Age of acquisition and phonology in lexical processing

Josephine Monaghan

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Abstract

The work presented in the current thesis was aimed at identifying the exact locus of the age of acquisition (AoA) effect within the systems responsible for word and picture processing. Chapter One reviews some of the current influential models of word and picture production and discusses the effects that AoA (and frequency) have upon these processes. Current theories of AoA are also discussed. Chapters Two and Three assess the locus of the AoA effect in the word naming task. The results of these experiments lead to the conclusion that AoA (and frequency) exert their effects in the connections between orthography and phonology in single word naming. Chapter Four then tested the alternative claim that AoA affects the level of phonological output processing by investigating the AoA effect in a phonological segmentation task and by relating the size of the AoA effect in this task and in a word naming task to individual differences in phonological skill. The results of this comparison demonstrate that AoA is unrelated to explicit phonological processing. Chapter Six then investigated the effect of AoA (and other variables) in the picture naming task by relating aphasic patient's level of impairment to the variables that affect their picture naming performance. The results of this study suggest that AoA influences the strength of the connections between semantics and phonology in picture naming. The present thesis concludes that AoA influences the strength of the connections between input (orthography and semantics) and phonological output. The final Chapter discusses the implications of the present results for current theories of AoA and for models of word and picture production.

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Declaration

This thesis contains original work completed by myself under the supervision of Andrew Ellis.

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CHAPTER ONE

THE EFFECTS OF AoA, FREQUENCY AND PHONOLOGY ON LEXICAL PROCESSING

1.1 Introduction

A large amount of research has been devoted to improving our understanding of the processes involved in recognising, comprehending, and naming written words and pictures. By using tasks assumed to test particular processing components of the language system a vast amount has been discovered about how each of these components works. However, whilst the basics of these processing components are understood relatively well, how these processes are conceptualised in terms of, for example, the storage of items and the relationships between different processes is still a matter of theoretical debate.

Much understanding of how particular processes work within the language processing system has come through the investigation of the properties of objects, words and their names that influence these processes. Examination of the properties that affect different processing components of the language system allows theories to be developed that can explain how the system operates. One such variable that has received a large amount of attention within this research is that of a word's frequency of occurrence. Frequency has been viewed as a fundamental part of processing in the naming of pictures and written words and has, as a consequence, been incorporated as an integral part of processing in many models of picture and word naming. Indeed, the validity of many such models has been measured by their ability to explain the effects of frequency.

In recent years, however, a literature has built up which suggests that frequency may not be quite as important or as influential as was first assumed. A number of authors have identified an alternative variable – age of acquisition (AoA) - that appears to influence many of the same processes as frequency. Moreover, a number of studies have found a much larger independent effect of AoA than of word frequency on many tasks that were previously assumed to be predominantly influenced by frequency.

The discovery of AoA as a highly influential variable, and one that has more of an influence than frequency in picture and word production, causes problems for many current theories of word and picture naming. These theories currently offer no explanation of AoA and would appear unable to explain this effect in their present form.

The important step for future work on the modelling of language processing would be to create a model that incorporates an AoA effect and one that can offer some explanation as to the emergence of this effect along with a maintained explanation of the smaller but still apparent frequency effect. One obstacle to the development of such models has been the lack of any conclusive evidence about the precise location at which AoA exerts its effect within the language processing system and, crucially, an explanation of how/why the AoA effect emerges as such a strong influence upon this system.

The aim of the current thesis was, therefore, to identify the exact locus of the AoA effect and provide some conclusive evidence for this. In so doing, it was hoped that some explanation of how the AoA effect emerges might become apparent. The location of the AoA effect will be investigated in the current thesis by assessing AoA's relationship to phonological processing in the word and picture naming tasks. Chapters Two and Three will assess the relationship between AoA and the spelling-sound consistency effect in word naming. By identifying the locus of the consistency effect and AoA's relationship to this, one should be able to locate the level of effect of AoA in word production with some degree of confidence. Chapter Four will then assess the often cited phonological completeness hypothesis (Brown & Watson, 1987) that proposes that AoA is located at the level of phonological processing and exerts its effect by influencing the ease with which phonological representations can be retrieved from the phonological output lexicon. This hypothesis will be tested by assessing the effects of AoA in a phonological segmentation task. By then further investigating the relationship between phonological skill and the AoA effects in this segmentation task and in a word naming task, the claim that AoA influences the phonological level of processing can be tested explicitly.

A final investigation that should allow some further insight into the locus of the AoA effect will be completed with a group of aphasic patients. Each patient's picture naming ability will be assessed in relation to the variables that affect their naming success. By then comparing the effects that patients show to the level of their impairment within the language processing system, one should be able to identify the locus of these effects - and in particular the locus of the AoA effect - more precisely.

The results of these experiments will then be discussed in terms of their implications for current theories of AoA and current theories of picture and word production.

The present Chapter will provide a review of the AoA and frequency effects and a discussion of the processes believed to be involved in the recognition and naming of pictures and words. The review will begin by discussing in more detail the AoA effect, the frequency effect, and the relationship between the two. It will then go on to discuss the tasks of word and picture naming. This discussion will include evaluation of some of the more popular current theories of picture and word naming, and will also discuss the effects that AoA and frequency have upon these processes. The review will then conclude with a discussion of some of the current theories of AoA.

1.2 Age of acquisition

1.2.1 The AoA effect

The AoA effect discussed in the current review refers only to the effect within picture and word naming processes. The effect of AoA has also been reported in word recognition (in the lexical decision task) and in memory tasks, however, such effects are not of primary interest here.

The AoA effect within word and picture naming tasks describes the fact that words that are learnt early on in life are named significantly faster than words that are learnt later on in life.

1.2.2 Measures of AoA

The AoA variable is typically measured using subjective ratings from adults. This measure was developed by Carroll and White (1973a) who asked adults to estimate the age at which they believe that they learnt a particular word and its meaning in either spoken or written form. Ratings were made on a nine-point scale ranging from 1 (learnt before 2 years of age) to 9 (learnt after the age of 13 years). A second rating scale was developed by Gilhooly and Logie (1980a;b) that used the same instructions as those given by Carroll and White (1973a), but that involved a seven-point rating scale from 1 (learnt before 2 years of age) to 7 (learnt after 13 years of age). This measure was then used to assess the AoA of a large number of words and this rating corpus has been used widely ever since.

However, the subjectivity of such measures means that there is no real empirical evidence to prove that this measure is actually directly assessing the effects of when words were learnt. For example, the item's familiarity, its frequency of occurrence, or even its length may influence adult ratings of the age that they *think* they learnt that particular word (Morrison & Ellis, 2000).

A number of studies have attempted to demonstrate the validity of this measure. For example, Carroll and White (1973a) reported a significant correlation of 0.85 between adult AoA ratings and the age at which children were able to name such items. In addition, Gilhooly and Gilhooly (1980) found a correlation of 0.93 between adult AoA ratings and the norms of the Mill Hill Vocabulary Scale that provides a measure of the number of children of a particular age that know different words.

More recently, however, Morrison, Chappell and Ellis (1997) developed an objective measure of AoA. Morrison et al. (1997) presented 14 groups of 20 children ranging from 2 years and 6 months to 10 years and 11 months with 297 pictures. Children were asked to name each picture. The objective AoA measure was defined as the age at which 75% of children within a particular age band correctly recognised and named a picture with or without help from a phonetic (initial sound) cue.

The advantages of this objective AoA measure are clear. Such a measure is without doubt assessing directly the age at which children learn particular words, and so its validity is virtually unquestionable. In addition, this objective measure has actually provided a direct test of the validity of the previous subjective measures of AoA. Indeed, this objective measure of AoA was found to have a significant correlation of 0.75 with a subjective adult rating measure of AoA obtained by Morrison et al. (1997), thereby providing strong support for the claim that subjective measures of AoA are in fact valid.

1.3 Word frequency

1.3.1 The frequency effect

The frequency effect that will be discussed in the present review is that involved in word and picture naming processes. Like

AoA, frequency has also been reported as an important influence in other tasks, such as word recognition (lexical decision) and memory tasks, but these are not of primary interest here.

The frequency effect in word and picture naming describes the fact that words that have a higher frequency of occurrence in the language appear to be named faster than words that have a lower frequency of occurrence.

1.3.2 Measures of frequency

Frequency as a variable is assessed by the number of times a word occurs within spoken or written adult language (typically per million words). Such frequency counts are assumed to be reliable estimates of the amount of experience skilled adults have had with particular words in their written and/or spoken form.

One of the first widely used frequency measures was that developed by Thorndike and Lorge (1944) that assessed the frequency of occurrence of written words in a large sample of English texts. The most commonly used frequency counts today, however, are the written word frequency count of Kucera and Francis (1967) and the Celex Lexical Database (Baayen, Piepenbrock, & Van Rijn, 1993) spoken and written word frequency counts.

The Kucera and Francis (1967) written word frequency count assessed the number of times per million words any particular word occurred within a number of specified written American English texts varying from newspapers to novels.

The Celex Lexical Database (Baayen et al., 1993) contains a written word frequency count (per million words) of British English taken from a number of English texts and a spoken word frequency count (per million words) of British English taken from a number of samples of spoken English. Consequently, the Celex lexical database offers three different frequency measures - a written word frequency per million words, a spoken word frequency per million words, and a combined written and spoken word frequency count per million words. The recency of the Celex database and its use of both spoken and written British English make this the most valid frequency count in experiments using British adult participants.

1.4 The relationship between AoA and frequency

The reason that AoA has recently been found to have similar effects on many processes that were previously attributed solely to the effects of frequency is due to the fact that frequency and AoA are inter-correlated variables. Indeed, Carroll and White (1973a) reported correlations of –0.67 between their AoA measure and the Thorndike – Lorge (1945) frequency count, and a correlation of –0.59 between AoA and the Kucera–Francis (1967) frequency count.

More recently, Morrison et al. (1997) reported a correlation of –0.35 between their objective AoA measure and the Kucera-Francis (1967) frequency count, and a correlation of -0.47 between objective AoA and the Celex spoken and written combined frequency count. What these significant correlations between frequency and AoA demonstrate is that high frequency words are more likely to have been learnt early, and low frequency words learnt later on in life. The results of any experiment measuring the effects of frequency without controlling for the words AoA are, therefore, likely to be confounded by the ease of processing early versus late acquired words. Indeed, the following section that reviews the effects of these two variables in the word and picture naming tasks demonstrates that, once AoA is controlled, the frequency effect in these tasks is much reduced. However, even with frequency controlled, the AoA effect in these tasks is highly prominent.

1.5 The relationship between AoA and cumulative frequency

Lewis and colleagues (Lewis 1999; Lewis, Gerhand & Ellis, 2001) have recently questioned the reality of the AoA variable, suggesting instead that it may be a confound of a cumulative frequency effect. Cumulative frequency describes the total number of times an individual has been exposed to a particular item. Like AoA and frequency of occurrence, AoA and cumulative frequency

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are highly inter-correlated variables - words that are learnt early on in life will have a greater cumulative frequency than will words that are learnt later on in life. However, unlike frequency of occurrence, cumulative frequency is not controlled for in studies looking at the effects of AoA and it is this confound with cumulative frequency that Lewis (1999; Lewis et al., 2001a) claimed causes the emergence of a significant AoA effect in word and picture naming.

Lewis (1999) developed a mathematical model to explain the cumulative frequency effect. One prediction that extended from Lewis' (1999) model was that both AoA and frequency of occurrence should have equivalent effects on RTs in any particular task. In order to test this prediction Lewis, Ghyselinck & Brysbaert (2001) assessed the effect sizes of AoA and of frequency in a number of word processing tasks, including an immediate and a speeded word naming task. In direct opposition to the predictions of Lewis (1999), however, the results of the immediate word naming task demonstrated a significant effect of AoA but a non-significant effect of frequency and in the speeded word naming task AoA was again significant while the effect of frequency only approached significance. On the basis of their study Lewis et al. (2001b) acknowledge that AoA cannot be dismissed as a mere confound of cumulative frequency.

1.6 Word recognition and naming

1.6.1 The word naming task

The word naming task requires participants to name aloud single written words as quickly and as accurately as possible. The response times to this task measure the delay between the appearance of the word and the onset of the participant's response.

1.6.2 The processes involved in recognising and naming written words

The successful recognition and naming of written words involves a number of processes and translation mechanisms. Exactly how the processing of a word within this system occurs is a matter of considerable theoretical debate.

The model of skilled adult reading that shall be predominantly used to explain the processes involved in successful single word reading here and throughout this thesis is the parallel distributed processing model of Plaut, McClelland, Seidenberg and Patterson (1996). This model views the reading process as occurring within a single route from orthographic input representations to phonological output representations. The main alternative view of single word reading is that proposed by the dual route model of word reading (e.g. Coltheart, Rastle, Perry, Langdon & Ziegler, 2001) that claims that it is necessary to postulate two reading routes in order to explain skilled adult reading. The dual route model shall be discussed briefly here, before a more detailed description of Plaut et al.'s (1996) model is provided.

1.6.2.1 The dual route cascaded model of reading (Coltheart et al., 2001)

As the title of this model of skilled adult reading indicates, the fundamental property of the dual route model is that skilled adult readers have at their disposal two possible routes for the reading of single words – a lexical route and a non-lexical route. The dual route cascaded model of Coltheart et al. (2001) can be seen in Figure 1.1. In the non-lexical route, the reading of words and nonwords occurs through the use of a grapheme-to-phoneme correspondence (GPC) rule system that translates the letters of words into their corresponding sounds according to the spelling-to-sound correspondence rules of English. In the lexical route words are read through the activation of a word specific store that contains a single orthographic representation of each word that is learnt. This representation then activates a phonological representation of the word in a phonological output store, which again stores individual corresponding entries of the phonology of every word learnt. This phonological output unit can be accessed directly from the visual word store or via the semantic system (in effect, therefore, making this a three route model of skilled adult reading). The output from the lexical and non-lexical processing

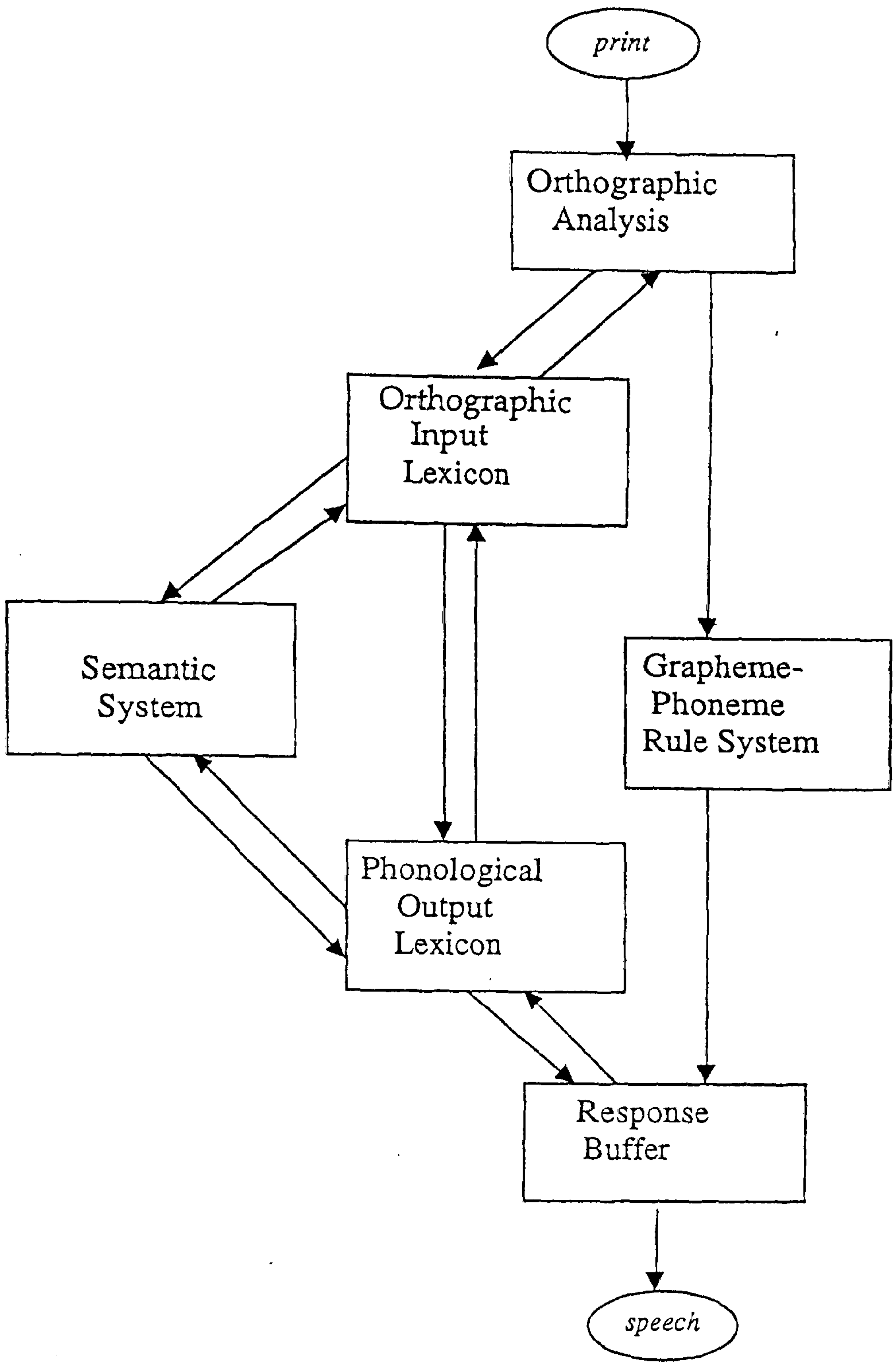

Figure 1.1 The dual route cascaded model of skilled adult reading (Coltheart et al., 2001). Successful nonword reading occurs via the non-lexical GPC route, successful word reading occurs via both the non-lexical and lexical routes, though the non-lexical route will read exception words incorrectly. Reading via the lexical pathway may involve the third, semantically mediated route, particularly when there is damage to the direct lexical route in deep dyslexia.

routes then interact in a final processing stage at the level of a phoneme system where the final output of the word is produced.

Proponents of the dual route model argue that lexical and non-lexical routes are necessary in order to explain the successful reading of exception words and nonwords by skilled adult readers. Whilst exception words (and all familiar words) can be read by the lexical route, nonwords cannot be because they do not have a stored representation in this system. Nonwords can, however, be read correctly by the non-lexical route via GPC rules, but exception words will be read incorrectly by this route as they do not follow GPC rules of English. The third reading pathway - the semantically mediated lexical route - is necessary in this model in order to explain the reported effect of the semantic variable of imageability upon single word naming (e.g., Strain, Patterson & Seidenberg, 1995), and is also crucially involved in Coltheart et al.'s (2001) explanation of the pattern of performance of deep dyslexic patients.

1.6.2.2 A parallel distributed processing model of reading (Plaut et al., 1996)

An alternative view of skilled adult reading is provided by the parallel distributed processing model of Plaut et al. (1996). This model claims that skilled adult reading occurs within a single route wherein distributed orthographic representations activate directly their corresponding distributed phonological representations. The model of skilled adult reading provided by Plaut et al. (1996) can be seen in Figure 1.2. The early simulations of Plaut et al.'s (1996) model involved a single route of 105 orthographic units (representing component letters of words), that were directly connected to 61 phonological units (representing component sounds of words) via 100 hidden units. This single route learnt to read by learning spelling-to-sound correspondences implicit in the words upon which it was trained.

Plaut et al. (1996) demonstrated that this single orthography-phonology route is capable of reading consistent words, exception words and nonwords successfully. On the basis of their model's ability to read both nonwords and exception words in a single route, Plaut et al. (1996) concluded that one does not need to postulate two separate routes to reading in order to successfully explain the reading behaviour of skilled adult readers. This argument is in support of other connectionist models that successfully explain the reading process within a single orthography-phonology route (e.g., Harm & Seidenberg, 1999; Seidenberg & McClelland, 1989).

The reason that Plaut et al.'s (1996) model can successfully read nonwords and exception words in a single route is that this model does not store a localist, whole-word representation of every word that it learns. Instead the orthographic input and the phonological output units store words as a pattern of distributed

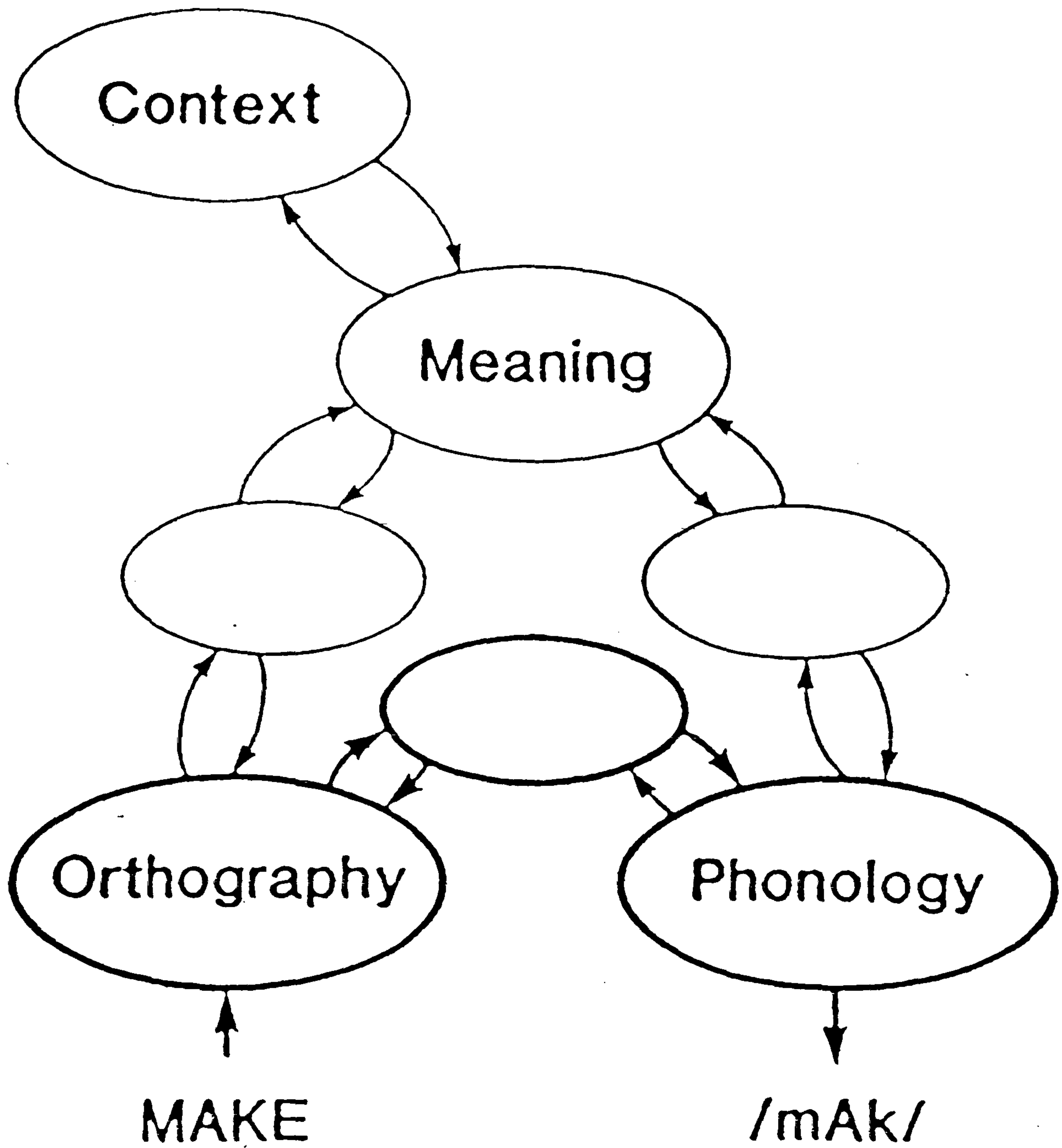

Figure 1.2 The levels of processing in the parallel distributed processing model of Plaut et al. (1996). Words are read mainly by the direct orthography-phonology route, though low frequency exception words in Plaut et al.'s (1996) final simulation are read via a contribution from semantics. Pictures are named by accessing the items semantic concept (meaning) which can then activate the items phonological output. Context is not involved in the reading and/or naming of single items.

representations over these processing units. Consequently, both consistent and exception words and nonwords can be read through the activation of the item's appropriate phonemes from the activated orthographic representations.

The concept of distributed representations clearly makes the explanation of the word naming system far simpler. It also makes far more sense that words are stored as distributed representations. Indeed, the dual route theory's proposal that every learnt word has its own individual representation within a mental lexicon becomes difficult to accept when one recognises how economical the brain is in terms of storage and processing demands, and that a skilled adult reader's vocabulary likely extends over 30,000 words.

In a final simulation Plaut et al. (1996) implemented a contribution from a semantic pathway to help reading in the phonological pathway (in effect, therefore, creating two routes from orthography-phonology in this model). One of Plaut et al.'s (1996) main justifications for this implementation was that imageability (a known semantic variable) has been reported to affect naming latencies to exception words (e.g., Strain et al., 1995). As Plaut et al. (1996) argue, if a semantic variable influences word naming then it must be the case that the semantic and phonological pathways interact to support the successful reading of all words. The degree to which the semantic and phonological pathways contribute to the reading of particular words in this model is assumed to depend upon the ease with which each pathway learns particular words. The orthography-phonology route is assumed to become most competent at reading high frequency words and words with consistent GPCs. As a result, the successful reading of low frequency words, and particularly low frequency exception words, is believed to require a contribution from the semantic pathway. In contrast to their earlier simulations, therefore, Plaut et al. (1996) argue that exception words (especially those of low frequency) are only read successfully via a contribution from the semantic system.

The connectionist model of Plaut et al. (1996) appears to be the most useful and valid model of single word reading available at present. A further advantage of this model is that the implementation of a semantic system means that this model is also capable of explaining the processes involved in picture naming. This model will, therefore, be that used as the basis of all explanations of the processes and effects found in the current thesis. A full diagram of the processes involved in word and picture production in Plaut et al.'s (1996) model can be seen in Figure 1.2.

1.6.3 The influences of frequency and AoA on word naming

The apparent effects of word frequency upon word naming latencies have long been reported. The first of such reports was by Preston in 1935, who demonstrated that words that had a high estimated frequency of occurrence in the Thorndike (1931) word frequency count were named significantly faster than words that had a low estimated frequency of occurrence on this count.

However, it was not until the 1970's that the effect of frequency upon word naming latencies became established as an apparently robust and highly influential variable. One study that had a strong influence in terms of the impact of the word frequency effect in word naming was that of Forster and Chambers (1973). They presented participants with 15 high frequency words and 15 low frequency words taken from the Thorndike-Lorge (1944) frequency word count. The participants were directed to name these letter strings and an equal number of nonwords as quickly as possible. Forster and Chambers (1973) found a significant frequency effect upon naming latencies such that high frequency words were named significantly faster than low frequency words. In addition, Forster and Chambers (1973) assessed the effects of frequency in the delayed naming task in which participants had to wait 2 seconds following the presentation of the stimulus before they named it. Frequency did not affect delayed naming RTs in this experiment, thereby demonstrating that frequency exerts its effect prior to articulatory processes.

A large number of other studies have reported an equivalent effect of word frequency upon word naming latencies, and a non-significant effect upon delayed naming (e.g. Andrews, 1992; Berry, 1971; Besner & McCann, 1987; Connine, Mullennix, Shernoff, & Yelen, 1990; Frederiksen & Kroll, 1976; Landauer, Ross, & Didner, 1979; McRae, Jared, & Seidenberg, 1990; Paap, McDonald, Schvaneveldt, & Noel, 1987). However, none of these studies controlled for AoA. As a consequence, more recent studies have demonstrated that the effect of frequency in this task is reduced once AoA is controlled for, and moreover, have demonstrated that AoA itself is a highly influential variable within the word naming task.

Gilhooly and Logie (1981a) first demonstrated the effects of AoA on word naming latencies using a multiple regression technique. They discovered that AoA was the strongest predictor of word naming latencies, whereas word frequency did not account for any of the variance in word naming speed once AoA had been taken into account. Using a factorial design, Morrison and Ellis (1995) replicated the results of Gilhooly and Logie (1981a), showing a significant effect of AoA on word naming when frequency was controlled, and a non-significant effect of frequency when AoA was controlled. In further experiments they found that neither AoA nor frequency had an effect upon delayed naming RTs, thereby showing that, like the frequency effect, the AoA effect is not located in articulation processes.

Many other studies have reported the effects of AoA on word naming (e.g. V. Coltheart, Laxon, & Keating, 1988; Gilhooly, 1984), and some have similarly failed to find an effect of frequency once AoA is controlled for (e.g. Barry, Hirsh, Johnston, & Williams, 2001; Brown & Watson, 1987; Yamazaki, Ellis, Morrison, & Lambon Ralph, 1997). However, other recent studies have reported an effect of frequency as well as an effect of AoA in the word naming task using both multiple regression (Morrison & Ellis, 2000) and factorial analyses (Brysbaert, Lange & Van Wijnendaele, 2000; Gerhand & Barry, 1998).

