 bit vectors. The vectors were presented at the input one at a time. The task for the network was to predict the next letter. The network had 5 input units, 5 output units, 20 hidden units and 20 context units. The network was trained on 10 complete presentations of the 4963 vector sequence. It was impossible for the network to learn the sequence in so few presentations (and indeed it does not). It is characteristic of this type of model that during training the error on predicting the next input does not decrease to any great extent. However, while the error is relatively high at the start of a new word, as more letters are presented to the network the error declines since the word becomes more predictable. The network also has high errors on the y when e is input as part of *the y.....* because it has been exposed to the highly frequent pattern *the*. Elman did not intend this simulation to be treated as a model of word acquisition. The simulation simply serves as a demonstration of the fact that there seems to be information in the input that could serve as a cue to the boundaries of linguistic input (such as word end), which can be

learned. Saffran, Aslin and Newport (1996) found that 8-month old infants could learn word boundaries from exposure to the input. In the case of the network developed as part of this research programme, the network was required to predict the next letter that would occur given the letters it had seen previously. It was hypothesised that on a "next letter" prediction task of this kind, a neural network would learn that after the input [-s] there was a high probability that the next input would be a word-ending marker.

5.2 Model 1

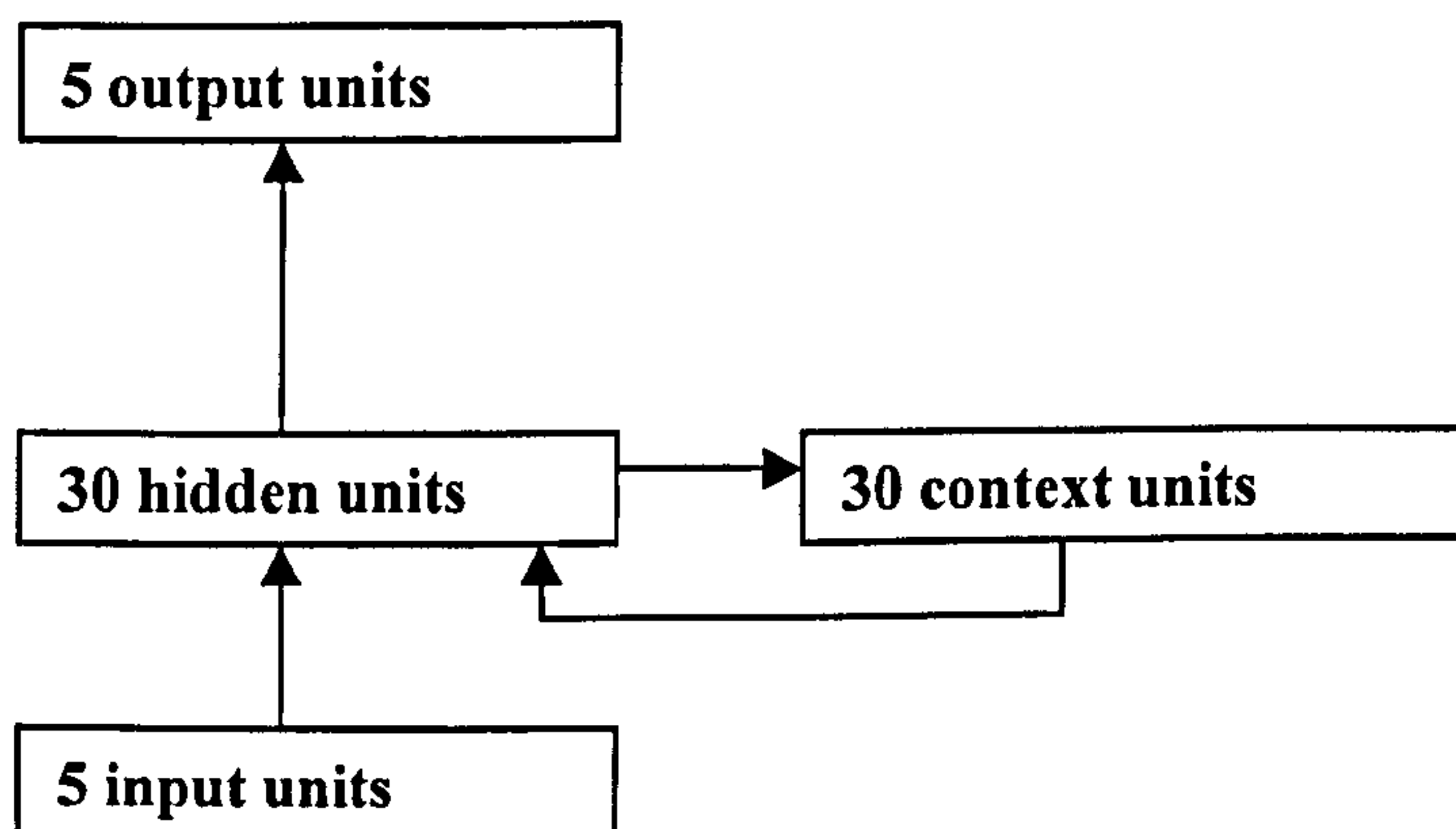
5.2.1 Training set and coding scheme

Two hundred sentences of child directed speech were taken from the Wells study which is included in the CHILDES corpora (MacWhinney & Snow, 1985). An additional character to mark word ending was added to the end of each word and the words (including the word ending markers) were concatenated to form a stream of 3596 letters. There were 26 randomly assigned 5 bit vectors, one for each letter in the alphabet, and the word-ending marker was encoded using a 27th 5 bit vector.

5.2.2 Architecture

The architecture of the network is shown in Figure 5.1. A simple recurrent network was built with 5 input units, 30 hidden units, 5 output units and 30 context units. The network was trained with a learning rate of 0.1 and a momentum of 0.3. Networks with other numbers of hidden units were investigated but the most satisfactory performance was recorded when 30 hidden units were adopted.

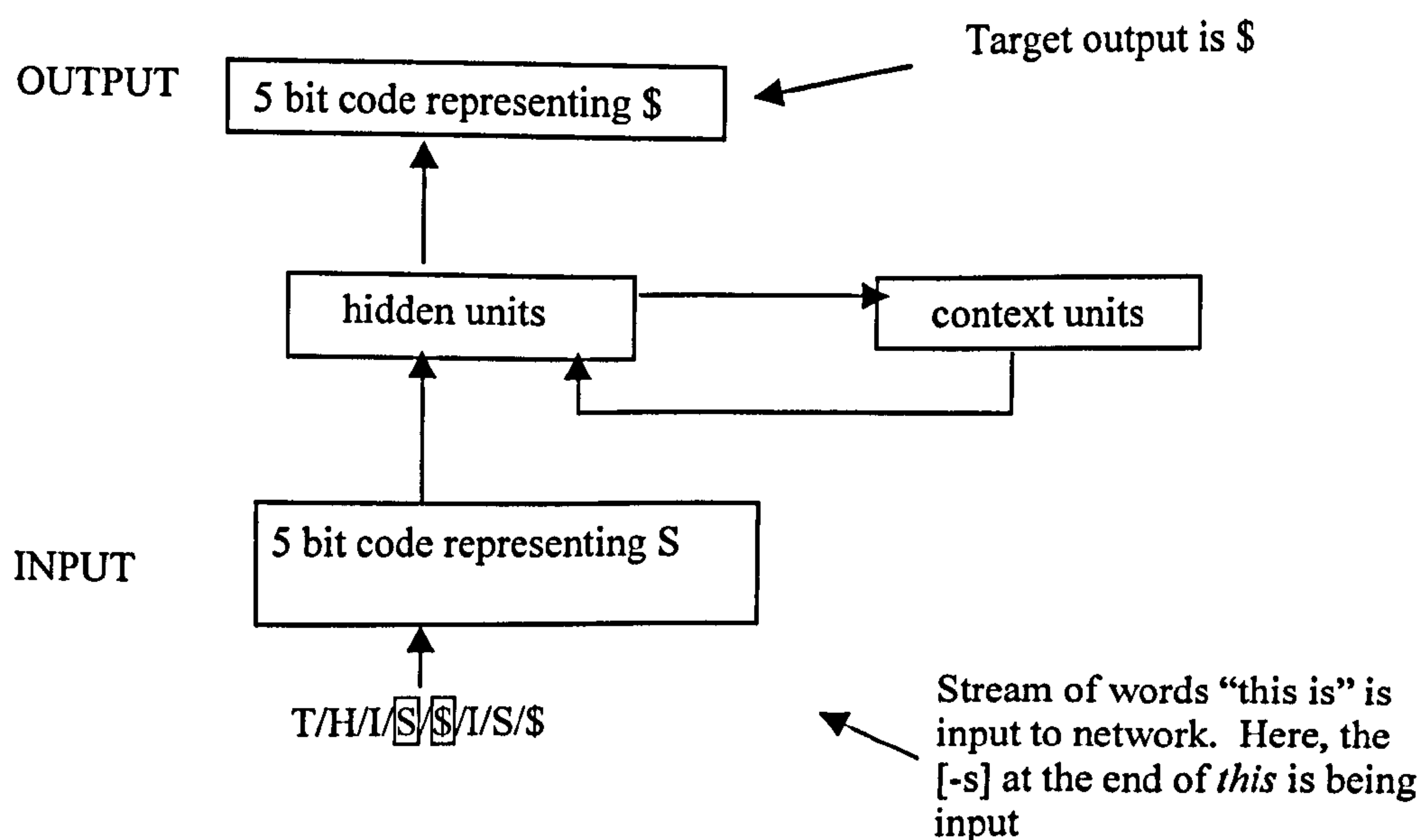
Figure 5.1. Simple recurrent network architecture used in neural net 1.



5.2.3 Task

As represented in Figure 5.2, a stream of 3596 letters was presented letter by letter to the 5 input units. The network had to learn to predict the next letter in the sequence. For convenience the term letter is used to include the word-ending marker.

Figure 5.2. Diagram to represent letter prediction task



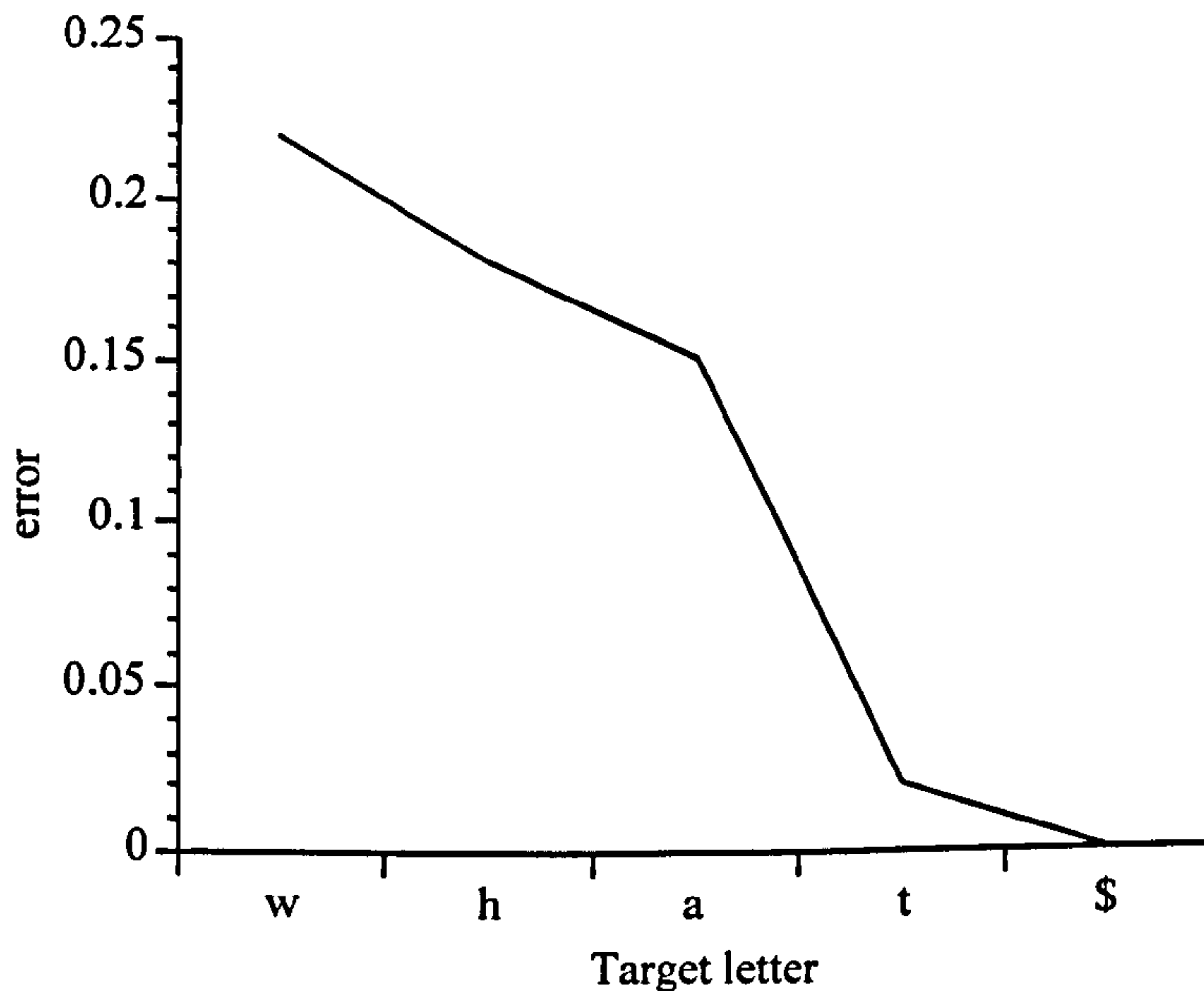
5.2.4 Training

The network was trained on 280 complete presentations of the letter sequence. The back propagation learning algorithm used the difference between the desired output and the actual output to adjust the weights in the network at each time step.

5.2.5 Test Sets and Results

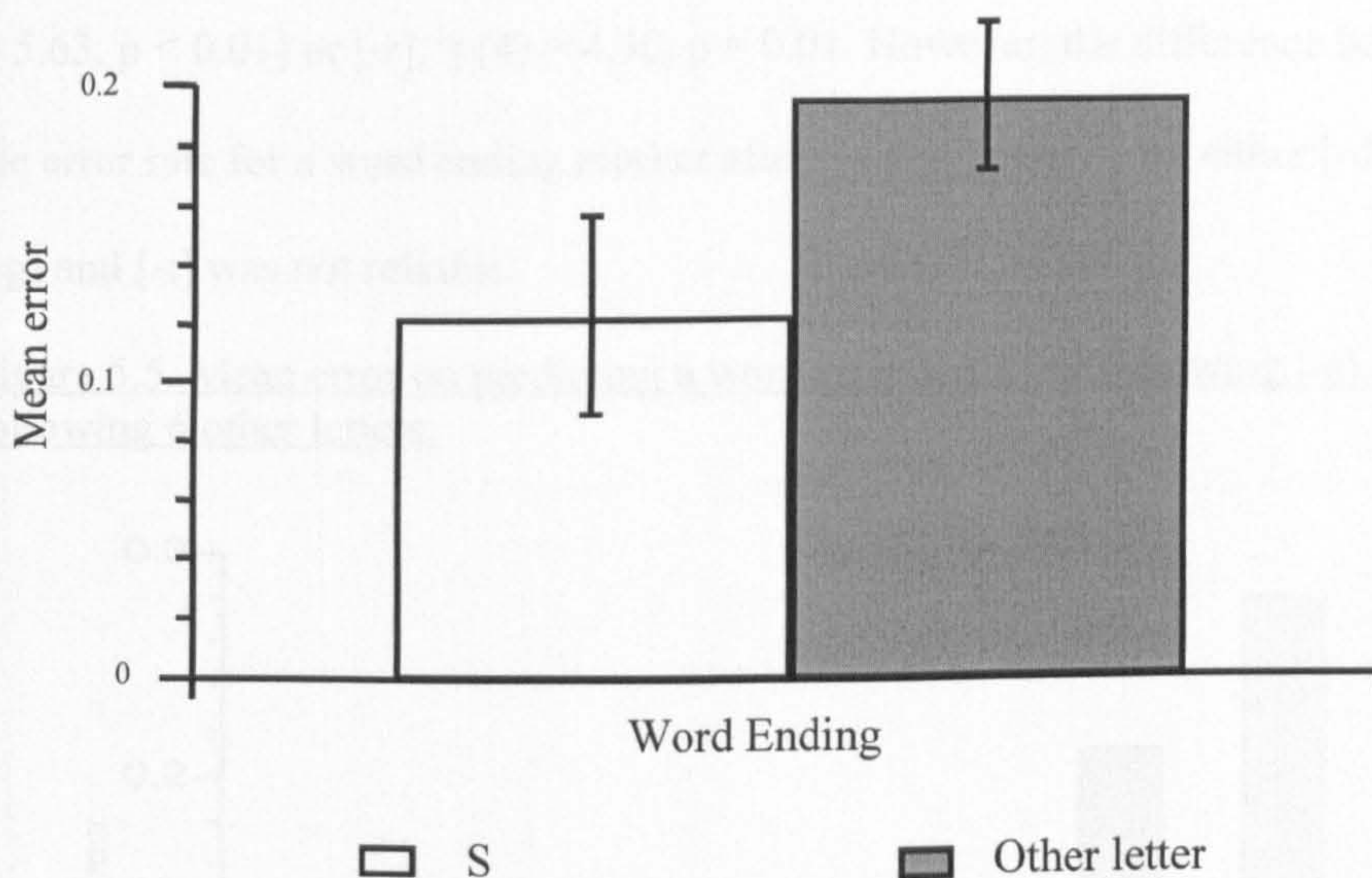
It was impossible for the network to learn the precise sequence of letters in the input. For instance after *C A T* has been presented to the network there is a probability that [-s] might be the next input. However many other letters might come next e.g. *a* to make *catapult*, or *h* to make *Cathedral*. Nevertheless the network extracted sequential patterns. Figure 5.3 shows the typical error after training on one of the words from the training set. From Figure 5.3 it is evident that at the beginning of the word *what*, the error was high for the letter *w* but as more letters were presented the error in predicting the next letter decreased until by the word end (i.e. when the correct output was the word ending marker) the error was relatively low.

Figure 5.3. The error between the target and actual output of the network for each letter of the word "what"



The network's ability to learn that [-s] is a good predictor of word finality was tested using 18 unseen words that ended in [-s] and another 18 unseen words that ended in other letters. Appendix C.1 shows the words that were used in each test set and provides more information on the selection of this test set. Each word ending in a letter other than [-s] was matched in word length with a word ending in [-s]. From Figure 5.4 it is evident that the network was more accurate (i.e. the error was lower) at predicting a word ending marker after an [-s] than after all other letters combined, $t(17) = -2.08$, $p = 0.0500$.

Figure 5.4. Mean error on predicting a word ending marker following [-s] or following any other letter.

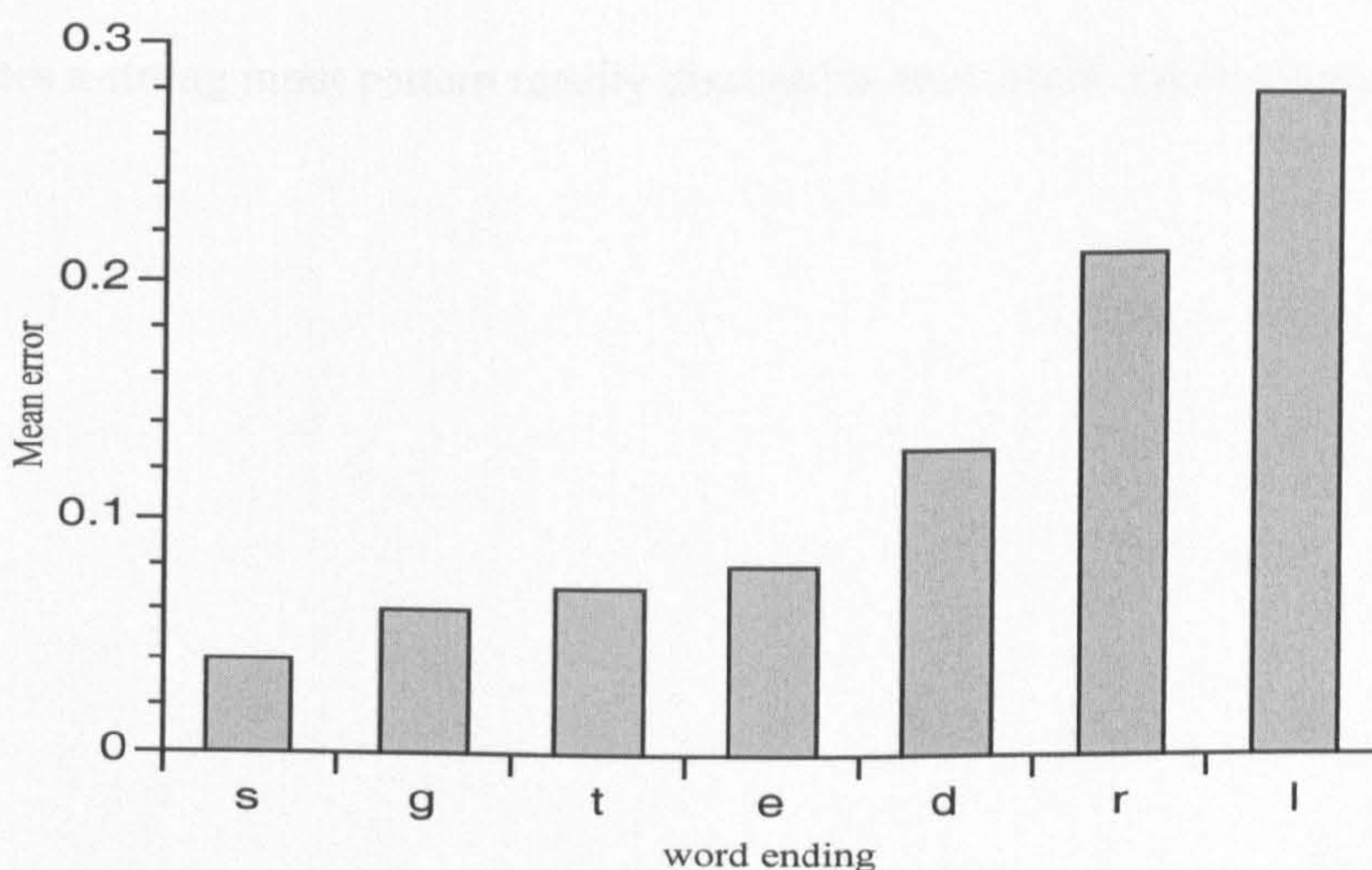


Having seen that there was evidence that [-s] was linked with word finality, a test was also conducted to see if other letters that end English inflectional morphemes/derivational affixes were also linked to word finality in the same way. Thus, the network's ability to learn that [-s] is a good predictor of word finality was further tested by comparing the output for 5 unseen four letter words that ended in [s] with the output for six sets of five unseen four letter words that ended in either [-d], [-e], [-g], [-l] [-r] and [t] respectively. See appendix C.2 for list of words used. These letters were chosen because they end several frequently occurring inflectional morphemes/derivational affixes in English. See appendix C.3 for a list of English inflectional morphemes/derivational affixes that end in these letters.

At a descriptive level, from inspecting Figure 5.5 it appears that the mean error on predicting a word-ending marker is lower after [-s] than after any of the

other letters tested. The difference between the mean error rate for a word ending marker after an [-s] was reliably lower than that recorded after [-l] ($t(4) = 5.63, p < 0.01$) or [-r], $t(4) = 4.30, p = 0.01$. However, the difference between the error rate for a word ending marker after [-s] compared with either [-d], [-e], [-g] and [-t] was not reliable.

Figure 5.5. Mean error on predicting a word ending marker following [-s] or following 6 other letters.



5.3 Discussion

The phoneme [s] (like several other test letters) appears to be a good predictor of word finality. It seems that in child directed speech at least, there is a discernable pattern in the input in which the presence of the phoneme [-s] creates an expectation that this signals the end of a word.

The role of [-s] as an indicator of word finality should be investigated further using connectionist models. In particular it would be interesting to run this simulation without the inclusion of a word-ending marker (c.f. Brent & Cartwright, 1996; Cairns, Shillcock, Chater & Levy, 1997). Furthermore the rate at which the presence of [-s] erroneously predicts a word-ending marker was not investigated in this model and this factor needs to be considered in future work.

Despite the opportunities for further testing of this model, the findings presented here provide further support for the argument that the pattern of input experienced by language learners provides an equally, if not more, valid explanation of the constraints on the use of plurals in compounds, than that put forward by proponents of the dual mechanism model. If, as indicated here, [-s] is strongly associated with word finality, then including it within a compound violates a strong input pattern readily discernible from child directed speech.

Chapter 6

6.1 Introduction

The connectionist network described in Chapter 5 investigated the role that the link between [-s] and word finality in the input might play in constraining the treatment of plural morphology in compounds. Another input driven constraint on compounding worth investigating is the competition between the plural and possessive [-s] morphemes in English. This issue was also investigated using connectionist models. In this Chapter, 2 models that investigate this competition between plural and possessive morphology in English are described. A third model, that further investigates this constraint but uses a different methodology, is described in the next Chapter.

6.2 Model 2

6.2.1 Background

As mentioned in Chapter 4, connectionist models are able to learn sequential patterns. The objective of this network was to learn whether highly consistent patterns in the input (i.e. that a plural noun is rarely followed by another noun while a possessive noun is always followed by a second noun) can drive learning about how to manipulate plurals within noun-noun compounds. The network was required to predict the next word to occur given the words it had seen previously. It was impossible for the network to predict the exact word that followed in the input. However, the network should be able to learn from which syntactic category the next item is likely to come.

Elman (1990) was interested in whether it was possible to learn word classes from word order. He trained an SRN to discover lexical classes from the order in which words appeared in the input. Sentences were generated from a lexicon of 29 items. The sentences were formed using a grammar in which there were subject noun/verb agreements, different verb argument structures (i.e., intransitive, transitive, optionally transitive) and subject object relative clauses (allowing multiple embeddings with complex long-distance dependencies). Ten thousand random two and three word sentences were formed using 15 sentence templates. Each sentence was formed by randomly selecting a word that was appropriate for a particular slot in a sentence frame. A localist coding scheme was employed in which each word was represented by an individual code. The coding did not indicate that any word was from the same syntactic category as another word. The 27,534 word vectors in the 10,000 sentences were concatenated to form a training pattern of 27,534, 31-bit vectors (two additional input units were built into the model but were not used in this simulation). There were no breaks between successive sentences. The network contained 31 input units, 31 output units and 150 context units. The task was to predict the next word in the sequence. The network was trained on 6 complete repetitions of the training set. The words were input one at a time. For each word there was a limited number of legitimate successors. The network was expected to learn the frequency of occurrence of each of the possible successors. If the network learned these frequencies then words that are likely to occur in similar slots might be expected to be represented in a similar way in the hidden units. A cluster analysis of the way in which the words were represented in the hidden units revealed that the network had discovered that there were several major

categories of word types. Two major categories, nouns and verbs, were found. The verb category was further broken down into transitive, intransitive and optionally transitive. The noun category was broken down into animate and inanimate nouns. Thus from word order alone the network learned that some verbs need to be followed by a noun but others do not. The network had no semantic representations but the results indicate that an important component of meaning seems to be context (i.e. consistent patterns exist in which certain words frequently co-occur in particular sequences with some words, but not with other words).

The experiment reported here was based on Elman's (1990) study in that the network was trained on a stream of sentences made up from a limited lexicon of words and the network was required to predict the syntactic category of the next word to occur, given the words that had occurred previously. The lexicon from which the training set was constructed consisted of nouns, verbs, determiners and adjectives (the training set is shown in Table 6.1). Representatives of these syntactic types were used to make up legal sentences. Sentences made up of different numbers of words were tested. Sentences in which determiners, adjectives, nouns, deverbal nouns and verbs occurred in different (but legal) orders were tested (examples of the sentences generated are shown in Appendix D.1). Similarly to the performance of Elman's (1990) model, this network was expected to be able to make a first order distinction between the function of the various syntactic types (learning that the words could be classified as nouns and verbs, determiners and adjectives). Furthermore, although the possessive and the plural [-s] were encoded in exactly the same manner in the input, it was predicted that the network would learn a second order

distinction (a distinction that could only be learnt once the first order distinction had been learnt) that only “verbs” could appear after some [-s] morphemes and only “nouns” could appear after other [-s] morphemes. This is relevant for compounding because the possessive [-s] which is attached to a noun can precede a second noun while the regular plural [-s] also on a noun cannot. The network was trained on one group of nouns that were represented as having the properties of singulars, possessives and plurals (e.g. *hen, hens, hen's*). A second set was only represented as singulars and plurals (*coat, coats*), a third group was only represented as singulars and possessives (*wig, wig's*) and a fourth group was represented as singulars only (*bar*) (see Table 6.1). Possessives and regular plural nouns were differentiated from singular nouns because they were encoded as ending in [-s]. A set of deverbal nouns were encoded by using the localist code for the verb (e.g., *drive*) and then representing the fact that they ended in the derivational affix [-er] (e.g., *driv(e) + e r = driver*). Nouns represented as singulars were followed by verbs ending in [-s] (to represent the third person singular). Nouns represented as plurals were followed by verbs that did not end in [-s]. Possessives were followed by deverbal nouns (i.e. verbs plus the the derivational morpheme [-er]). Thus the differences between plural and possessive nouns were only represented to the network by the fact that they occurred in different sequences in the input. It was predicted that the tokens making up the 4 groups of words (1.singulars, possessives and plurals; 2.singulars and plurals; 3.singulars and possessives; 4. singulars only) would cluster together in the hidden layer representations.

Table 6.1 Composition of the training set

Nouns			Adjectives	Verbs	determiners	Sentence	
plural +	plural +	possessives		(+ er		ending	
singular +	singular	+ singulars		became		marker	
possessive		only		deverbal			
				nouns)			
dog	coat	wig	bar	big	paint	the	\$
cat	tent	gown	bat	brave	move		
hen	hat	top	cot	busy	drive		
pig	shoe	bag	van	pretty	fight		
bed	sock	log	cake	green	eat		
man	tooth	pen	cup	sharp	grow		

6.2.2 Training set and coding scheme

The network was trained on a concatenated stream of 2000 legitimate English sentences constructed from a lexicon of 37 words. Nouns with the properties of singulars, plurals and possessives were included with equal type frequencies in the input. A sentence-ending marker was attached to each sentence and the sentences (including the sentence-ending marker) were concatenated to form a stream of 14,600 words. Each word (including the sentence-ending marker) was encoded using a 38-bit localist coding scheme.

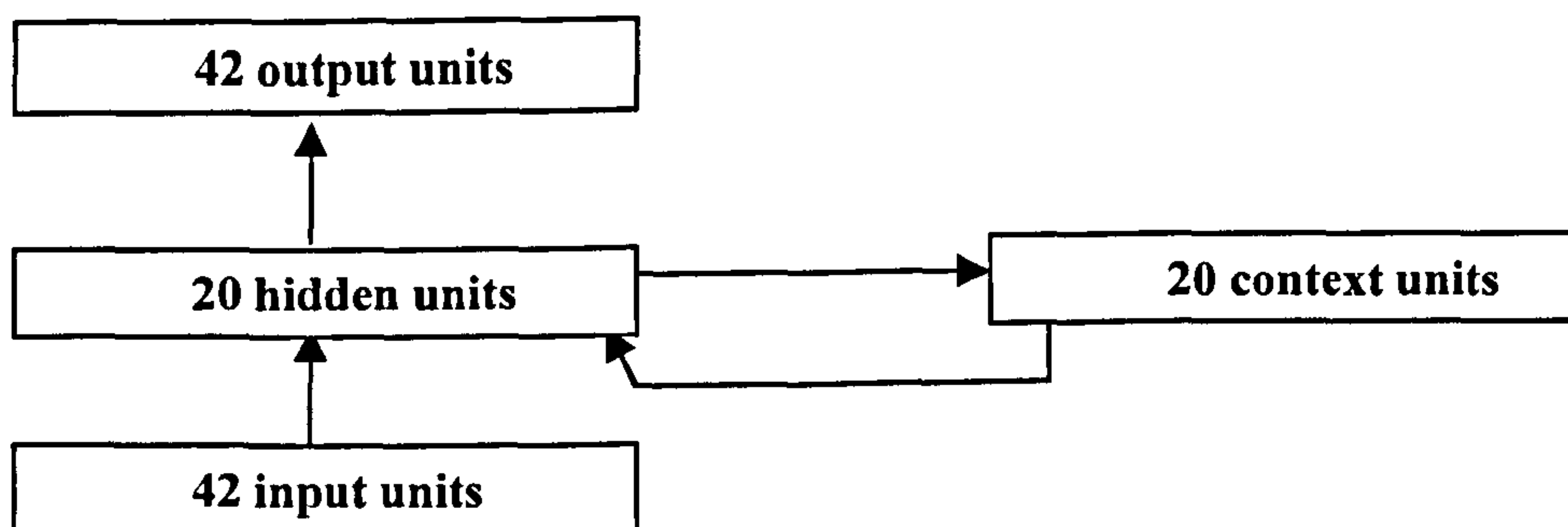
The presence or absence of [-s] at the end of a word was also explicitly coded using 2 additional input units because the focus of this model was to investigate whether items ending in [-s] (phonetically identical items) could be differentiated depending on the co-occurrence patterns in which they occurred in the input.

Thus, for example, the code for the singular noun *cat* would be *localist code for cat + [-s] off*, for the plural noun *cats* it would be *localist code for cat + [-s] on* and for the possessive noun *cat's* it would be *localist code for cat + [-s] on*. The presence or absence of [-er] at the end of a word was also explicitly coded using 2 additional input units. The code for the deverbal noun *driver* would be *localist code for drive + [-er] on*.