The word naming task, therefore, reflects a good example of how frequency becomes much less influential once AoA is controlled for. Nevertheless, recent investigations of the word naming task have demonstrated the continuing influence of frequency on word naming latencies once AoA is controlled for. These studies have also demonstrated the powerful and robust effect of AoA upon word naming latencies.

1.6.4 The spelling-sound consistency effect

Another important variable that affects naming latencies in the word naming task is that of a words spelling-sound consistency. Spelling-sound consistency is defined as the degree to which a word's pronunciation can be predicted from its spelling (e.g. Patterson & Morton, 1985). Consistent words include all words within a particular word family whose pronunciation is always predictable from the way in which the word is spelt (e.g. all words ending in –AKE rhyme with one another). In contrast, other word families share a spelling that is not always pronounced in the same predictable way (e.g. most words ending in –AND rhyme with BAND but the word WAND makes this word family inconsistent). Whilst most words in these inconsistent families share a pronunciation that is predictable from their spelling (the regular pronunciation), one or (at most) two words within these families have an exceptional (unpredictable and irregular) pronunciation, such as WAND within the present example.

A number of studies have demonstrated that consistent words are named faster than regular inconsistent or exception words, with the largest difference in terms of naming speed being between consistent and exception words (e.g. Baron & Strawson, 1976; Gough & Cosky, 1977; Parkin, 1982; Stanovich & Bauer, 1978; Waters & Seidenberg, 1985).

Importantly, in terms of the present review, a large number of studies have since demonstrated an apparent interaction between consistency and frequency within the word naming task, such that low frequency exception words are named more slowly than high frequency exception words and consistent words of both high and low frequency (e.g. Andrews, 1992; Brown & Watson, 1994; Hino & Lupker, 2000; Jared, 1997; Paap & Noel, 1991; Seidenberg, 1985; Seidenberg, Waters, Barnes, & Tanenhaus, 1984; Taraban & McClelland, 1987; Waters & Seidenberg, 1985).

A further interesting study by Strain et al. (1995; see also Strain & Herdman, 1999) reported an interaction between frequency, consistency and imageability, such that the slowest naming latencies in the word naming task were to exception words of both low frequency and low imageability.

None of these studies have controlled for AoA, however. Given the prominence of the AoA effect, and the smaller effect of frequency once AoA is controlled in the word naming task, it would be interesting to see whether AoA rather than, or in addition to, frequency interacts with spelling-sound consistency. Moreover, it is notable that a number of studies have reported non-significant effects of imageability upon word naming once AoA (and frequency) have been controlled for (e.g. Brown & Watson, 1987; Brysbaert et al., 2000; V. Coltheart et al., 1988; Gilhooly & Logie, 1981a; Morrison & Ellis, 2000). Consequently, identifying whether the interaction between frequency, imageability and consistency reported by Strain et al. (1995) continues once AoA is controlled would be an important and interesting study to complete. These issues will be addressed in the present Chapters Two and Three.

1.7 Picture recognition and naming

1.7.1 The picture naming task

The picture naming task requires participants to name aloud pictures of objects as quickly as possible. The reported naming latencies within this task measure the delay between the appearance of the picture and the onset of the participant's response.

1.7.2 The processes involved in recognising and naming pictures

Picture naming is assumed to involve the sequential processing of at least three representations of an object: 1) a structural representation that contains information about the objects visual form, 2) a semantic representation that specifies the functional and associative characteristics of the object, and 3) a phonological representation which contains information about the pronunciation of the word (Humphreys, Riddoch, & Quinlan, 1988). To date, however, no theory of picture naming has incorporated the level of initial object recognition into their model (e.g. Dell, 1986; Dell, Schwartz, Martin, Saffran & Gagnon, 1997; Plaut et al., 1996). This is because incorporating so many processes in a single model is beyond the scope of current computational modelling (e.g. Dell et al., 1997). Nevertheless it is clear that, following on from an assumed level of structural representation, the model of Plaut et al. (1996) is perfectly capable of explaining the retrieval of a pictures name in phonology from its semantic concept. Indeed, Plaut and Kello (1999) have demonstrated that this model is proficient at learning to produce a name in phonological output direct from semantic activation.

In contrast, other models of single word production and picture naming claim that an additional intermediary level of word (lemma) representations is necessary for a semantic representation of a picture to activate its phonology (e.g. Dell, 1986; Dell et al., 1997; Levelt, Schriefers, Vorberg, Meyer, Pechmann, & Havinga, 1991; Levelt, 1999). This word level is presumed to contain a word node for every single object name that the model learns. Activation of a word node from the semantic representation then activates the word's corresponding phonemes in the phoneme layer. However, the proposal of such a localist word lexicon is questionable. Indeed, as was noted in the discussion of the dual route model of Coltheart et al. (2001), the inclusion of a localist word level that contains a representation for every single word that is learnt is not particularly appropriate in light of the large vocabulary that adults possess.

Consequently, the connectionist model of Plaut et al. (1996) may be viewed as a simple and viable interpretation of the picture naming process. This model would predict that picture naming moves directly from the recognition of the picture, through activation of its semantic representation, to direct access of the picture's name in the phonological output system. Similar to its explanation of the frequency effect in the early simulations of word reading, frequency presumably affects picture naming success by influencing the strength of the connections between semantic and phonological units, with high frequency items having stronger connections than low frequency items.

1.7.3 The effects of AoA and frequency on picture naming

A number of studies have reported the effects of frequency upon picture naming, wherein high frequency picture names are named faster than low frequency picture names. The most famous of such studies was completed by Oldfield and Wingfield (1965). They presented 12 participants with 16 object pictures, which were distributed evenly throughout the full range of word frequencies on the Thorndike – Lorge (1944) frequency count. The results of this study demonstrated a significant effect of frequency such that objects with high frequency names were produced much faster than objects with low frequency names. A number of other studies have since replicated the frequency effect upon naming latencies (e.g. Bartram, 1974; Humphreys, Riddoch, & Quinlan, 1988; Huttenlocher & Kubicek, 1983) and upon error rates (Vitkovitch & Humphreys, 1991) in the picture naming task.

However, none of these studies controlled for the AoA of the picture names. The fact that AoA and frequency are highly inter-correlated suggests that AoA, perhaps in addition to frequency, may also have an effect upon picture naming latencies in this task. Indeed in the first study to investigate the effects of both frequency and AoA in picture naming Carroll and White (1973b) found that the frequency effect was redundant once AoA was controlled, whereas the AoA effect was highly significant with frequency controlled.

Morrison, Ellis and Quinlan (1992) have further demonstrated the significance of the AoA effect and the redundancy of the frequency effect once AoA is controlled for in the picture naming task. They re-analysed Oldfield and Wingfield's (1965) data incorporating measures of the stimuli's AoA, word length and the more accepted frequency count of Kucera and Francis (1967) into a multiple regression analysis. This re-analysis revealed a significant effect of AoA upon the naming speed of Oldfield and Wingfield's (1965) stimuli, but no effects of frequency or word length. Following on from this, Morrison et al. (1992) completed their own picture naming experiment using 58 pictures that had values on AoA, Kucera-Francis (1967) written word frequency, word length, imageability and manmade/natural category membership. In multiple regression and stepwise regression analyses the only variables found to predict significant unique variance of naming latencies were AoA and word length. There was no effect of frequency independent of AoA and word length. Gilhooly and Gilhooly (1979) have also replicated such an effect of AoA and a non-significant effect of frequency upon picture naming latencies.

However, other studies have reported effects of both frequency and AoA independent of each other in this task (e.g., Barry, Morrison, & Ellis, 1997[1]; Cirrin, 1983[2]; Ellis & Morrison, 1998; Lachman, 1973; Lachman, Shaffer, & Hennrikus, 1974; Snodgrass & Yuditsky, 1996). Those recent studies that have reported effects of both frequency and AoA have, importantly, included a much larger number of experimental items in their studies. Such an inflated number of items will have increased the statistical power of the regression analyses and may, therefore, go some way to explaining why previous studies failed to find a significant effect of frequency in addition to AoA (e.g., Gilhooly & Gilhooly, 1979; Morrison et al., 1992). Indeed, when Barry et al. (1997) investigated the naming latencies of 195 pictures in a multiple regression analysis with the predictors of AoA, frequency, familiarity, imageability, visual complexity, name agreement and word length, significant effects of AoA, frequency and name

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[1] Ellis & Morrison (1998) completed a re-analysis of the results of Barry at al. (1997) and Snodgrass & Yuditsky (1996) using an objective measure of AoA (Morrison et al., 1997) instead of the rated, subjective measure originally used. This re-analysis revealed AoA to be the strongest predictor of naming speeds in both experiments. Whilst frequency continued to have a significant contribution in Barry et al.'s (1997) study, frequency only approached significance in Snodgrass & Yuditsky's (1996) study.

[2] It is perhaps worth noting that the studies of Cirrin (1983) and Lachman et al. (1974) only found a significant effect of rated, subjective frequency, and not of objective frequency, which may explain the stronger predictive value of frequency relative to AoA in these two studies.

agreement were reported. Interestingly, Barry et al. (1997) also included a multiplicative term in their analysis that represented the interaction between AoA and frequency. This term was significant in the analysis, suggesting that frequency has a greater effect upon picture naming latencies when the items are late acquired.

All of the above studies on picture naming have involved the use of multiple regression analysis. This choice of analysis is understandable given the number of variables that need to be controlled for in the picture naming task, however, such analyses are not without their problems. As the discussion above suggests, for results to be reliable, a large number of items have to be used. In addition, however, most of the variables included in studies on picture naming are highly inter-correlated (e.g. AoA, frequency, imageability, familiarity and word length). This can result in the problem of multicollinearity wherein one variable subsumes the variance associated with another highly inter-correlated variable. Such problems of multicollinearity may, therefore, explain the lack of a frequency effect in some of the studies discussed above.

In response to the problems of assessing picture naming using multiple regression analysis, Barry et al. (2001) completed a picture naming study using a factorial design wherein AoA (Experiment 1) and frequency (Experiment 2) were manipulated independently. Experiment 1 involved 48 pictures, 24 early and 24 late acquired items that were controlled across sets for frequency, familiarity, name agreement, image agreement, visual complexity and word length. Experiment 2 involved 24 high frequency and 24 low frequency items that were controlled on the aforementioned variables in addition to AoA. The results of these experiments revealed a highly significant effect of AoA on picture naming latencies, but no effect of frequency. Indeed, the difference in naming RTs to high and low frequency items was just 5ms.

Because Barry et al. (2001) used a factorial design that avoids problems associated with highly inter-correlated variables they argue that their study allows "closure on the debate concerning the major determinant of picture naming latencies" (pp.368), with AoA and not frequency affecting picture naming speeds. Though Barry et al. (2001) do note that had their frequency word sets included more late acquired items they might have observed a frequency effect carried by such late acquired items (cf. Barry et al., 1997). Similar findings of a significant effect of AoA, but not of frequency, in a picture naming task using a factorial design has been reported by Bonin, Fayol and Chalard (2001) in French-speaking adults.

It seems to be the case, therefore, that despite previous belief in the power of the frequency effect in picture naming, the most important influence in terms of naming speed is actually AoA. Whether frequency actually has an effect in this task is still under debate. The results of the factorial analyses suggest that frequency does not exert an influence on picture naming independent of AoA (e.g. Barry et al., 2001; Bonin et al., 2001). It may, however, be the case that, as Barry et al. (1997) noted, frequency continues to have an effect, but does so only for late acquired words.

1.8 Summary of the AoA and frequency effects in word and picture naming

The current review has presented a large amount of research demonstrating the robust effect of AoA on picture and word naming. In addition, the present review has demonstrated a continuing effect of frequency upon word naming, though when AoA is controlled the size of this effect is much reduced. The effect of frequency upon picture naming latencies is, however, less reliable, being significant in many regression analyses (e.g., Barry et al., 1997; Morrison & Ellis, 1998) but not in factorial analyses (e.g., Barry et al., 2001; Bonin et al., 2001).

Despite the recent upsurge in studies reporting strong AoA effects in these language processing tasks, few theories of AoA have been offered and, moreover, few existing theories of word naming and/or reading have acknowledged the effect of AoA in their models. As the Introduction to this Chapter suggested, the dearth of conclusive evidence as to the location of the AoA effect in the language processing system may be a cause of the lack of recognition of the AoA effect. The next goal for research on the AoA effect would, therefore, seem to be to identify the exact locus of the

AoA effect (and, in relation to this, the locus of the frequency effect) within the language processing system. This would allow theories explaining the AoA effect to become established, and encourage current word and picture naming models to begin to incorporate AoA into their models. In addition, current models of word and picture naming may have to re-assess their explanations of the frequency effect that is modelled in the connectionist networks as a robust and integrative part of processing. The present review has demonstrated that the effect of frequency on word and particularly on picture naming is not as large or as robust as was previously assumed. The following section will discuss current views on the locus/loci of the AoA effect prior to moving on to discuss those few theories of AoA that have been offered thus far. The final section of this Chapter will then briefly assess the validity of current views of the frequency effect.

1.9 Theoretical accounts of AoA

The present review has demonstrated very clearly that AoA exerts a significant influence upon naming latencies in both picture naming and written word naming. The important task for current research would seem to be the development of theoretical accounts of AoA, including explanations of where AoA exerts its main effect within the language processing system, and why AoA contributes such an important influence at that particular level of processing (i.e. through what mechanism does the AoA effect emerge). The following section will assess the possible locus/loci of the AoA effect in word and picture naming. Those few theories of AoA that have been proposed to date will then be described.

1.9.1 The locus of the AoA effect

The fact that AoA has been found to have a significant effect upon both word naming and picture naming has suggested to many authors that AoA may have a common locus of effect. Although the semantic system might be involved in the successful naming of some words (cf. Plaut et al., 1996), phonological output is assumed to be the only level of processing that is involved in the naming of all pictures and words. As a consequence many authors have assumed that AoA exerts its effect at the level of phonological output (e.g. Brown & Watson, 1987; V. Coltheart et al., 1988; Ellis & Morrison, 1998; Gerhand & Barry, 1998; Morrison & Ellis, 1995; Morrison et al., 1992). In addition, the lack of an effect of AoA within the delayed naming task (e.g. Morrison & Ellis, 1995) suggests that AoA exerts its effect prior to articulatory processes.

1.9.2 The logogen model

The first explanation offered for the AoA effect was in terms of a logogen-like system in which AoA affects the accessibility of lexical memory (Gilhooly & Gilhooly, 1979). In the earliest version of the logogen system (cf. Morton, 1969) each word is assumed to have its own individual logogen that is activated when incoming sensory and contextual information reaches a specified threshold.

Gilhooly and Gilhooly (1979) proposed that AoA affects the thresholds of the logogens – with early acquired words having lower thresholds than later acquired words. Gilhooly and Gilhooly (1979) argue that late acquired words are likely learnt in terms of definitions involving early acquired words. Thus, every time such late acquired words receive activation they will in turn partially activate associated early acquired words. Such continual priming of early acquired words will result in a reduced threshold of their logogens, thereby allowing easier accessibility to these words in lexical memory.

The postulation of AoA as a factor that influences the threshold level of logogens in lexical memory provides little insight into the exact locus of AoA, however. This is because contrary to current theories of word and picture naming, Gilhooly and Gilhooly's (1979) logogens are assumed to include both semantic and phonological information about each word.

A later version of the logogen model (cf. Morton, 1979; Morton & Patterson, 1980) allowed a more specific understanding of the potential locus of the AoA effect within this model. The modified version of this logogen model proposed separate levels of input and output logogen systems with visual input logogens (graphemic or pictorial) activating phonological output logogens either directly (in word naming) or via activation of the cognitive system (in picture naming) wherein semantic information about the item is retrieved. Postulating such separate levels of processing is far more alike to current theories of word and picture production.

Furthermore, this revision allows a more specific location of the AoA effect to be defined in the logogen model. According to Gilhooly and Watson (1981; see also Gilhooly & Logie, 1981b), because AoA affects word and picture naming latencies, then the locus of the AoA effect might be within the phonological output logogen system. This is because word and picture naming only share this level of processing. Gilhooly & Watson (1981), therefore, concluded that the AoA effect in word and picture production is a consequence of the fact that early acquired word logogens have a lower threshold of activation in the output logogen system than do late acquired word logogens.

1.9.3 The phonological completeness hypothesis

An alternative, and widely accepted, theory of the AoA effect is proposed by the phonological completeness hypothesis of Brown and Watson (1987). Like Gilhooly and Watson (1981), the phonological completeness hypothesis proposes that the AoA effect is located in the phonological output store. This hypothesis is, therefore, also perfectly capable of explaining the effects of AoA in both word and picture naming because processing in these two tasks is shared at the level of phonological output. However, the way in which the phonological completeness hypothesis conceives of the effect of AoA within this store is very different to that proposed by the logogen model of Gilhooly and Watson (1981). The phonological completeness hypothesis argues that the AoA effect emerges as a consequence of the quality of the phonological representations within this store. More specifically, this hypothesis argues that early acquired words are stored as whole word representations in the phonological output store. However, as a child acquires more vocabulary, the phonological store has to become more economical and so begins to store later learnt words in a more segmented form. The storage of phonological representations in a segmented form is more economical as it allows the same representation of a syllable/phoneme to be shared by all words that contain that segment. However, a consequence of this more efficient storage strategy is a processing cost for late acquired words because of the extra time needed to generate the whole word phonological representation of such words. In contrast, the phonological representation of early acquired words is already stored as a whole and so early acquired words can be retrieved and named more quickly than later acquired words.

The phonological completeness hypothesis receives strong echoes in a number of theories of childhood vocabulary development (e.g. Ferguson, 1986; Fowler, 1991; Jusczyk, 1986;

1993; Metsala & Walley, 1998; Walley, 1993). These theories similarly propose that children's first learnt words are stored as holistic representations in the phonological store and that, as vocabulary size increases, later learnt words begin to be stored in an increasingly segmented form. However, unlike the phonological completeness hypothesis, none of these theories claim that the initial holistic representation of early learnt words is maintained through adulthood. Instead these theories claim that segmented representations either overlay (e.g., Ferguson, 1986; Jusczyk, 1986; 1993; Walley, 1993), or entirely replace (e.g., Fowler, 1991; Metsala & Walley, 1998; Walley, 1993) the initial holistic representation.

By locating the AoA effect at the level of phonological output, the phonological completeness hypothesis has some appeal in so far as it can explain why the AoA effect is found in both word and picture naming (cf. Gilhooly & Watson, 1981; Gilhooly & Logie, 1981b). However, this hypothesis is not entirely compatible with the theories of vocabulary development discussed above. Clearly, therefore, although the phonological completeness hypothesis has been widely cited as a possible explanation of the AoA effect there is little in the way of direct evidence to support it. Indeed, this hypothesis has never been tested experimentally. This issue is taken up in the present Chapter Four that tests the phonological completeness hypothesis experimentally and also assesses the more general claim that AoA is located at the level of phonological output (cf. Gilhooly & Watson, 1981; Gilhooly & Logie, 1981b).

1.9.4 A connectionist account of the AoA effect

Ellis and Lambon Ralph (2000) developed a connectionist network in an attempt to demonstrate that AoA can successfully be simulated in such networks, just as frequency can be (e.g., Harm & Seidenberg, 1999; Plaut et al., 1996; Seidenberg & McClelland, 1989). In the past it has been argued that the modelling of AoA effects in such neural networks would be impossible due to catastrophic interference (e.g. Morrison & Ellis, 1995; Gerhand & Barry, 1998). Catastrophic interference describes the pattern of behaviour in neural networks where, if one set of patterns is trained and then replaced by training on a second set of items, the representations of the first learnt items (the 'early acquired' items) will deteriorate and be gradually lost as the second set (the 'late acquired' items) are learnt.

However, Ellis and Lambon Ralph (2000) demonstrated that catastrophic interference can be avoided when training in a connectionist network is cumulative. That is, training on the first set of items is not halted when training on a second set of items begins, but instead training of the first set of early entered items continues and is interleaved with the training of the second set of late entered items.

Ellis and Lambon Ralph's (2000) distributed connectionist network was comprised of a set of 100 input units that are fully interconnected to 100 output units via 50 hidden units. This network was trained on 200 different patterns that were divided into 100 'early' and 100 'late' entered patterns. The early patterns were initially presented to the network for 250 epochs of training after which time the other 100 'late' patterns were added to the early patterns and presented for training. Thus the late entered patterns were trained alongside the early patterns using cumulative, interleaved learning.

After training, Ellis and Lambon Ralph (2000) demonstrated that their network successfully simulated the AoA effect found in skilled adult readers, with the network's sum-squared error being significantly smaller for early entered than for late entered patterns. That is, the network was consistently more successful at producing the correct output for early entered patterns. This AoA effect was still present after 100,000 epochs of training when the cumulative frequency of presentation for early and late entered patterns was all but equal (ratio 1.003:1).

In a later simulation Ellis and Lambon Ralph (2000) demonstrated that frequency effects could also be modelled in their network (cf. Harm & Seidenberg, 1999; Plaut et al., 1996; Seidenberg & McClelland, 1989). Ellis and Lambon Ralph (2000) divided the 100 early and 100 late entered patterns into subsets of 25 patterns to be trained at high frequency (10 presentations per epoch) and 75 to be trained at low frequency (1 presentation per epoch). The early entered patterns were trained for 750 epochs after which the late entered patterns were presented for training interleaved with the earlier patterns. After 5,000 epochs of training the performance of the network on these patterns was assessed. The results demonstrated clear effects of AoA and of frequency, such that the lowest error rates in the network were to early entered high frequency patterns and the highest error rates in the network were to low frequency late acquired patterns.

This network is the first to simulate the effects of AoA within a connectionist framework. Ellis and Lambon Ralph's (2000) network is clearly important, therefore, not only in demonstrating that the AoA effect can successfully be modelled within such a framework, but also in allowing some insight into the possible mechanism lying behind the AoA effect. Indeed, on the basis of the behaviour of their model Ellis and Lambon Ralph (2000) argued that the human lexical system actually structures itself according to the first words that it learns. Ellis and Lambon Ralph (2000) assumed that both AoA and frequency influence the connections between the input and output units. AoA and frequency effects arise in these connections because early entered (and/or high frequency) patterns have the chance to structure the network into a configuration that is advantageous to them before the late patterns enter training, or the low frequency patterns can establish their connections.

As a consequence of this head start, when late entered (or low frequency) patterns are learnt the network has lost much of its plasticity and so is less able to represent these patterns. Consequently, whilst late entered (or low frequency) patterns can modify the structure of the network (they are still learnt and produced with success) they will never attain representations comparable to those of early entered (or high frequency) patterns. That is, they are always in competition with the better established connections for the early acquired patterns.

In opposition to the phonological completeness hypothesis (Brown & Watson, 1987) and the logogen model (Gilhooly & Watson, 1981; Gilhooly & Logie, 1981b), therefore, Ellis and Lambon Ralph (2000) claim that AoA influences the connections between input and output, with early acquired words having better established stronger connections. Ellis and Lambon Ralph's (2000) explanation of the AoA effect predicts that AoA will exert an effect whenever a task requires activation of connections between processing levels. This prediction, therefore, proposes that the AoA effect in single word naming has a different locus of effect than does the AoA effect in picture naming. That is, AoA influences the ease with which phonology is accessed from orthography in word naming, and from semantics in picture naming.

However, like the phonological completeness hypothesis (and the logogen model), the explanation of AoA offered by Ellis and

Lambon Ralph's connectionist network (2000) has yet to receive any strong experimental support. At present, therefore, it is impossible to choose between these different explanations with any level of certainty.

1.10 Current theories of frequency: A note on the validity of Plaut et al.'s (1996) connectionist model

The fact that AoA has been demonstrated to have a prominent effect upon the word and picture naming tasks that were initially assumed to be primarily influenced by frequency suggests that explanations of the frequency effect must be reassessed. Indeed, while the evidence suggests a continuing role for the frequency effect in word naming, the evidence for a frequency effect in picture naming is more unreliable. In both cases, the effect of frequency (with AoA controlled) is certainly smaller than was initially presumed. These results clearly have consequences for current theories of word naming and, in particular, picture naming.

In terms of Plaut et al.'s (1996) model of word reading and picture naming, the frequency effect is believed to have a strong influence on the strength of the connections between input (orthography and semantics) and phonological output. Such an explanation of the frequency effect may be entirely valid. However, this model needs to recognise that the effect of frequency on word and picture naming is far smaller than previously thought. This would appear to be particularly true for picture naming wherein the effect of frequency is not often reported once AoA is controlled.

The model of Plaut et al. (1996) (amongst others), therefore, needs to place less emphasis on frequency in terms of the structure of the cognitive architecture and mechanisms inherent in the model. As the current review suggests, the frequency effect may no longer be the most important variable that these models must contend with. Furthermore, this model also needs to recognise the predominant role of AoA in word and picture naming. Plaut et al.'s (1996) model is an adaptive network very similar to that developed by Ellis and Lambon Ralph (2000). It would appear entirely reasonable to assume, therefore, that if Plaut et al. (1996) incorporated cumulative learning as the form of training in their model, an AoA effect could be easily simulated. Until they do so, however, the validity of this model will remain questionable.

1.11 The aims of the current thesis

The main aim of the current thesis was to investigate where, within the language processing system, AoA exerts its effect(s). The need to provide conclusive evidence of this locus is clear from the current review for a number of reasons. Firstly, identifying the locus/loci of the AoA effect will allow theories of AoA currently offered to be tested directly. Such findings may also allow models of word and picture naming to be developed that place emphasis on the influence of AoA rather than on frequency. The current work will further re-assess the current models of skilled word reading and picture naming in terms of their ability to explain the current results. Priority will be given to the connectionist model of Plaut et al. (1996) that can offer an account of both word and picture naming processes.

Chapters Two and Three set out to investigate the locus of the AoA effect within single word reading. This was completed by assessing the relationship between AoA and spelling-sound consistency. As was noted in Section 1.5.4, consistency has long been recognised as having a strong influence upon word naming latencies and is also believed to interact with frequency. Given the similar levels of effect of frequency and AoA it is plausible that AoA will also interact with consistency. Chapter Two set out to test this possibility.

Chapter Three then followed up the investigation of the AoA effect in single word reading by examining the locus of the consistency effect. Plaut et al.'s (1996) early simulations located consistency in the connections between orthography and phonology. However, on the basis of the report of an effect of imageability on word naming by Strain et al. (1995), Plaut et al.'s (1996) later simulation claimed that exception words are named more slowly than consistent words because they are read via the semantic pathway. Chapter Three set out to test the claim that imageability affects word naming latencies and interacts with consistency and frequency (once AoA is controlled).

By assessing the relationship between AoA and consistency and by then determining the locus of the consistency effect one should be able to identify the locus of the AoA effect in single word naming. This investigation also allowed further assessment of the apparent interaction between frequency and consistency. As Section 1.5.4 noted, no study reporting such an interaction has controlled for AoA, thereby rendering those results inconclusive at present.

Chapter Four set out to further investigate the locus of the AoA effect by explicitly testing the explanation of the AoA effect offered by the phonological completeness hypothesis of Brown and Watson (1987). The phonological completeness hypothesis states that AoA is located within the phonological output lexicon. The results of the experiments in Chapters Two and Three should already have provided some indication as to the locus of the AoA effect. However, given the wide acceptance of the phonological completeness hypothesis it is of vital importance that this theory be directly tested. Consequently, Experiment 6 of Chapter Four used a phonological segmentation task to test the predictions of the phonological completeness hypothesis. According to this hypothesis, participants should be faster to segment late acquired words that are stored in a more fragmented form than to segment early acquired words that are stored as whole word representations. This experiment also directly assessed whether AoA is located in phonological output by examining the relationship between individual's phonological skill and the size of any AoA effects in the segmentation task and in a word naming task.

The final study of the present thesis aimed to investigate the locus of the AoA effect in picture naming. This was completed by assessing the picture naming success of a group of aphasic patients in relation to the variables that affect their naming success. By then relating the effects these patients show in the picture naming task to their level of impairment within the language processing system, one should be able to identify clearly the level of effect of such variables, and in particular, the effect of AoA.

The final Chapter will then attempt to bring together the findings of the present experiments in order to conclude upon the locus/loci of the AoA effect. Plaut et al.'s (1996) model of word and picture naming will also be evaluated, as will the present theories of AoA.

CHAPTER TWO

DO AoA AND FREQUENCY INTERACT WITH SPELLING-SOUND CONSISTENCY?

2.1 Introduction

Chapter One argued that one of the reasons why there has been a reluctance to incorporate the effect of AoA into current models of word and picture naming may be due to the lack of conclusive evidence as to the exact locus of this effect within the language processing system. The aim of the present Chapter was, therefore, to investigate in some detail the locus of the AoA effect within the word naming task. This was done by exploring the relationship between AoA and spelling-sound consistency.

Consistency is a variable that has a robust effect upon word naming latencies, with consistent words being named significantly faster than exception words (e.g. Baron & Strawson, 1976; Gough & Cosky, 1977; Parkin, 1982; Stanovich & Bauer, 1978; Waters & Seidenberg, 1985). By investigating whether AoA interacts with consistency one may be better able to identify the locus of AoA in word naming. If AoA interacts with consistency then it could be concluded that AoA exerts its effect at the same level of processing as does the consistency effect. In contrast, if these two variables are unrelated then this might suggest that AoA influences word naming at a later level of processing than the consistency effect, perhaps at the level of phonological output. The present Chapter will assess the relationship between AoA and consistency. Chapter Three will then go on to assess the locus of the consistency effect. By investigating the relationship between AoA and consistency and by then identifying the locus of the consistency effect one should be able to begin to understand the locus of the AoA effect within the word processing system.