6.2.3 Architecture

It was necessary to use an architecture which was both able to learn temporal sequences (such as *-possessive noun- [-s]-noun* and *-plural noun- [-s]-verb*) and make predictions about which items were likely to occur next in these sequences. Elman (1990) showed that simple recurrent networks (SRN) are able to perform both temporal sequence processing and prediction. Furthermore, Elman showed that the representations that develop in the hidden layer of SRNs provide information about how the task is being learned by the network. The SRN used (see Figure 6.1) consisted of three layers: 42 input units, 20 hidden units and 42 output units; (the input and hidden layers were fully connected as were the hidden and output layers) with an added 20 context units fully connected to the hidden layer. Networks with different numbers of hidden units were tested but the best performance was recorded when 20 hidden units were used.

Figure 6.1 Architecture used for neural network 2

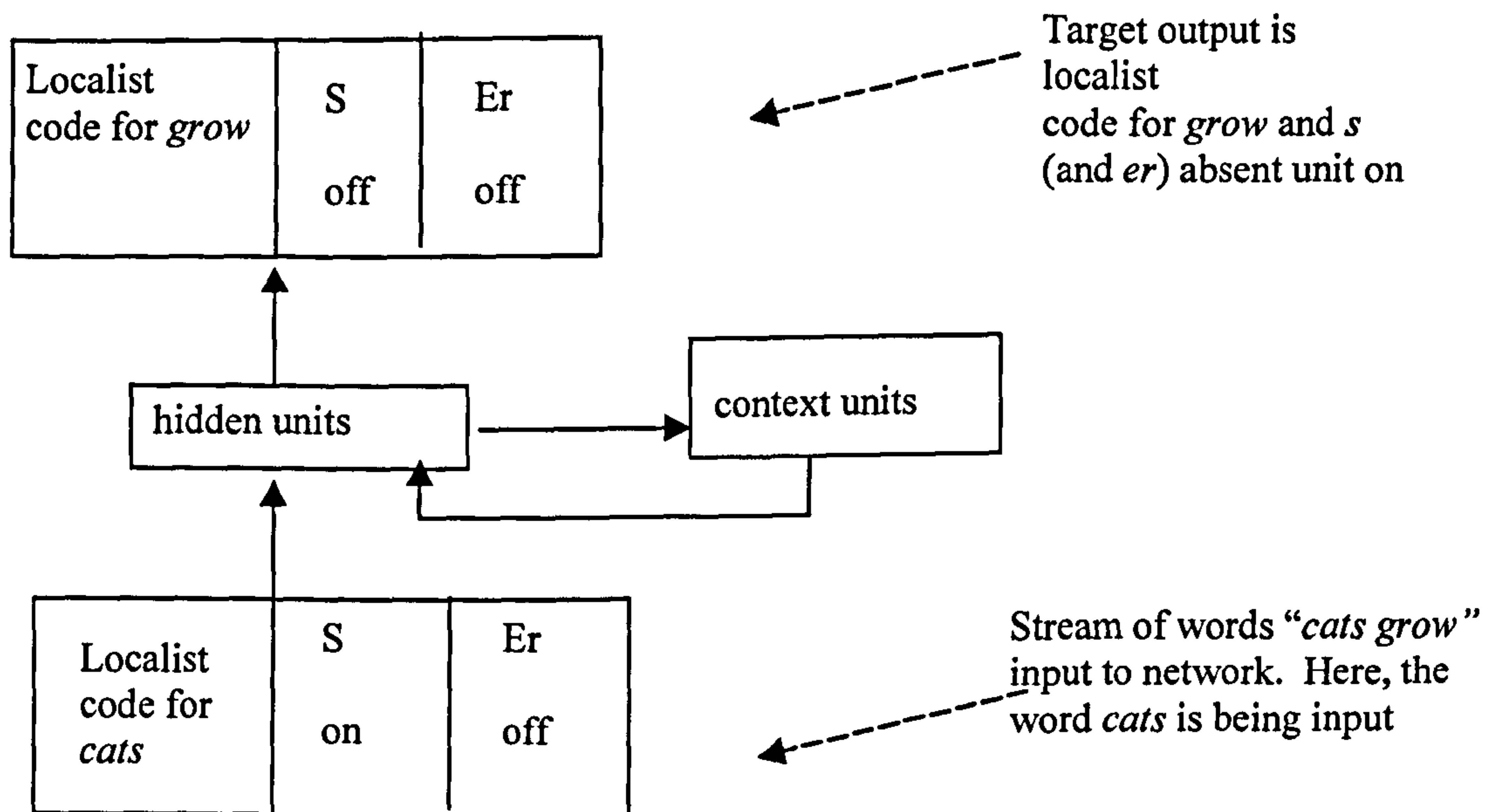


The associative capability was implemented as follows. The context units held a representation of the state that the hidden units were in as a response to the previous input. This representation of the state of the hidden units at the previous time step was then fed back from the context units into the hidden units as additional input (Elman, 1990). The network was trained with back-propagation learning (Rumelhart, Hinton & Williams, 1986). The SRN was trained with a learning rate of 0.1 and a momentum of 0.3.

6.2.4 Task

The stream of 14,600 words were presented word by word. The network had to learn to predict the next word in the sequence, and whether it ended in an [-s] or not and [-er] or not given the words (and whether they ended in [-s] or not) that had preceded it in the input. Figure 6.2 shows a diagram of how the word prediction task was implemented.

Figure 6.2. Diagram to represent word prediction task



6.2.5 Training

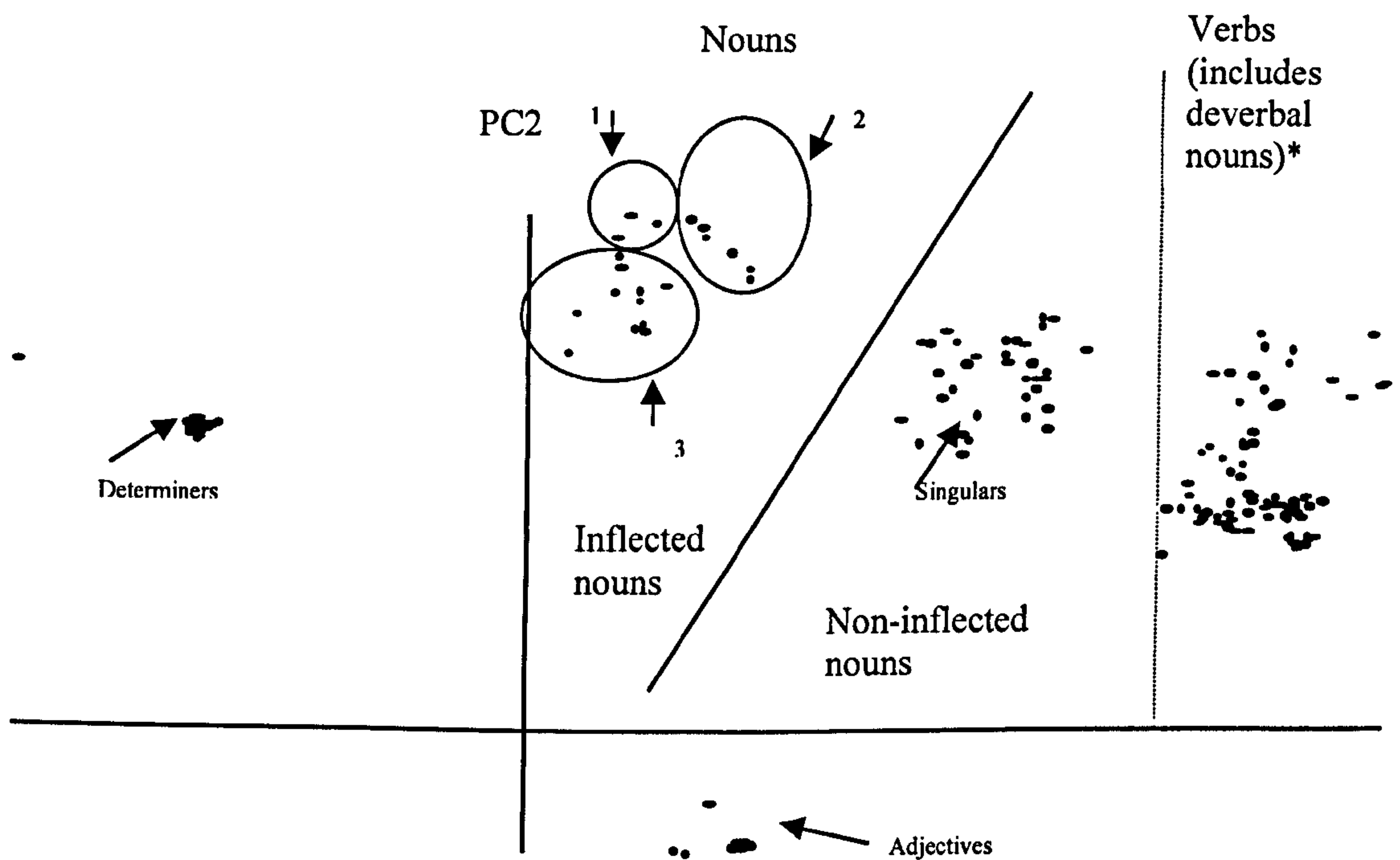
The network was trained on 10 presentations of the training set of the 14,600 words. Elman (1990) argues that in a word prediction task of this sort, (even though the training set in this case was only made up of 38 stems with or without inflection) it is impossible for the network to learn the exact pattern of words that followed each other in the input (especially as the full pattern was presented as infrequently as 10 times). Similarly a child would not be expected to memorise exact sentences they had heard. However, it is more interesting that networks of this sort seem able to learn that individual words can appear in combination with some words but not with others. Specifically, in the network reported here it was expected that the network would learn that some words could follow [-s] when it is performing one function but not when it is performing another function. If such generalisations do emerge they should be

evident in the network's hidden layer representations that develop during training.

6.2.6 Results

Several trained nets were analysed and each showed a similar pattern of results. Figure 6.3 shows a typical representation of the first two principal components of the hidden unit representations. The dotted line superimposed on the PCA diagram shows the divide between the way nouns and verbs (includes deverbal nouns) are represented in the hidden units. It is also apparent that the network has represented determiners and adjectives separately. The model also learnt to distinguish between stem forms of nouns and inflected forms. Most interestingly, nouns which were included in the training set as both "plurals and possessives", nouns that were only included as "possessives" and nouns which were only included in the "plural" form do not overlap within the cluster of inflected nouns ending in [-s]. Therefore, model 2 showed that a neural net was able to differentiate the plural and possessive [-s] depending on the words that followed it in the input, even though the two types of [-s] had exactly the same encoding characteristics.

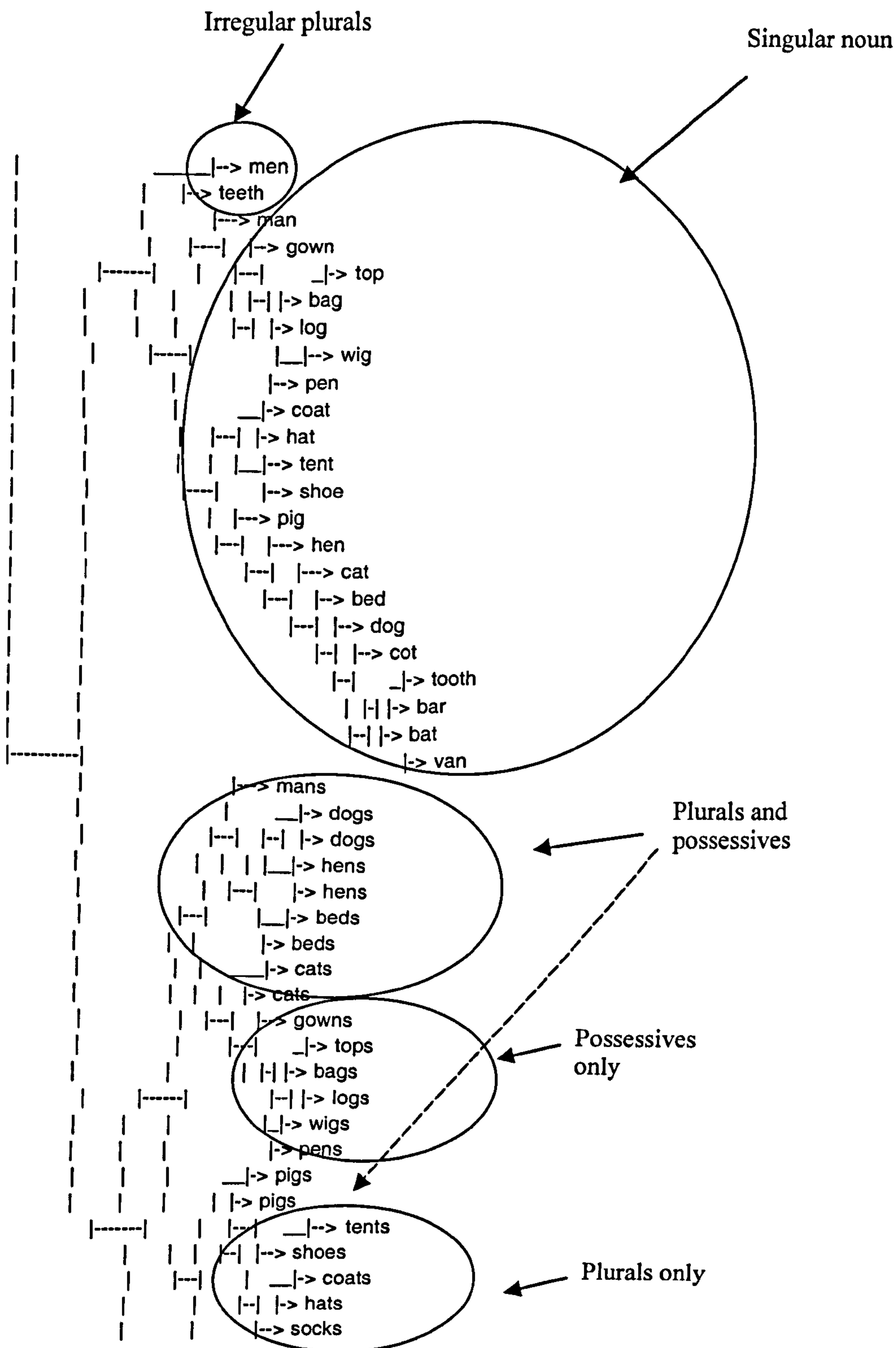
Figure 6.3. First two principal components of the hidden layer representations in model 2: area 1 = plurals and possessives; area 2= possessives; area 3 = plurals
Neural network 3



* Appendix E.1. shows the way verbs ending in [-s], verbs not ending in [-s] and deverbal nouns were represented in the hidden layers of Model 2

Figure 6.4 shows a cluster analysis of the nouns used in the training set. From Figure 6.4 it is evident that the network was very successful at clustering together nouns which performed similar functions in the training set (except for the treatment of *pigs* which was included in the training set with the properties of both a possessive and a plural noun but is clustering between items that were only represented as plurals and items that were only represented as possessives). Irregular plurals cluster with singular nouns in the hidden layers, i.e. with other items that do not end in [-s]. This is as expected as the network had no semantic information to use to disambiguate these words from singular nouns that also do not end in [-s]. However, the network has separated them out from the singular nouns indicating that the sequences they occur in may be sufficiently different to distinguish them from singular nouns (Singular nouns are followed by verbs ending in [-s] while irregular nouns are followed by verbs that do not end in [-s]. Furthermore, irregular nouns do not tend to be followed by a second noun).

Figure 6.4 Hidden Unit Cluster analysis of nouns in the training set for model 2



6.3 Model 3

6.3.1 Background

In the previous simulation, the network was able to group nouns that occurred in both the plural and the possessive or in the plural only form or the possessive only form. However, the network could not completely disambiguate plurals from possessives. In this next simulation, the network that was used in model 2 was amended to include 2 extra input units that encoded whether the subject of the sentence in which the word occurred was either a plural or a singular noun. Encoding the whole sentence in terms of whether the thing being referred to was plural or singular was intended to represent the situation in which the language learners hears a sequence of language while attending to either plural or singular things. Hence, although “plural” or “possessive” words were coded as ending in [-s], only items in sentences referring to plural items were encoded as ending in [-s] and being plural. Possessive nouns were encoded as ending in [-s] but being part of singular sentences. See Table 6.2 for examples of how the words making up the sentences in the input were encoded. The words making up the sentences were presented word by word. The network had to learn to predict the next word in the sequence, and whether it ended in an [-s] and was plural or singular, given the words (and whether they ended in [-s] and were plural or not) that had preceded it in the input. The same architecture and training set utilised in model 2 were employed. The learning rate and momentum was also the same as in model 2. It was predicted that with the addition of this minimal semantic information, the network would be able to disambiguate “plural” nouns from “possessive” nouns. In the hidden units, it was expected that the plural and possessive nouns would be represented separately.

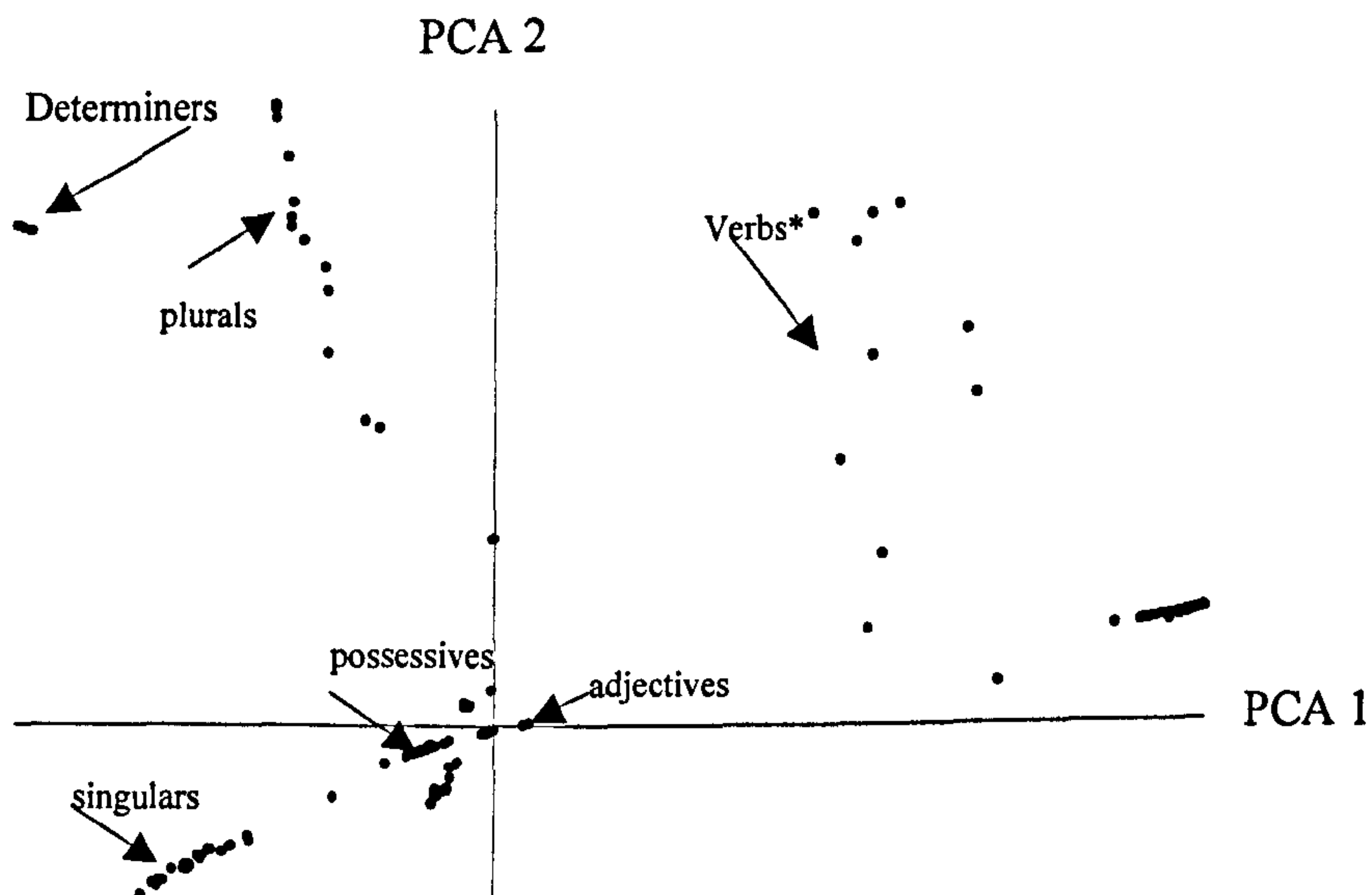
Table 6.2 Examples of coding scheme for model 3

Sentence	Localist word code	plural	S present or not	Er present or not
The cats feed	the	YES	YES	NO
	cat	YES	YES	NO
	feed	YES	YES	NO
The cat's feeder	the	NO	YES	NO
	cat	NO	YES	NO
	feeder	NO	YES	YES
The cat feeds	The	NO	NO	NO
	cat	NO	NO	NO
	feeds	NO	NO	NO

6.3.2 Results

Several trained nets were analysed and each showed a similar pattern of results. Figure 6.5 shows a typical representation of the first two principal components of the hidden unit representations. From the PCA it is evident that once again nouns and verbs, determiners and adjectives are represented separately in the hidden units. With the addition of the semantic information it is now evident that singular, plural and possessive nouns are all represented separately. Interestingly, both plurals and singulars i.e., items that may be followed by a verb, lie in similar positions on the x axis, while the possessives are clustering with adjectives (i.e., with other items that are followed by nouns). Therefore, model 3 shows that learning about the different functions of the [-s] morpheme is enhanced with the addition of the very minimum of semantic information.

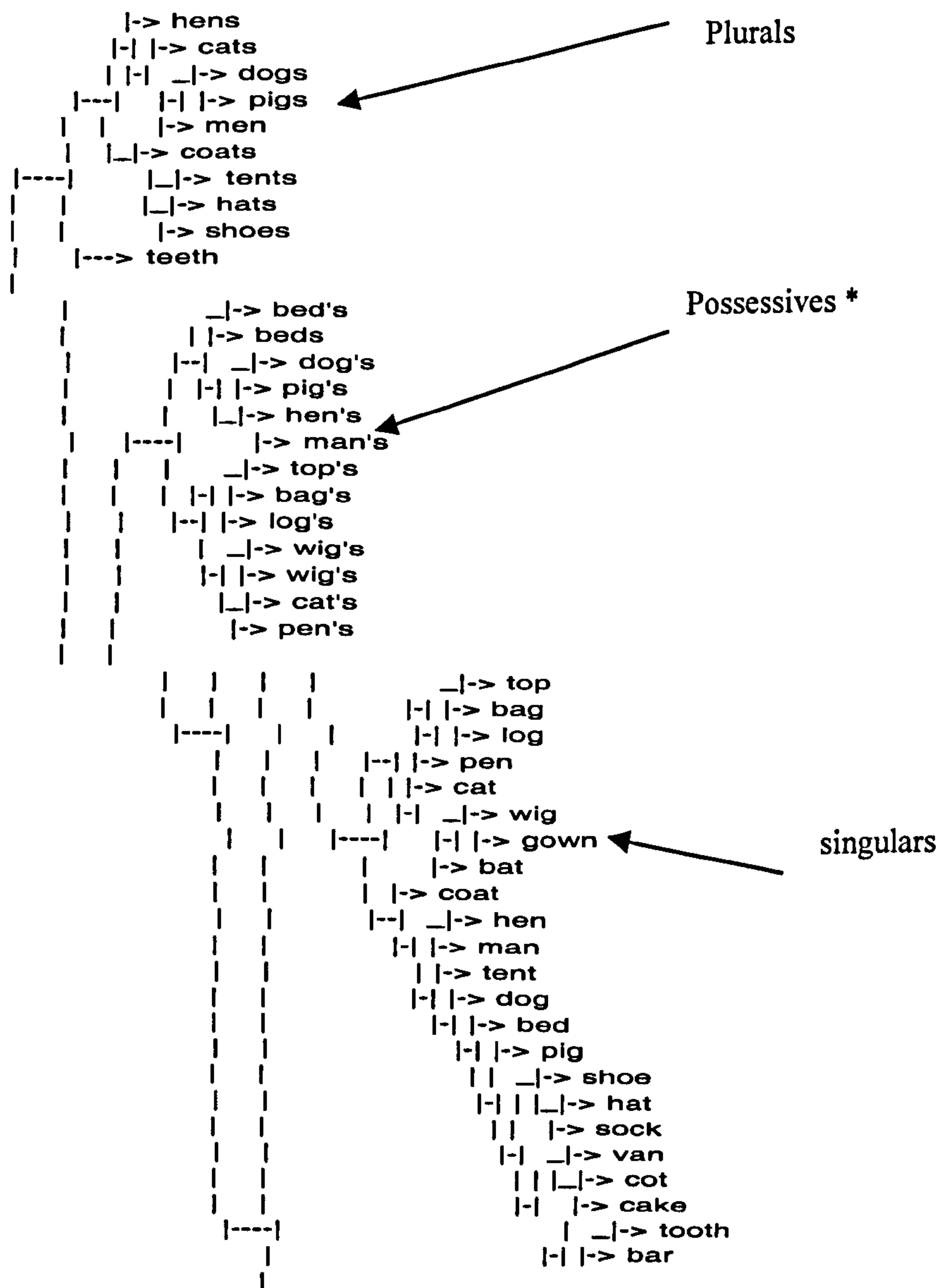
Figure 6.5. First two principal components of the hidden layer representations in Model 3



* Includes deverbial nouns.

Figure 6.6 shows a hidden unit cluster analysis of the nouns used in the training set. From Figure 6.6 it is evident that the network was very successful at clustering together nouns that performed similar functions in the training set. In this simulation the network was able to disambiguate words that appeared as both plurals and possessives.

Figure 6.6 Typical Cluster analysis of nouns used in training set



* The apostrophe is shown to distinguish possessives from regular plurals in this diagram but it was not represented in the training set.

6.4 Discussion of connectionist networks 2 and 3

Models 2 and 3 were able to learn that [-s] followed by one set of words was different from [-s] followed by a different set of words even though the [-s] was

encoded in exactly the same way in the input. The same might be true for the language learner. Both the possessive [-s] and the plural [-s] sound the same phonetically but the patterns in which the two different types of morpheme appear in the input may be sufficiently distinct as to indicate that one type of morpheme performs a specific linguistic function and the other performs another type of linguistic function. The results of model 3 suggest that learning that the plural and possessive morphemes are only legal in certain sequences may be refined as the child learns that semantically, the plural morpheme refers to many things, while the possessive morpheme usually refers to one thing.

Chapter 7

7.1 Background

In the two models described in Chapter 6, it has been demonstrated that an SRN is capable of learning about grammatical type from a training set in which each word token is encoded using a localist coding scheme. In these earlier models, items in the training set were not explicitly coded as being representative of a particular syntactic type (e.g. as being nouns or verbs). Instead, learning about the distinct linguistic functions that the different syntactic types perform emerged during training. However, a disadvantage of these models was that it was only possible to use a small lexicon of words because of the complexity of the learning task. The model reported in this chapter was trained on a much larger training set than the earlier models. This simulation sought to reproduce the behaviour of an older child, with a much larger vocabulary, who has knowledge, though perhaps not at a metalinguistic level, of the different functions performed by the different syntactic types.

The aim of this simulation was to investigate whether the fact that the possessive [-s] morpheme is always followed by a second noun but the plural [-s] morpheme is rarely followed by a second noun is implicated in compound formation in English. A simple recurrent network (SRN) was utilised so that at any point in time the state of the hidden units at the previous time step were used as additional input (Elman, 1990). Thus it was expected that the model would be able to learn sequential mappings. The network was trained on a large training set of real child directed speech in which the frequencies in which the various

types of morphology occurred were not manipulated in any way. The syntactic type of each word was used as the input to the network. The frequency in which regular and irregular plurals and possessives were included in the training set was determined by the frequency in which they appeared in the child directed speech that was used as the input to the model. Table 7.1 illustrates that some items appear in sequence with other items in the input (e.g. possessives are always followed by singular nouns) but other items do not appear in sequence with other items (e.g. regular plurals are not followed by singular nouns). The performance of the network was investigated using a syntactic type prediction task in which one of three syntactic types was input (a possessive, a regular plural or an irregular plural) and the network predicted which syntactic type it expected to see next in the input stream. The ability of the network to learn this task was tested using the same task. The difference (error) between the actual output of the network and the output for noun, verb, other and word ending was calculated. It was predicted that the error would be high for all items after possessives except nouns. Conversely it was predicted that there would be a high error on predicting a noun after a plural of either kind.

7.2 Model 4

7.2.1 Training set and coding scheme

The exact composition of the training set is shown in Table 7.2. Irregular and regular plurals and possessives together form less than 2% of the input. Items coded as “others” included anything that was not a noun or a verb (e.g. adjectives, determiners, adverbs and prepositions). 2182 sentences, made up from 9999 words, from the Wells study from the CHILDES corpora

(MacWhinney & Snow, 1985) were concatenated and used as input. A sentence ending marker was also included in the training set. The frequency with which items from various syntactic categories followed irregular plurals, regular plurals and possessives is shown in Table 7.1.

Table 7.1. Frequency with which items from various syntactic categories followed irregular plurals, regular plurals and possessives (percentage frequency shown in brackets) in the training set.

Item following plural or possessive	Irregular plurals (n=9)	Regular plurals (n=95)	Possessives (n=39)
Others	3 (33)	40 (42)	0
Sentence ending marker	0	30 (32)	0
Singular nouns	2 (22)	0	39 (100)
Verbs	1 (11)	24 (25)	0
Regular plurals	1 (11)	1 (1)	0
Irregular plurals	2 (22)	0	0

Table 7.2 Composition of training set

Item	Number of tokens in training set	Cumulative total	Percentage of tokens in training set	Cumulative percentage
Irregular plurals	9	9	0.09	0.09
Possessives	39	48	0.39	0.48
Regular plurals	95	143	0.95	1.43
verbs	624	767	6	8
Sentence ending markers	1415	2182	14	22
Singular nouns	3014	5196	30	52
others	4803	9999	48	100

Possessives were only ever followed by singular nouns in the input. Regular and irregular plurals were followed by a range of items but never by a singular noun. Each item was encoded using a 7 bit vector. Three input units encoded syntactic category (noun, verb, other) and two inputs encoded whether the item was plural or not. Two input units encoded the presence or absence of the [s] morpheme. Thus for both regular plurals and possessives the input units for noun and [s] morpheme present would both be activated. A possessive was disambiguated from a regular plural, however, because the plural input unit was “on” for a plural but “off” for a possessive. The presence of [-s] at the end of a verb was not encoded in this simulation. Examples of how items from different syntactic categories were encoded is shown in Table 7.3.

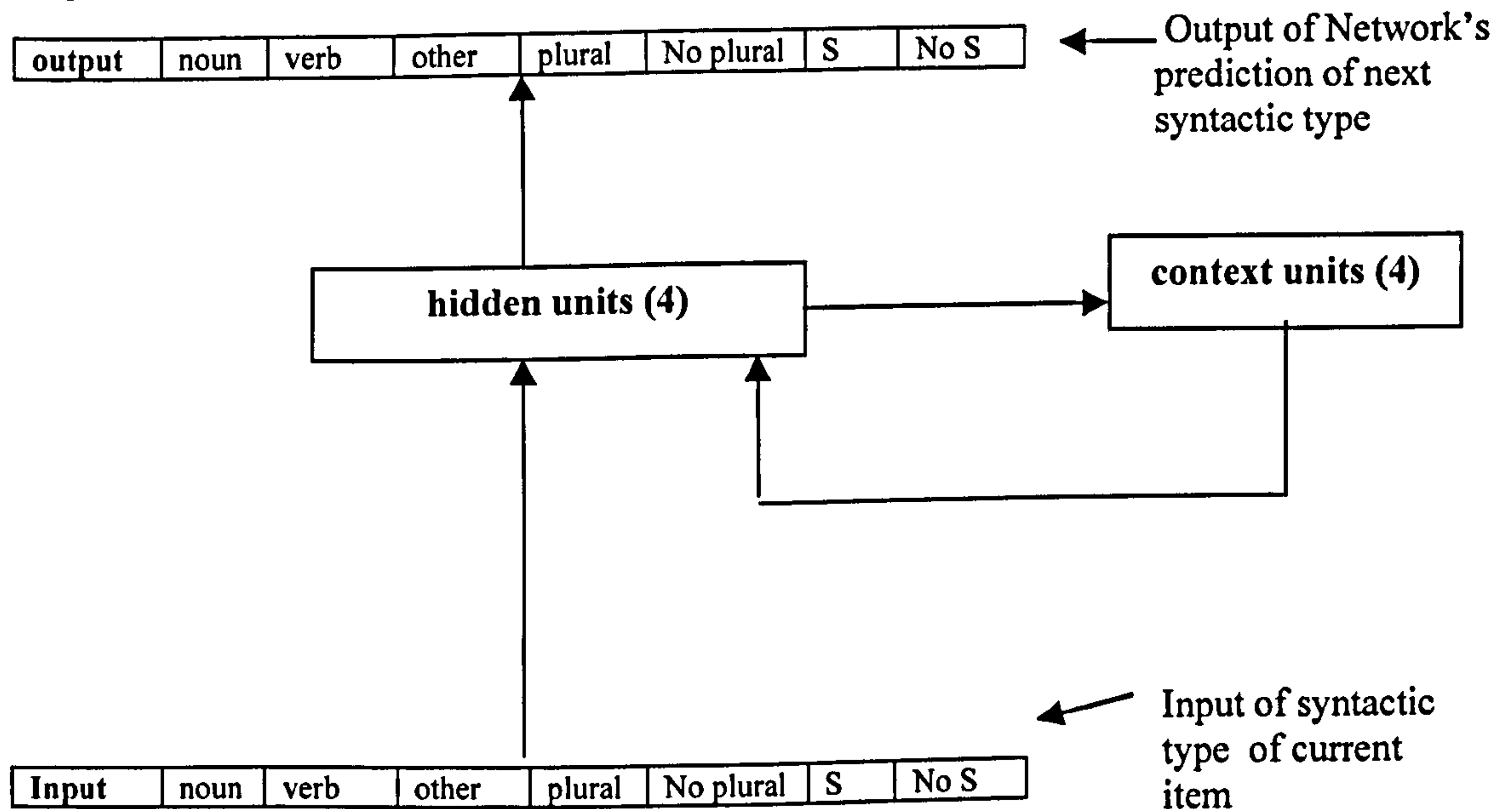
Table 7.3. Examples of coding scheme

Item	Syntactic category			Type of noun		S present or not	
	noun	verb	other	singular	plural	S	No S
rats	YES	NO	NO	NO	YES	YES	NO
mice	YES	NO	NO	NO	YES	NO	YES
rat's	YES	NO	NO	YES	NO	YES	NO
chaser	YES	NO	NO	YES	NO	NO	YES
the	NO	NO	YES	NO	NO	NO	NO
chase	NO	YES	NO	NO	NO	NO	NO
Sentence ending marker	NO	NO	NO	NO	NO	NO	NO

7.2.2 Architecture

The architecture of the network is shown in Figure 7.1. The network had 7 input units, 4 hidden units, 7 output units and 4 context units. A simple recurrent architecture was adopted so that at any point in time the state of the hidden units at the previous time step were used as additional input (Elman, 1990). The SRN was trained using a learning rate of 0.1 and a momentum of 0.3.