The present Chapter will also investigate the relationship between frequency and consistency with AoA controlled. The interaction between frequency and consistency has been reported numerous times (e.g. Andrews, 1992; Brown & Watson, 1994; Hino & Lupker, 2000; Jared, 1997; Paap & Noel, 1991; Seidenberg, 1985; Seidenberg et al., 1984; Taraban & McClelland, 1987; Waters & Seidenberg, 1985), leading to the assumption that frequency exerts its effect at the same level of processing as does the consistency effect. However, none of these studies has controlled for AoA. As Chapter One highlighted, the effect of frequency on word naming latencies is much reduced when AoA is controlled (e.g., Brown & Watson, 1987; Brysbaert, 1996; Brysbaert et al., 2000; Gerhand & Barry, 1998; Gilhooly & Logie, 1981a; Morrison & Ellis, 1995; 2000). It is, therefore, possible that the strength of the interaction between frequency and consistency will also be reduced once AoA is controlled. In order to understand the true effect of frequency upon word naming its relationship with consistency once AoA is controlled must be investigated.

The aims of the current chapter were, therefore, to investigate the relationship between frequency and consistency once AoA is controlled, and also to investigate any possible relationship between AoA (independent of frequency and other factors) and consistency. Thus, two experiments were carried out: Experiment 1 manipulated frequency and consistency in word sets matched on AoA (and other variables), while Experiment 2 manipulated AoA and consistency in word sets matched on frequency (and other variables). Chapter Three will then go on to investigate the locus of the consistency effect in order to allow some conclusions to be made about the locus of the AoA (and frequency) effects on the basis of their relationship to consistency.

In the current experiments, consistent words came from word families that share the same pronunciation of their shared word body (e.g. all words ending in _AKE rhyme with one another and so are consistent), whilst the exception words had pronunciations that were at variance with the majority of the other words in that word family (e.g. WAND, cf. BAND, HAND, LAND, SAND etc.). Words with unique, or unusual word bodies (e.g. YACHT, SOAP, LAUGH) and words from inconsistent families in which no particular pronunciation dominates (e.g. BROWN, DOWN, TOWN, versus BLOWN, GROWN, SHOWN) were not included in the current experiments.

2.1.1 A note on the use of by-items analysis of variance

The results of the present experiments (and those throughout the thesis) will only report the findings of by-subjects analyses. By-subjects analysis is used to test the generalisation from a subset of chosen participants to the (much) larger set of possible participants. Similarly, the aim of by-items analysis is to test the generalisation of a subset of chosen items when these are drawn at random from a much larger possible vocabulary of words (Clark, 1973). However, the word sets selected for the current experiments do not constitute a small random selection of a larger set of possible words. Instead they are limited by, for example, their spelling-sound consistency and are manipulated on one factor whilst controlling for many others. Such limitations mean that the items used in at least some of the conditions (e.g. low frequency exception words controlled for AoA, imageability, and length) constitute a substantial proportion of all such possible items[1].

Raaijmakers, Schrijnemakers, and Gremmen (1999) and Wike and Church (1976) have shown that the use of by-items analyses with matched word sets increases the likelihood of a Type II error rather than reducing the likelihood of a Type I error. Raaijmakers et al. (1999) argued that "contrary to current practice, in many cases there is no need to perform separate subject and item

[1] The same is true of all the sets of experimental stimuli used throughout this thesis.

analyses since the traditional F_1 [the by-subjects analysis] is the correct test statistic. In particular this is the case when item variability is experimentally controlled by matching." (p. 416). In the current experiments then, where a number of variables are controlled and/or manipulated, use of by-items analyses is both inappropriate and unsuitable given the likelihood of Type II errors. By-subjects analyses are, therefore, the only necessary test for the current experiments.

2.2 Experiment 1 - Does frequency interact with spelling-sound consistency once AoA is controlled?

2.2.1 Method

2.2.1.1 Participants

Twenty participants took part in Experiment 1. All were undergraduate or postgraduate students from the University of York who were native English speakers, with normal or corrected-to-normal vision, and who were paid for their participation.

2.2.1.2 Materials

The experimental stimuli consisted of 80 monosyllabic words, with 20 high frequency consistent words, 20 low frequency consistent words, 20 high frequency exception words, and 20 low frequency exception words. The word sets used in Experiment 1 are shown in Appendix 1. High frequency words had frequencies greater than 14 per million in both the Kucera and Francis (1967) count and the combined spoken and written Celex frequency count (Baayen et al., 1993). Low frequency words had frequencies of less than 13 in both frequency counts.

2.2.1.3 Matching on other variables

The four word sets were matched on imageability, AoA, number of orthographic neighbours (N) and word length (number of letters). New imageability ratings were obtained from 25 undergraduate psychology students at the University of York who were each given a booklet containing 220 words (110 consistent and 110 exception words) presented in a random order. The instructions given to participants followed those of Gilhooly and Logie (1980a;b) who asked participants to rate the imageability of a word using a seven point scale, depending upon the ease with which the word aroused a mental image/sensory experience (from 1 = poorly imageable to 7 = highly imageable). One hundred and sixty five of the words had imageability ratings in the Gilhooly and Logie (1980a;b) norms. The correlation between those ratings and the new ones was .82.

New AoA ratings were also obtained from 24 undergraduate psychology students at the University of York. Participants were given the same 220 words and were given instructions adapted from Carroll and White (1973a) and Gilhooly and Logie (1980a;b) which asked them to estimate the age at which they believed that they and others first learnt each word and its meaning, in either spoken or written form. Ratings were made on a nine-point scale. The middle 7 points (from 2 = 1-2 years to 8 = 13-17 years of age) corresponded to the 7-point scale of Gilhooly & Logie (1980a;b), with additional points being added at each end of the scale (1 = 0-1 years; 9 = 17+ years of age) in order to encourage use of the full range. Scores of 1 and 2, and 8 and 9 were then combined to collapse the scale onto that of Gilhooly and Logie (1980a;b). One hundred and eleven of the words had AoA ratings in the Gilhooly and Logie (1980a;b) norms. The correlation between those ratings and the new ones was .91.

2.2.1.4 Procedure

The stimuli were presented in the centre of an Apple Mac Centris 660av computer screen in black 48 point lowercase print, using Geneva font. The screen was approximately 60 cm away from the participant. Reaction times to words were recorded using a voice key-activating microphone, which timed the interval between the appearance of a word and the onset of the participant's response. Participants were asked to read the words aloud as quickly and as accurately as possible (avoiding any hesitations or incidental noises) when they appeared on the computer screen. Participants were given 30 practice trials that included words of all types to be used in the following experiment (consistent and exception, high and low frequency). The orthographic bodies of these practice words were different from those included in the experimental trials in order to avoid any possible priming effects within the experiment itself. After a short interval, the 80 experimental words were presented randomly in a single block.

On each trial participants were presented with a fixation point for 750 ms. The fixation point was replaced without delay by the target word, which remained on the screen until the participant made a response. The screen then went blank for 1000 ms before the next fixation point was presented. Any pronunciation errors and/or voice key activation errors made by participants were noted by the experimenter.

2.2.2 Results

Fifty-seven out of a total of 1,600 responses (3.6%) were deleted from further analysis. Thirty-five of these (2.2%) were due to mispronunciations of the words, 18 (1%) were due to accidental activation of the voice key, while 4 (0.3%) were removed due to the extreme length of the reaction times (greater than 1,500 ms). The mean naming latencies of correct responses in the four word sets, and the total mispronunciation error rates (in percent) are shown in Table 2.1.

	Consistent		Exception	
	M	SD	M	SD
High frequency				
Reaction time	507	57	505	57
% error	0.25		0.75	
Low frequency				
Reaction time	501	48	539	65
% error	1.50		6.25	

Table 2.1 Mean reaction times and standard deviations in ms, and total mispronunciation errors (%) for each word type in Experiment 1.

2.2.2.1 Reaction time analysis

Analysis of variance was carried out on the RT data with spelling-sound consistency and word frequency as the two factors. In this analysis, the main effect of consistency was significant, $F(1,19) = 29.67$, $MSE = 6684.45$, $p<0.01$, with naming RTs being faster to consistent words (504 ms) than to exception words (522 ms). The main effect of word frequency was also significant, $F(1,19) = 43.37$, $MSE = 4107.69$, $p<0.01$, with naming RTs being faster to high frequency words (506 ms) than to low frequency words (520 ms). Importantly, the interaction between word frequency and spelling-sound consistency was also significant, $F(1,19) = 93.33$, $MSE = 7872.71$, $p<0.01$. The form of the interaction is shown in Figure 2.1. Simple main effects analyses showed that the 38 ms difference between naming RTs to low frequency consistent and

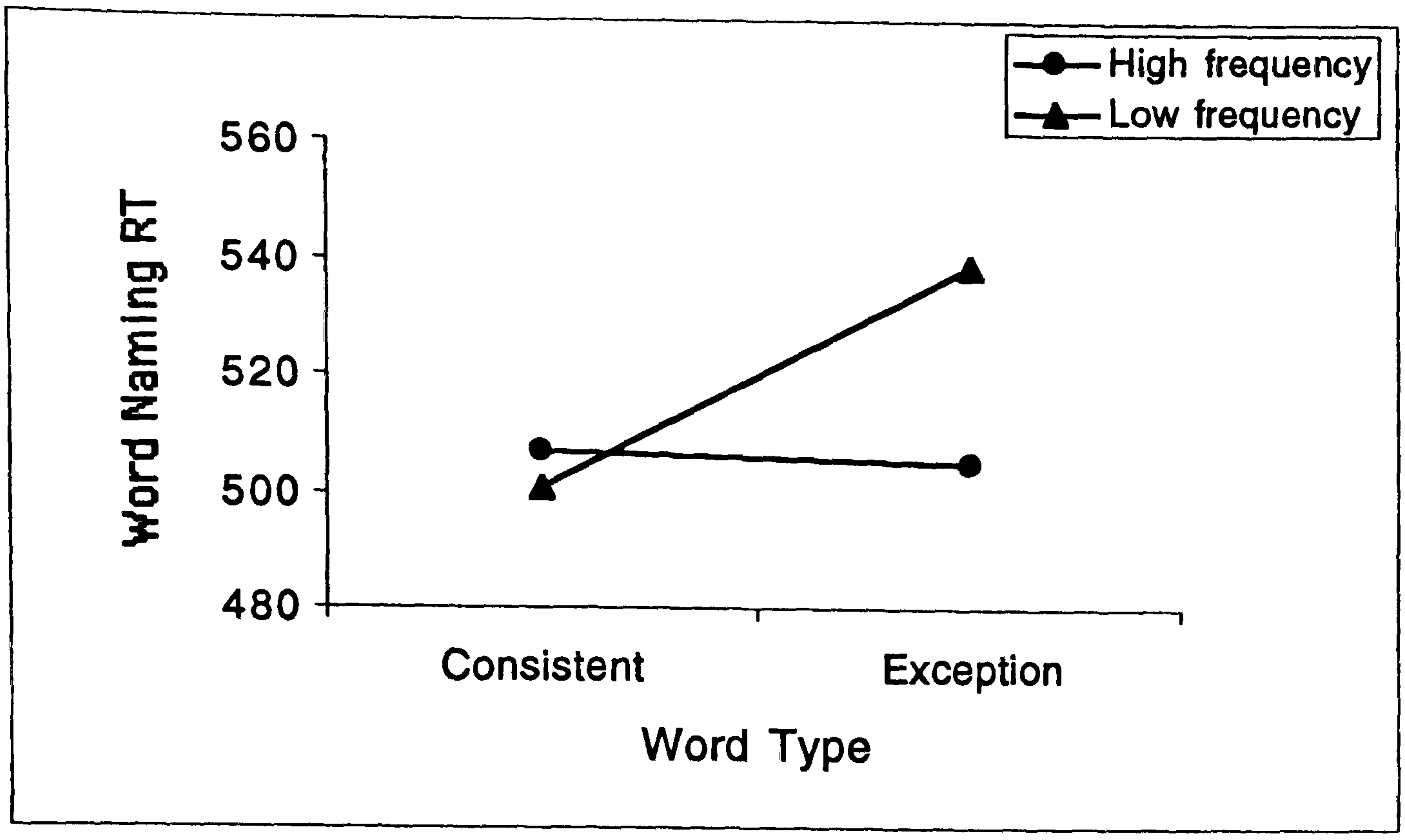

Figure 2.1 The interaction between word frequency and consistency in Experiment 1.

exception words was significant, $F(1,19) = 102.74$, $MSE = 14532.87$, $p<0.01$, but that the 2 ms difference for high frequency words was not, $F(1,19) = 0.14$, $MSE = 24.29$, n.s. Similarly, the 34 ms difference between high and low frequency exception words was significant, $F(1,19) = 100.15$, $MSE = 116.59$, $p<0.01$, as was the 6 ms difference between high and low frequency consistent words, $F(1,19) = 4.86$, $MSE = 62.48$, $p<0.05$, although clearly - as is shown in Figure 2.1 - the frequency effect is much larger for exception words than for consistent words.

2.2.2.2 Error analysis

The very low error rates preclude the use of analysis of variance. Analysis of the mispronunciation error rates using the

Wilcoxon signed ranks test revealed a significantly higher rate of errors to exception words than to consistent words, $Z = -2.45$, $p < .05$, and significantly more errors to low than to high frequency words, $Z = -3.28$, $p<0.01$. In addition, significantly more errors were made to low frequency exception words than to high frequency exception words, $Z = -3.01$, $p<0.01$, though the difference between the number of errors made to high versus low frequency consistent words was not significant, $Z = -1.69$, n.s.

2.2.3 Discussion

Experiment 1 showed that frequency affects word naming latencies even when AoA is controlled (Brysbaert et al., 2000; Gerhand & Barry, 1998; Morrison & Ellis, 2000). Frequency interacted with consistency, with low frequency exception words being named more slowly than high frequency exception words or consistent words of both high and low frequency. This is the same result as has been reported in many previous studies (Andrews, 1992; Brown & Watson, 1994; Hino & Lupker, 2000; Jared, 1997; Paap & Noel, 1991; Seidenberg, 1985; Seidenberg et al., 1984; Taraban & McClelland, 1987; Waters & Seidenberg, 1985), though this is the first study in which AoA has been controlled. Error rates were generally low, but most errors did occur to low frequency exception words.

2.3 Experiment 2 - Does AoA interact with spelling-sound consistency?

2.3.1 Introduction

Experiment 1 established that frequency genuinely does interact with spelling-sound consistency in word naming and that neither the main effect nor the interaction is due to any confounding with AoA. It remains possible, though, that AoA itself interacts with spelling-sound consistency. AoA has been shown many times to affect word naming speed, but its possible interaction with consistency has never been explored. Such an investigation could, however, allow real insight into the locus of the AoA effect in word naming. Experiment 2, therefore, compared the naming of sets of early and late acquired words with consistent or exceptional pronunciations that were matched on frequency, imageability, N and length.

2.3.2 Method

2.3.2.1 Participants

Thirty participants took part in Experiment 2. All were undergraduate or postgraduate students from the University of York who were native English speakers, with normal or corrected-to-normal vision, and who were paid for their participation.

2.3.2.2 Materials

The experimental stimuli consisted of 80 monosyllabic words taken from the larger set of 220 consistent and exception words previously rated for AoA in Experiment 1. These words were divided into four word sets of 20 - one set of early acquired consistent words, one set of late acquired consistent words, one set of early acquired exception words and one set of late acquired exception words. The early/late AoA division was based upon the median AoA rating of the full set of 220 previously rated words, which was 3.58 (approximating to 5-6 years of age). The sets were matched on frequency (Celex combined and Kucera & Francis (1967)), number of orthographic neighbours (N), word length and imageability (using the ratings from Experiment 1). The word sets used in Experiment 2 are shown in Appendix 2.

2.3.2.3 Procedure

The conditions of presentation and instructions were the same as those used in Experiment 1. Participants were given 30 practice trials which included words of all types to be used in the experiment (consistent and exception, early and late acquired). The orthographic bodies of these practice items were different from those included in the experimental trials.

2.3.3 Results

One hundred and fourteen out of a total of 2,400 responses (4.8%) were deleted from further analysis. Seventy of these (2.9%) were due to mispronunciations of the words, 40 (1.7%) were due to accidental activation of the voice key, while 4 (0.2%) were removed due to the extreme length of the reaction times (greater than 1,500 ms). The mean naming latencies of correct responses in the four word sets, and the total mispronunciation error rates (in percent) are shown in Table 2.2.

		Consistent		Exception	
		M	SD	M	SD
Early AoA					
	Reaction time	544	55	556	59
	% error	0.17		2.67	
Late AoA					
	Reaction time	551	52	583	67
	% error	1.00		7.83	

Table 2.2 Mean reaction times and standard deviations in ms, and total mispronunciation errors (%) for each word type in Experiment 2.

2.3.3.1 Reaction time analysis

Analysis of variance was carried out on the RT data with spelling-sound consistency and AoA as the two factors. In this analysis, the effect of consistency was significant, $F(1,29) = 37.99$, $MSE = 14020.07$, $p<0.01$, with naming RTs being faster to consistent words (548 ms) than to exception words (570 ms). The effect of AoA was also significant, $F(1,29) = 42.89$, $MSE = 8950.84$, $p<0.01$, with naming RTs being faster to early learned words (550 ms) than to later learned words (567 ms). In addition, the interaction between AoA and spelling-sound consistency was significant, $F(1,29) = 23.13$, $MSE = 3297.72$, $p<0.01$. The form of the interaction is shown in Figure 2.2. Simple main effects analyses showed that the 32 ms difference in RTs to late acquired consistent and exception words was significant, $F(1,29) = 47.05$, $MSE = 15458.48$, $p<0.01$, as was the smaller 12 ms difference between early acquired consistent and exception words, $F(1,29) = 10.15$, $MSE = 1859.31$, $p<0.01$. Conversely, the 27 ms difference in

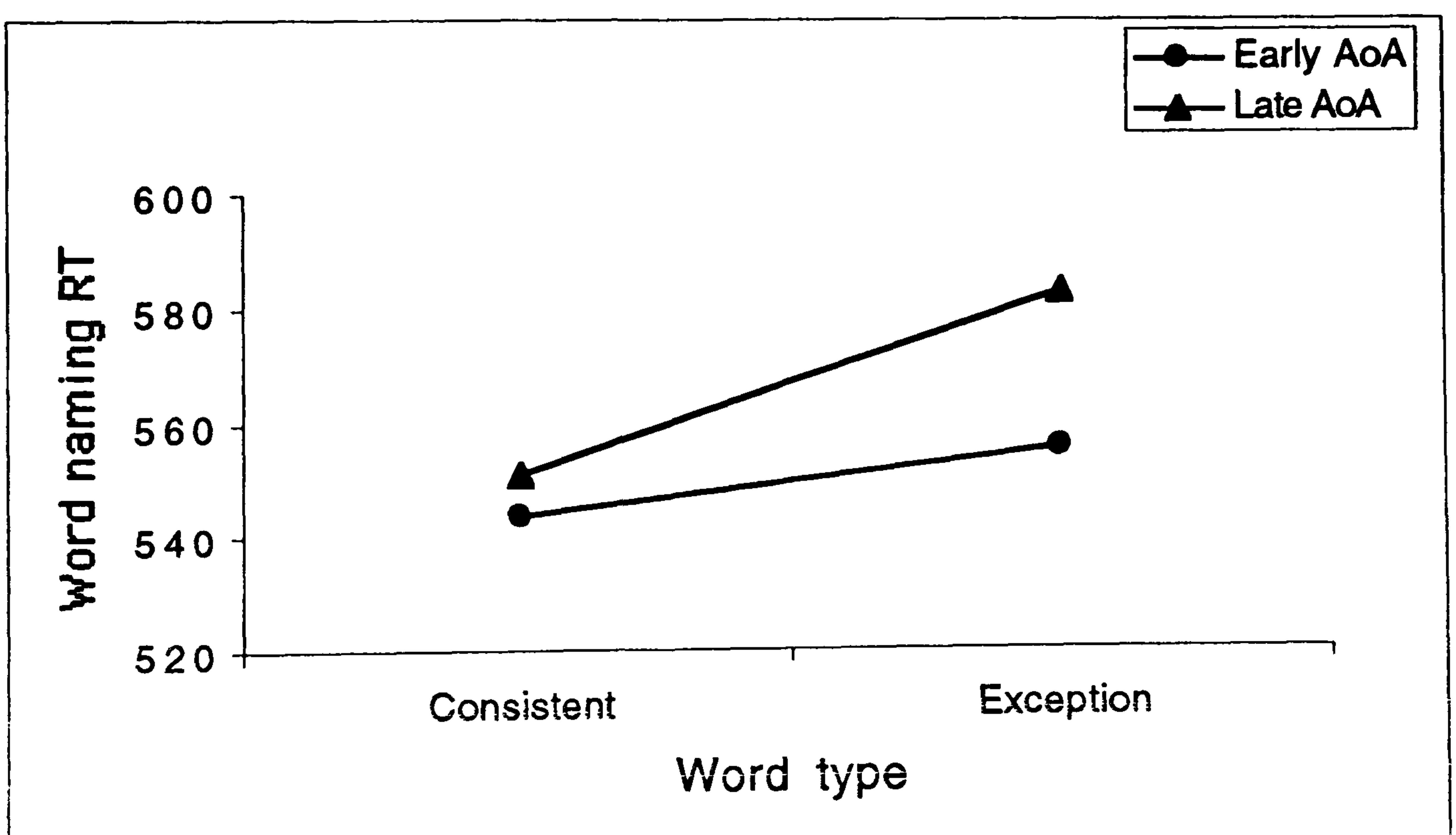

Figure 2.2 The interaction between AoA and consistency in Experiment 2.

naming RTs to early and late acquired exception words was significant, $F(1,29) = 48.41$, $MSE = 238.76$, $p<0.01$, as was the 7 ms difference in naming RTs to early and late acquired consistent words, $F(1,29) = 6.15$, $MSE = 112.47$, $p<0.05$. As Figure 2.2 clearly demonstrates, the strength of the AoA and consistency effects was stronger for exception words and late acquired words respectively, thus the interaction appears to be a consequence of the slower naming of late acquired exception words.

2.3.3.2 Error analysis

Analysis of the mispronunciation error rates using the Wilcoxon signed ranks test revealed a significantly higher rate of errors to exception words than to consistent words, $Z = -4.19$, $p<0.01$, and significantly more errors to late than to early acquired words, $Z = -3.65$, $p<0.01$. Significantly more errors were also made on late than early acquired exception words, $Z = -3.62$, $p<0.01$, but the difference between error rates to early and late acquired consistent words was not significant, $Z = -1.69$, n.s.

2.3.4 Discussion

Experiment 2 found a significant main effect of AoA on word naming speed, demonstrating once again that this variable affects word naming when frequency, imageability and other factors are controlled (e.g., Brown & Watson, 1987; Brysbaert, 1996; Brysbaert et al., 2000; Gerhand & Barry, 1998; Gilhooly & Logie, 1981a;

Morrison & Ellis, 1995; 2000). There was also a significant main effect of consistency. Importantly, there was a significant interaction between AoA and consistency, with late acquired exception words being named more slowly than early acquired exception words or consistent words of both early and late AoA. Again there were few errors, however, the majority of these did fall to late acquired exception words.

2.4 General Discussion

The two experiments reported here demonstrate that both frequency and AoA affect word naming speed. This is in support of the more recent studies discussed in Chapter One that report effects of both frequency and AoA in the word naming task (e.g. Brysbaert, 1996; Brysbaert et al., 2000; Gerhand & Barry, 1998; Morrison & Ellis, 2000). Spelling-sound consistency had a significant effect in both experiments, thus demonstrating the robustness of this word naming phenomenon in English. In addition, Experiment 1 demonstrated that frequency continues to interact with consistency when AoA is controlled and Experiment 2 demonstrated that AoA itself also interacts with spelling-sound consistency. These interactions suggest that both AoA and frequency exert their effects at the same level of processing as does the consistency effect.

In many connectionist models of word reading consistency is often presumed to affect the connection strengths between orthographic input and phonological output (cf. Harm &

Seidenberg, 1999; simulations 1-3 of Plaut et al, 1996; Seidenberg & McClelland, 1989), thereby suggesting that both frequency and AoA also affect this level of processing in single word reading.

However, in the final simulation of their model, Plaut et al. (1996) argued that the consistency effect is a consequence of the fact that the successful reading of low frequency exception words requires a contribution from the semantic pathway. This explanation would suggest that AoA and frequency may also influence word naming latencies because late acquired and/or low frequency exception words require help from the semantic system in order to be read successfully.

Chapter Three set out to investigate in some detail the locus of the consistency effect in word naming. The general discussion of Chapter Three will then provide a detailed discussion about the locus of the AoA and frequency effects in word naming in relation to the locus of the consistency effect.

CHAPTER THREE

DOES SPELLING-SOUND CONSISTENCY INTERACT WITH IMAGEABILITY?

3.1 Introduction

Chapter Two concluded that both frequency and AoA affect word naming speed and interact with spelling-sound consistency. This indicates that AoA and frequency have the same locus of effect as does the consistency effect. The aim of the current Chapter was, therefore, to investigate where consistency exerts its effect so that the locus of the AoA and frequency effects in word naming can be identified. Many connectionist models have successfully simulated the consistency effect by placing its effect in the connections between orthography and phonology with consistent words having stronger connections than exception words (e.g. Harm & Seidenberg, 1999; simulations 1-3 Plaut et al., 1996; Seidenberg & McClelland, 1989). However, the final simulation of Plaut et al.'s (1996) model implemented a contribution from a semantic pathway and thus explained the consistency effect as a consequence of the fact that exception words require a contribution from this semantic pathway in order to be read successfully.

The main justification for Plaut et al.'s (1996) final simulation was the report by Strain et al. (1995) that the semantic variable of imageability influences word naming and interacts with consistency. Strain et al.'s (1995) study manipulated consistency, frequency and imageability in the word naming task. In their Experiment 1, the results demonstrated significant main effects of both consistency and frequency, but no main effect of imageability. Similarly, while the interaction between consistency and frequency was significant, there was no significant interaction between consistency and imageability, although the three-way interaction between consistency, frequency and imageability did approach significance ($p = 0.09$). In their Experiment 2, Strain et al. (1995) manipulated consistency and imageability using only low frequency words. In contrast to their Experiment 1, Experiment 2 revealed significant main effects of both consistency and imageability. The interaction between consistency and imageability was also significant. The form of this interaction was such that low frequency exception words were read aloud particularly slowly if they were also of low imageability, but high imageability exception words were read aloud as quickly as were consistent words of either high or low imageability. Similar results were reported in Strain et al.'s (1995) Experiment 3 in which participants were encouraged to name the item within 350 ms. Again the interaction between imageability and consistency was significant. In all three of Strain et al.'s (1995) experiments the majority of errors were to low frequency, low imageability, exception words.

The results of Strain et al.'s (1995) study have clearly had fundamental theoretical impact, resulting in Plaut et al.'s (1996) simulation of a semantic contribution to the successful reading of low frequency exception words. However, there are a number of problems with Strain et al.'s (1995) study, the most important one in terms of the present interests being the fact that Strain et al.'s (1995) word sets were not controlled for AoA. Imageability is highly inter-correlated with AoA, such that high imageability words are mainly early acquired, whilst low imageability words are mainly late acquired. It is, therefore, possible that the imageability effects reported by Strain et al. (1995) are confounded with AoA. This possibility is made more real by the findings of a number of studies that have reported a non-significant effect of imageability on word naming latencies once AoA (and frequency) have been controlled (e.g., Brown & Watson, 1987; Brysbaert et al., 2000; V. Coltheart et al., 1988; Gilhooly, 1984; Gilhooly & Logie, 1981a). Furthermore, a re-analysis of Strain et al.'s (1995) results by Gerhand (1998) reported that the low imageability words in Strain et al.'s (1995) study were of significantly later AoA than the words in the high imageability sets. When Gerhand (1998) added AoA as a covariate into an analysis of the naming latencies to the exception words of Strain et al.'s (1995) Experiment 2, the effect of imageability disappeared.

All of the above evidence suggests that not only might the main effect of imageability reported by Strain et al. (1995) actually reflect an effect of AoA, but the reported interaction between imageability and consistency may also reflect what is, in actual fact, an interaction between AoA and consistency. This possibility is made more real by the results of the present Experiment 2 in Chapter Two that revealed a significant interaction between AoA and consistency.

Given the theoretical importance of Strain et al.'s (1995) results on the modelling and the presumed locus of the consistency effect in Plaut et al.'s (1996) model, identifying whether the reported effects of imageability are real, or are just an artefact of AoA, is of great importance to the present thesis. Consequently, the experiments in the current Chapter set out to investigate the effects of imageability and its relationship with consistency in the word naming task once AoA (and frequency) are controlled. Experiment 3 examined the effect of imageability and consistency on word naming with AoA controlled. Experiment 4 also manipulated imageability and consistency with AoA controlled, but used only words of low frequency. Experiment 5 set out to replicate Experiment 2 of Strain et al. (1995). These experiments should allow a clearer understanding of the locus of the consistency effect and, therefore, allow identification of the AoA and frequency effects in word naming.