Figure 7.1. Network architecture



7.2.3 Task

In both the training and test phases, the network was required to predict the next input.

7.2.4 Training

The network was trained on 10,000 repetitions of the training set. This high number of presentations of the input was necessary because the training set was large and items of particular interest i.e. possessives (0.39% of the input), regular plurals (0.95% of the input) and irregular plurals (0.09% of the input) formed such a low proportion of the input.

7.2.5 Test Phase

After training, the network was presented with the following sequences:

- *possessive followed by singular noun*
- *possessive followed by verb*
- *possessive followed by other*
- *possessive followed by sentence ending.*

- *Regular plural followed by singular noun*
- *regular plural followed by verb*
- *regular plural followed by other*
- *regular plural followed by sentence ending.*

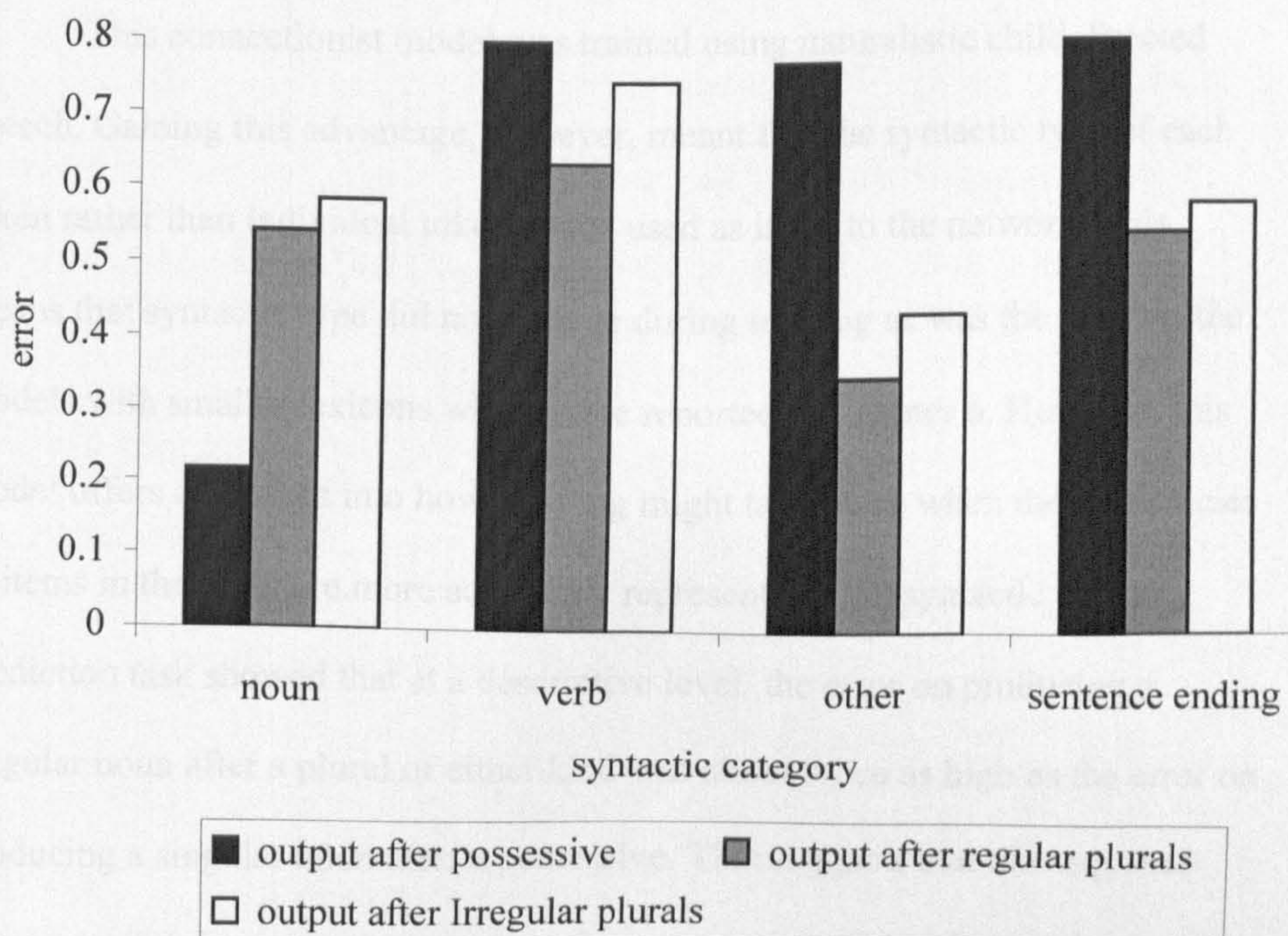
- *Irregular plural followed by singular noun*
- *irregular plural followed by verb*
- *irregular plural followed by other*
- *irregular plural followed by sentence ending.*

Thus, for example, in the test pattern *possessive followed by singular noun* the code for *possessive noun* was input and the target output was *singular noun*. However the network might not output the exact output for *singular noun*. The actual output of the network and the output for the target syntactic type (i.e. the output for *singular noun* in this example) were compared and an error figure was calculated based on the difference between the two output weight values.

7.2.6 Results

The error between the actual output and the target output was recorded after the network was presented with the test sequences. Many runs of the simulation were carried out but each produced almost identical results. Figure 7.2 illustrates that at a descriptive level the error on producing a singular noun after a possessive was about half as high as the error on producing a singular noun after a plural of either type¹.

Figure 7.2. Error on producing nouns, verbs, other items and word endings after possessives, regular plurals and irregular plurals



¹ It was not possible to carry out a statistical test on the error rates shown in Figure 7.2 as the figures shown relate to the output of 1 test rather than to the output of several tests.

Also at a descriptive level the error on producing other items and sentence-ending markers was lower after plurals than possessives. The network produced a high rate of error when the target output after a plural noun was a verb, despite the fact that in the input verbs followed regular plurals (25% of the time that regular plurals occurred) and irregular plurals (11% of the time that irregular plurals occurred). However, the training set contained very few verbs (6.24 % of the training set). Given that verbs were so underrepresented in the input it was unlikely that they would be predicted as the next item in a next word prediction task to any great extent.

7.2.7 Discussion

This connectionist model was trained using naturalistic child directed speech. Gaining this advantage, however, meant that the syntactic type of each token rather than individual tokens were used as input to the network. This means that syntactic type did not emerge during training as was the case for the models with smaller lexicons which were reported in Chapter 6. However, this model offers an insight into how learning might take place when the frequencies of items in the input are more accurately represented. The syntactic category prediction task showed that at a descriptive level, the error on producing a singular noun after a plural of either kind was about twice as high as the error on producing a singular noun after a possessive. This suggests that the sequence *possessive [-'s] – noun* was represented more consistently in the training set than the pattern *plural [-s] noun*. There is also a suggestion that other items and sentence-ending markers following plurals but not possessives is a consistent pattern detectable from the input. Furthermore these consistent patterns in the

input seem to be discernable to the network despite the fact that they occur in low frequencies in the messy context of child directed speech.

Regular plurals and possessives were disambiguated in the input by the fact that the plural input unit was on in the case of a regular plural but off in the case of a possessive and from the patterns in which they occurred in the input. From the results of this simulation there is a suggestion that the network was able to discern that the *noun –morpheme [-s]* pattern occurred in different patterns when it was plural to when it was singular. Some items follow one pattern (i.e. a second noun follows the *noun [-s] morpheme* pattern when it is singular but not when it is plural) while other items follow the reverse pattern (i.e. word ending markers and other items follow the pattern *noun- [-s] morpheme* when it is plural but not singular). That a neural network model with no explicit grammatical structure showed some suggestion of being able to recognise these linguistic patterns seems to provide further support for the idea that there is sufficient evidence in the input to constrain learning that a second noun is not included after a plural because the pattern *noun-morpheme [-s]- noun* is used to denote possession not plurality.

7.3 General Discussion of connectionist models

Connectionist model 1 showed that a connectionist model can learn that the [-s] morpheme tends to nearly always occur at the end rather than in the middle of a word. By extension it seems likely that the language learner is also sensitive to these patterns in the input. Connectionist models 2 and 3 provide further evidence for an associative account of compounding. Simply by exposure to the [-s] morpheme (i.e. without the plural or the possessive [-s] morpheme

being explicitly labeled as being different from each other), the model is sensitive to the fact that the same [-s] morpheme occurs in different patterns in the input (Model 2). With the addition of the absolute minimum of semantics, namely whether the subject of the sentence is a singular or a plural thing, the model seems able to differentiate between the plural and the possessive morpheme (Model 3). In Model 4, syntactic category was explicitly encoded in the input and real child directed speech was used as input and thus the different syntactic categories were represented in the actual frequency that they occurred in real child directed speech. Under these more realistic input conditions there was still a suggestion that the network was able to recognise that the *noun* –*morpheme [-s]* pattern occurred in different patterns when it was plural to when it was singular. Specifically, the network showed some indication of being able to discern that nouns follow possessives but not plurals of either type and also of being able to detect that “other items” and word ending markers follow plurals of either type but not possessives.

The results of this work with connectionist models provide some insight into how an input driven constraint on compound formation might develop in the human language learner. From model 1 it is evident that a connectionist model trained on child directed speech was able to learn that [-s] is associated with word finality. A child exposed to this input might also learn that a relationship exists between [-s] and word-finality in the input. This overwhelming pattern of [-s] at the end of words might influence the child to omit [-s] from the middle of words. Model 2 showed that the network was able to learn that words that it encountered behaving as plurals were different from words behaving as possessives even though both items were encoded exactly the same way in the

input. Thus the network had only the order in which the words appeared to support this learning. The same might be true for the child learning language. Both the possessive [-s] and the plural [-s] sound the same phonetically but the child may learn from the patterns in which the two different types of morpheme appear in the input that one type of morpheme is appropriate in some circumstances but not in others. It might be that the child learns that the possessive morpheme is followed by a noun so when forming compound words it is not appropriate to follow the plural morpheme with another noun. From model 3 it is evident that this learning that the plural and possessive morphemes are only legal in certain sequences may be refined as the child learns that semantically the plural morpheme refers to many things while the possessive morpheme refers to one thing. Model 4 suggested that it might be possible for the child to learn that the *noun –morpheme [-s]* pattern occurs in different patterns when it was plural to when it was singular in conditions where the input was a naturalistic representation of child directed speech.

Thus the results of this series of connectionist models together with the results of the lexical decision study described in Chapter 3 provide support for an input based constraint on compound formation in English. When faced with a noun-noun compound the language user may delete the plural morpheme from the end of the first noun, not because regular items of morphology are different in kind from irregulars and represented as “rules” in the brain, but simply because this pattern is used to denote possession not plurality in English. However, some regular plurals (e.g. *drinks* in *drinks cabinet*) may occur before a second noun if this pattern has been encountered sufficiently frequently in the input to counter competition with the possessive structure. Language users of low

proficiency (SLI children, (van der Lely & Chriatian, 2000) ESL participants (Lardiere, 1995a; Murphy, 2000) and young children (Murphy et al, in preparation) may include regular plural in compounds because they have yet to master the competitive relationship between the regular plural and the possessive [-s] morphemes. Singular and irregular plural nouns may occur before a second noun because they do not end in [-s] (and as such are not linked to word finality or competition with the possessive [-s] morpheme).

Chapter 8

8.1 Introduction

At the end of each of the experimental chapters of this thesis, a general discussion section was presented which offered interpretations of the findings. Conclusions were drawn as to how the outcome of that study/studies contributed to the debate over whether the way plural morphology is treated in compounds is mediated by internal or externally driven constraints. The objective of this final chapter is not then to reiterate all these conclusions but rather to draw them together for the purposes of assessing the combined contribution of this work.

8.2 Internal or External constraints on plurals in compounds?

The focus of this research programme was to investigate whether the treatment of plural morphology in compounds is constrained by internal or external factors.

There is general acceptance that regular and irregular morphology is treated differently by language users (Marcus et al, 1995). The key issue is whether the difference in the way the two types of morphology is treated is constrained by internal innate factors or by the patterns and frequencies in which the two types of morphology appear in the input to which the language learner is exposed. Both

Pinker and Prince's (1998) dual mechanism model and Kiparsky's (1982) level ordering model (as it relates to compounding) argue that the difference in the way the two types of morphology are treated results from innate and internal constraints. One of the lines of evidence used to support this viewpoint was the data presented by Gordon (1985) from native English children and Clahsen et al (1993) from native German children which showed that regular plurals were always omitted from the middle of noun-noun compounds but irregular plurals were always included in these structures. Interestingly, the children tested in these experiments were prepared to include irregular plurals in compounds even though they never heard structures like this (they would have heard *tooth-brush* not *teeth brush* and *mouse-trap* not *mice-trap*) in child directed speech. Thus Gordon claimed that there was a learnability problem (it was impossible for the children to have learnt to include irregular plurals in compounds solely from the input they received) and as such the treatment of plurals in compounds must be constrained by internal innate factors. It was hypothesised in this research programme, however, that a series of external constraints could in fact account for the evidence collected in previous compound production studies. To confirm these predictions two studies with native English speakers were carried out. The first investigated the role that external factors such as the modality in which the experimental stimulus was presented or the modality in which participants were asked to respond would affect the type of compounds

produced (see Chapter 2). The second experiment was the first in which participants have been asked to process compounds on line. The advantage of this methodology was that it meant that participants could be presented with structures that they might never produce. Several of the external factors that have been hypothesised to affect the treatment of plurals in compounds were tested in this experiment which is described in detail in Chapter 3. In addition 4 connectionist models were also developed. Model 1 examined the idea that [-s] is associated with word finality and as such is avoided in the middle of words such as compounds. Model 2, 3 and 4 considered whether competition between the regular plural and possessive morpheme in English might lead to the regular plural being omitted from noun-noun compounds. From this programme of work considerable evidence was collected to suggest that there are several external constraints on the treatment of plural morphology in compounds. These are summarised below.

8.2.1 Length of Exposure

From the results of a series of studies testing native English speaking children (Gordon, 1985; Oetting & Rice, 1993; Nicoladis, 2000; van der Lely & Christian, 2000) it is clear that while the omission of regular plurals from compounds is a robust phenomenon there appears to be a developmental trend in which as children mature they include fewer irregular plurals in compounds. Studies of native adult

English speakers have shown that they include irregular plurals in compounds roughly at chance (Murphy, 2000) or hardly at all (in 4.8 % of compounds produced (Lardiere & Schwartz, 1997)). Supporters of the view that the treatment of plurals in compounds is mediated by internal constraints, have not predicted such a developmental trend, nor can they explain such a shift in compounding behaviour. The question of how the child learns to omit irregular plurals from compounds has not been systematically addressed. A child's growing proficiency in using language might seem an obvious answer. Nevertheless, both the dual mechanism model and the input-based account proposed in the previous chapters argue that irregular morphology is mediated by associative mechanisms. Thus the finding that the treatment of irregular plurals changes with age does not distinguish between the input driven or internal constraint based accounts of compounding. However, the fact that ESL participants included regular and irregular plurals in compounds does call into question the view that compounding is mediated by internal constraints (Lardiere, 1995a; Murphy, 2000). Both the dual mechanism (Pinker, 1999) and the level ordering models (Kiparsky, 1982) make the testable prediction that regular plurals should never appear in a compound. Yet ESL subjects produced many compounds including these structures (roughly at chance in Lardiere's study and in 15% of compounds in Murphy's study). Furthermore in a study testing native English speaking children Murphy et al (in preparation) found that young children

included regular as well as irregular plurals in compounds. The SLI children tested by van der Lely and Christian (2000) who are argued to be developmentally delayed in their language (Leonard, 1998) also included regular as well as irregular plurals in compounds. These findings point to the fact that novice English speakers (either young children, developmentally delayed children or ESL learners) will include both regular and irregular plurals in compounds. Taking all these compounding studies together provides support for the idea that length of exposure to English, an external constraint, influences the type of compounds produced. Further cross-sectional studies in which children of different ages are measured on the same task together with longitudinal studies need to be conducted to investigate this issue further.

8.2.2 Frequency of Exposure

The majority of the studies from which the conclusions regarding compounding have been drawn have replicated Gordon's (1985) methodology and presented the plural aurally to the participant in the compound-eliciting prompt. Lardiere and Schwartz's (1997) study is in fact the only experiment in which the plural was not mentioned before the participant was asked to produce the compound. It was argued in Chapter 2 that the mentioning of the plural by the experimenter might induce participants to include the plural in the compound they produced, given that they had just heard the plural in the elicitation prompt. To test

this idea a study was carried out (reported in Chapter 2) in which half of the participants were asked to supply compounds using aural stimuli (in which the plural was mentioned in the compound eliciting prompt) and half were asked to supply compounds using visual stimuli (in which the plural was not mentioned in the compound eliciting prompt). The modality in which participants were asked to respond was also manipulated. The rate at which regular plurals were included in compounds was not affected by either presentation or response modality. However the rate of inclusion of irregular plurals in compounds was affected by presentation modality. More irregular plurals were included when the stimuli were presented aurally than when they were presented visually. The possible presence of a priming effect may account for some of the variability in the rate of inclusion of irregular plurals in compounds in the various compound studies. The interesting fact is that, it seems possible to prime irregulars and not regulars. This may occur because the two types of plural are mediated by different mechanisms as argued by the dual mechanism model. However, an alternative explanation might be because the two types of plural occur in very different type frequencies in the input. Regular plurals make up 98% of noun types and 97% of noun tokens (Marcus, 1995a). 98% of all nouns in English add an [-s] sound to make their plural. And 97% of all plural usage in English involves the processing of the [-s] sound at the end of a noun. Thus regular plurals have a high type frequency and irregular plurals have a low type frequency.

Bybee's (1995) network model argues that high type frequency items have high lexical strength. Low type frequency items have low lexical strength and unless individual items possess high token frequency (and with it high lexical strength) they tend to be treated in the same way as high type frequency items. In the case of compounding this means that low token frequency irregulars are likely to be omitted from compounds in the same way as the high type frequency regulars. However, in the data reported in the modality study (Chapter 2) it was the high token frequency irregulars which patterned with the high type frequency regular plurals in that they were omitted from compounds. A better explanation for the data may come from Ellis & Schmidt's (1995) model. Ellis and Schmidt showed that in the very earliest stages of language learning both regular and irregular morphology were subject to token frequency effects. With increased exposure to a language, however, token frequency effects on the regular plurals disappeared due to the power law of practice. The power law of practice states that the amount of improvement shown in the processing of particular items decreases as a function of increasing exposure to those items (Anderson, 1982). Thus as performance approaches asymptote on very frequently encountered items it is difficult to influence performance by introducing extraneous variables such as changing presentation modality. Thus in English the regular plural affix develops "high lexical strength" (cf. Bybee, 1995) and becomes invulnerable to contextual effects. It may be that language users adopt the high type

frequency regulars as a template and extend this pattern first to high token frequency irregulars then eventually to low token frequency irregulars. Thus as well as amount of exposure, it seems that the different type and token frequencies in which regular and irregular plurals occur in the input may provide another external constraint on the treatment of plurals in compounds.

Further data on how the high type frequency regular and low type frequency irregular plurals are treated in compounds comes from the results of the lexical decision task reported in Chapter 3. In this experiment despite the prediction of the dual mechanism model that regular and irregulars would never pattern together, no statistically reliable difference was found between the time it took to process regular and irregular plurals in compounds. However, although the dual mechanism model also predicts that irregular plurals should occur easily in compounds, at a descriptive level, it was found that they took longer to process in these structures and regular plurals, which are prohibited by the dual mechanism from occurring in compounds, were processed more quickly. The difference in processing time between the two types of plural did approach significance. Furthermore, when all types of regular morphology (regular plurals, possessives and comparatives/superlatives) were collapsed together there was a reliable difference between the time it took to process this group of regular morphological items and irregular plurals. Again it was irregular plurals that the dual mechanism model predicts should occur easily in compounds

that took longer to process than regular morphology. Reaction time to respond to both types of plural (regular and irregular) was also collapsed together and compared to reaction time to process other types of morphology (possessives and comparatives/superlatives) collapsed together. This analysis showed that it was plural morphology that took longer to process in these structures than other types of morphology. If frequency of occurrence of items in the input influences the treatment of morphology before nouns then the results are as predicted. It is not surprising that when forced to process morphology in compounds that native speakers process regular morphology (items that have high type frequency in English) faster than irregular morphology (items that have low type frequency in English). Thus, items of regular morphology such as possessive nouns and comparatives and superlatives which occur more frequently before a second noun are processed more quickly than either type of plural. The dissociation seems to be between items (comparatives/superlatives and possessives) that frequently precede a noun in general language and items which rarely occur before other nouns (i.e., plurals of either type) and not between regular and irregular morphology as would be predicted by the dual mechanism model.

8.2.3 Token frequency

The token frequency of individual regular plurals (high type frequency items) did not affect the rate that they were included in compounds. However, there was evidence that the token frequency of individual irregular plurals (low type frequency items) did affect the way they were treated in both the modality study (Chapter 2) and the lexical decision task (Chapter 3). Haskell et al (in press) claim that both types of plural are dispreferred before a second noun because of a semantic constraint that dictates that the plural status of a noun is not marked before a second noun. Irregulars are more preferred because they are not affected by a second constraint, the phonetic constraint, which leads to items that sound like regular plurals being dispreferred before a second noun. However, the most parsimonious explanation would seem to be one based on frequency in the input. Regular plurals are high type frequency items and language users will have had sufficient exposure to learn that they are omitted before a second noun. Thus the individual token frequency of regular plurals is no longer relevant to their treatment in compounds. However, irregular plurals are low type frequency items and their individual token frequency does influence how they will be treated in compounds.

Further evidence of the role of frequency in compound production comes from the way nouns ending in phonetic [-s] were treated in the lexical decision task (reported in Chapter 3). While compounds with non-head nouns ending in phonetic

[-s] were matched for frequency as a group with the other word groups tested, some items had greater frequency than others. Some items such as *cuss* and *dross* are used very infrequently and these items took longer to process. Conversely, very frequent non-head nouns ending in [-s] i.e. *gas*, *grass*, *cross*, *news*, *glass* and *bus* were processed relatively quickly. Thus frequency plays an important role in how quickly items ending in phonetic [-s] are responded to in compounds. Further studies using either artificial languages or neural network models in which the relative frequencies of regular and irregular plurals are manipulated need to be carried out to provide more evidence for the role of frequency in the treatment of plurals in compounds.

8.2.4 Competition between the regular plural and the possessive morpheme in

English

The low type frequency irregular plurals seem, therefore, to be included in compounds roughly at chance by adult native English speakers because they are encountered so infrequently in the input. But what of the high type frequency regular plurals? All the evidence seems to point to regular plurals being mediated, as the dual mechanism suggests, by a rule which is learnt by a certain age or level of proficiency in English. Once this putative rule is mastered it seems impossible to prime subjects to override the rule and include regular plurals in compounds and the token frequency of individual regular plurals does not seem to affect the way they

are treated in compounds. The interesting question is whether there are any explanations other than the hypothesis that regular plurals are mediated by a rule which could explain the fact that the omission of regular plurals from compounds is so robust.

The majority of compound research to date has been carried out in English. Clahsen et al (1995) argued that German children (like the English children tested by Gordon (1985)) also dissociated regular and irregular plurals in compounds. However, subsequent research has questioned whether there really is one default regular plural in German which is omitted from all compounds produced. There is evidence that regular plurals are included in Dutch (Schreuder, Neijt, van der Weide & Baayen, 1998), Spanish (Lardiere, 1995a) and French (Murphy, 2000). Thus the question is why might regular plurals be omitted from English compounds but licensed in compound production in other languages. What is special about the regular [-s] plural morpheme in English? The research presented and discussed in the previous chapters strongly suggests that in English the fact that the regular plural and the possessive are both marked by the addition of the [-s]/ [-'s] morpheme/phoneme is responsible for the fact that the regular plural [-s] does not occur before a second noun in English. English irregular plurals are not formed by the addition of the [-s] morpheme, thus they do not compete with the possessive structure and they may be included in compounds by language learners who have not learned that plurality is

not marked in the middle of compounds. In the lexical decision task reported in Chapter 3 when a series of two word combinations were presented to native adult English speakers, possessive nouns were easier to process than plural nouns in the middle of compounds even though they share exactly the same phoneme (and are allegedly both derived from a rule). Furthermore, model 2 (reported in Chapter 6) showed that linguistic sequences including possessives were different from linguistic sequences including plurals although both items were encoded exactly the same way in the input. The network had only the order in which the words appeared in the input to drive this learning. The same might be true for the child learning language. Both the possessive [-s] and the plural [-s] sound the same phonetically but the child may learn from the patterns in which the two different types of morpheme occur in the input that one type of morpheme is appropriate in some circumstances but not in others. It might be that the child learns that the possessive morpheme is followed by a noun so when forming compound words it is not appropriate to follow the plural morpheme with another noun. Model 3, (reported in Chapter 6) suggests that when semantic information is available learning that the plural and possessive morphemes are only legal in certain sequences may be refined as the child learns that semantically the plural morpheme refers to many things while the possessive morpheme usually refers to one thing. The results of Model 4 (reported in Chapter 7) suggest that even though possessives and plurals of both types were represented

very infrequently in the input, (taken from real child directed speech) the network showed some suggestion that it might be able to detect that possessives are only followed by a second noun and regular plurals despite sharing the same phonology as possessives may be followed by items from any syntactic type.

8.2.5 [-s] as an indicator of word finality

Another input driven constraint may result from the fact that the [-s] phoneme may be associated with word ending and as such English speakers find it difficult to process [-s] in the middle of words such as compounds. It took longer for native speakers in the lexical decision task reported in Chapter 3, to process compounds in which the non-head noun ended in the phoneme [-s] rather than in any other phoneme. This would suggest that there is something special about [-s]. Furthermore the results of model 1 (Chapter 5) indicated that the [-s] morpheme tends to nearly always occur at the end rather than in the middle of a word. A child exposed to this input might also learn that a relationship exists between [-s] and word-finality in the input. This overwhelming pattern of [-s] at the end of words might influence the child to omit [-s] from the middle of words.

8.2.6 Summary of the role of external constraints on compounding

Thus several types of external constraint on compounding related to length of exposure, relative frequency of regular and irregular plurals in the input, competition

between the regular plural and the possessive [-s] morpheme and the role of the [-s] phoneme as an indicator of word ending have been identified in this research programme.

8.3 Other external-based explanations of the treatment of plurals in compounds

8.3.1 Constraint satisfaction model

Haskell et al also offer an explanation for the differences between regular and irregular plurals in compounds which does not rely on qualitative differences between regular and irregular morphology. Haskell et al's constraint satisfaction model proposes, for the first time, a mechanism by which children might learn how to treat plurals in compounds (See Chapters 1 and 3 for a discussion). Haskell et al argue that two input driven constraints linked to noun usage actually drive the dissociation between regular and irregular plurals in compounds. The first constraint which Haskell et al term the semantic constraint refers to the fact that items that precede nouns in English (adjectives and other nouns) are not marked for plurality. The second constraint, the phonetic constraint refers to the fact that while many different sounding words may precede a noun, words sounding like regular plurals rarely do. Thus, the influence of the semantic and the phonetic constraints working in tandem leads to very few plurals that end in [-s] appearing before a noun. When

the item is plural but does not end in [-s], only the semantic (and not the phonetic constraint) is invoked and under these circumstances some plurals that do not end in [-s] (i.e. irregular plurals) may be produced before a second noun.

The data from the lexical decision test presented here only offers limited support for the constraint satisfaction model. There is support for the semantic constraint in that both types of plural are processed slowly in compounds. However it might be expected that regular plurals, which are influenced by both constraints, would be the slowest to process. This was not the case. There was no difference in the time it took to process the two types of plural. At a descriptive level, irregulars i.e. items that are only influenced by the semantic constraint were processed more slowly than regular plurals. Furthermore, there is only mixed support for the phonetic constraint. Items that do not end in an [-s] are processed more quickly than items that do end in an [-s] a finding which supports the phonetic constraint. However, possessive [-s] is processed more quickly than plural [-s]. If the phonetic constraint exists then there should be no difference between the way different types of morpheme [-s] are processed if they both sound like regular plurals (which they do). Furthermore processing of individual word tokens ending in [-s] should be related to how closely they resemble the sound of regular plurals. However in the lexical decision task, *news* which sounds like a regular plural was processed relatively quickly. Individual item frequency seemed to dictate how quickly items ending in

[-s] were processed and not how closely the items resembled regular plurals. Thus it seems that the constraint satisfaction model may provide too simplistic an explanation of how compound production might be constrained by external factors. It seems that it is a combination of external factors working together that constrain the production of plural morphology in compounds.

8.4 Internal based explanations of the treatment of plurals in compounds

As well as finding support for input based constraints the work reported here also questions the dual mechanism model. Unlike Beck's (1997) production data for regular and irregular verbs, there was no difference in the time taken to process regular and irregular plurals in the lexical decision task (Chapter 3). However, similar to Beck's findings it took less time to process all types of regular morphology collapsed together than it took to process irregular plurals (the only type of irregular morphology tested). Thus a difference between the treatment of regular and irregular morphology in compounds, as predicted by the dual mechanism model, was found. However, the results were not in the direction implied by the dual mechanism model. Irregular plurals which should be easily included in compounds (Marcus, et al, 1995) took longer to process than regular morphology. Furthermore, contrary to the predictions of the dual mechanism model, adults seem to have no difficulty processing other items of regular morphology (i.e., items which

are allegedly produced at a post-lexical stage) within compounds (cf. Marcus et al, 1995). Thus there was limited support for the dual mechanism model's explanation of the treatment of plural morphology in compounds.

8.5 Final Conclusions

Evidence has been presented here for the existence of several external, input based constraints on the treatment of plural morphology in compounds. The literature review presented in Chapter 1 highlighted the effects that level of proficiency in English appears to have on the type of compounds produced. The modality study described in Chapter 2 uncovered the fact that the number of irregular plurals included in compounds can be increased by mentioning the plural in the elicitation prompt. The high type frequency regulars seem to be immune to this external priming effect because they are so frequent in the input but the lower type frequency irregulars are affected by this factor. It is argued that this priming effect on irregular but not regular plurals is symptomatic of the imbalance in the frequency of regular and irregular plural in English. Irregular plurals are so infrequent in the input that adult native English speakers are unsure of how to treat them in compounds and include them in these structures more or less at chance and their treatment is affected by external factors. The omission of regular plurals from compounds is, however, a very robust effect. Thus, it is argued that the dissociation

between the treatment of regular and irregular plurals in compounds, so favoured by supporters of the dual mechanism model, actually arises out of the mismatch between the type frequency of regular and irregular plurals in compounds. The interesting question is why are regular plurals omitted from compounds. The finding of the lexical decision task (Chapter 3) and connectionist models 2, 3 and 4 (presented in Chapter 6 and 7) support the idea that there is sufficient evidence in the input to indicate that regular plurals are omitted from English compounds because of competition with the possessive morpheme. Model 1 described in chapter 4 and the findings of the lexical decision task also support the idea that [-s] is associated with word finality and this factor also contributes to [-s] being omitted from the middle of words such as compounds.

Given this evidence for these various input driven constraints on compounding it is concluded that English noun-noun compounding is not good evidence to support the dual mechanism model's argument that regular and irregular morphology are mediated by dissociated processing and representation systems.