3.2 Experiment 3 - Does imageability interact with spelling-sound consistency?

3.2.1 Method

3.2.1.1 Participants

Twenty participants took part in Experiment 3. All were undergraduate or postgraduate students from the University of York who were native English speakers, with normal or corrected-to-normal vision, and who were paid for their participation.

3.2.1.2 Materials and Procedure

The experimental stimuli consisted of 80 monosyllabic words taken from the larger set of 220 consistent and exception words previously rated for imageability and AoA in Experiment 1 of Chapter Two (cf. Section 2.2.1.3). These words were divided into four word sets with 20 high imageability consistent words, 20 low imageability consistent words, 20 high imageability exception words, and 20 low imageability exception words. The division into high and low imageability groups was based upon the median imageability rating of the original set of 220 words, which was 4.58. These word sets were matched on AoA, frequency (Celex combined and Kucera & Francis (1967) counts), N and word length (number of letters). The majority of the words were of relatively low frequency. The word sets used in Experiment 3 are shown in Appendix 3.

The experimental design and procedure were otherwise exactly the same as in Experiments 1 and 2 of Chapter Two. Thirty practice items were used that reflected the characteristics of the words in the current experiment (consistent and exception, high and low imageability items). The orthographic bodies of these practice items were different from those of the experimental items.

3.2.2 Results

Seventy three out of a total of 1,600 responses (4.5%) were deleted from further analysis. Fifty one of these (3.2%) were due to mispronunciations of the words, 17 (1%) were due to accidental activation of the voice key, while 5 (0.3%) were removed due to the extreme length of the reaction times (greater than 1,500 ms). The mean naming latencies of correct responses in the four word sets, and the total mispronunciation error rates (in percent) are shown in Table 3.1.

3.2.2.1 Reaction time analysis

Analysis of variance was carried out on the RT data, with spelling-sound consistency and imageability as the two factors. The effect of consistency was significant F (1,19) = 45.26, MSE = 9897.25, $p<0.01$, with naming RTs being faster to consistent words

	Consistent		Exception	
	M	SD	M	SD
High imageability				
Reaction time	520	54	543	65
% error	0.00		6.00	
Low imageability				
Reaction time	518	59	538	69
% error	2.00		4.75	

Table 3.1 Mean reaction times and standard deviations in ms, and total mispronunciation errors (%) for each word type in Experiment 3.

(519 ms) than to exception words (541 ms). In contrast, the 4 ms difference in naming RTs to high and low imageability words was not significant, F (1,19) = 1.57, MSE = 242.21, n.s. The interaction between consistency and imageability was also non-significant, F (1,19) = 0.37, MSE = 44.82, n.s.

3.2.2.2 Error analysis

Analysis of the mispronunciation error rates using the Wilcoxon signed ranks test revealed a significantly higher rate of errors to exception words than to consistent words, Z = -3.41, $p<0.01$, but no difference in the number of errors made to words of high or low imageability, Z = - 0.60, n.s. In addition, there was no difference in the number of errors made to exception words of high or low imageability Z = -1.02, n.s., or in the number of errors made to high and low imageability consistent words, Z = -0.91, n.s.

3.2.3 Discussion

With word sets matched on frequency and AoA, there was no significant effect of imageability and no interaction between imageability and consistency within the RT data. Similarly, whilst more errors were made to exception than consistent words, there was no difference in the number of errors made to high and low imageability words. The results do not, therefore, lend support to the claims of Strain et al. (1995). However, the frequencies of the words used in the present Experiment 3 (0 - 181 occurrences per million words of English, with a mean of 19.39) were not as consistently low as those employed in Strain et al.'s (1995) Experiment 2 and it may be for that reason (rather than the controlling of AoA) that imageability failed to reach significance in the present Experiment 3. Indeed, when Strain et al. (1995) used words of varied frequency in their Experiment 1, no effect of imageability was reported. In order to conclude that the lack of an imageability effect in Experiment 3 was because AoA was controlled, therefore, the frequency of the experimental items should be of the same low frequency as in Strain et al.'s (1995) Experiment 2. Consequently, the present Experiment 4 set out to test whether the semantic variable of imageability continues to have an effect on single word naming and to interact with consistency, even when AoA is controlled, when the items are of only low frequency.

3.3 Experiment 4 - Does imageability interact with spelling-sound consistency *and* frequency?

3.3.1 Introduction

Experiment 4 set out to investigate the effects of imageability and consistency for words matched on AoA, length, N and frequency, using words with frequencies of 12 or less occurrences per million words of English in both the Celex combined and Kucera and Francis (1967) word frequency counts. These stimuli were more in line with the stimuli used in Strain et al.'s (1995) Experiment 2 where effects of imageability were reported. In addition, the same number of participants (40) as used in Strain et al.'s (1995) Experiment 2 were recruited for the present experiment.

3.3.2 Method

3.3.2.1 Participants

Forty participants took part in Experiment 4. All were undergraduate or postgraduate students from the University of York who were native English speakers, with normal or corrected-to-normal vision, and who were paid for their participation.

3.3.2.2 Materials and Procedure

The experimental stimuli consisted of 72 monosyllabic words. These were taken from the original set of 220 consistent and exception words previously rated in Chapter Two (cf. Section 2.2.1.3), plus an additional set of 80 words for which AoA and imageability ratings were obtained using the same scales as described in Chapter Two. The experimental stimuli were divided into four word sets of 18 - one set of high imageability consistent words, one set of low imageability consistent words, one set of high imageability exception words, and one set of low imageability exception words. The division into high and low imageability groups was based upon the median imageability value (4.58). The words all had frequencies of 12 or less occurrences per million in the Celex combined and the Kucera and Francis (1967) word frequency counts. The sets were matched on frequency, AoA, N and number of letters. The word sets used in Experiment 4 are shown in Appendix 4.

The experimental design and procedure were the same as in Experiments 1-3. The 30 practice items used in the present experiment had the same characteristics as those of the experimental items (consistent and exception, high and low imageability items of low frequency).

3.3.3 Results

One hundred and seventy seven out of a total 2,880 responses (6.3%) were deleted from further analysis. One hundred and three of these (3.6%) were due to mispronunciations of the words, 62 (2.2%) were due to accidental activation of the voice key, while 12 (0.4%) were removed due to the extreme length of the reaction times (greater than 1,500 ms). The mean naming latencies of correct responses in the four word sets, and the total mispronunciation error rates (in percent) are shown in Table 3.2.

		Consistent		Exception	
		M	SD	M	SD
High imageability					
	Reaction time	544	62	588	79
	% error	0.14		7.64	
Low imageability					
	Reaction time	555	69	583	79
	% error	1.67		4.86	

Table 3.2 Mean reaction times and standard deviations in ms, and total mispronunciation errors (%) for each word type in Experiment 4.

3.3.3.1 Reaction time analysis

Analysis of variance was carried out on the RT data with spelling-sound consistency and imageability as the two factors. This analysis revealed a significant effect of consistency, $F(1,39) = 79.28$, $MSE = 51831.45$, $p<0.01$, with naming RTs being faster to consistent words (555 ms) than to exception words (583 ms). However, the 3 ms difference in naming RTs between high and low imageability words was non-significant, $F(1,39) = 1.91$, $MSE = 307.48$, n.s. The interaction between consistency and imageability was significant, $F(1,39) = 12.30$, $MSE = 2621.27$, $p<0.01$, but the form of this interaction was quite different from that reported by Strain et al. (1995). Indeed, simple main effects analyses showed that the 44 ms difference in naming speed between high imageability consistent and exception words was significant, $F(1,39) = 86.42$, $MSE = 38882.46$, $p<0.01$, as was the 28 ms difference between low imageability consistent and exception words, $F(1,39) = 37.34$, $MSE = 15570.27$, $p<0.01$, though the consistency effect was numerically much larger for the high imageability words. In contrast, the 11 ms difference in naming speeds between high and low imageability consistent words was significant, $F(1,39) = 17.63$, $MSE = 2362.14$, $p<0.01$, however, the 5 ms difference in naming RTs between high and low imageability exception words was not significant, $F(1,39) = 2.36$, $MSE = 566.61$, n.s.

The present interaction between imageability and consistency is clearly in the opposite direction to that reported by Strain et al. (1995). As Figure 3.1 shows, rather than slower naming of low imageability than of high imageability exception words, the present interaction was a consequence of slower naming of low imageability *consistent* words than of high imageability *consistent* words. The

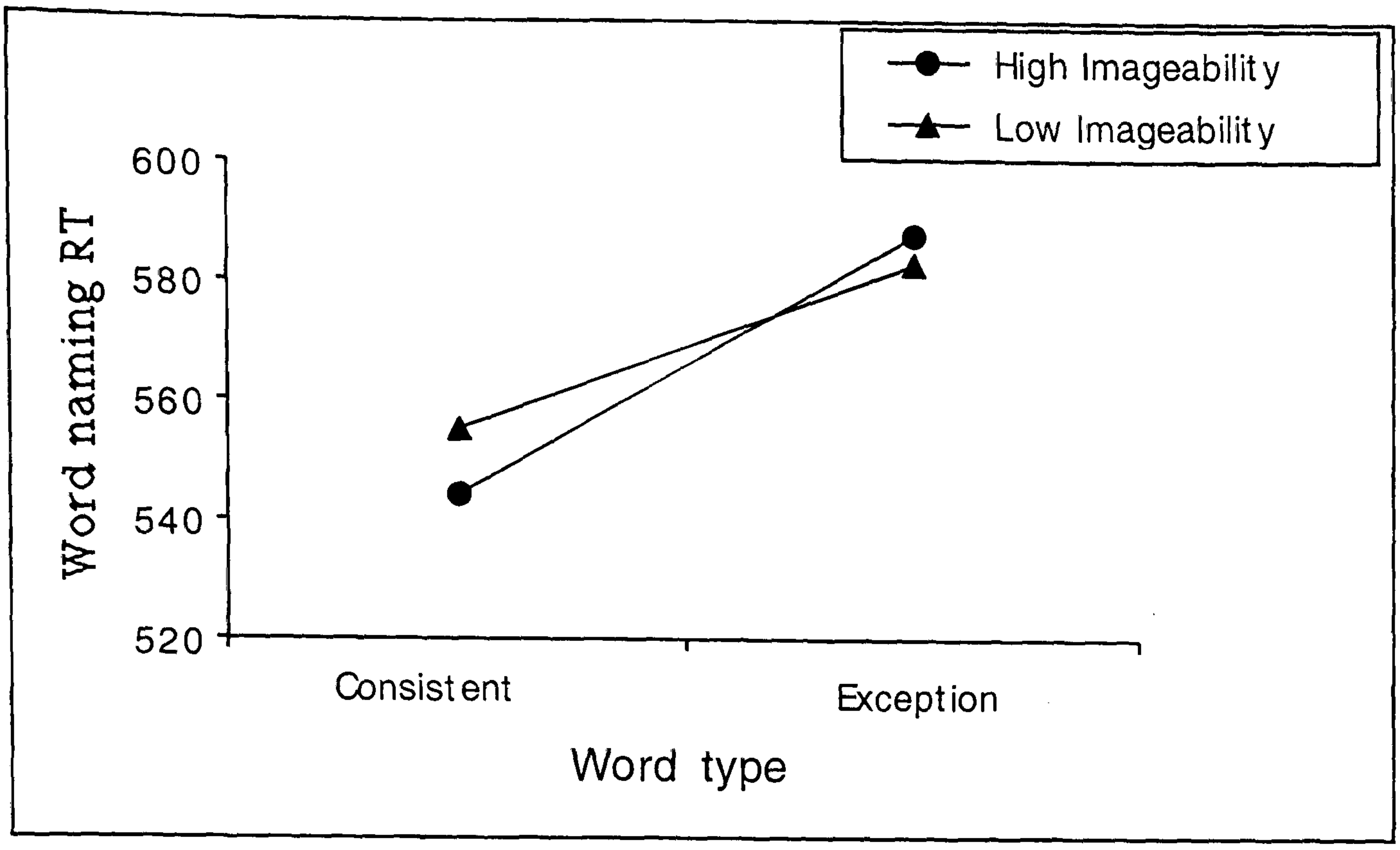

Figure 3.1 The interaction between imageability and consistency in Experiment 4.

cause of this interaction appears to be the consequence of the slow naming of a small number of low imageability consistent items (notably SPECK and SPURT). Indeed, with the RTs to these two words removed[1] from the analysis the mean RT for low imageability consistent words was reduced by 10 ms to 545ms thus causing the interaction between imageability and consistency to become non-significant, F (1,39) = 1.50, MSE = 299.75, n.s.

3.3.3.2 Error analysis

Analysis of the mispronunciation error rates using the Wilcoxon signed ranks test revealed a significantly higher rate of

[1] The removal of these two items did not change the values of the low imageability consistent word set characteristics to any significant extent.

errors to exception words than to consistent words, $Z = -4.99$, $p<0.01$, but no difference in the number of errors made to words of high or low imageability, $Z = -1.00$, n.s. However, more errors were made to exception words of high imageability than to exception words of low imageability, $Z = -2.21$, $p<0.05$, and more errors were also made to low imageability consistent words than to high imageability consistent words $Z = -2.80$, $p<0.01$.

3.3.4 Discussion

Experiment 4 found an effect of spelling-sound consistency on word naming speed. However, with AoA controlled, imageability had no main effect on word naming speed in this experiment. This result is in direct contrast to the results of Strain et al.'s (1995) Experiment 2 that reported significantly faster naming of high than low imageability words. This result is, however, in keeping with the results of previous studies of word naming that have failed to find an effect of imageability when AoA and frequency are controlled (e.g., Brown & Watson, 1987; Brysbaert et al., 2000; V. Coltheart et al., 1988; Ellis & Morrison, 2000; Gilhooly & Logie, 1981a).

Experiment 4 did find an interaction between imageability and consistency, but this interaction was quite different in character to that reported by Strain et al. (1995) - instead of a difference in naming RT between high and low imageability exception words, Experiment 4 found a difference between high and low imageability consistent words. Moreover, inspection of the RTs to individual items in the present Experiment 4 indicated that the imageability by consistency interaction appeared to be the consequence of the slow naming of a small number of low imageability consistent items. Once those items were removed from the analysis, the interaction between imageability and consistency disappeared. Error rates showed no indication of an imageability by consistency interaction in the direction predicted by the results of the Strain et al. (1995) study.

Like Strain et al.'s (1995) Experiment 2, the present Experiment 4 used only words of low frequency, so the difference between the present results and those of Strain et al. (1995) cannot be attributed to any differences in the frequency of the items used (as may have been the case in Experiment 3). The results of this experiment thus suggest that once AoA (and frequency) are controlled, imageability no longer affects word naming speed, not even for low frequency exception words. This finding, therefore, calls into question Plaut et al.'s (1996) justification for a contribution from semantics in the successful reading of low frequency exception words.

3.4 Experiment 5 - A replication of Strain et al.'s (1995) Experiment 2

3.4.1 Introduction

The present Experiment 4 failed to find an effect of imageability on word naming speed, nor was there any indication of an interaction between imageability and consistency in the direction predicted by the results of Strain et al.'s (1995) study. There were, however, some differences in design and procedure between the present Experiment 4 and Strain et al.'s (1995) Experiment 2 that may have played some role in explaining the different results of the two experiments.

One difference is in terms of the definition of consistency employed in these two experiments. Whilst the present Experiment 4 defined consistent and exception words according to the consistency of the spelling-sound correspondences of the word body, Strain et al. (1995) combined this definition of consistency with one of grapheme-phoneme regularity in order to differentiate their consistent and exception words. Thus in Strain et al.'s (1995) Experiment 2, items like CHASM were classified as an exception word because the regular pronunciation of CH (i.e. the most common pronunciation) is as in CHASTE and CHARM. However, on the basis of the consistency definition employed in the current Experiment 4, CHASM is a member of a small consistent word family that shares its pronunciation with all other words ending in -ASM (cf., SPASM).

A further difference between Strain et al.'s (1995) Experiment 2 and the current Experiment 4 is the inclusion of two syllable words in Strain et al.'s (1995) word sets. The definition of consistency for two syllable words is somewhat complex, however (e.g. Jared & Seidenberg, 1990). As a consequence, some of the two syllable words in Strain et al.'s (1995) sets are irregular according to grapheme-phoneme correspondence rules, but could be classified as consistent. For example, Strain et al. (1995) included items like BOULDER and TREASURE in their exception word sets. This is because the pronunciation of OU and EA in these words are at odds with the more common and thus regular pronunciation of these graphemes as in MOUSE, SOUTH; BEAT, HEAT. However, in terms of consistency of pronunciation, such words could be grouped with other two syllable words that share the same spelling of the word body, such as, MOULDER, SHOULDER and SMOULDER; MEASURE and PLEASURE, thus making these words part of a small consistent word family in which all word pronunciations rhyme. Clearly, therefore, the inclusion of one and two syllable exception words that have an irregular grapheme-phoneme correspondence, yet consistent pronunciation of their word bodies in Strain et al.'s (1995) Experiment 2 creates an anomaly between the definition of consistency as it is in Experiment 4 of the current Chapter and as it is in Experiment 2 of Strain et al. (1995).

Given the contrast between Strain et al.'s (1995) findings and those of the present Experiment 4, and the importance of establishing whether or not imageability plays a part in determining word naming speed in the current thesis, Experiment 5 attempted a replication of Strain et al.'s (1995) Experiment 2 that was as close as possible. As well as using the same items, the same font for presenting the words and the same procedure as regards exposure durations, number of practice trials, etc were employed. In addition, participants with a wider range of ages than in the previous experiments were recruited (the participants in Strain et al.'s (1995) Experiment 2 were aged 22 to 70 years).

This replication should allow an exploration of the possibility that imageability does have an effect on word naming speed under the conditions of Strain et al.'s (1995) study. If this is the case, the present replication will also then allow an analysis of the results with AoA as a covariate to determine whether imageability continues to have an effect under these conditions when AoA is controlled.

3.4.2 Method

3.4.2.1 Participants

Forty participants took part in Experiment 5. Participants consisted of undergraduate and postgraduate students and members of staff from the University of York who were native

English speakers, with normal or corrected-to-normal vision. The students were paid for their participation. The mean age of the participants was 27 years (range 18 to 62).

3.4.2.2 Materials

The experimental stimuli consisted of the 64 monosyllabic and disyllabic low frequency words used in Strain et al.'s (1995) Experiment 2 (16 high imageability consistent words, 16 low imageability consistent words, 16 high imageability exception words, and 16 low imageability exception words). AoA ratings for the 64 experimental stimuli were obtained from 20 undergraduate and postgraduate students at the University of York. The instructions and rating scale used were exactly the same as those used for the ratings in Chapter Two (cf. Section 2.2.1.3). The word sets used in Experiment 5 are shown in Appendix 5.

3.4.2.3 Procedure

The procedure and experimental design for this experiment followed those of Strain et al. (1995) as precisely as possible. The stimuli were presented in black, lowercase, 24 point Geneva font. Participants were presented with 26 practice trials that included monosyllabic and disyllabic words of medium frequency (between 30 and 70 occurrences per million; Kucera & Francis, 1967). Following on from this, the experimental stimuli were presented in two blocks separated by a short break. The two experimental blocks contained equal numbers of high and low imageability consistent and exception words and each block began with three medium frequency filler items. The order of presentation of these blocks was counterbalanced across participants. Conditions of presentation and instructions were otherwise the same as in the previous experiments, with each trial beginning with a fixation point for 750 ms after which the target word was displayed until it was pronounced, the intertrial interval was 1,000 ms (these were the same conditions as employed by Strain et al. (1995)).

3.4.3 Results

Two hundred and fourteen out of a total 2,560 responses (8.36%) were deleted from further analysis. One hundred and fifty six of these (6.1%) were due to mispronunciations (regularisations) of the target word, 52 (2.03%) were due to accidental activation of the voice key, and 6 (0.23%) were deleted due to the extreme length of their reaction times (greater than 1,500 ms)[2]. The mean naming latencies of the correct responses in the four word sets, and the total regularisation error rates (in percent) are shown in Table 3.3 along with the comparable data from Strain et al.'s (1995) Experiment 2[3].

3.4.3.1 Reaction time analysis

Analysis of variance was carried out on the RT data with spelling-sound consistency and imageability as the two factors. This analysis revealed a significant effect of consistency, $F(1,39) = 11.05$,

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[2] Strain et al. (1995) employed a different strategy of dealing with their errors and deleting outliers. Error RTs were deleted, but then replaced by that individual's average RT for that particular word set. Outliers were determined according to the test described by Johnson & Leone (1968) (see Strain et al.'s Experiment 1 for a detailed explanation of their test). These outliers were similarly replaced by that individuals mean RT for that particular word set. However, whether this strategy or the one employed in the current results section is used makes no difference to the results of the current analyses or the covariate analysis. The results have been reported according to the strategy of dealing with errors reported in the previous experiments of this Chapter to maintain cohesion between the present results and those of Experiments 3 and 4 in this Chapter.

[3] Strain et al. (1995) only report regularisation errors in their data. Consequently, the errors reported in Table 3.3 and those included in the error analysis in Experiment 5 are the regularisation errors only (the occurrence of other types of mispronunciation errors in Experiments 1 - 5 were, in any case, uncommon).

	Consistent		Exception	
	M	SD	M	SD
High imageability				
Reaction time	554	56	552	59
Strain et al.	*535*		*537*	
% error	0.00		4.22	
Strain et al.	*0.00*		*2.03*	
Low imageability				
Reaction time	570	62	595	71
Strain et al.	*542*		*579*	
% error	0.00		20.16	
Strain et al.	*0.00*		*14.06*	

Table 3.3 Mean reaction times and standard deviations in ms, and total regularisation errors (%) for each word type in Experiment 5. Comparable figures from Strain et al.'s (1995) Experiment 2 are shown in italics.

MSE = 5213.57, p<0.01, with consistent words being named faster (562 ms) than exception words (574 ms). The effect of imageability was also significant, *F*(1,39) = 116.96, *MSE* = 34800.27, p<0.01, with high imageability words being named faster (553 ms) than low imageability words (583 ms). The interaction between imageability and consistency was also significant, *F*(1,39) = 28.89, *MSE* = 7001.18, p<0.01. The form of this interaction can be seen in Figure 3.2. Simple main effects analysis revealed that the 25ms difference in naming latencies to low imageability consistent and exception

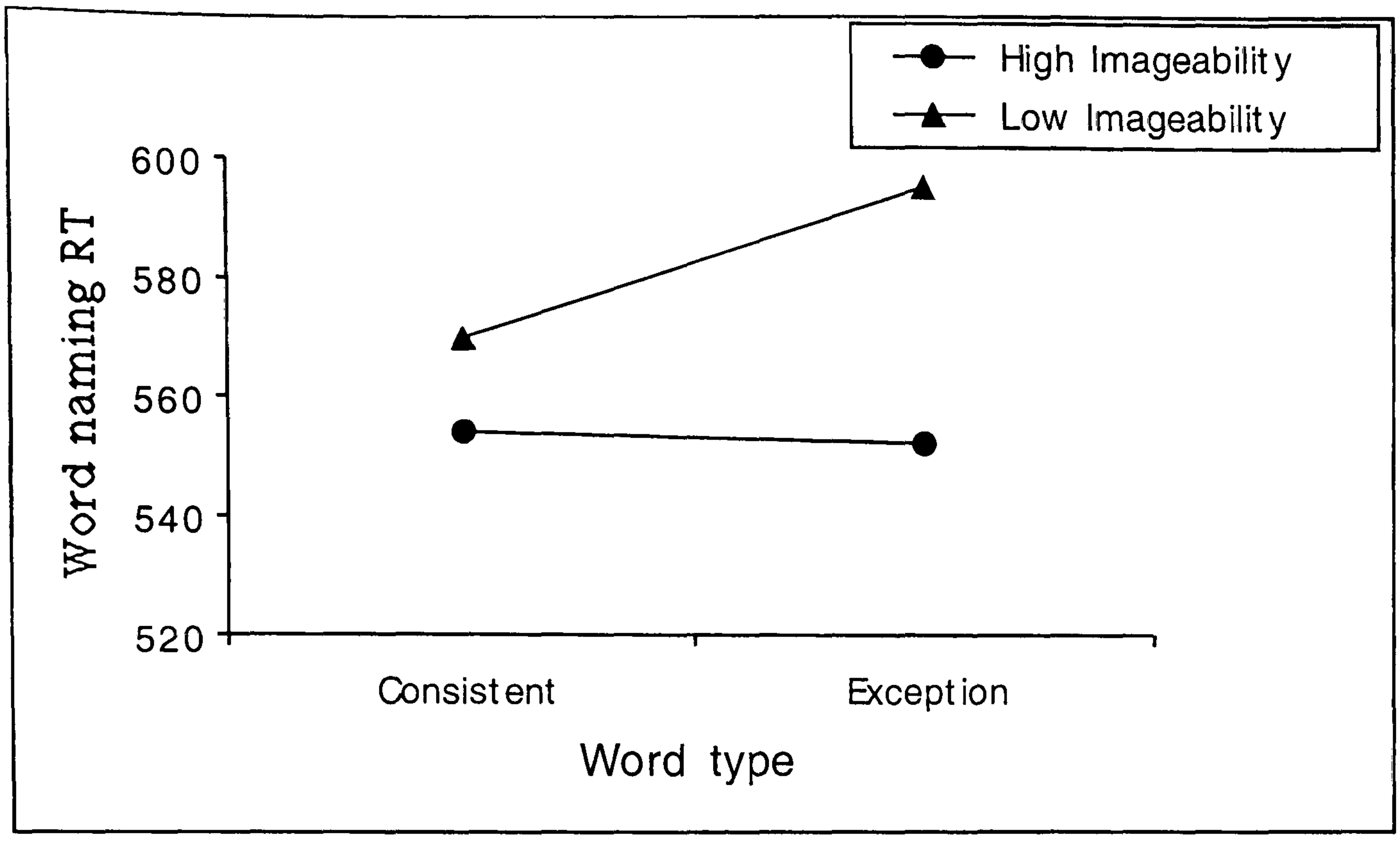

Figure 3.2 The interaction between imageability and consistency in Experiment 5.

words was significant, $F(1,39) = 28.18$, $MSE = 12149.00$, $p < 0.01$, while the 2 ms difference between high imageability consistent and exception words was not significant, $F(1,39) = 0.23$, $MSE = 65.76$, n.s. Similarly, the 43ms difference in naming RTs between high and low imageability exception words was significant, $F(1,39) = 95.74$, $MSE = 36509.79$, $p<0.01$, as was the 16ms difference between high and low imageability consistent words, $F(1,39) = 33.38$, $MSE = 5291.66$, $p<0.01$. The size of the imageability effect was much larger for the exception words, however.

3.4.3.2 Error analysis

Regularisation errors were subjected to a Wilcoxon signed ranks analysis. This analysis revealed a significantly higher rate of errors to exception words than to consistent words, $Z = -3.18$, $p<0.01$, and a significantly higher rate of errors to low imageability items than to high imageability items, $Z = -2.98$, $p<0.01$. In addition, significantly more errors were made to low imageability exception words than to high imageability exception words, $Z = -2.98$, $p<0.01$, while there was no significant difference in the number of errors made to high and low imageability consistent words, $Z = -0.00$, n.s.

3.4.4 Reanalyses of Experiment 5 and Strain et al.'s (1995) Experiment 2 with AoA controlled

3.4.4.1 Comparison between the results of the present Experiment 5 and the results of Strain et al.'s (1995) Experiment 2

The similarity of effects in the by-subjects analysis suggests that there are no differences in the data between the current Experiment 5 and Strain et al.'s (1995) own Experiment 2. Table 3.3 allows a direct comparison between these two studies. Whilst t-tests on the RT data reveal a significant difference between the overall mean RTs of these two experiments, $t(1,126) = 2.58$, $p = 0.01$, with slower naming RTs in Experiment 5 than in Strain et al.'s (1995) Experiment 2, this difference was equal over all four word sets. Furthermore, the pattern of the RTs is very similar: in both studies there was no difference in naming RTs to high imageability consistent and exception words, and the slowest RTs in both cases were to low imageability exception words.

Similarly, whilst the regularisation error rates in the present Experiment 5 were higher than in Strain et al.'s (1995) study, there was no significant difference in overall regularisation error rates, $t(1,126) = 1.04$, n.s. The distribution of errors was also very similar, with the majority falling to low imageability exception words in both studies. Appendix 5 shows the distribution of these errors over the individual items. Where there were differences between the regularisation error rates of the two studies for any particular word, they can be mostly attributed to either differences in regional pronunciations of some words, (e.g. MISCHIEF has an exceptional pronunciation in southern accents, "mischiff", but is pronounced consistently in most Northern accents, "mischeef"), or simple unfamiliarity of some items - particularly in written form - to the participants in Experiment 5 (e.g. CACHE, SLEIGHT, STINGY).