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Appendices

Appendix A: Materials used for Experiment 1 (described in Chapter 2)

Appendix A.1. Full list of stimuli used in Experiment 1 (VC = vowel change)

Noun	Type	Noun	Type	Verb
Children	Irregular (en)	Babies	regular	Protects
Mice	Irregular (VC)	Cats	regular	Watches
Men	Irregular (VC)	Boys	regular	Kicks
Teeth	Irregular (VC)	Bones	regular	Breaks
Feet	Irregular (VC)	Hands	regular	Washes
Geese	Irregular (VC)	Swans	regular	Keeps
Women	Irregular (VC)	Girls	regular	Paints
Wolves	Voicing change	Foxes	regular	Feeds
Knives	Voicing change	Forks	regular	Uses
Leaves	Voicing change	Flowers	regular	Picks

Appendix A.2. Frequency counts for stimuli used in Experiment 1

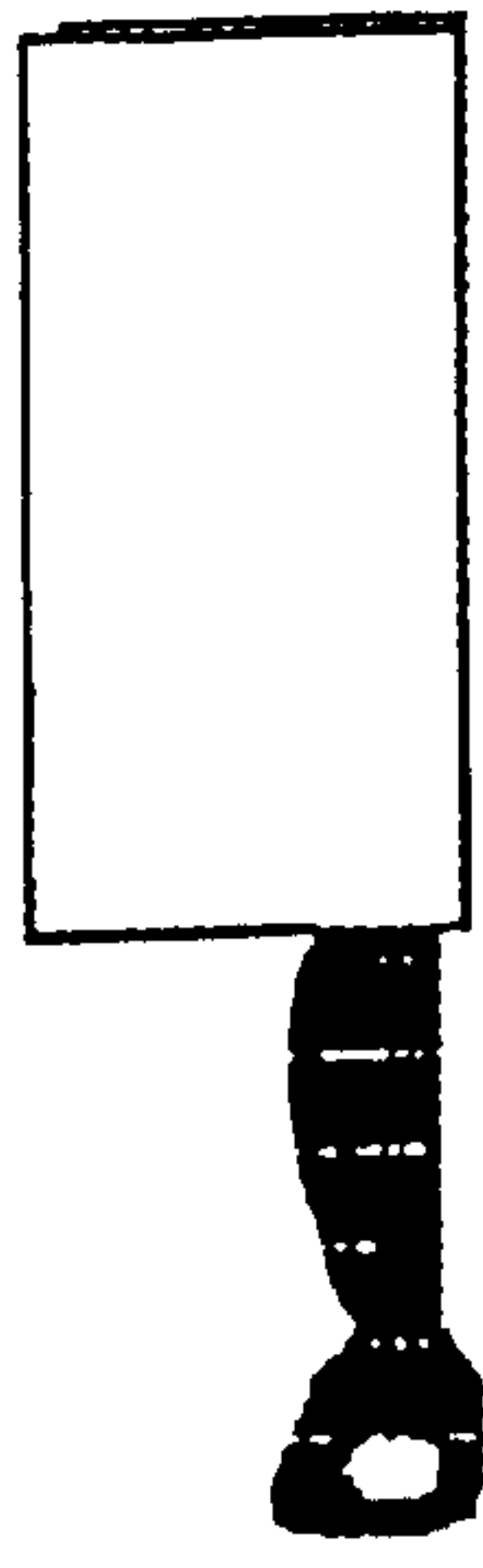
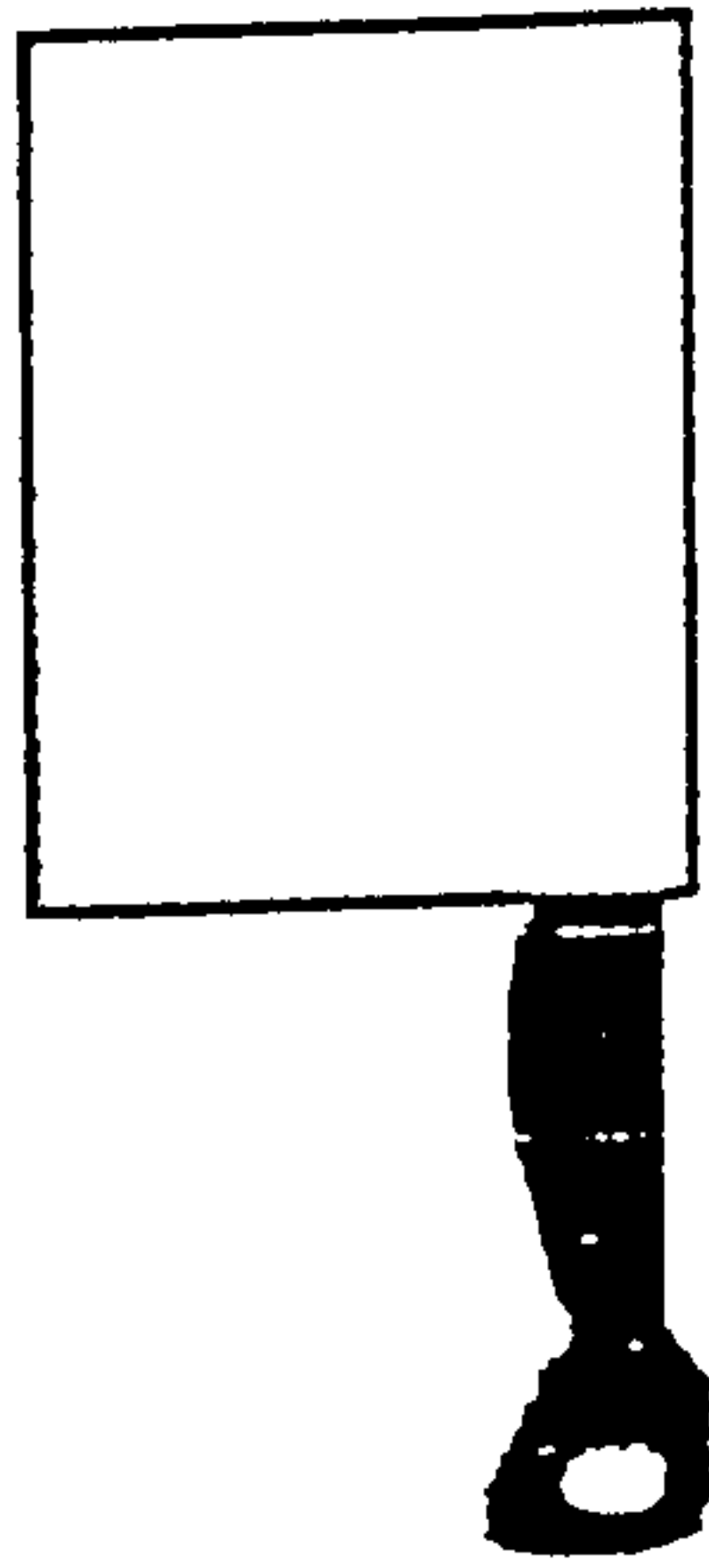
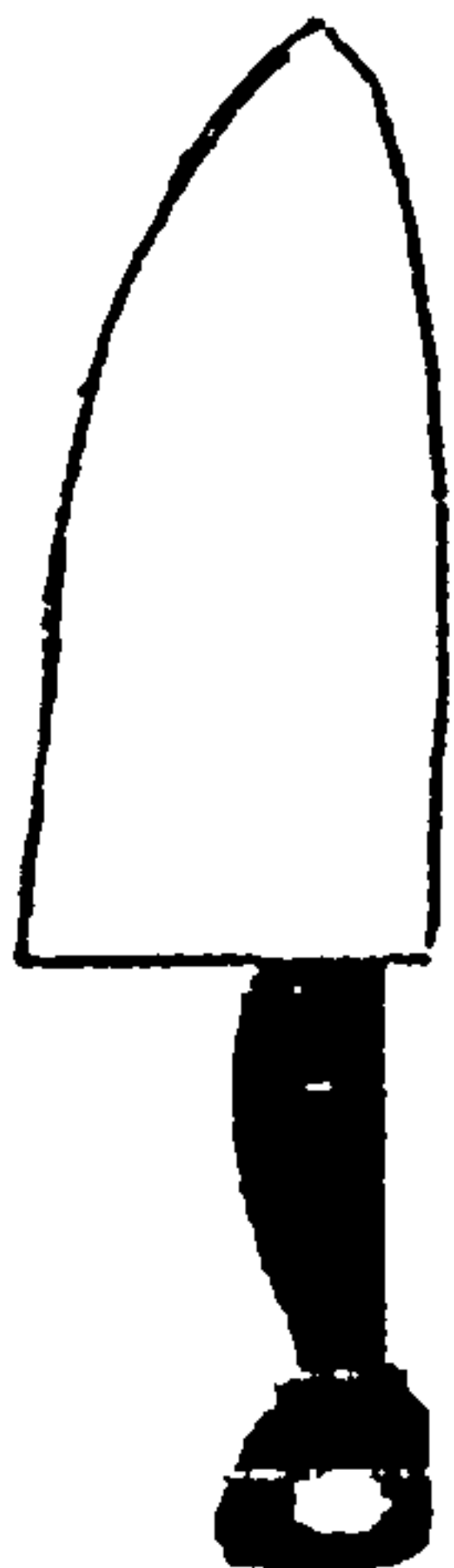
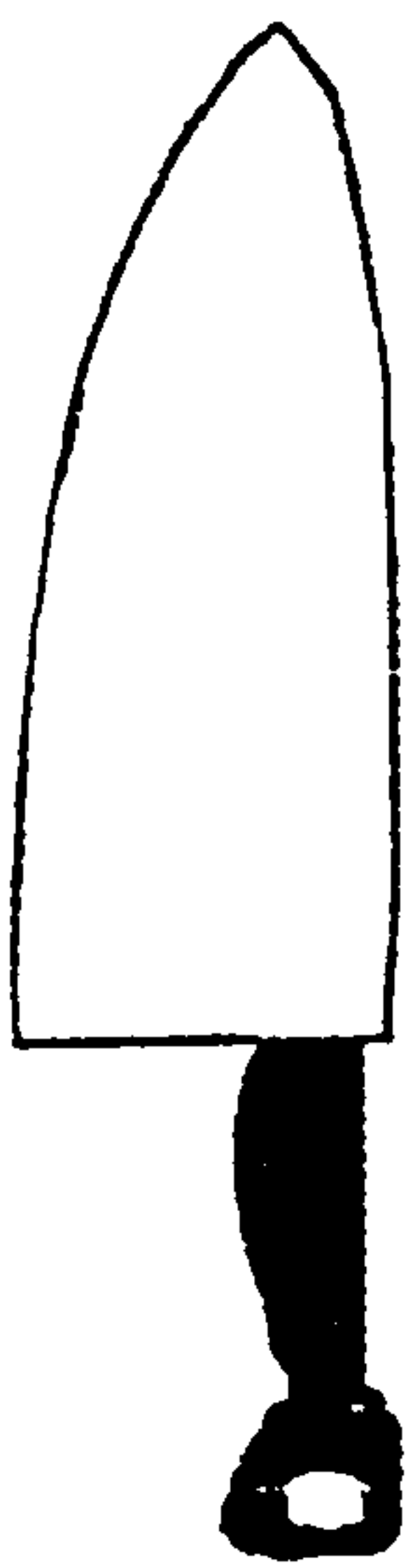
Frequency of use of nouns (from Kucera & Francis, 1967)

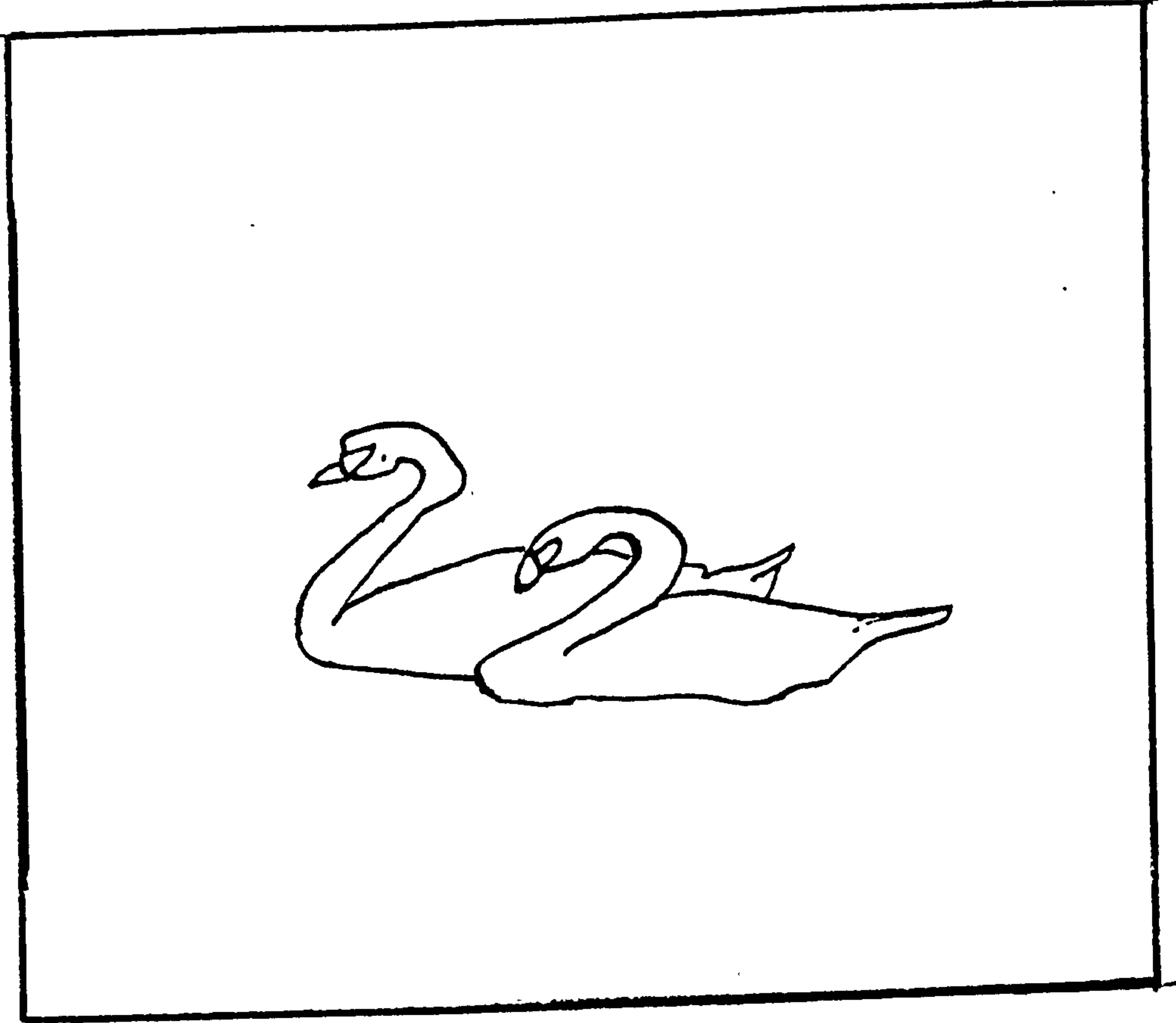
Regular plural nouns		
Noun	Plural frequency	Percentage use in plural form ¹
Hands	285	28
Girls	139	27
Boys	138	25
Flowers	54	41
Bones	20	27
Cats	17	29
Babies	12	13
Forks	2	9
Swans	1	20
Foxes	0	0
Category mean	66.8	21
Voicing change plural nouns		
Noun	Plural frequency	Percentage use in plural form
Leaves	21	39
Knives	7	8
Wolves	4	31
Category mean	10.66	26

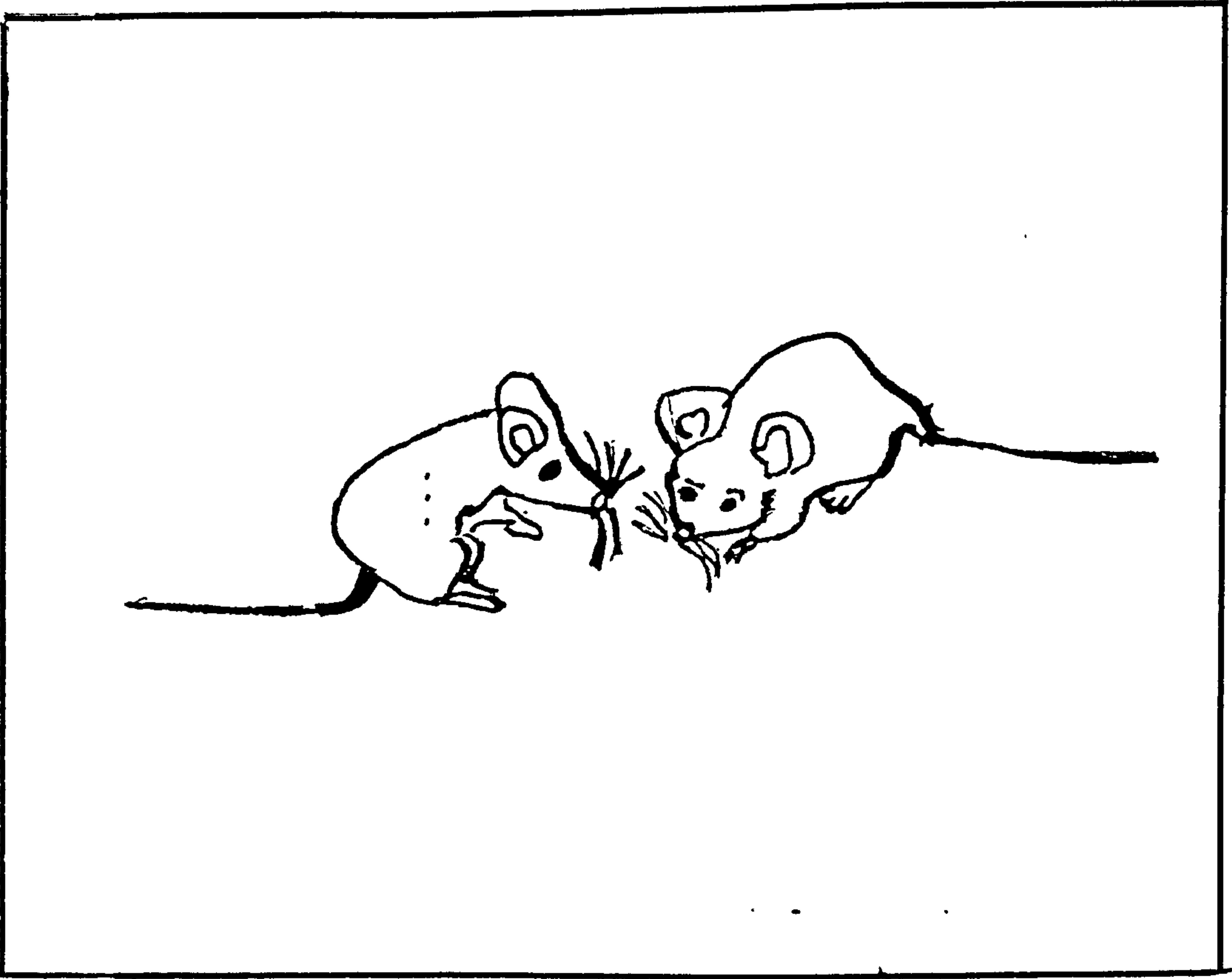
¹ Percentage use in plural form refers to the proportion of times that the noun is used in the plural form out of all times that the noun is used in single and plural form.

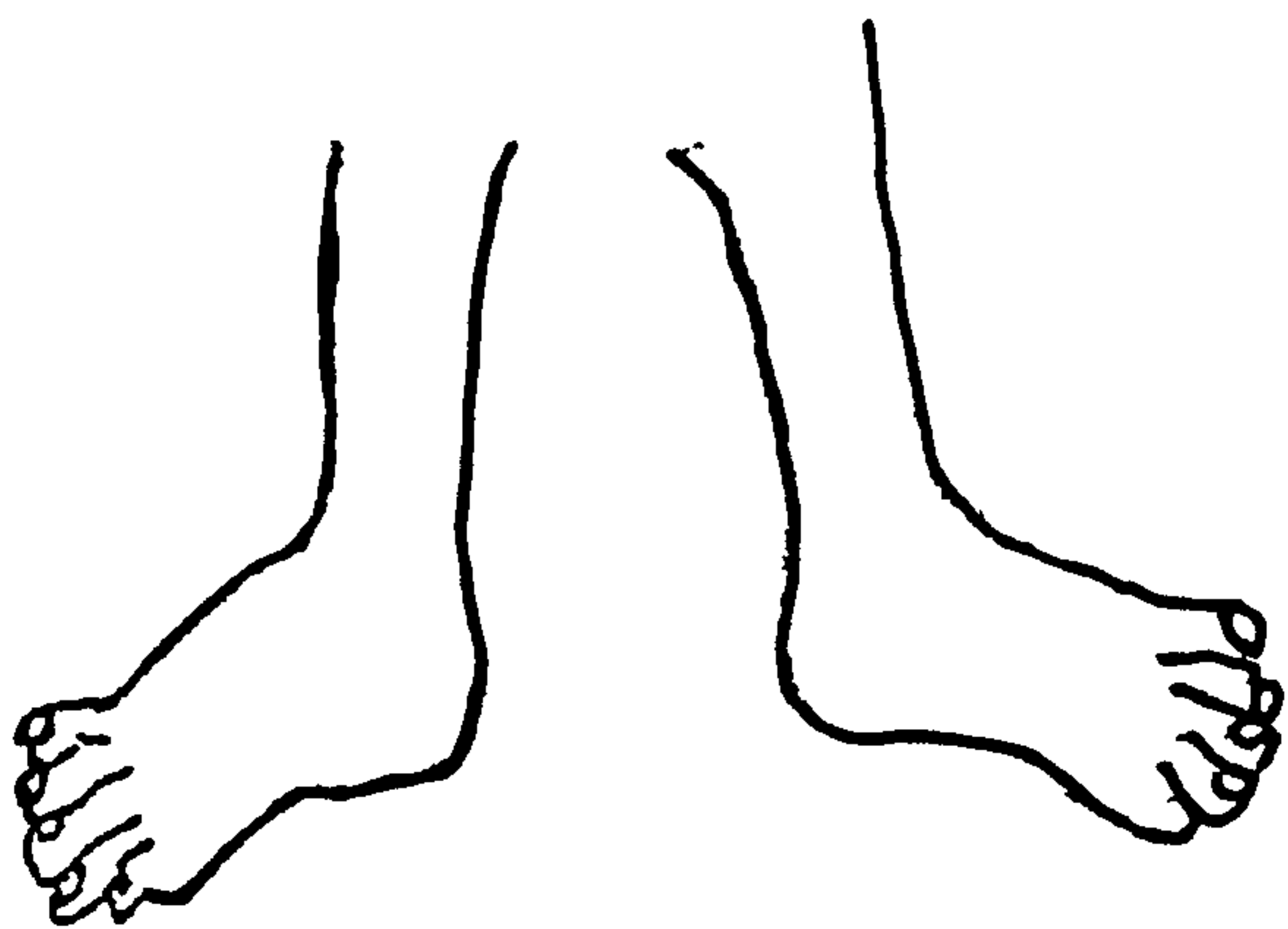
Irregular plurals		
Noun	Plural frequency	Percentage use in plural form
Men	752	26
Children	346	36
Feet	283	44
Women	184	28
Teeth	102	45
Mice	9	31
Geese	3	30
Category mean	239.85	34.28

Appendix A.3. Examples of picture stimuli used in Experiment 1.









Appendix B: Materials used for Experiment 2 (described in Chapter 3).

Appendix B.1. Full list of real words used as stimuli in Experiment 2

Regular plurals

cuts maker

twins_minder

claims_processor

Automatic_Weapons_locator

records_keeper

Admissions_coordinator

drinks_server

wages_earner

calves_exerciser

nurses_trainer

foxes_watcher

cases_carrier

horses_groomer

houses_finder

gates_opener

cats_feeder

dogs_washer

parks_runner

athletes_trainer

logs_carrier

cars_washer

terms-user

schools_inspector

months_counter

hands_washer

weeks_planner

Possessives

girlsPainter

taxis_driver

cars_seller

swans_keeper

goats_washer

mugs_user

cars_protector

finer_payer

gowns_maker
 dogs_walker
 guns_holder
 rats_feeder
 birds_trainer
 lamps_lighter
 meals_server
 jumpers_knitter
 bolts_mender
 pigs_feeder
 plumbers_employer
 cows_leader

Singular non - head nouns ending in phoneme s

kiss_stealer
 lass_chaser
 floss_holder
 brass_player
 hiss_maker
 class_judger
 mess_maker
 dross_seeker
 fuss_maker
 grass_cutter
 moss_clearer
 loss_leader
 glass_washer
 pass_marker
 cuss_sayer
 bliss_maker
 mass_producer
 bass_player
 gas_heater
 bus_traveller
 news_editor
 cross_stitcher
 ass_feeder
 boss_judger

Comparatives/superlatives

finest_singer
 slower_walker
 highest_scorer
 higher_achiever

lowest_payer

biggest_seller

fastest_walker

bigger_talker

Irrgular plurals

teeth_cleaner

feet_washer

womenPainter

lice_finder

men_chaser

geese_keeper

mice_chaser

oxen-herder

children_minder

Singular non-head nouns not ending in the phoneme

[-s]

nurse_feeder

car_parker

claim_staker

record_holder

case_loser

log_burner

athlete_watcher

wage_payer

dog_trainer

park_cleaner

friend_seeker

horse_rider

calf_washer

class_avoider

cat_minder

fox_chaser

admission_checker

gate_closer

automatic_weapon_loader

house_carer

twin_tester

drink_mixer

Appendix B.2. Full list of nonsense words used in Experiment 2 (described in Chapter 3).

apems_attle
aptissot_cuortonator
ashtites_theoner
bebber_tekker
bers_furd
bettest_sibber
bilers_dixum
bis_trepetter
biss_jagder
biss_prater
borts_treeter
bress_plener
bruss_mener
bulds_epe
bulps_miter
bupps_nurt
cet_fouter
cet_wetner
cetpes_exoteser
cets_predestor
chindrel_mulder
cip_mener
cips_mener
ciss_soper
cliep_prucettor
clieps_prucettor
cluss_jenger
cols_silder
crette_wefther
cettes_wefther
cruss_stalcher
culs_lieser
daint_sirter
daints_sirter
dits_bes
dits_dommer
druss_sooper
dut_wetper
duts_wetper

duts_wetper
faas_pener
fais_maper
fenest_sepger
fentest_wilper
fluss_hulter
foop_wetner
frount_muter
frounts_muter
fuxe_weshder
fuxes_weshder
geeds_wetper
gepe_oniter
gibes_oniter
gis_houder
gluss_wimper
goops_kimper
gorts_peinder
gress_cammer
gubs_hunder
gumps_muter
hemps_wetper
heptets_nist
hetner_atheoper
hoss_miper
huase_fonter
hules_fonter
hupte_gruoter
huptes_gruoter
huttest_scuper
Iss_fooper
janters_kripper
kete_keddier
ketes_keddier
ketpe_exoseser
kets_fouter
kets_wetner
kuss_steoler
lembs_lopther
libs_lonper
loce_fenper
luper_piter

luss_choter
meps_clouper
min_cashber
mins_raim
mins_uper
miols_sirper
mofs_prunuder
muce_chiper
mun_muler
murths_conper
natse_theoner
natses_theoner
nins_inosor
pent_rasser
pents_rasser
planders_improber
pols_fooper
pous_mirper
ridurd_koomer
ridurds_koomer
rinss_fooper
scheels_onspitor
shelks_fon
sneols_pice
suler_wilper
sweds_keeter
teris_doper

Appendix C: Materials used for Model 1 (described in Chapter 5).

Appendix C.1 Test set 1 for Model 1

18 unseen 4 letter words that ended in [-s] and another 18 unseen 4 letter words that ended in other letters.

Ending in [-s]

News, lens, adds, bars, cats, dogs, eggs, guys, hits, lots, mugs, nits, pots, runs, sits, tops, wigs, zits,

Ending in other letters

saga, comb, talc, hand, tale, chef, bang, fish, bank, fail, dorm, sign, trip, tear, daft, zulu view, they.

Selection procedure

Items ending in [-s]

News and lens were selected for testing as they are mentioned in Haskell et al (in press) as singular nouns that sound like regular plurals. To complete the test set 16 items were chosen each beginning with a different letter of the alphabet.

Items ending in other letters

A set of items were chosen which ended in different letters of the alphabet.

Appendix C.2. Test set 2 for Model 1

5 four letter words that ended in [s] and 5 four letter words that ended in either [-d], [-e], [-g], [-l] [-r] and [t] respectively.

Ending in [-s]

News, lens, adds, bars, cats,

Ending in [-d]

Hand, bind, clad, fond, glad

Ending in [-e]

Tale, dole, file, gate, hide

Ending in [-g]

bang, clog, long, pang, ring,

Ending in [-l]

Fail, ball, coal, dial, gill

Ending in [-r]

tear, boar, dear, ewer, over

Ending in [-t]

Daft, bent, cast, fast, gust

Appendix C.3. List of English inflectional morphemes/derivational affixes that end in [-d], [-e], [-g], [-l] [-r] and [t] respectively.

d – ends regular past inflectional morpheme [-ed]

g – ends present participle inflectional morpheme [-ing]

r – ends comparative inflectional morpheme [-er]

t – ends superlative inflectional morpheme [-est]

e – ends derivational affixes, [-able] and [-ive,]

l – ends derivational affixes [-ial] and [-ial]

Appendix D: Materials used for Model 2 (described in Chapter 6).

Appendix D.1. Examples of sentences generated

Example of “singular” sentence

The big dog moves.

The big dog moves the brave cat.

Example of “regular plural” sentence

The brave cats fight

The brave cats fight the busy painter.

Example of “irregular plural” sentence

The busy men paint

The busy men pint the cat’s driver

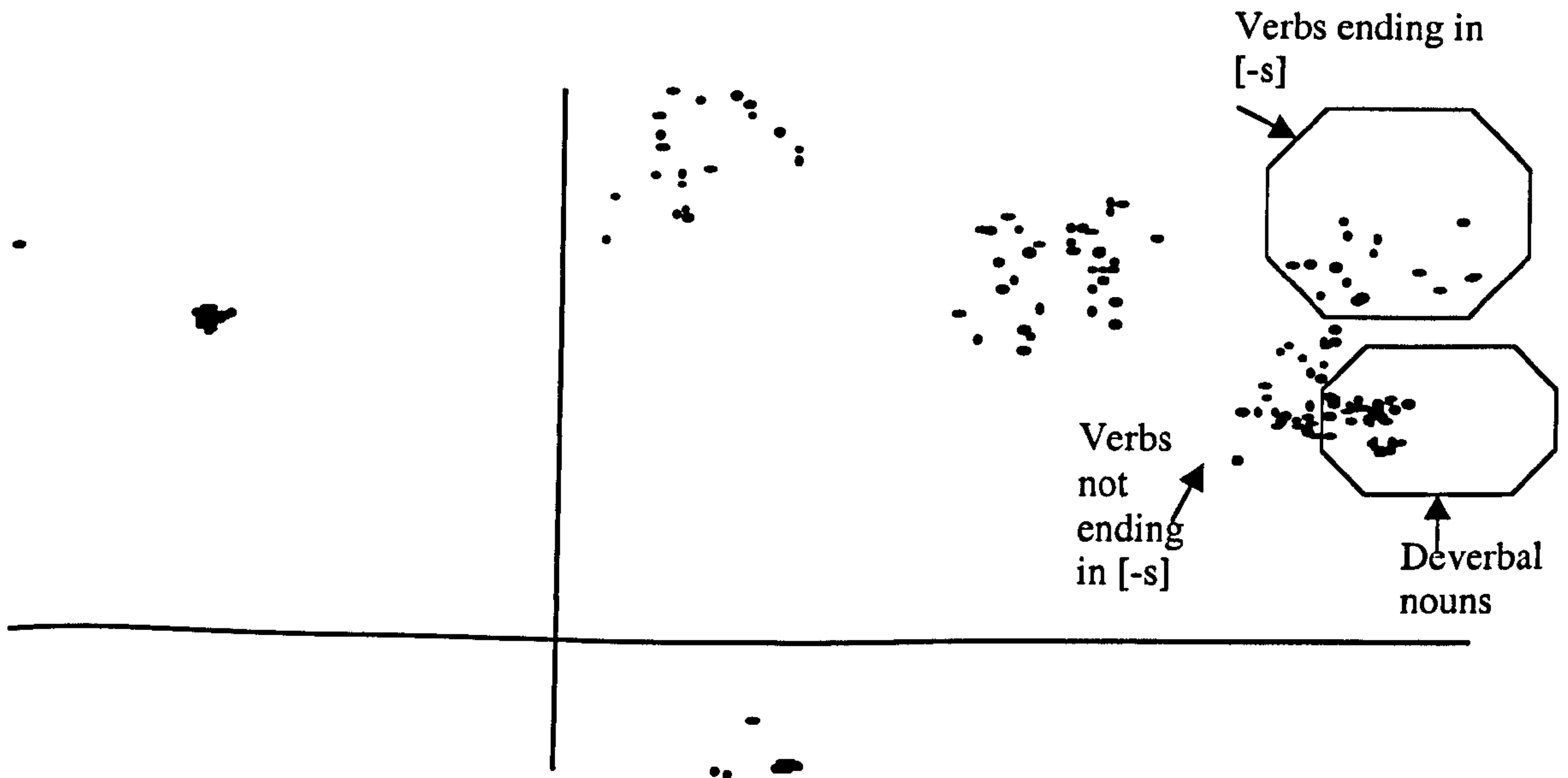
Example of “possessive” sentence

The big pig’s eater

The big pig’s eater fights the brave cat

Appendix E. Additional results of model 2

E.1. The way verbs ending in [-s], verbs not ending in [-s] and deverbal nouns were represented in the hidden layers of Model 2.



**Appendix F. Disc containing raw data for experiments 1 (Chapter 2)
and experiment 2 (Chapter 3)**