3.4.4.2 Reanalyses of the data from the present Experiment 5 with AoA as a covariate

In order to check whether imageability was confounded with AoA in the word sets used by Strain et al. (1995) in their Experiment 2, and in the present Experiment 5, an analysis of variance was carried out with the new AoA ratings for each word in the four sets as the dependent variable, and with consistency and imageability values as the independent variables. There was no significant difference in the AoA values between the consistent and exception words, although this difference did approach significance, $F(1,15) = 4.02$, $MSE = 2.11$, $p=0.063$. However, the difference in AoA values between high and low imageability items was highly significant, $F(1,15) = 71.47$, $MSE = 69.99$, $p<0.01$, with the mean AoA for the high imageability words (3.35, equivalent to an estimated learning age of 5 to 6 years) being earlier than for the low imageability words (5.44, equivalent to an estimated learning age of 9 to 10 years). This confound is in the same direction as that reported by Gerhand (1998) using different AoA ratings. The pattern of these differences can be seen in Figure 3.3.

Although the Introduction of Chapter Two argued against the need for routine analyses of variance by-items, analysis of

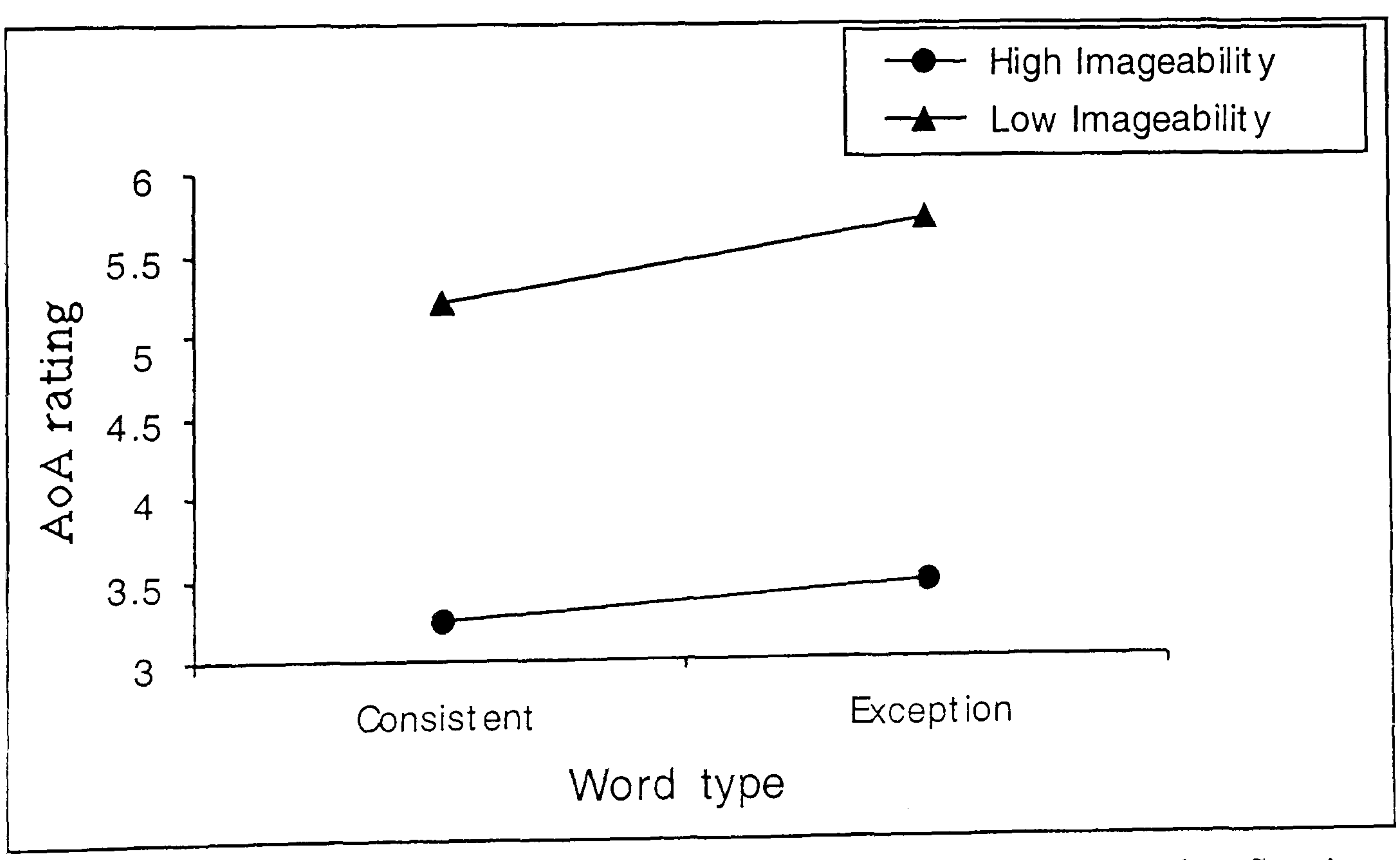

Figure 3.3 The relationship between the word sets in Strain et al.'s (1995) Experiment 2 and their rated AoA values.

covariance is based on that form of analysis. In the by-items analysis of naming RTs from Experiment 5, the main effect of imageability was significant, $Fi(1,63) = 6.31$, $MSE = 13262.11$, $p<0.05$[4]. However, both the main effect of consistency, $Fi(1,63)= 1.22$, $MSE = 2569.60$, n.s., and the interaction between consistency and imageability, $Fi(1,63) = 1.34$, $MSE = 2806.48$, n.s., were non-significant. When AoA was entered as a covariate, the consistency effect and the interaction between consistency and imageability did not attain significance, $Fi(1,63)= 2.86$, $MSE = 5278.24$, n.s., and $Fi(1,63)= 2.09$, $MSE = 3869.21$, n.s., respectively. However, the previously significant effect of imageability disappeared completely, $Fi(1,63) = 0.08$, $MSE = 153.72$, n.s., while the effect of AoA was significant, $Fi(1,63) = 9.30$, $MSE = 17175.14$, $p<0.01$. The adjusted means for each word type in the covariate analysis can be seen in Appendix 6.

3.4.4.3 Reanalysis of the data from Strain et al.'s (1995) Experiment 2 with AoA as a covariate.

A similar pattern of results was found in a reanalysis of the data from Strain et al.'s (1995) Experiment 2. Using the RTs reported by Strain et al. (1995) for their Experiment 2, by-items analysis of variance revealed the same significant main effects of

[4] The problem with using by-items analyses is the increased risk of a Type II error. However, given that the variable of interest here - imageability - was significant in this analysis, the use of by-items analysis for the covariate analysis is appropriate.

both consistency, $Fi(1,63) = 4.22$, $MSE = 5948.27$, $p<0.05$, and of imageability, $Fi(1,63) = 6.84$, $MSE = 9628.52$, $p<0.05$, that Strain et al.'s (1995) analysis did. In addition, the interaction between imageability and consistency approached significance, as reported by Strain et al. (1995), $Fi(1,63) = 3.57$, $MSE = 5023.27$, $p=0.064$. A reanalysis of this data was then carried out with the new AoA ratings as a covariate. The adjusted means for each word type in this analysis can be seen in Appendix 6. The results of this analysis revealed that whilst the effect of consistency remained significant, $Fi(1,63) = 9.12$, $MSE = 10040.97$, $p<0.01$, the effect of imageability disappeared, $Fi(1,63) = 0.85$, $MSE = 938.80$, n.s. As in the analysis of the data from Experiment 5, the effect of AoA was significant, $Fi(1,63) = 17.78$, $MSE = 19563.83$, $p<0.01$. In this analysis the interaction between imageability and consistency became significant, $Fi(1,63) = 5.91$, $MSE = 6507.27$, $p<0.05$[5].

3.4.5 Discussion

Experiment 5 attempted an exact replication of Strain et al.'s (1995) Experiment 2. The results found in the straightforward

[5] AoA is not controlled for in the assessment of the interaction in this analysis, therefore, the significance of this interaction does not provide support for the imageability effect. Moreover, inspection of the adjusted means indicates that the emerging interaction between imageability and consistency in this analysis might be caused by the faster naming of low imageability consistent words than of high imageability consistent words once AoA is controlled. This is not the form of interaction that would be predicted from the results of Strain et al. (1995).

analyses support those reported by Strain et al. (1995), with significant main effects of both consistency and imageability, and an interaction between imageability and consistency. The form of this interaction was the same as that reported by Strain et al. (1995), with low imageability exception words being named significantly more slowly than high imageability exception words and consistent words of both high and low imageability.

However, an analysis of variance with AoA as the dependent variable revealed that the high imageability items in this study had significantly earlier AoA values than did the low imageability words. Moreover, when AoA was entered as a covariate in a reanalysis of both the current Experiment 5 RT results and the those of Strain et al.'s (1995) Experiment 2, the previously significant effect of imageability disappeared completely. The effect of AoA was highly significant in both cases. These results are similar to those reported by Gerhand (1998), however, the current analysis was based on all the words in Strain et al.'s (1995) Experiment 2, not just the exception words.

These results suggest that any experimental differences between Strain et al.'s (1995) study and Experiment 4 of this Chapter are insufficient to explain the lack of an effect of imageability in Experiment 4. Even when the experimental stimuli and procedures were identical to those of Strain et al.'s (1995) study, once AoA was controlled, imageability ceased to affect word naming or interact with consistency. This suggests quite strongly that Strain et al.'s (1995) results were simply an artefact of the AoA effect in word naming - with AoA controlled, imageability does not affect the speed of processing in this task.

3.5 General Discussion

3.5.1 Does imageability interact with spelling-sound consistency?

The present experiments aimed to investigate whether imageability continues to affect word naming, and to interact with consistency (Strain et al., 1995), once AoA (and frequency) are controlled. The present Experiment 3 found a significant effect of consistency, but no effect of imageability and no interaction between imageability and consistency. Experiment 4 examined imageability and consistency using only words of low frequency and similarly found an effect of consistency, but not of imageability, and also found no significant difference between the naming speed of low frequency, low imageability exception words and low frequency, high imageability exception words once AoA and (low) frequency were controlled.

Experiment 5 attempted a replication of Strain et al.'s (1995) Experiment 2. The straightforward analysis in this experiment supported the results of Strain et al. (1995) - demonstrating significant main effects of consistency and of imageability, and a significant interaction between imageability and consistency.

However, when AoA was entered as a covariate in an analysis of the RT data in Experiment 5 and in the RT data of Strain et al.'s (1995) Experiment 2 the effects of imageability disappeared. The effects of AoA were highly significant in both cases.

These results are in keeping with previous studies that have failed to find an effect of imageability when frequency and AoA are controlled (e.g., Brown & Watson, 1987; Brysbaert et al., 2000; V. Coltheart et al., 1988; Gilhooly & Logie, 1981a; Morrison & Ellis, 2000), and thus clearly highlight the importance of controlling AoA when assessing a variable's influence on the word naming task, particularly when those other variables correlate with AoA.

The present experiments further suggest that a failure to control AoA when varying imageability was responsible for the interaction between imageability and consistency for low frequency words reported by Strain et al. (1995). Thus, the current experiments suggest quite strongly that the semantic variable of imageability does not affect word naming speeds, not even for low frequency exception words.

Given that Strain et al.'s (1995) findings formed the basis of Plaut et al.'s (1996) implementation of a contribution from semantics in the successful reading of low frequency exception words in their model, the present findings call into question this explanation of the consistency effect. There is no evidence that the semantic variable of imageability affects word naming, and there are no reports at present of any other semantic variables that interact with consistency in single word naming. The results of the present Chapter, therefore, suggest that the evidence for a semantic contribution to the rapid conversion of orthography to phonology for individual words by skilled readers is currently very weak. Even when consideration is restricted to low frequency exception words, low imageability words are not named any more slowly than high imageability words. Thus Plaut et al.'s (1996) implementation of a necessary contribution from semantics in successful exception word reading appears, at present, somewhat unjustified. Moreover, these results extend themselves to suggest that models that involve multiple, independent routes from print to sound, such as Coltheart et al.'s (2001) dual-route model have no need to posit a contribution from semantically-mediated routes to speeded single word naming in skilled adult participants.

In terms of current connectionist models of skilled adult reading, if semantics are not the source of the consistency effect then the locus of this effect must be within the connections between orthography and phonology as was proposed in the earlier simulations of Plaut et al.'s (1996) model (see also Harm & Seidenberg, 1999; Seidenberg & McClelland, 1989).

The aim of the current Chapter was to locate the consistency effect within the word processing system so that the effects of AoA and frequency within word naming could be identified. The proceeding discussion will briefly summarise the results of Chapter

Two that assessed AoA and frequency's relationship to consistency before going on to assess the locus of these effects in terms of Plaut et al.'s (1996) model and Ellis and Lambon Ralph's (2000) theory of AoA.

3.5.2 A return to the results of Chapter Two

Chapter Two assessed the effects of frequency, AoA and consistency on word naming latencies. The results of these experiments demonstrated significant main effects of frequency, AoA and consistency on word naming speed. In addition, there were significant interactions between frequency and consistency and between AoA and consistency. In Experiment 1 of Chapter Two, low frequency exception words were named more slowly than high frequency exception words or consistent words of both high and low frequency. Experiment 2 of Chapter Two revealed significantly slower naming of late acquired exception words than early acquired exception words or consistent words of both early and late AoA. The conclusion made in Chapter Two was that frequency and AoA have the same locus of effect as does the spelling-sound consistency effect because both variables interact with consistency in word naming.

3.5.3 Explanations of the frequency by consistency interaction, and of the AoA by consistency interaction in single word naming

3.5.3.1 Plaut et al.'s (1996) parallel distributed processing model of single word naming

The connectionist model of Plaut et al. (1996) will be discussed in terms of its initial simulations of single word reading wherein the orthography to phonology pathway was assumed to be capable of successfully reading all single words. As the results of the present Experiments 3, 4 and 5 have demonstrated, there is little in the way of evidence to suggest a role of semantics in the reading of single words. The early simulations of Plaut et al.'s (1996) model explain both the frequency and the consistency effects in terms of the strength of the connections between orthography and phonology. The strength of the connections between these two processing units affects the accuracy of the models response, with stronger connections producing lower error scores. Furthermore, the strength of these connections is a function of how often those connections are activated and are, therefore, dependent upon the degree to which a particular word is exposed to the model. Thus words that are of high frequency and/or have a pronunciation of a word body that occurs in a number of other words will develop stronger connections and so be read with greater accuracy.

Consistent words that share their orthographic and phonological word body with other words will have that word body exposed to the model quite frequently during training. In contrast, words that have an exceptional pronunciation of their word body do not share that pattern of connections between orthography and phonology with any other words (or at least only with one or two other words). This lack of exposure results in only weak connections for exception words. In addition to this, for the model to successfully name an exception word, these weaker connections have to fight against the stronger connections of their orthographic neighbours that have a different and more common pronunciation of that word body. Thus exception words are read less accurately than other words in these models because they are exposed to the model relatively infrequently and also have competition from the more frequently exposed, more common pronunciation of their neighbours.

Whilst high frequency exception words can overcome this disadvantage due to the stronger connections they will develop from their more frequent exposure, low frequency exception words have connections that remain weak and so the model struggles to name them accurately. Consequently, low frequency exception words have a much higher error score in the model than do high frequency exception words or consistent words of both high and low frequency.

Plaut et al.'s (1996) model is capable of simulating both the frequency and the frequency by consistency interactions reported in the human literature; this model produces higher error rates to low frequency exception words than to high frequency exception words and high and low frequency consistent words.

However, Plaut et al.'s (1996) model does not offer an explanation of the AoA effect or of the interaction between AoA and consistency in single word naming. This is despite the fact that this model would appear to be capable of incorporating such effects into the current structure of its network. This is because it is an adaptive model - it learns from experience - and so it may be capable of not only simulating an effect of AoA, but also of offering an explanation of how the AoA effect emerges during development.

The locus of the AoA effect in this model would be in the connection strengths between orthography and phonology where frequency and consistency also exert their effects, thereby explaining why both AoA and frequency interact with consistency. Unlike frequency, however, AoA does not form a part of this model's architecture, and as such, this model is unlikely to be able to simulate an AoA effect in its current form. Indeed, as Ellis and Lambon Ralph's (2000) network demonstrates, in order to simulate an AoA effect in such a connectionist model, its learning mechanism would have to be altered to one that involves cumulative learning. Such cumulative learning would be possible within this model, and would not only add to its applicability -

making it a far more accurate reflection of the gradual word learning process in childhood - but would also allow a possible simulation of the AoA effects in single word reading. As of yet, however, this model has made no attempt to simulate or explain the AoA effect and, as a consequence, it is difficult to evaluate or predict its success at doing so.

3.5.4.2 Ellis and Lambon Ralph's (2000) connectionist theory of the AoA effect

The only connectionist framework to have successfully simulated the AoA effect in single word naming is the connectionist network of Ellis and Lambon Ralph (2000). Ellis and Lambon Ralph (2000) propose that both AoA and frequency exert their effects in the connections between input and phonological output. This theory is, therefore, entirely compatible with the results of Chapter Two.

Ellis and Lambon Ralph (2000) explained the effects of AoA and frequency in terms of the network's plasticity with early entered and/or high frequency patterns actually shaping the structure of the network into the most advantageous and efficient configuration for the correct production of these early entered/frequently exposed patterns. As a consequence, when late acquired patterns are entered into training, the network will have lost much of its plasticity. Thus, whilst late entered patterns can modify the structure of the network somewhat, they are always in competition with the better established connections for the early acquired patterns. In a similar fashion, low frequency patterns are not exposed to the network often enough for them to influence the configuration of the connections to any significant extent.

More recent simulations of this network conducted by Lambon Ralph (in Monaghan & Ellis, in press) demonstrated that this approach is also capable of simulating the interactions between AoA and consistency and between frequency and consistency. These simulations were completed by altering the predictability of the input and output patterns in the network in an attempt to simulate something similar to the learning of early and late acquired consistent (predictable patterns) and exception (less predictable patterns) words. The patterns used in these simulations approximated to CVC monosyllabic words. The consistency of the patterns was varied by changing the predictability of the vowel from input to output units. Thus consistent items were made by creating output patterns that were simple copies of the input patterns, such that, if the input pattern was $c_2v_7c_4$, the output pattern was also $c_2v_7c_4$. Exceptional items were created by changing the predictability of the output pattern from the pattern in the input such that, for example, the input pattern of $c_5v_9c_1$ would map on to the output pattern of $c_5v_2c_1$.

This is the same form of predictability as occurs in the majority of the words used in Experiments 1 and 2 of Chapter Two wherein the consistency of the words is determined by the pronunciation of the vowel. That is, the exception words pronunciation differs from the more common pronunciation of that word body only in terms of the pronunciation of the vowel (e.g. WAN cf. CAN, MAN, TAN; SEW cf. DEW, FEW, NEW).

In the simulations, 80 consistent and 20 exception patterns were entered into training from the outset (the early patterns). A further 80 consistent and 20 exception patterns were entered into training after 750 epochs (the late patterns). Ten of the early and late exception patterns and 65 of the consistent early and late patterns were trained with a low frequency (one presentation per epoch); the remaining patterns were trained with high frequency (10 presentations per epoch). After training on 1,750 epochs the networks performance on the patterns was tested using an analysis of variance on the output error scores. The results of this analysis revealed a significant effect of consistency - consistent, predictable patterns produced lower error scores than did exception, less predictable patterns. The network also successfully simulated effects of AoA (lower error scores for early than for late entered patterns) and frequency (lower error scores for high than for low frequency items).

In addition to this, the network also produced an interaction between consistency and frequency, such that error scores were significantly higher for low frequency exception patterns than for high frequency exception patterns, or consistent patterns of high and low frequency. This mirrors the interaction between frequency and consistency reported in Experiment 1 of Chapter Two.

The network also successfully simulated the interaction between AoA and consistency reported in Experiment 2 of Chapter Two, with error scores being significantly higher for late entered exceptional patterns, than for early entered exceptional patterns or consistent patterns entered early or late in training.

The interaction between AoA and consistency and between frequency and consistency in Ellis and Lambon Ralph's (2000) network was explained as a natural part of the network's development. As was discussed previously, early acquired patterns and high frequency patterns structure the network into a configuration advantageous to the production of their output from their input. This allows a processing advantage for early acquired and/or high frequency words in the network regardless of the predictability of the words phonological output from its orthographic input.

Late acquired and low frequency patterns struggle to become established due to the loss of plasticity in the network. However, as Ellis and Lambon Ralph (2000) argued, the loss of plasticity in the network will only affect processing of such items when their pattern of connections between input and output differs from those patterns already established by early acquired and/or high frequency items. That is, late and/or low frequency items with a consistent pattern of connections will be able to utilise those connections already established by similar early acquired/high frequency words.

The problem for late entered and/or low frequency words, therefore, only occurs when their pattern of input and output is different from those patterns already established in the network. Thus late acquired and/or low frequency exception words that do not share connections established by early acquired/high frequency words will struggle to modify the network's structure in order to represent their mappings entirely successfully. As a consequence, late acquired and/or low frequency exception words will be read more slowly and less accurately than late acquired and/or low frequency consistent words, early acquired consistent and exception words and high frequency consistent and exception words.

The connectionist network of Ellis and Lambon Ralph (2000) thus provides a successful simulation of both the frequency by consistency interaction and of the AoA by consistency interaction reported in the present Chapter Two by placing these effects in the connections between orthographic input and phonological output. Consequently this network must be considered the most successful of the connectionist frameworks in terms of explaining the results reported in the present Chapters Two and Three. At present, therefore, this network would appear to hold the most satisfactory explanation of both the frequency and the AoA effects in single word reading.

3.6 Conclusion

The results of the present Chapters Two and Three demonstrate that frequency continues to affect single word naming and continues to interact with spelling-sound consistency even when AoA is controlled. In addition, AoA was also found to have a significant effect on single word naming, and to interact with spelling-sound consistency. The experiments in Chapter Three demonstrate that imageability does not affect single word naming latencies, nor does it interact with spelling-sound consistency once AoA is controlled. The lack of any evidence for an interaction between spelling-sound consistency and this semantic variable suggests that the consistency effect is not influenced by any contribution from semantics. This finding thus disputes the final simulation of Plaut et al.'s (1996) connectionist model of single word reading that incorporated a contribution from semantics for the successful reading of low frequency exception words.

The present results, therefore, favour the explanation of the consistency and frequency effects put forward in the earlier simulations of Plaut et al. (1996) in which frequency and consistency exert their effects within the connections between orthography and phonology. The finding that AoA also interacts with consistency suggests quite strongly that this variable also exerts its effect in these connections in single word naming. Although the connectionist model of Plaut et al. (1996) does not incorporate an effect of AoA, the successful simulations of the interactions between AoA and consistency, and between frequency and consistency in the connections between orthography and phonology in the connectionist network of Ellis and Lambon Ralph (2000) provides further evidence for this locus of both the AoA and frequency effects in single word naming.

CHAPTER FOUR

DOES AoA INFLUENCE THE LEVEL OF PHONOLOGICAL OUTPUT PROCESSING?

4.1 Introduction

The results of the present Chapters Two and Three have suggested that in single word naming AoA exerts its effect within the connection strengths between orthography and phonology. This is because AoA interacts with the spelling-sound consistency effect, which is believed to affect the strength of these connections in single word naming. Such a locus of the AoA effect is in support of Ellis and Lambon Ralph's (2000) theory that claims that AoA affects the strength of connections between orthography and phonology in word naming, and between semantics and phonology in picture naming.

However, an alternative explanation of the AoA effect is that it affects the ease with which phonological representations are retrieved from the phonological output store (e.g., Brown & Watson, 1987; Gilhooly & Logie, 1981b; Gilhooly & Watson, 1981). One such theory that places the AoA effect at the phonological level of processing - and one that has been widely cited as a potential explanation of the AoA effect - is the phonological completeness hypothesis of Brown and Watson (1987). The phonological completeness hypothesis proposes that the AoA effect is a consequence of the quality of an individual's phonological representations, with early acquired words being stored in a more complete phonological form than are late acquired words.

Placing the locus of the AoA effect in the phonological output store can clearly explain why effects of AoA are found in the tasks of word and picture naming as the level of phonological processing is shared in these two tasks. However, this locus is not entirely compatible with the fact that AoA and spelling-sound consistency interact. If spelling-sound consistency affects the strength of connections between orthography and phonology, then for AoA to interact with this variable suggests that AoA also influences the strength of these connections.

The purpose of the current Chapter was, therefore, to assess the claims of the phonological completeness hypothesis that locate the AoA effect at the level of phonological processing. Prior to discussing the current experiment, the phonological completeness hypothesis, along with support and opposition for this view from vocabulary development theories, will first be discussed in more detail.

4.1.1 The phonological completeness hypothesis (Brown & Watson, 1987)

The phonological completeness hypothesis of Brown and Watson (1987) claims that the AoA effect emerges as a consequence of the quality of an individual's phonological representations in the phonological output lexicon. Specifically, the hypothesis holds that early acquired words are stored as whole-word representations in the phonological lexicon. However, as a child's vocabulary increases, the phonological store is forced to become more economical in terms of its storage and so begins to represent later learned words in a more segmented form. This greater segmentation of phonological representations is more economical because it allows the same representation of a syllable/phoneme to be used for all words that contain that segment. A consequence of this more efficient storage strategy, however, is a processing cost laid on later acquired words as the time needed to assemble a whole word representation from its component segments will be longer than that needed to retrieve the whole word representation of early acquired words. According to the phonological completeness hypothesis, it is this processing cost for later acquired words that causes the AoA effect found in adults.

The phonological completeness hypothesis finds strong echoes in a number of recent theories of childhood vocabulary development (e.g., Ferguson, 1986; Fowler, 1991; Jusczyk, 1986; 1993; Metsala & Walley, 1998; Walley, 1993). These theories similarly argue that early learnt words are stored as whole word representations, and that, as a consequence of increasing vocabulary size, the child is forced to store later acquired words as more segmented phonological representations in the phonological store. Unlike the phonological completeness hypothesis, however, these theories state that early holistic representations become segmented as the child's vocabulary increases, so that both early and late acquired words are stored in a segmented form in the mature lexicon.

The extent to which the segmentation of early words is believed to replace the initial holistic representation differs over theories. Certain of these developmental theories state that holistic representations are never entirely replaced by segmented representations but instead maintain something of their more holistic quality through adulthood, with segmented representations becoming overlaid on, rather than replacing the holistic representations (e.g., Ferguson, 1986; Jusczyk, 1986; 1993; Walley, 1993). In contrast, other theories of vocabulary development propose that early holistic representations are entirely replaced by segmental representations through a gradual restructuring of the entire phonological store. This restructuring is believed to occur over time with the final resulting structure in which individual phonemes are the predominant units of processing only emerging in middle childhood following levels of representation at the syllable, and at the onset-rime level of the word (e.g., Fowler, 1991; Metsala & Walley, 1998; Walley, 1993).

The lexical restructuring model of Metsala and Walley (1998) is one such theory that argues for a gradual but complete restructuring of phonological representations in which the final result is the representation of all words at the phoneme level. In contrast to the other vocabulary development theories discussed so far, the lexical restructuring model offers an account of the AoA effect that is proposed to be a consequence of the quality of the phonological representations following the restructuring process. However, in direct opposition to the phonological completeness hypothesis this model argues that early acquired words actually undergo more extensive segmental restructuring at an earlier stage than do later acquired words. According to the lexical restructuring model because early acquired words are of high familiarity during early childhood they will need to be accessed rapidly and automatically on many occasions. It would, therefore, appear to make sense that such early acquired words have undergone extensive segmental restructuring so that they can be recognised and produced in a more efficient adult-like way. In opposition to the phonological completeness hypothesis (Brown & Watson, 1987), therefore, the lexical restructuring model (Metsala & Walley, 1998) argues that the AoA effect is a consequence of early restructuring with early acquired words having better established, more fine-grained phonological representations (see also Metsala, 1997; 1999).

The phonological completeness hypothesis of Brown and Watson (1987) has clear echoes in many developmental theories of vocabulary development to the extent that these theories similarly argue that early acquired words are initially stored as whole word phonological representations. However, none of the developmental theories suggest that early acquired words maintain a purely holistic representation. Instead this holistic representation is either overlaid by a segmented representation (e.g. Ferguson, 1986; Jusczyk, 1986; 1993; Walley, 1993), or is entirely replaced by a segmented representation (e.g. Fowler, 1991; Metsala & Walley, 1998; Walley, 1993). The only one of these vocabulary developmental theories that offers an account of the AoA effect is the lexical restructuring model of Metsala and Walley (1998) which argues that early acquired words undergo segmental restructuring prior to later acquired words, and so attain a better established, more fine-grained level of representation. This allows early acquired words to be accessed and produced both more rapidly and more accurately.

Clearly, therefore, whilst both the phonological completeness hypothesis and the lexical restructuring model assume that AoA affects the quality of an individual's phonological representations, the way in which they conceive of these representations is very different. Moreover, whilst both of these accounts of AoA have some intuitive appeal, neither has much in the way of empirical support. Indeed, although the phonological completeness hypothesis continues to be quoted in the AoA literature as a potential explanation for this effect, it has never been tested experimentally. To what extent early learnt words maintain their initial holistic quality and, if they do, how this influences skilled adult processing, remains an unanswered question. In addition, placing the AoA effect within the phonological output system is not compatible with the results of the present Chapters Two and Three, and the connectionist model of Ellis and Lambon Ralph (2000). Such a locus of the AoA effect, therefore, needs to be tested empirically.

The main aim of the current experiment was to investigate the claims of the phonological completeness hypothesis experimentally. Experiment 6a used a phonological segmentation task in order to test the proposal that early acquired words have holistic representations while later acquired words have more segmented representations. If early acquired words are stored in a more complete form, then adult participants should be slower to segment early acquired words than late acquired words. The second part of the experiment compared individuals' phonological skill with the size of their AoA effects in the segmentation task and a word naming task in order to test more directly the argument that the AoA effect is a consequence of the quality of an individual's phonological representations (e.g., Brown & Watson, 1987; Metsala & Walley, 1998).

4.2 Experiment 6a - Are early acquired words stored purely as whole word phonological representations?

If, as the phonological completeness hypothesis proposes, the advantage for early acquired words is due to the maintenance of their initial holistic representations through adulthood, then adults should be slower to segment the sounds of early acquired words than to segment the sounds of late acquired words (that are already stored in such segments). This would be an unusual result because where effects of AoA have been reported previously, the processing advantage has been for early acquired words over late acquired words, whereas the phonological completeness hypothesis predicts an advantage for late acquired words in such segmentation tasks. In contrast, the lexical restructuring model predicts that adults should be faster at segmenting early acquired words than late acquired words due to the more extensive, earlier segmental restructuring of these early acquired words. In order to assess the predictions of these two theories, the present study used a phonological segmentation task that required adult participants to segment early and late acquired words.

The phonological segmentation task used in the present Experiment 6a was one that required participants to take away some of the initial sounds of a word (indicated by a cue) and then produce the remainder of the word as quickly as possible. Words were presented visually on a computer screen. Each word remained on the screen for 1,000 ms, allowing more than enough time for the words (both early and late acquired) to access their phonological representations. Directly following the presentation of the word, a cue was presented on the screen that indicated what sounds were to be deleted from the previously presented word. The cue in the experimental conditions required participants to delete the initial consonant in a cluster (e.g., FROG - F → "rog"), the onset of the word (e.g., SPOON - SP ⟶ "oon"), or the first syllable of the word (e.g., HAVOC - HA ⟶ "vok"). A large number of filler items were also included in the experiment. These filler items were included so as to deter participants from guessing the type of segmentation prior to presentation of the cue. Many of these filler items also had irregular spelling-sound correspondences so as to discourage participants from using an orthographic strategy to segment the items. With irregular words the use of an orthographic strategy would result in a large number of errors.

4.2.1 Method

4.2.1.1 Participants

Fifty participants took part in the present experiment. All were undergraduate students from the University of York who were native English speakers, with normal or corrected-to-normal vision and who had no self-reported reading difficulties. All were paid for their participation.

4.2.1.2 Materials

The stimuli in the segmentation task consisted of 200 monosyllabic and disyllabic words; these items included three sets of 40 experimental items and 80 filler items that required segmentation at different points within the word.

The first set of experimental items consisted of 20 pairs of monosyllabic words, one early acquired and one late acquired, that required segmentation of the initial consonant cluster of the word (e.g., SKIRT ⟶ S - KIRT). Each pair of words was matched on the phonemes of the initial consonant clusters (e.g., SKIRT and SKETCH), thereby controlling for the transitional probability[1] of the phonemes at the point of segmentation and the nature of the first phoneme of the response. The second experimental word set consisted of 20 pairs of monosyllabic early and late acquired words that required segmentation at the onset-rime level of the word (e.g., SPOON ⟶ SP – OON). Each pair of words was matched on the initial phoneme and vowel of the word (e.g., SPOON and SPOOL), again, therefore, allowing control of the transitional probability of the phonemes at the point of segmentation. The final experimental word set consisted of 20 pairs of disyllabic early and late acquired

[1] Transitional probability describes the fact that some phonemes occur together more frequently than do others, and that some pairs of phonemes are more easily separable than others are. By controlling for the co-occurrence of phonemes – in each pair both the early and the late words shared the same phonemes at the point of segmentation – any such confounds were eliminated.

words that required segmentation at the syllable boundary (e.g., RIBBON $\longrightarrow$ RI – BBON). These word pairs were matched on the initial phoneme of the word and the initial phoneme of the second syllable (e.g., RIBBON and REBEL).

In each condition, early acquired words were words that had an AoA rating of less than 3.15 (acquired before 5-6 years of age), while late acquired words were words that had an AoA rating of more than 3.7 (acquired after 5-6 years of age). The early and the late acquired words in each set were matched on Celex (combined written and spoken) word frequency, imageability, length (number of letters) and number of orthographic neighbours (N). The three sets of early and late acquired words were also matched across conditions on these variables. The word sets used in the segmentation task can be seen in Appendix 7.

The age of acquisition ratings and the imageability ratings were taken, when available, from the Gilhooly and Logie (1980a;b) norms. Where such norms were not available, new AoA and imageability ratings were obtained. New AoA ratings were taken from 40 undergraduate and postgraduate students at the University of York. Half of these subjects were given a booklet containing 193 words to be rated, and the other half received a booklet containing 300 words. Words were presented in a random order. The instructions and rating scale used were the same as those used in the present Chapter Two (cf. Section 2.2.1.3). Of these 493 words rated, 199 already had AoA ratings in the Gilhooly and Logie

(1980a;b) norms. The correlation between those ratings and the new ones was 0.93.

New imageability ratings were taken from 40 undergraduate and postgraduate students at the University of York. Half of these participants received a booklet containing 193 words, and the other half received a booklet containing 300 words to be rated. These words were presented in a random order. The instructions and scale for the imageability ratings followed those in the present Chapter Two (cf. Section 2.2.1.3). Of these words, 199 had imageability ratings in the Gilhooly and Logie (1980a;b) norms. The correlation between those ratings and the new ones was 0.87.

In addition to the above sets of words, 80 filler items were devised in order to avoid participants being able to guess in advance the type of segmentation required. The filler items consisted of 40 monosyllabic words that required segmentation at the level of the vowel - coda (e.g., DOU - BT), 20 disyllabic words that required segmentation of the onset and vowel of the word (e.g., F - EVER), and 20 disyllabic words that required segmentation at the level of the final vowel – coda part of the word (e.g., FATI - GUE). Many of these filler items had irregular spelling-sound correspondences such as those in the current examples. Such words were included in order to discourage participants from using orthographic cues to help them complete the segmentation of any particular word. With irregular words the use of an orthographic strategy would result in numerous errors, for example, when segmenting FEVER at the onset and vowel, the incorrect response of "ever" (cf. "eever") would be produced.

4.2.1.3 Procedure

The presentation of the segmentation task was visual. The stimuli were presented in the centre of an Apple Mac Centris 660av computer screen in black 48 point lower case print, using Geneva font. The screen was approximately 60 cm away from the participant. Reaction times were recorded using a voice key-activating microphone. Participants were told that they would first be presented with a word on the computer screen that they should read silently to themselves. Immediately following this word they would then be presented with a cue that would be a part of the word that they had just read. They were then informed that their task was to pronounce the sounds of the word that remained once the sounds represented by this cue had been taken away from the word. The experimenter then went through four examples with the participant in order to ensure they understood what was required for this task. The participants then completed ten practice examples. Following on from this, participants were given 50 practice trials that included all types of segmentation that were to appear in the following task. After a short interval the experimental and filler items were presented in two blocks of 100 words with a short break in between. The words were divided between blocks such that the two words from each matched pair were presented in different blocks. The two blocks included equal numbers of early and late acquired words, and equal numbers of all the types of possible segmentation required. Presentation of the two blocks was counterbalanced across participants.

On each trial participants were presented with a fixation point for 750ms. The fixation point was followed without delay by the whole target word which remained on the screen for 1000 ms. This word was replaced without delay by the cue representing the sounds that were to be deleted from the previously presented word. This cue remained on the screen until the participant made a response. The RTs, therefore, measured the interval between the appearance of the cue and the onset of the participant's response. The screen then went blank for 1000 ms before the next trial began. The experimenter noted any segmentation errors or voice key activation errors occurring during the task.

4.2.2 Results

Six hundred and fourteen out of a total of 6,000 responses (10.2%) were excluded from the reaction time analysis due to segmentation errors (6.0%) or voice-key errors (4.2%). The mean latencies of the correct responses, and the total segmentation error rates (in percent) in each of the three segmentation conditions can be seen in Table 4.1.

	Early AoA		Late AoA	
	M	SD	M	SD
Consonant Cluster				
Reaction time	784	107	808	113
% error	2.40		3.30	
Onset - Rime				
Reaction time	663	83	665	80
% error	1.80		2.20	
Syllable Juncture				
Reaction time	858	125	845	118
% error	11.70		14.60	

Table 4.1. Mean RTs and standard deviations in ms and segmentation error rates (%) for each of the three segmentation conditions in Experiment 6a.

4.2.2.1 Reaction time analysis

An analysis of the participants' performance over all three segmentation conditions was carried out on the RT data using an analysis of variance with segmentation condition and AoA as the two factors. In this analysis the overall effect of AoA was not significant, F (1,49) = 1.10, MSE = 1377.57, n.s. However, the effect of segmentation condition was significant, $F(2,98) = 236.54$, MSE = 3929.37, $p<0.01$, as was the interaction between AoA and segmentation condition, $F(2,98) = 8.74$, MSE = 973.93, $p<0.01$.

T-tests revealed that segmentation in the onset-rime condition (664 ms) was significantly faster than in the consonant cluster condition (796 ms), $t(1,49) = 16.20$, $p<0.01$, and that segmentation in the consonant cluster condition was significantly faster than in the syllable juncture condition (852 ms), $t(1,49) = -6.21$, $p<0.01$.

In addition, t-tests showed that the effect of AoA was significant in the consonant cluster condition, $t(1,49) = -3.66$, $p<0.01$. Contrary to the predictions of the phonological completeness hypothesis, early acquired words were segmented significantly faster (784 ms) than late acquired words (808 ms) in the consonant cluster condition. The effect of AoA was not significant in the onset-rime condition, $t(1,49) = -0.33$, n.s., or the syllable juncture condition, $t(1,49) = 1.53$, n.s.

4.2.2.2 Error analysis

The relatively low error rates precluded the use of analysis of variance. Analysis of the segmentation error rates using the Wilcoxon signed ranks test revealed a significantly higher rate of segmentation errors to late than to early acquired words, $Z = -2.85$, $p<0.01$. The error rates also differed significantly between segmentation conditions, with the syllable juncture segmentation condition showing significantly more errors than the consonant cluster condition, $Z = -5.12$, $p <0.01$, or the onset rime condition, $Z = -5.57$, $p<0.01$. There was no difference in the number of errors made between the consonant cluster and the onset rime condition, $Z = -1.28$, n.s.

Moreover, whilst there was no difference in the number of segmentation errors made between the early and late acquired words in both the consonant cluster condition, $Z = -1.07$, n.s., and the onset rime condition, $Z = -0.80$. n.s., there were significantly more errors made to late acquired words in the syllable juncture segmentation condition, $Z = -2.40$, $p<0.05$.

4.2.3 Discussion

The segmentation task was completed in order to test the claims of the phonological completeness hypothesis (Brown & Watson, 1987) which argues that early acquired words are recognised and named faster than late acquired words because they have more holistic representations in the phonological output store. The results of the present experiment provide no support for this theory. Indeed, contrary to the phonological completeness hypothesis (and the lexical restructuring model of Metsala and Walley (1998)), there was no overall difference in the speed with which early and late acquired words were segmented over the three segmentation conditions. The only segmentation condition that revealed a significant effect of AoA in the RT analysis was the consonant cluster segmentation condition. However, the AoA effect was such that early acquired words were segmented faster than late acquired words. There was no significant effect of AoA in the error rates of the consonant cluster condition, although the error rates were very low in this condition. In the syllable juncture condition where error rates were larger, significantly more errors were made to late than to early acquired words. The reason for an AoA effect in the error rates of this condition, despite the lack of an AoA effect in the RT data, is unclear. Nevertheless, this result does provide further evidence against the phonological completeness hypothesis that would predict more errors to early acquired words than to late acquired words. The combined results of this experiment clearly go against the phonological completeness hypothesis that would predict faster and more accurate segmentation of late acquired than early acquired words in all conditions.

In addition, there is little clear support for the lexical restructuring model (Metsala and Walley, 1998) that would predict faster segmentation of early acquired than late acquired words. This was only the case in the consonant cluster condition. The reason that, in the RT data, an AoA effect is only found in the consonant cluster segmentation condition may be a consequence of the fact that the consonant cluster segmentation condition requires the finest level of segmentation (at the phoneme level) of the three segmentation conditions. The present results are, therefore, compatible with the view that early acquired words achieve a better established and finer grained level of segmentation than do late acquired words at the level of phonemes only. Thus, whilst both early and late acquired words have a well established syllable and onset rime level of segmentation in the phonological store, early acquired words may maintain a more fine-grained level of segmentation at the level of phonemes, thereby explaining the occurrence of an AoA effect only at this level of segmentation. If this is the case, then the size of the AoA effect in this segmentation condition should correlate significantly with the level of the individual's phonological skill. This was tested in the second part of the present study.

4.3 Is the AoA effect a consequence of the quality of the phonological representations?

The second part of the current experiment was aimed at testing more directly whether the AoA effect is, in actual fact, a consequence of the quality of a speaker's phonological representations as the phonological completeness hypothesis (Brown & Watson, 1987) and the lexical restructuring model (Metsala & Walley, 1998) both assert. The finding of an AoA effect in the consonant cluster segmentation task suggests that this is a possibility, but does not provide conclusive evidence for this. However, if AoA is located in phonological processing then there should be a clear relationship between an individual's phonological skill (as assessed by performance in the segmentation task) and the size of the AoA effect shown in the consonant cluster segmentation condition. This is because the quality of individual's phonological representations is dependent upon the level of that person's phonological skill. Thus, those participants who perform best in the segmentation task (those who perform the task most quickly and accurately) should show larger AoA effects.

The phonological completeness hypothesis and the lexical restructuring model would also predict a relationship between phonological skill and the AoA effect size in word naming. In addition to the comparison between phonological skill and any AoA effects in the segmentation task, therefore, participants were given a word naming task that manipulated AoA and spelling-sound consistency in order to assess the relationship between phonological skill and the size of the AoA effect in word naming. The inclusion of this word naming task allows a further comparison between phonological skill and the size of the consistency effect. If, as was concluded in Chapter Three, consistency affects the connection strengths between orthography and phonology then one would expect that the size of this effect would be unrelated to that individual's phonological ability.

A final comparison completed in the current study was between individual differences in skilled adults' word and nonword naming and their phonological skill. The quality of a child's phonological representations is highly related to their word and nonword reading skill (e.g., Brown, 1997; Elbro, Borstrom, & Peterson, 1998; Fowler, 1991; Metsala, 1999; Metsala, Stanovich & Brown, 1998; Metsala & Walley, 1998; Swan & Goswami, 1997; Walley, 1993). Consequently, if phonological skill is to predict any individual differences in skilled adults then there should be clear differences between the quality of adult's phonological representations and their word and nonword reading skills. Thus, in addition to the segmentation task of Experiment 6a, Experiments 6b and 6c involved word and nonword naming tasks that were presented to the same adult participants. Experiment 6b was a replication of Experiment 2, Chapter Two (using different items) in order to produce AoA and spelling-sound consistency effects in the word naming task.

By investigating individual differences in phonological skill, the size of any AoA effects in the segmentation task and the size of the AoA effect in word naming, the locus of the AoA effect proposed by the phonological completeness hypothesis and the lexical restructuring model can be tested more directly. In addition, the predicted lack of a relationship between consistency effect sizes and phonological skill can be assessed in order to confirm the assumption that this effect is unrelated to explicit phonological processing. A relationship between segmentation skill and word and nonword naming will confirm that phonological skill continues to predict individual differences in skilled adult participants.

4.3.1 Experiment 6b - Word naming task

4.3.1.1 Method

4.3.1.1.1 Participants

The participants in the word and nonword naming tasks were the same 50 participants that completed the segmentation task in Experiment 6a. Each participant completed the three tasks in the same order with the segmentation task being presented first, followed by the word and nonword naming tasks.

4.3.1.1.2 Design and Procedure

Experiment 6b was a replication of Experiment 2, Chapter Two, manipulating AoA and spelling-sound consistency in the word naming task. The experimental stimuli consisted of 72 monosyllabic words, with 18 early acquired consistent words, 18 late acquired consistent words, 18 early acquired exception words, and 18 late acquired exception words. All of the words in this task were different from those used in the segmentation task. As a consequence, the words differed from those used in Experiment 2, Chapter Two, however, the selection and matching of items was exactly the same as in Experiment 2 of Chapter Two. Thus, early acquired words had an AoA rating of less than 3.58, late acquired words had a rating of more than 3.58 (approximating to 5-6 years of age), and consistency was defined as the predictability of the words pronunciation from its orthographic word body.

The word sets were matched on word frequency (Celex combined and Kucera & Francis (1967) frequency counts), imageability, orthographic neighbourhood size (N), and word length (number of letters). The AoA and imageability ratings for these items were taken from the 220 words that were rated for use in Experiments 1 to 4 in Chapters Two and Three. The word sets used in Experiment 6b are shown in Appendix 8. The conditions of presentation (including the practice items used) and instructions were exactly the same as those in Experiment 2 of Chapter Two.

4.3.1.2 Results

Two hundred and seven out of a total of 3,600 responses (5.8%) were deleted from further analysis. One hundred and seventeen of these (3.3%) were due to mispronunciations of the words, eighty three (2.3%) were due to accidental activation of the voice key, while seven (0.2%) were removed due to the extreme length of the reaction times (greater than 1,500 ms). The mean naming latencies of correct responses in the four word sets and the total mispronunciation error rates (in percent) are shown in Table 4.2.

		Consistent		Exception	
		M	SD	M	SD
Early AoA					
	Reaction time	575	69	578	67
	% error	0.44		0.56	
Late AoA					
	Reaction time	581	70	604	69
	% error	3.90		8.33	

Table 4.2 Mean RTs and standard deviations in ms and mispronunciation error rates (%) for each word type in the word naming task of Experiment 6b.

4.3.1.2.1 Reaction time analysis

Analysis of variance was carried out on the RT data with spelling-sound consistency and AoA as the two factors. The effect of consistency was significant, $F(1,49) = 49.98$, $MSE = 253.61$, $p<0.01$, with naming RTs being faster to consistent words (577ms) than to exception words (593 ms). The effect of AoA was also significant, $F(1,49) = 17.09$, $MSE = 485.59$, $p<0.01$, with naming RTs being faster to early learned words (578 ms) than to later learned words (591 ms). In addition, the interaction between AoA and spelling-sound consistency was significant, $F(1,49) = 16.71$, $MSE = 315.55$, $p<0.01$. Simple main effects analysis revealed that the 26 ms difference in naming RTs to early and late acquired exception words was significant, $F(1,49) = 30.82$, $MSE = 434.73$, $p<0.01$, while the 6 ms difference in naming RTs to early and late acquired consistent words was not significant $F(1,49) = 0.47$, $MSE = 366.41$, n.s. Similarly, the 23 ms difference in response times to late acquired consistent and exception words was significant $F(1,49) = 65.83$, $MSE = 260.47$, $p<0.01$, while the 3 ms difference between early acquired consistent and exception words was not significant $F(1,49) = 2.59$, $MSE = 308.69$, n.s. Clearly, therefore, as Figure 4.1 shows, the interaction between AoA and consistency was a consequence of the slow naming of late acquired exception words.

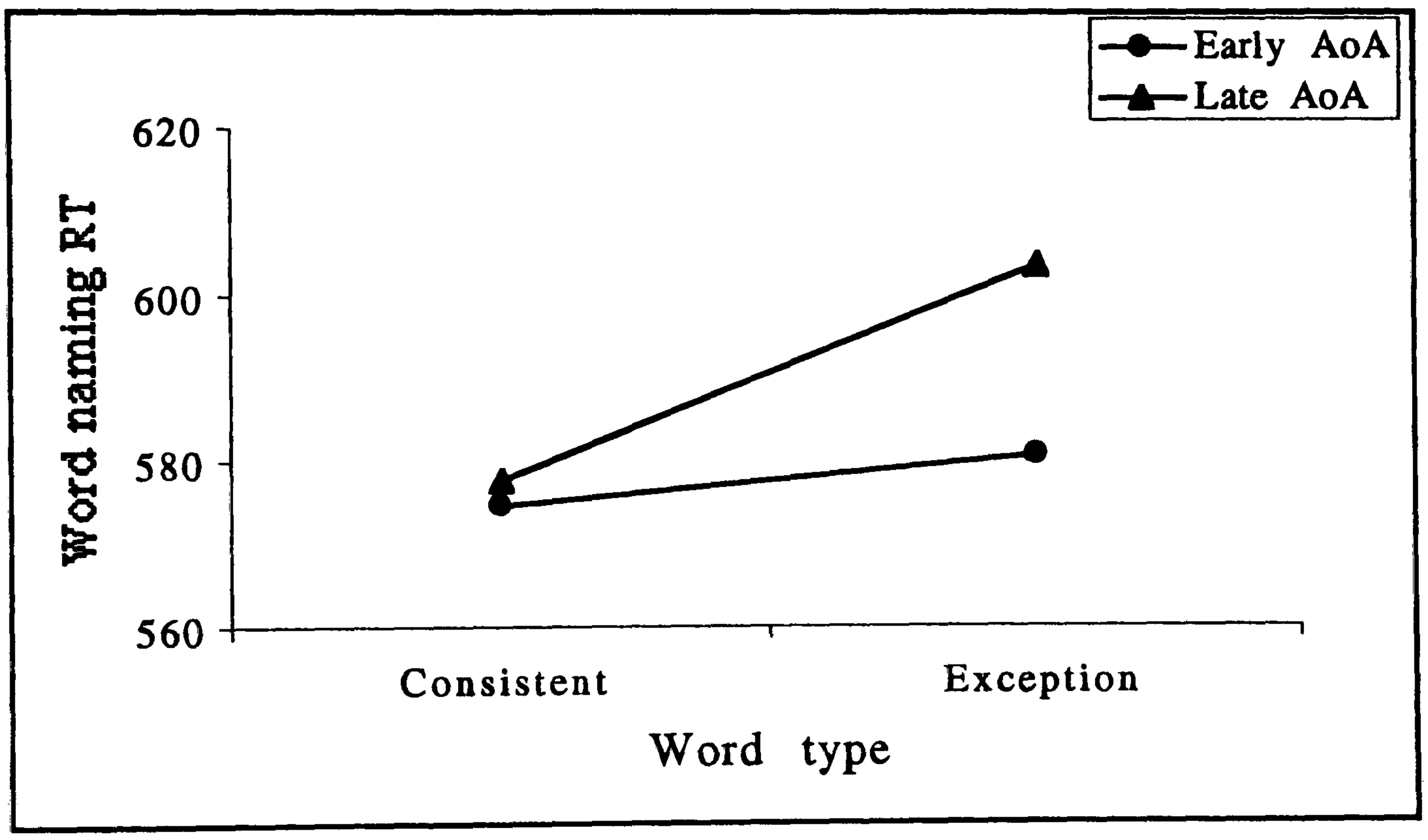

Figure 4.1 The interaction between AoA and consistency in the word naming task of Experiment 6b.

4.3.1.2.2 Error analysis

Analysis of the mispronunciation error rates using the Wilcoxon signed ranks test revealed a significantly higher rate of errors to exception words than to consistent words, $Z = -5.71$, $p<0.01$, and significantly more errors to late than to early acquired words, Z = -3.53, $p<0.01$. Significantly more errors were also made on late than early acquired exception words, Z = -3.57, $p<0.01$, but the difference between error rates to early and late acquired consistent words was not significant, Z = -0.34, n.s.

4.3.1.3 Discussion

The results of the word naming task in Experiment 6b replicate the findings of Experiment 2, Chapter Two with both AoA and consistency significantly affecting word naming latencies. AoA and consistency also interacted such that late acquired exception words were named significantly more slowly than early acquired exception words or consistent words of early and late AoA. However, the nature of the interaction in the current Experiment 6b was much stronger than that in Experiment 2, with the consistency effect only being significant for late acquired words and, conversely, the AoA effect only being significant for exception words. In Experiment 2 the interaction was clearly a consequence of slower naming of late acquired exception words, however, there were also small but significant effects of consistency for early acquired words and of AoA for consistent words in that experiment.

4.3.2 Experiment 6c - Nonword naming task

4.3.2.1 Method

4.3.2.1.1 Design and procedure

The experimental stimuli consisted of 10 one syllable, 10 two syllable, and 10 three syllable nonwords. All the nonwords were created by changing the initial letter of real words to make an orthographically realistic, non-homophonic nonword (e.g., PAKE, BUDDLE). The orthographic bodies of these nonwords were different from the bodies of the experimental stimuli in the segmentation task. The nonwords used in this task are shown in Appendix 9.

The conditions of presentation and instructions were the same as those in the word naming task (cf. Experiment 2, Chapter Two). Participants were given 12 practice trials, consisting of four one syllable, four two syllable, and four three syllable nonwords. After a short break the experimental stimuli were presented in a single randomised block.

4.3.2.2 Results

One hundred and twenty one responses out of 1,500 (8.1%) were deleted from further analysis. Of these, 94 (6.3%) were mispronunciation errors, and 27 (1.8%) were due to accidental activation of the voice key. The mean reaction time for the nonword naming task was 749 ms.

4.3.3 Comparison between phonological skill and word and nonword naming skill

In order to test specifically whether or not the AoA effect is located at the level of phonological processing the current analysis investigated whether AoA is related to phonological skill. This was completed by assessing the relationship between individual's segmentation skill and their AoA effect sizes in the consonant cluster segmentation condition and in the word naming task. In addition, the current analysis also investigated the relationship between phonological skill and a number of other variables (word and nonword naming and the consistency effect size) in order to achieve a more rounded understanding of the relationship between phonological skill, reading skill and variables that (potentially) affect these two abilities. The variables thus included in the current comparison were:

1. Individual's phonological skill as measured by a) segmentation speed across all three segmentation conditions and b) segmentation errors across all three segmentation conditions.

2. Individual's word naming skill as measured by a) word naming speed and b) word naming (mispronunciation) errors.

3. Individual's nonword naming skill as measured by a) nonword naming speed and b) nonword naming (mispronunciation) errors.

4. Individual's AoA effect size in a) the word naming task and b) the consonant cluster segmentation task (where there was a significant effect of AoA).

5. Individual's consistency effect size in the word naming task.

The effect size statistic used to calculate the AoA and consistency effect sizes was the standardised mean difference *d* as described in Metsala et al. (1998). The AoA effect size was calculated by subtracting the mean RT to late acquired words from the mean RT to early acquired words for each individual, and then dividing by the pooled standard deviation of these two word sets for that person. The consistency effect size was calculated in a similar way, subtracting the mean RT to the exception words from the mean RT to consistent words for each individual and then dividing by the pooled standard deviation of these two word sets for that individual. These calculations provided a measure of the magnitude of each individual's AoA and consistency effect sizes independent of that individuals actual speed of responding. Thus any relationships between AoA and/or consistency effect sizes and phonological skill and word and nonword reading skill will be independent of processing speed (cf. Bowers & Wolf, 1993). The descriptive statistics for these three effect sizes, including the mean and the distribution of the variables can be seen in Table 4.3.

	M	SD	Range
AoA Effect Size: Consonant Cluster	0.17	0.33	-0.86 - 0.85
AoA Effect Size: Word Naming	0.16	0.28	-0.36 - 0.82
Consistency Effect Size	0.20	0.21	-0.40 - 0.81

Table 4.3 The mean, standard deviation and the range of the AoA and consistency effect sizes in Experiment 6.

Table 4.4 shows the correlations between each of the variables included in the present comparison. The significance of all correlations is at the 1-tailed level.

4.3.3.1 Comparison of word and nonword naming skill

The RTs to nonwords (mean 749ms) were slower than the RTs to words (mean 584ms) in the two naming tasks. Direct comparisons of word and nonword reading speeds are not appropriate, however, because the word and nonword stimuli were not matched for length or other factors (such as number of orthographic neighbours). As the correlations in Table 4.4 demonstrate, however, the relationship between word and nonword naming is highly significant with the two naming RTs correlating at 0.74. Word and nonword error rates also correlated significantly at

	1	2	3	4	5	6	7	8	9
1.Segmentation RT	-	0.64**	0.55**	0.45**	0.37**	0.28*	0.05	-0.25*	0.10
2. Nonword RT		-	0.74**	0.52**	0.46**	0.44**	0.03	-0.13	-0.10
3. Word RT			-	0.36**	0.28*	0.27*	-0.04	-0.15	-0.01
4. Segmentation Errors				-	0.59**	0.59**	-0.10	-0.33**	-0.21
5. Nonword Errors					-	0.61**	0.02	-0.20	-0.15
6. Word Errors						-	0.10	-0.19	-0.08
7. AoA Effect Size: Consonant Cluster							-	-0.01	-0.02
8. AoA Effect Size: Word Naming								-	-0.11
9. Consistency Effect Size									-

$^{**}p<0.01$, $^{*}p<0.05$ (1 tailed)

Table 4.4 Correlation matrix for variables in the segmentation, word naming and nonword naming tasks of Experiment 6

0.61. Participants who read words quickly and accurately also read nonwords quickly and accurately. Such a relationship has been reported in the developmental literature (e.g., Coltheart & Leahy, 1996; Metsala, 1997), and the present results demonstrate that this relationship persists in skilled adult readers.

4.3.3.2 Comparison of phonological skill with word and nonword naming skill

In addition to a strong relationship between word and nonword naming skill, the current comparison also revealed a significant relationship between each individual's phonological skill and their word and nonword naming skill, such that participants with better phonological skill also displayed more proficient word and nonword reading ability. Thus, overall segmentation speed correlated highly with word naming speed (0.55) and nonword naming speed (0.64), and showed smaller but still significant correlations with word naming errors (0.28) and nonword naming errors (0.37). In addition, segmentation error rates correlated significantly with word naming speed (0.36), word error rates (0.59), nonword naming speed (0.52), and nonword error rates (0.59).

The relationship between phonological skill and word and nonword reading skill previously reported in children (e.g., Wagner, Torgeson, Rashotte, Hecht, Barker, Burgess, Donahue & Garon, 1997) and developmental dyslexics (e.g., Bruck, 1990; 1992;

Elbro, Nielson, & Peterson, 1994; Elbro et al. 1998; Metsala, 1999; Pennington, Van Orden, Smith, Green, & Haith, 1990; Swan & Goswami, 1997) is replicated here with skilled adult participants. This result demonstrates a continuing relationship between an individual's phonological skill and their word and nonword reading skill through adulthood.

4.3.3.3 Comparison of phonological skill and the AoA effect size in segmentation and word naming

The previous section demonstrated that phonological skill continues to predict skills that are dependent upon phonological processing in skilled adult readers. If AoA is to be construed as a phonological effect then there should be a significant relationship between an individual's phonological skill and the size of their AoA effect in the segmentation task. This is because phonological skill is taken as a measure of the quality of phonological representations. As both the phonological completeness hypothesis of Brown and Watson (1987) and the lexical restructuring model of Metsala and Walley (1998) argue, better quality phonological representations allow early acquired words to achieve a superior level of representation than late acquired words. As a consequence there should be a larger AoA effect within the segmentation task for individuals with better phonological skill. Contrary to this prediction, however, no relationship was found between segmentation speed and the size of the AoA effect in the consonant cluster segmentation condition. Indeed these two variables correlated at only 0.05. Similarly, segmentation error rates did not correlate with the AoA effect size in the consonant cluster condition (-0.10).

The lack of a significant relationship between phonological skill and the size of the AoA effect in the consonant cluster condition suggests that, contrary to the assertions of the phonological completeness hypothesis (Brown & Watson, 1987) and the lexical restructuring model (Metsala & Walley, 1998), AoA does not exert its effect through the quality of phonological representations. If it did, the AoA effect shown by individuals in the consonant cluster segmentation condition would be strongly related to their level of phonological skill, but instead, as Figure 4.2 shows, participants displayed an AoA effect size of roughly equal

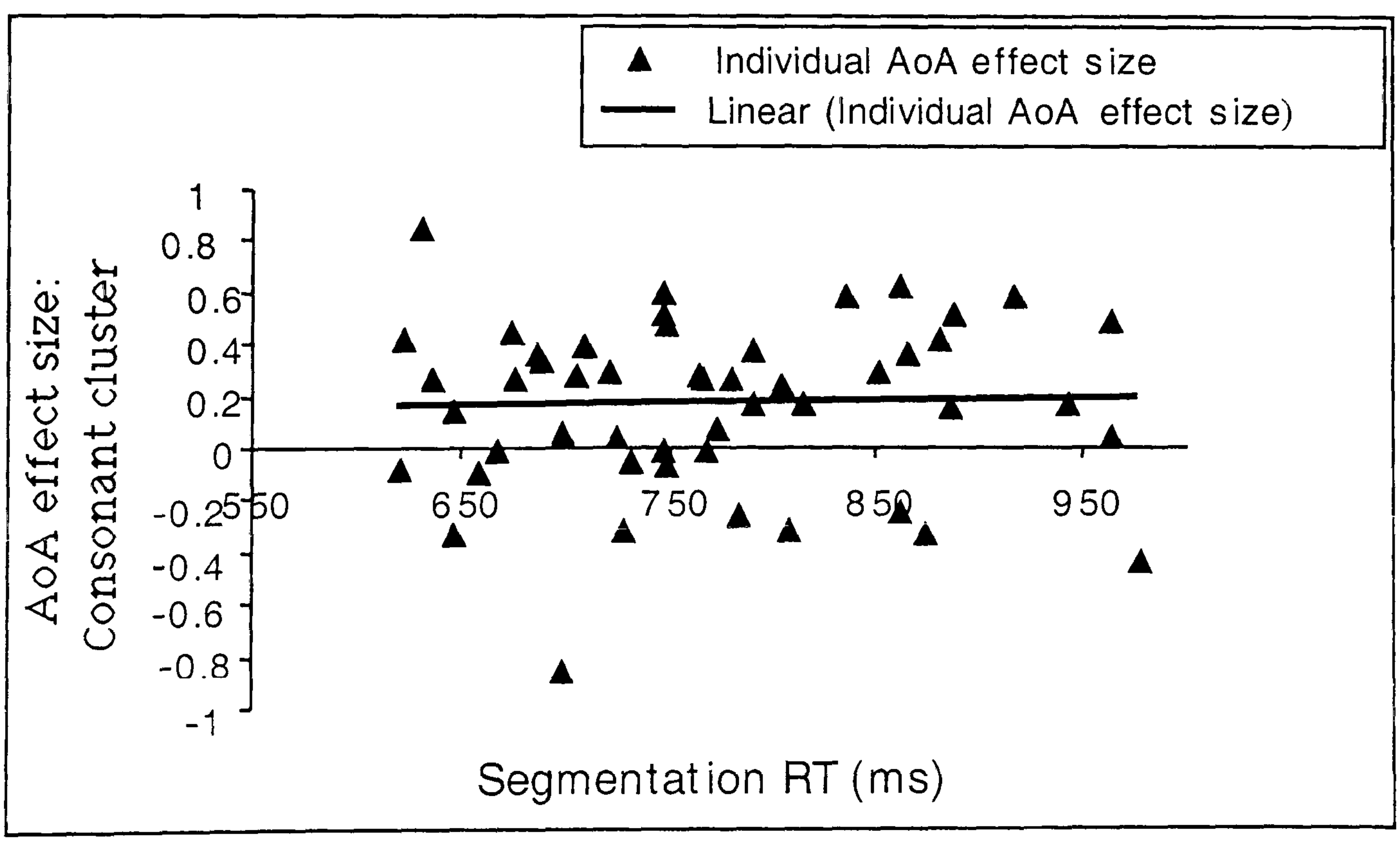

Figure 4.2 The relationship between phonological skill and the AoA effect size in the consonant cluster segmentation condition in Experiment 6.

magnitude irrespective of their level of phonological skill. This result suggests that AoA must exert its effect prior to the level of phonological processing and presumably, therefore, affects the strength of the connections between input and phonological output as Chapter Three concluded.

In contrast, the AoA effect size in the word naming task did correlate significantly with both segmentation speed (-0.25) and with segmentation error rates (-0.33). As Figure 4.3 shows, this relationship was such that individuals with better phonological skill showed a larger effect of AoA in the word naming task. This relationship does not contradict the lack of a relationship between phonological skill and the AoA effect size in the consonant cluster segmentation condition. Instead it suggests that good phonological

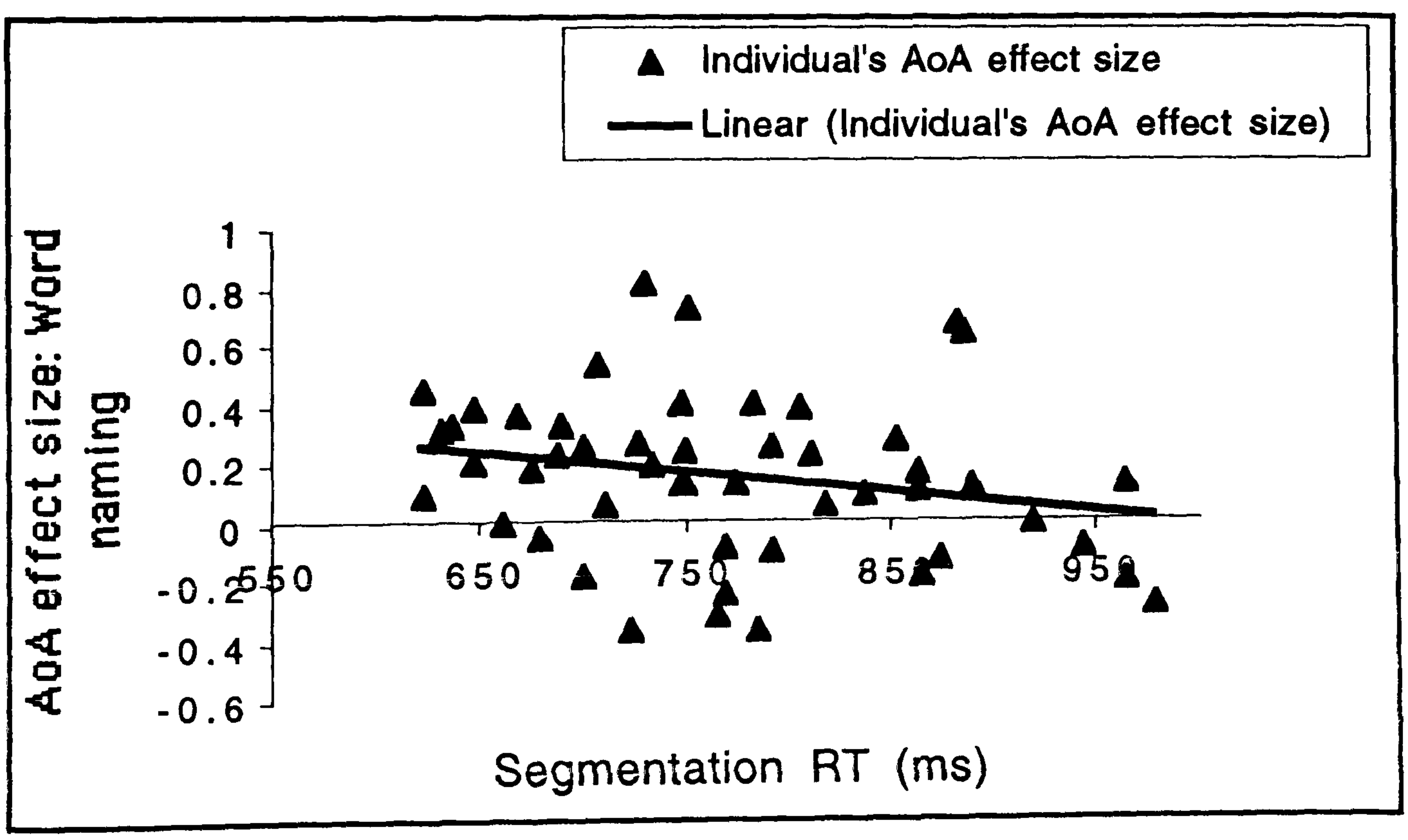

Figure 4.3 The relationship between phonological skill and the size of the AoA effect in the word naming task in Experiment 6.

skill may contribute to the *emergence* of the AoA effect during development without the AoA effect actually exerting its influence at the phonological level of processing in skilled adult readers. This possibility would support the claim that AoA exerts its effect in the connections between input (orthography/semantics) and phonological output with, perhaps, phonological skill helping the establishment of these connections during development. This important possibility will be returned to in the General Discussion.

4.3.3.4 Comparison of phonological skill and the consistency effect size in word naming

The final comparison investigated the relationship between phonological skill and the size of the consistency effect in word naming. No significant relationship was found in the current results: segmentation speed correlated at only 0.10 with the consistency effect size in word naming. The correlation between individual's segmentation error rates and their consistency effect size was also non-significant at -0.21. Although this relationship approached significance ($p = 0.069$), Figure 4.4 shows that there is no apparent relationship between segmentation error rates and the size of the consistency effect. That is, participants demonstrated a consistency effect size of relatively equal magnitude irrespective of their level of phonological skill.

Such a lack of a significant difference in the consistency effect size as predicted by phonological skill has been reported in the

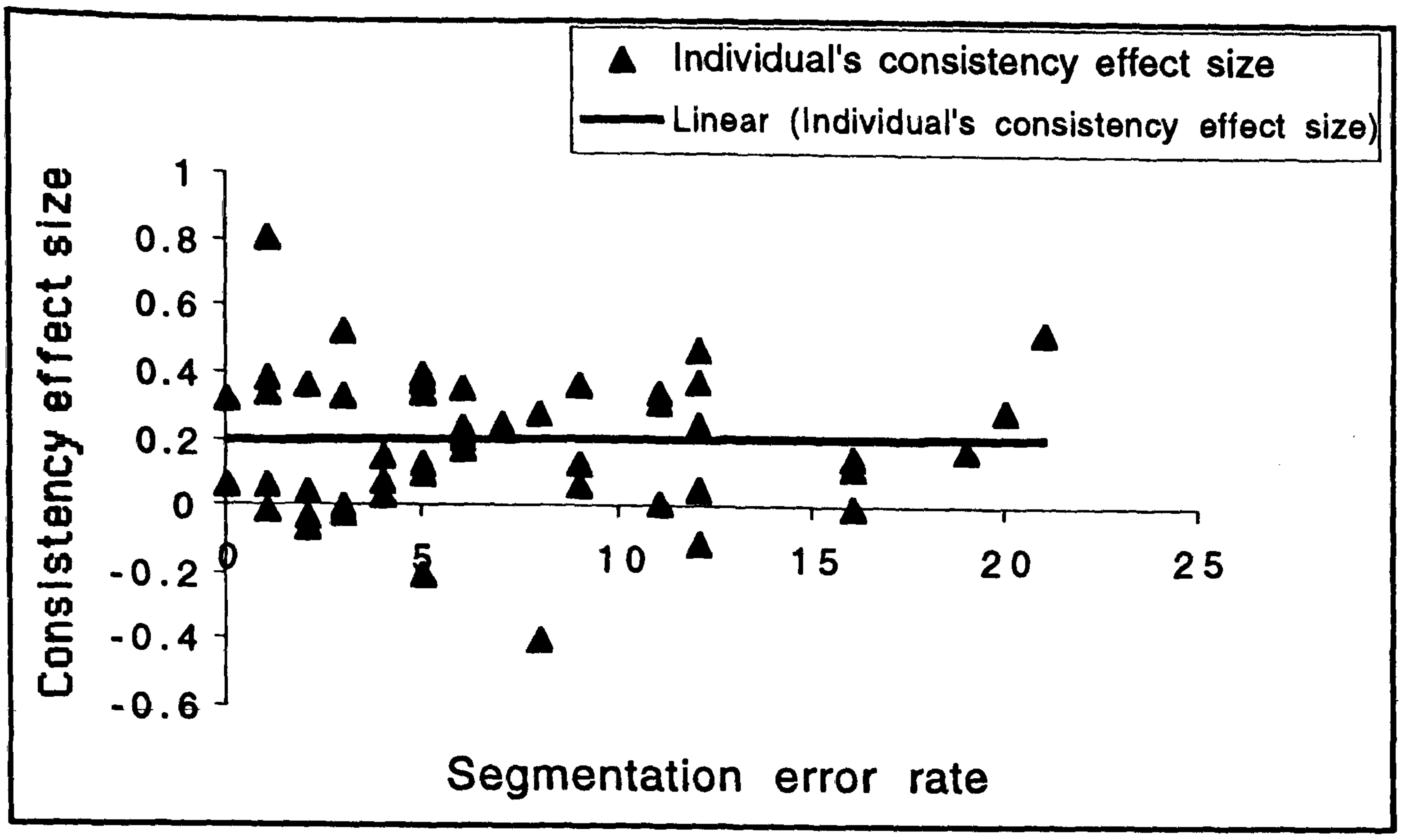

Figure 4.4 The relationship between phonological skill and the consistency effect size in Experiment 6.

developmental literature for children and developmental dyslexics (e.g., Brown, 1997; Metsala et al., 1998), suggesting that this effect is relatively unrelated to explicit phonological processing. This is in support of the claim that consistency affects processing prior to the level of phonological processing.

4.3.4 Discussion

Phonological skill (both speed and accuracy) has been shown to correlate with both word and nonword reading skill, such that individuals with greater phonological skill also read words and nonwords faster and with better accuracy. Word and nonword reading skill were also significantly related to one another. These relationships mirror previous findings in the developmental and reading disabled literature, demonstrating that phonological skill continues to predict word and nonword reading ability in skilled adults. The lack of a relationship between phonological skill and the consistency effect size has also been previously reported in developmental studies. This non-significant relationship confirms the assumption that consistency exerts its effect prior to explicit phonological processing.

Phonological skill did not correlate with the size of the AoA effect in the consonant cluster segmentation condition. As with the consistency effect, this non-significant relationship suggests that AoA also exerts its effect prior to the level of phonological processing. The AoA effect is not, therefore, a consequence of the quality of an individual's phonological skill.

The current comparison did, however, find a significant relationship between phonological skill and the size of the AoA effect in the word naming task, such that individuals with better phonological skill demonstrated a larger AoA effect. Such a relationship has not been reported previously. This finding suggests that although AoA does not affect the quality of individual's phonological representations, the level of phonological skill during development may influence the emergence of this effect. If AoA is located in the strength of the connections between input and phonological output, phonological skill may help these connections to become established during development. This possibility will be discussed in detail in the General Discussion.

The important conclusion to be made here is that not only do the present results clearly contradict the claim that the AoA effect is mediated by differences in the fragmentation of the representations in the phonological output lexicon (cf. Brown & Watson, 1987), they also demonstrate that the AoA effect is located prior to the level of the phonological output lexicon.

4.4 General Discussion

The results of the segmentation task in Experiment 6a clearly go against the phonological completeness hypothesis of Brown and Watson (1987) that would predict faster segmentation of late acquired than of early acquired words. None of the segmentation conditions produced such an effect. Moreover, where there was an effect of AoA - in the initial consonant cluster condition - early acquired words were segmented faster than late acquired words. There is no support in the present data for the notion that early acquired words are stored as purely whole word representations.

In contrast, these results would initially appear to provide some support (albeit limited, given that no AoA effect was found for onset-rime or syllable juncture segmentation) for the lexical restructuring model of Metsala and Walley (1998) which argues that early acquired words undergo extensive and fine-grained segmentation early on in the restructuring of the phonological lexicon. The present results suggest, however, that the difference in the quality of segmental representations between early and late acquired words only emerges at the level of individual phonemes. There was no difference in the speed of, segmenting onsets and rimes, or syllables, for early and late acquired words, although more errors were made to late than to early acquired words in the syllable juncture condition.

Contrary to the claims of the lexical restructuring model (and the phonological completeness hypothesis), the results of the comparison between phonological skill and the AoA effect size in the consonant cluster segmentation condition suggest that the AoA effect is not a consequence of the quality of an individual's phonological skill. If it were, phonological skill would have successfully predicted the size of this AoA effect, yet the correlation between these two variables was clearly non-significant. This lack of a relationship places serious doubt on the claims of both the phonological completeness hypothesis and the lexical restructuring model. In addition, it also contradicts the claims of the other vocabulary developmental theories that were discussed in the Introduction which claimed that early words may have segmented representations overlaid on initial holistic representations (e.g., Ferguson, 1986; Jusczyk, 1986; 1993; Walley, 1993)[2].

One potential confound in the present study, however, was the use of visual presentation in the segmentation task. The present study attempted to deal with this potential problem by utilising a long delay between the presentation of the word and the segmentation cue and through the use of irregularly spelt filler items. Even so, by exposing participants to the items' orthography this form of presentation may have influenced the present results. Consequently, in order to provide more conclusive support for the current findings and subsequent arguments of the present study it would be beneficial to repeat the segmentation experiment (and then the comparison between variables) using auditory presentation of the stimuli.

Nevertheless, in the present study there is no evidence that the AoA effect is a consequence of the quality of an individual's phonological representations. This suggests, therefore, that AoA exerts its effect prior to the level of explicit phonological

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[2] The results of the segmentation task also oppose those theories of vocabulary development which claim that early acquired words have both a whole word representation and a more segmented representation. If this were the case, then there should have been no difference between the segmentation speed of all early and late acquired words in the segmentation task. The existence of an AoA effect in the consonant cluster segmentation condition thus opposes the claims of these models.

processing. On the basis of these results and those of the previous Chapters Two and Three it would appear that AoA does affect the strength of the connections between input and phonological output. Phonological skill did correlate with the AoA effect size in word reading, however. This relationship suggests that, whilst AoA does not influence phonological processing, an individual's phonological skill may influence the emergence of the AoA effect during development.

If, as the vocabulary developmental theories propose, initial holistic representations become increasingly segmented during vocabulary development, and particularly during reading development, then a vital part of this process is the establishment of connections between input (orthography/semantics) and increasingly segmented phonological representations of words.

According to Ellis and Lambon Ralph's (2000) network, the earlier connections are established, the more influence they will have on the very structure of the processing system. If AoA influences the very structure of the connections between input and phonological output then this might explain why AoA in word naming relates to phonological skill, and why AoA in the consonant cluster segmentation task does not.

If, as the lexical restructuring model argues, the first words to undergo extensive fine-grained segmental restructuring are early acquired words, then these words will necessarily be the first items to establish connections between input and phonological output. Phonological skill determines the degree of segmentation that can be achieved and so will influence the ability to establish high quality, accurate connections. Consequently, children with good phonological skill will achieve fine-grained segmented phonological representations of early acquired words and as a consequence will establish accurate and strong connections between input and phonological output. Late acquired words will also be segmented to a fine-grained level in such skilled children, however, the connections to such segmented representations will not be as strong as they are for early acquired words simply because they are established later on. In contrast, children with poor phonological skill will fail to restructure their phonological representations effectively - representations will be less well segmented and perhaps less accurate. Such poor representations will limit the ability to construct strong definite links between input and the phonological representations. A consequence of poor phonological skill is, therefore, an inability to establish strong effective connections for early acquired words and so the usual advantage of early established connections will be lost.

The present results indicate that individuals with poorer phonological skill do not acquire a significant advantage for early acquired words over late acquired words in word naming. One prediction that extends itself from the present explanation is that poor young readers, and perhaps also developmental dyslexics, will show reduced lexical effects such as those of AoA due to their even poorer phonological skill.

In addition, the loss of an advantage for early acquired words in individuals with poor phonological skill also predicts that there will not be an interaction between AoA and consistency in the word naming task for such individuals. The interaction between consistency and AoA in the present word naming task was such that late acquired exception words are named more slowly than early acquired exception words and consistent words of both early and late AoA. This is because exception words that are acquired early are able to establish strong connections that compensate for the unpredictability of their pattern of connections into phonology. However, if poor phonological skill causes a loss of the usual advantage of early acquired words then exception words will struggle to be read correctly regardless of the item's AoA. Some evidence for this claim comes from studies which have shown that, in poor young readers and dyslexic participants, there is an effect of consistency for both high and low frequency words, whereas normal readers only show a consistency effect for low frequency words (e.g., Bruck, 1990; Metsala et al., 1998; Waters, Seidenberg, & Bruck, 1984). If a part of the frequency effect in these studies is actually an AoA effect, it may well be the case that poor phonological skill reduces the ability to establish strong connections and so causes a consistency effect to emerge for early as well as for late acquired words.

The finding of an AoA effect in the consonant cluster segmentation condition that is unrelated to phonological skill demonstrates that AoA is not located at the phonological level of processing. It is, however, important to consider why one finds an AoA effect in a phonological segmentation task when AoA is not located in these representations. One possible reason for this effect might be that late acquired words simply never achieve as fine-grained a level of segmentation as do early acquired words. This may be because early acquired words undergo more extensive, fine-grained segmentation (cf. Metsala & Walley, 1998). Alternatively, faster segmentation of consonant clusters in early acquired words may be a remnant of initial attempts to segment words and establish connections by young children. For example, young children do appear to focus more on the initial and final letters of words in the early stages of reading development (cf., Ehri, 1992). Young children are also reported to make many errors in their early attempts to pronounce initial consonant clusters - with only one of the two consonants being produced (cf., Barlow & Dinnsen, 1998). A result of this may be that early phonological representations store the two consonants of an initial cluster separately from each other, or perhaps store the first consonant of a cluster entirely separately from the rest of the word, whilst later learnt words have phonological representations of consonant clusters that are less explicitly segmented. Consequently, adults remain able to segment consonant clusters of words that were learnt early more easily than words that were learnt later on.

The present study does not allow a definitive explanation as to why there is an AoA effect when segmentation is required at the level of consonant clusters (or individual phonemes). The important point to be made here is that the present results not only contradict the claims of the phonological completeness hypothesis, they also suggest quite strongly that AoA does not affect the phonological level of processing. The alternative account able to explain the present results is that, as was concluded in the present Chapter Three, AoA exerts its effect through the strength of the connections established between input and phonological output (e.g. Ellis & Lambon Ralph, 2000). Phonological skill predicts the AoA effect size in word naming because the level of an individual's phonological skill affects the establishment of the connections between input and phonological output where the AoA effect resides. Thus, while the quality of an individual's phonological representations does not constitute the locus of the AoA effect, they may well influence the emergence of the AoA effect in the connections between input and phonological output in skilled adult readers.

CHAPTER 5

AN INVESTIGATION OF THE VARIABLES AFFECTING APHASIC PATIENTS' PICTURE NAMING SUCCESS - A LITERATURE REVIEW.

5.1 Introduction

The work completed in this thesis has been aimed at identifying where, within the language processing system, AoA exerts its effect. The Experiments of Chapter 4 suggest that the AoA effect is not located at the level of phonological processing itself. Further, this work, and that of Chapters Two and Three suggest that AoA may reside within the connections between different processing levels, with early acquired words having greater connection strengths between orthography and phonology, and between semantics and phonology, than do late acquired words. These stronger connections allow early acquired items to be read aloud/named more quickly and more successfully than later acquired items (cf. Ellis & Lambon Ralph, 2000). The current thesis has not yet specifically examined the effect of AoA in the picture naming system, however. The aim of the current study was, therefore, to investigate the exact locus of AoA in the picture naming task more specifically.

This investigation will be completed through an assessment of the characteristics of pictures and their names that affect the naming success of aphasic patients. Aphasic patients often have difficulty in naming pictures of objects. It is also the case, however, that they typically remain able to name some objects whilst having great difficulty with others (cf. Lambon Ralph, Sage, & Roberts, 2000; Nickels, 1997). Aphasic patients naming success can be predicted by a number of characteristics of the object (at the level of visual input and/or semantics) and its name (in the access and/or retrieval of phonology). Moreover, as Chapter One discussed, the processes involved in picture naming comprise a number of processing stages. Consequently, aphasic patients could have damage to any one of these processing levels. That is, aphasia could occur as a consequence of an impairment specific to the semantic system (thus affecting the stored concepts of objects), the phonological output system (affecting the phonological representations of pictures names) and/or the connections between the two (affecting the access of phonological representations from semantics), (cf. Lambon Ralph, Moriarty, Sage, et al., in press).

The occurrence of aphasic picture naming deficits that are specific to a semantic level of impairment have been reported many times in the neuropsychological literature (e.g., Gainotti, Silveri, Villa & Miceli, 1986; Hillis, Rapp, Romani, & Caramazza, 1990; Howard & Orchard-Lisle, 1984; Nickels & Howard, 1994). Nickels and Howard (1994) reported a number of aphasic patients with such a specific level of semantic impairment. These patients showed poor performance on tests of conceptual knowledge - the Pyramids and Palm Trees task and a synonym judgement task. In addition the errors made by these patients in a picture naming task were predominantly semantic. Such a pattern of performance and a high proportion of semantic errors in the absence of phonological errors lead to the diagnosis of a specific impairment to the semantic level of processing in these patients.

Other aphasic patients have been reported who have a severe picture naming deficit that is not predicted by their semantic processing abilities. Many such patients have, consequently, been assumed to have an impairment at the phonological level of processing (e.g., Caramazza & Hillis, 1990; Kay & Ellis, 1984; Nickels & Howard, 1994). A case-series study of 21 aphasic patients by Lambon Ralph et al. (in press) provides an example of 2 patients (AC and JM) that had a pure phonological impairment. These two patients showed normal performance on a number of semantic comprehension tests, but were impaired on tests of phonological processing such as word and nonword repetition, thereby suggesting that damage to the phonological system itself was responsible for the poor picture naming performance in these two aphasic patients.

A recent study by Lambon Ralph et al. (2000) has also reported two clear cases of aphasic patients that have damage specific to the connections between the semantic and phonological levels of processing. These two patients (GM and JS) showed normal performance over seven tests of semantic comprehension. Similarly, their performance on a number of tests of phonological processing was completely normal. Despite the intactness of semantic and phonological processing in these two patients their picture naming performance was very poor, thereby leading Lambon Ralph et al. (2000) to conclude that these two patient's level of damage must be within the connections from semantics to phonology.

Clearly, therefore, an aphasic patient's picture naming impairment can be a consequence of damage to the semantic system, to the phonological system or to the connections that link these two processing levels. However, the normally extensive damage caused by head injury in aphasic patients means that the majority of aphasics will have damage to more than one of these levels of processing. Consequently aphasic patients may have, for example, damage to both semantics and phonology (e.g., Hirsh & Ellis, 1994; Lambon Ralph et al., in press), or damage to phonology and to the connections between semantics and phonology (e.g., Kay & Ellis, 1987), and so on.

The fact that aphasic patients can have damage to one or more of the processing levels within the picture naming system suggests that they will be affected by different variables in the picture naming task. This is because different characteristics of objects and their names are also assumed to affect different levels of processing within this system. By identifying the variables that have an effect on a particular patient's naming success and then relating this to their level of impairment, one may be better able to identify the locus of such effects, and in particular the effect of AoA.

The purpose of the present study was, therefore, to extend the previous work of the thesis in order to investigate the locus of the AoA effect in the picture naming task in more detail. This will be done through the investigation of the variables that affect picture naming success in any particular aphasic patient and relating these effects to that patient's level of impairment. This should help to locate the effects of factors such as AoA and frequency within the picture naming system. The rest of this Chapter will review previous studies that have investigated factors affecting picture naming success in aphasic patients. The proceeding Chapter will then present the study.

5.2 What variables affect picture naming success in aphasic patients?

There are many characteristics of an object and its name that have been identified as playing an important role in aphasic patients picture naming success. These include AoA, word frequency, object familiarity, word length, imageability, operativity, animacy (cf. Nickels, 1997; Nickels & Howard, 1995) and visual complexity (e.g. Cuetos, Aguado, Izura & Ellis, submitted).

As would be expected, however, given the fact that these variables affect different levels of processing, and that patients can have different levels of impairment, studies often report differences in the variables that affect group naming performance. Moreover, recent studies that have examined the naming success of individual patients have demonstrated that different variables affect different patients. Nickels and Howard (1995) were the first to report this difference between individual patients in relation to group naming performance. In their Study 1, Nickels and Howard (1995) presented 12 aphasic patients with 104 object pictures to name on five separate occasions. Responses were classified as correct if the target word was produced at any point during the naming attempt. The group's naming success for each item over all five administrations (a score between 0 and 5 on each item) was entered into a multiple regression analysis as the dependent variable along with the predictors of AoA, object familiarity, frequency, word length, imageability, concreteness, operativity and visual complexity. In a simple correlation analysis, all variables except frequency and visual complexity correlated significantly with group naming success. In the simultaneous multiple regression analysis, however, only AoA, operativity and word length were found to make a significant independent contribution to group naming success.

In addition to this group analysis, Nickels and Howard (1995) also performed simultaneous multiple regression analysis on each individual patient's naming success. The results of these analyses demonstrated clearly that not all patients were affected by those variables that affected group naming performance, nor were all the patients affected by the same variables. Thus only 5 of the 12 patients showed an effect of AoA, 7 showed an effect of operativity, and 2 showed an effect of word length. One patient also showed an effect of frequency, despite this variable having a non-significant effect on group naming performance. None of the other variables (imageability, concreteness, visual complexity or familiarity) had an effect on any of the patients' naming performance.

In their second study, Nickels and Howard (1995) attempted to replicate the findings of their Study 1 using stimuli selected to increase the independence between variables, and to increase the variability in word length. These 130 stimuli were presented to 15 aphasic patients who named the stimuli over two testing sessions. Each patient named each picture once only. A stricter scoring criterion was adopted in this study with responses only classified as correct if the initial response was the target name. The group's naming performance on the 130 items was entered into a multiple regression analysis with all those variables investigated in Study 1 (except visual complexity that was excluded due to its lack of significance in Study 1). The results of the simple correlation analysis replicated those of Study 1 with all variables correlating significantly with naming performance apart from frequency. However, in the simultaneous multiple regression analysis, whilst AoA and word length continued to have a significant effect, operativity failed to reach significance in this study. For this group of patients, imageability also proved to be a significant predictor of naming success. No other variable (frequency, familiarity, or concreteness) reached significance.

As in Study 1, Nickels and Howard (1995) then carried out a regression analysis of each individual patient's naming performance. The results of this analysis again revealed differences between those variables affecting individual patient's naming performance and those affecting group naming. Thus, only 3 of the 15 patients showed an AoA effect, 9 showed an effect of word length, and 2 showed an effect of imageability. In addition, one patient showed an effect of operativity and one an effect of familiarity. None of the patients demonstrated an effect of frequency or concreteness. Nickels and Howard (1995) argued that the small influence of AoA in this study at the level of individual patients might have been a consequence of the high inter-correlation of frequency and familiarity with AoA. With frequency removed from the analysis, AoA remained significant for only 3 patients; when both frequency and familiarity were removed a further 3 patients demonstrated a significant effect of AoA.

Cuetos et al. (submitted) completed a similar study to Nickels and Howard (1995) with 16 Spanish aphasic patients. These patients named 131 pictures 3 times on separate occasions. Responses were classified as correct if the target name was produced at any point during the naming attempt. The group naming performance was analysed in a simultaneous multiple regression analysis with the predictor variables of AoA, frequency, object familiarity, word length, imageability, animacy and visual complexity. In simple correlation analysis, naming success for the group was found to correlate most highly with AoA (-0.69) followed by frequency (0.61), familiarity (0.60), imageability (0.31) and word length (-0.28). Naming success did not correlate with visual complexity or animacy. In the multiple regression analysis these seven variables were found to account for 62% of the variance of the group's naming accuracy. Of these variables, AoA was found to account for the largest proportion of unique variance in group naming, followed by word frequency, object familiarity and visual complexity. Imageability, animacy and word length did not provide any significant contributions to predicting picture naming success once these other variables had been taken into account.

In the analysis of individual patient's naming success, however, as was the case in Nickels and Howard's (1995) studies, there was a great deal of variability in the factors affecting individual patient's naming success. In multiple regression analyses of each individual patient's naming performance, Cuetos et al. (submitted) found an effect of AoA in 10 of the 16 patients, an effect of frequency in 6 patients, an effect of familiarity in 5 patients, and an effect of visual complexity in 5 patients. In addition, an effect of imageability was found in 2 patients, an effect of animacy in 2 patients and an effect of word length in 3 patients. Clearly, therefore, in this study all the variables in the analysis had an effect in one or more patients, even though they did not all prove significant predictors of group naming performance.

5.2.1 Summary

The two studies of Nickels and Howard (1995) and Cuetos et al. (submitted) have demonstrated the clear importance of AoA as a robust factor in predicting the naming success of groups of aphasic patients. Other studies have also reported a significant effect of AoA in group naming success of aphasic patients (e.g. Ellis, Lum & Lambon Ralph, 1996; Feyereisen, Van der Borght, & Seron, 1988). What other factors affect naming success in groups of aphasics appears to be somewhat variable. Thus, at the group level, Nickels and Howard reported effects of AoA, operativity and word length in their Study 1, whilst in Study 2 the significant variables were those of AoA, word length and imageability. In contrast, Cuetos et al. (submitted) reported effects of AoA, word frequency, object familiarity and visual complexity. There is also significant variability at the level of individual patients, with no variable consistently affecting every individual patient's naming success.

5.3 Explaining the variability of effects on naming success both between studies and between patients

5.3.1 The heterogeneity of aphasic patients

As has already been alluded to in the Introduction of this Chapter, the variability of effects found both between studies and between individual patients is most likely a consequence of the fact that aphasics consist of a highly heterogeneous group of patients (Nickels & Howard, 1995). That is, different patients will have different levels of impairment and so will be affected by different characteristics of the experimental stimuli. Indeed, because aphasic patients could have damage to the semantic system, the phonological system, and/or the connections between semantics and phonology, and because different variables exert their effects at these different levels of processing, it is not surprising that different patients show different effects. As a consequence, studies that utilise different groups of patients will reveal different effects on group naming performance depending upon that groups make up.

More specifically, patients who have damage to the semantic system itself should be affected by those variables that exert their effects at the semantic level of processing, namely the variables of familiarity, imageability, operativity, and possibly animacy (if there is a category specific deficit). Familiarity and imageability have long been assumed to affect processing in the semantic system, with high familiarity/high imageability items having richer semantic representations than low familiarity/low imageability items (e.g., Cuetos et al., submitted; Lambon Ralph, Graham, Ellis & Hodges, 1998). In contrast, patients with an impairment in the phonological system will be affected by the phonological variable of word length. Patients who have damage to connections between semantics and phonology will demonstrate effects of variables that affect connection strengths, and possibly, therefore, will show effects of AoA and frequency. In addition, however, if AoA and frequency do affect the strength of connections between semantics and phonology then these variables may also exert an effect in patients with semantic and/or phonological levels of impairment. This is because patients with a semantic impairment will produce weakened semantic output, but the stronger connections from semantics to phonology for early acquired/high frequency words may help transmit this output and so allow successful activation of the corresponding phonological representations. Similarly, patients with weakened phonological representations may receive stronger input from early acquired/high frequency words and so will be more likely to achieve sufficient activation in order to retrieve those items.

Whilst no study to date has specifically tested these predictions in patients with aphasia, there are a number of studies that provide support for such predictions. Lambon Ralph et al. (1998) reported a naming study on a group of 8 semantic dementia patients. Semantic dementia, or progressive fluent aphasia, involves a progressive loss of semantic knowledge accompanied by severe anomia due to progressive atrophy of the anterior temporal lobes (Lambon Ralph et al., 1998). Lambon Ralph et al. (1998) reported effects of familiarity, AoA and frequency on this patient groups naming performance. At an individual level, all 8 patients showed an effect of frequency, 7 an effect of familiarity, and 6 an effect of AoA. One patient also showed an effect of visual complexity, one an effect of animacy and one an effect of word length. These results support the suggestion that semantic variables and those variables affecting connection strengths will be the variables that predominantly affect naming success in patients with a semantic level of impairment.

However, Hirsh and Funnell (1995) reported a semantic dementia patient with a severe semantic deficit who showed an effect of familiarity, but not of AoA. This result, and the fact that only 6 of the 8 patients in Lambon Ralph et al.'s (1998) study demonstrated an AoA effect, suggests that AoA may not always affect patients with a semantic level of impairment. It is worth noting, however, that the non-significant AoA effect reported by Hirsh and Funnell (1995) may have been due to a lack of statistical power in their regression analysis that included only 72 items and 6 predictor variables (Lambon Ralph et al. 1998). Furthermore, AoA correlated very highly with familiarity (-0.43) and with frequency (-0.40) in Lambon Ralph et al.'s (1998) study, which may have reduced the potential effects of AoA for individual patients (cf. section 5.3.2).

Interestingly, Hirsh and Funnell (1995) reported a second patient who appeared to have an impairment in the connections between semantics and phonology. This patient did show a significant effect of AoA on naming success.[1] This level of damage provides evidence for the claim that AoA affects these connection strengths. In addition, a case study by Hirsh and Ellis (1994) revealed an AoA effect in a patient who displayed both mild semantic and phonological deficits, thus suggesting that AoA does affect patients with impairments to semantics and/or phonology.

Overall, then, these patient studies do suggest that AoA (and possibly frequency) will show an effect in patients with a semantic impairment, and/or a phonological impairment. AoA will also likely be seen in patients who have an impairment in the connections between semantics and phonology, thereby suggesting a locus of AoA (and possibly frequency) within these connection strengths. If AoA is located in the connection strengths, aphasic patients that one might not expect to show an AoA effect would include those with a pure phonological output impairment, such as those patients with pure apraxia of speech that is assumed to be caused by damage to articulatory processes (e.g., Square-Storer & Roy, 1989). The strength of such patient's semantic - phonological connections should not affect articulatory processing and so should not influence their naming success to any significant degree.

[1]Hirsh and Funnell (1995) used stimuli that manipulated AoA and familiarity whilst holding frequency constant. Consequently we cannot identify the possibility of an additional effect of frequency in this patient.

5.3.2 The Problem of Multicollinearity

An alternative possible account of some of the variability of effects found between group studies and between patients is that the variables under consideration are too highly inter-correlated to be suitable for regression analysis. If variables are highly inter-correlated it can result in variables showing a significant effect purely because they are confounded with other influential variables. Such confounding is suggested by the results of the simple correlation analyses of Nickels and Howard (1995) and Cuetos et al. (submitted) wherein far more variables were reported to correlate with naming success than were significant predictors in the multiple regression analysis. Those variables that were only significant in the correlation analysis are, more than likely, only significant there because they correlate with a variable that is a significant predictor of naming accuracy. In this way, multiple regression can prove a useful tool in alleviating the problems of highly inter-correlated variables. This is because multiple regression assesses the unique independent contribution of a variable independent of all other predictors. However, if variables are very highly inter-correlated in multiple regression analyses this leads to the problem of multicollinearity wherein the significance of an important variable can be reduced as a consequence of its high inter-correlation with one or more other variables. That is, another inter-correlated variable may appropriate the significance of another influential variable. If this occurs then the true significance of important variables can be completely missed in a regression analysis.

An example of such a problem with multicollinearity is evidenced in Study 2 of Nickels and Howard (1995). The correlation between AoA and familiarity in this study was -.61, and between AoA and frequency it was -.29. Consequently, when both frequency and (most importantly) familiarity were removed from the regression analysis, the number of patients who showed a significant effect of AoA doubled from 3 to 6.

Clearly, therefore, whilst multiple regression can deal very well with a certain degree of inter-correlation, when this becomes too high, multicollinearity will result in an inability to assess the true effects of variables. Differences in the degree of inter-correlations between variables over studies might, therefore, explain why some studies report effects of variables like familiarity and frequency (e.g. Cuetos et al., submitted) while others do not (Nickels and Howard, 1995), and further, why some studies show an AoA effect in 10 out of 16 patients whilst others find it in only 3 out of 15 patients (cf. Cuetos et al., submitted; Nickels and Howard, 1995).

Another consequence of multicollinearity is highlighted in the results of the study on aphasic naming success completed by Ellis et al. (1996). Ellis et al. (1996) assessed the naming success of 6 aphasic patients on 139 pictures that were named three times each on separate occasions. In multiple regression analysis the only significant predictor of group naming performance was AoA. Analysis of individual patient's naming performance revealed an AoA effect in 3 patients, a familiarity effect in 2 patients and a frequency effect in 1 patient. In addition to these analyses, however, Ellis et al. (1996) also investigated the effects shown by each individual patient on each of the three separate administrations of the stimuli. This analysis revealed a great deal of inconsistency between the variables that affected picture naming success for each patient over the three administrations. That is, for each of the six patients, no variable successfully predicted naming success consistently over all three administrations. Ellis et al. (1996) attribute this inconsistency to the problem of multicollinearity, arguing that when predictor variables are highly inter-correlated, a small change in the items named right and wrong can dramatically change the outcome of regression analyses. Ellis et al. (1996) further argue that this problem is especially true for a task like picture naming wherein effects are relatively small and account for relatively little variance.

An additional explanation of some of this inconsistency may be attributable to the dependent variable used in the analysis of patient's naming success based on only one naming attempt. When items are named only once, the dependent variable is dichotomous (either 0 = named incorrectly, or 1 = named correctly). Thus whether or not an effect is significant depends upon a significant difference between the number of 0's and 1's in the data. This is in contrast to an analysis based upon a dependent variable in which naming can vary from 0 = named incorrectly to 3 = named correctly over all three naming trials. In such an analysis an effect can be significant if there is a significant difference between, for example, a score of 0 or 1 and a score of 2 or 3. The point here is, therefore, that the use of a dichotomous dependent variable might reduce the power of a regression analysis, thereby increasing the risk of Type II errors. Such a problem might have explained why, for example, Lambon Ralph et al. (1998) failed to find an AoA effect in 2 of their 8 patients, and why Hirsh and Funnell (1995) failed to find an AoA effect in one of their 2 patients.

These findings together highlight the potential problems of using regression analyses for variables that are highly inter-correlated and that have only relatively small effects. Indeed, for variables as highly correlated as, for example, AoA and familiarity (e.g. Lambon Ralph et al., 1998; Nickels and Howard, 1995) one can never be certain that the results of a regression analysis reflect the true influences of the variables under consideration, or simply reflect the confounding of variables. This may be particularly true when the dependent variable is a dichotomous variable. Therefore, as Ellis et al. (1996) conclude, in order to identify which variables truly affect a patient's naming success, those variables that have been identified within multiple regression analyses must be corroborated with results achieved using factorial analysis wherein an individual variable is manipulated whilst keeping all the other variables constant.

5.4 The Current Study

The aim of the current study was to investigate the variables that predict naming success in aphasic patients both at a group and at an individual level of analysis. In order to control for problems such as multicollinearity, those variables of interest will be manipulated using a factorial design, in addition to placing the results in a regression analysis. In addition to this, each individual patient's level of impairment will be assessed through the examination of their semantic and phonological abilities. Each patient's level of impairment will then be related to the variables that predict their naming performance. This should allow an identification of where, within the picture naming processes, such variables exert their effect. Particular focus in the current study will be on the effects of AoA (and frequency).

CHAPTER SIX

IDENTIFYING THE LOCUS OF AoA IN THE PICTURE NAMING TASK: AN INVESTIGATION OF THE VARIABLES AFFECTING APHASIC PATIENTS' PICTURE NAMING SUCCESS

6.1 Introduction

The literature review in Chapter Five concluded that aphasic patients with different levels of damage will show effects of different variables in the picture naming task. Whether a patient will show a particular effect or not depends upon their level of impairment and the locus of that variable's effect within the picture naming system. Thus, a patient with a semantic level of impairment should show effects of semantic variables (familiarity, imageability, animacy); patients with a phonological impairment should show effects of phonological variables (word length); and patients with damage to the connections between semantics and phonology should show effects of variables that affect these connection strengths and may, therefore, show effects of AoA and frequency. Variables that affect connection strengths may also show an effect in patients with a semantic or a phonological level of impairment as the stronger connections for early acquired/high frequency items will help to transmit weak semantic output and/or boost input to weak phonological representations. Such a relationship between a patient's level of impairment and the effects they show can, therefore, allow a more precise identification of the locus of certain variables within the picture naming system.

The aim of the current study was to investigate more specifically the exact locus of the AoA effect (and other variables) in the picture naming task through the testing of a group of aphasic patients' performance on the picture naming task. In addition to the picture naming task each patient was given two semantic and two phonological tasks in order to assess their level of impairment(s) within the picture naming system. By then relating each patient's level of impairment to the effects that they show in the picture naming task the locus of such effects can be identified more precisely.

Chapter Five also highlighted some of the problems associated with the use of multiple regression analyses when predictor variables are highly inter-correlated (e.g., Lambon Ralph et al., 1998; Nickels & Howard, 1995) and/or when analyses are based on results wherein pictures are named once only (e.g. Ellis et al., 1996). In order to alleviate such problems in the current study, picture naming performance was also assessed using a factorial design. The picture naming task in the current study involved 5 subsets of items that manipulated one variable (AoA, frequency, familiarity, length or animacy) whilst controlling for all other variables of interest. In addition to this factorial analysis, the total set of items were also entered into a regression analysis with the above variables plus imageability and visual complexity as the predictors. The results of each patient's picture naming performance on both the factorial and regression methods will then be compared in order to test the reliability of the current results over the two forms of analyses. This comparison also allows an investigation of the consistency of results obtained using both factorial and regression analyses.

6.2 A study of picture naming in aphasic patients

6.2.1 Method

6.2.1.1 Participants

Thirteen aphasic patients took part in the study. The patients were selected on the basis of a predicted picture naming performance within the region of 25 - 75% correct. All participants were at least 6 months post onset CVA (mean 40.3 months, SD 13.1) and had a level of comprehension sufficient to understand the requirements of the present study. There were 6 female and 7 male patients ranging in age from 41 to 82 years (mean 65.8 years, SD 13.1). All patients were right handed and were aphasic following CVA. Table 6.1 shows the general characteristics of the patients. All patients were seen for two testing sessions that were one week apart.

Case	Sex	Age in years	Former occupation	Years education	Months post-onset	Handed-ness
1	F	77	Book keeper	14	81	R
2	F	41	Administrator	11	27	R
3	M	61	Lecturer	18	49	R
4	F	76	Shop worker	14	52	R
5	F	59	Seamstress	10	6	R
6	M	65	Housing Inspector	9	22	R
7	M	82	Farmer	9	33	R
8	F	79	Shop worker	9	8	R
9	M	50	Joiner	11	18	R
10	F	77	Housewife	10	30	R
11	M	54	Manager	10	84	R
12	M	58	Manager	10	96	R
13	M	77	Manager	11	22	R

Table 6.1 General information of the 13 aphasic patients in the picture naming study.

Thirteen control participants were also tested on the picture naming task and the word-picture matching task. The control participants consisted of 7 female and 6 male participants that had a similar age-range (44 - 88 years, mean 69.1, SD 13.6) to the aphasic patient group.

6.2.1.2 Materials and procedure

6.2.1.2.1 Semantic tasks

Two semantic tasks were administered to the aphasic patients in order to assess each patient's level of comprehension. The tasks used were a spoken and written word-picture matching task and a synonym judgement task.

1. Word-picture matching task. A new word - picture matching task was developed for the current study. The test devised involved 25 target pictures that were presented along side three closely related semantic foils. The target word was written in the centre of the page, and was also spoken by the experimenter. Figure 6.1 shows an example of this newly developed word - picture matching task. Participants were asked to point to the picture that matched the word that was written on the page and spoken aloud by the experimenter. Participants were given four practice trials and then completed the 25 experimental items in one randomised block.

All of the target items had different picture names to those items in the picture naming task. Whilst some of the semantic foils had the same picture names as some of the items in the picture naming task, the pictures used were different. The target items and distracters can be seen in Appendix 10.

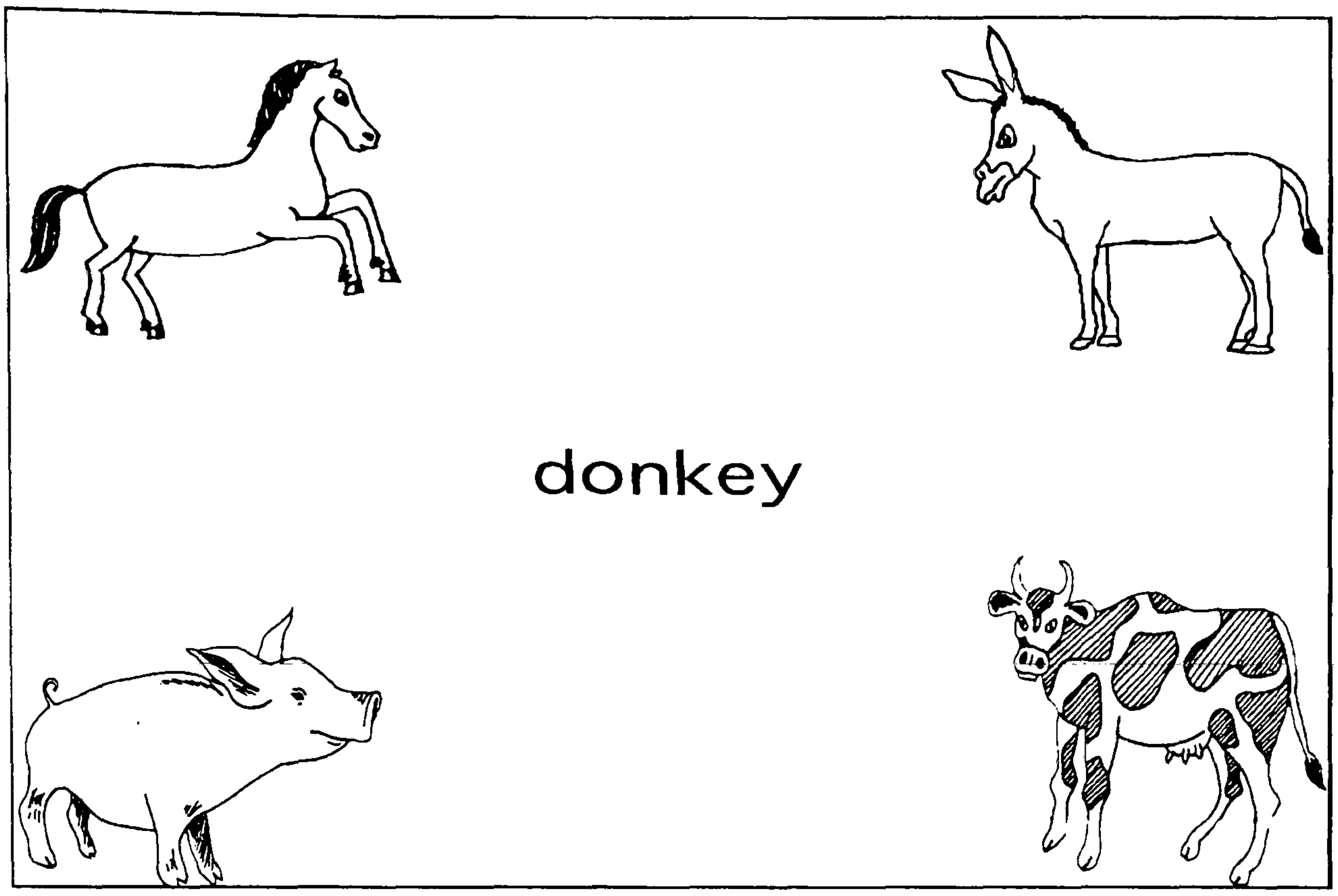

Figure 6.1 An example of the target and distracters of the word-picture matching task in the aphasia picture naming study.

2. *Synonym judgement task.* The synonym judgement task used was that developed by Warrington, McKenna & Orpwood (1998). This task involves 25 concrete and 25 abstract target words that are paired together with a synonym of higher frequency and a distracter item of similar frequency (e.g., MARQUEE = TENT or PALACE, and SEVER = CUT or PRUNE). The items were presented both visually and orally. Participants were required to choose the synonym of the target word from the distracter item, and were encouraged to guess if they were unsure about the correct answer. Concrete and abstract sections of the test were presented one after the other, and the order of presentation of the two sets was counterbalanced over participants. Four practice items were

adapted from the A.D.A Comprehension Battery synonym decision test (Franklin, Turner & Ellis, 1992).

6.2.1.2.2 Phonological tasks

Two phonological tasks were administered to the aphasic patients in order to test for any phonological impairments. The first task was a word and nonword repetition task that assesses both phonological input (auditory) and output (production) skills. The second task administered was the minimal pairs task which assesses phonological input skill. The use of an input phonology task was necessary in the present study in order to discriminate between patients with input and output phonological impairments as both of these processes are assessed in the repetition task.

1. Nonword minimal pairs. The minimal pairs task was taken from the A.D.A test battery (Franklin et al., 1992). This task consists of forty pairs of CVC nonwords, 20 pairs that sound the same (e.g., bip, bip), and 20 pairs that differ from one another by one or two features of the initial or final phoneme (e.g., ped, ged; gep, ged). Participants were asked to decide whether the items in a pair spoken by the experimenter sounded the same or different.

2. Word and nonword repetition. The word and nonword repetition task was taken from the A.D.A test battery (Franklin et al., 1992). Participants were required to repeat aloud 40 words and 40 nonwords spoken by the experimenter. Half of the items (20 words and 20 nonwords) were short items of one syllable in length while the other half were two syllables in length.

6.2.1.2.3 Picture naming task

The experimental stimuli were taken from the large set of norms developed by Morrison et al. (1997) that had the black and white line drawings of Snodgrass and Vanderwart (1980) rated on a large number of factors including AoA, familiarity, imageability, visual complexity and name agreement. One hundred and thirty four of these items were used in total, 127 of these were used to create 5 subsets that manipulated factorially AoA, frequency, familiarity, animacy and length.

1. AoA. The first set of pictures consisted of 25 early acquired and 25 late acquired picture names. The AoA measures used were the Morrison et al. (1997) objective and rated norms. Early words had an objective AoA measure of less than 39 months, (mean 28.3 months) and a rated AoA of less than 2.7 (mean 2.1, approximating to 3-4 years of age). The late acquired picture names had an objective AoA measure of more than 50 months, (mean 75.9 months) and a rated AoA of more than 2.7 (mean 3.1, approximating to 5-6 years of age).

2. Word Frequency. The second set of pictures consisted of 25 high frequency items and 25 low frequency items. High frequency items had a Celex combined written and spoken word frequency of more than 23 occurrences per million (mean 87.1). Low frequency words had a Celex combined frequency of less than 15 occurrences per million (mean 6.5). High and low frequency words were also high and low (respectively) on the Kucera and Francis (1967) written word frequency measure. In addition, any items that appeared to have a high level of usage in every day language despite low frequency ratings (e.g. kettle, sandwich, and shoe) were not used in the low frequency set. Similarly, any items that appeared to have low every day usage despite high frequency ratings (e.g. crown, gun, and swing) were not used in the high frequency sets.

3. Concept Familiarity. The third picture set consisted of 25 high familiarity objects and 25 low familiarity objects. The familiarity measure used was that collected by Morrison et al. (1997) that measured - on a 5 point scale - the degree to which individual's think about or come into contact with an object. High familiarity items had a familiarity rating of more than 3.6, (mean 4.2) and the low familiarity items had a rating of 3.0 or less (mean 2.5).

4. Animacy. The fourth set of pictures consisted of 25 living and 25 nonliving items. Living items consisted of animals (insects, birds, mammals and fish) and people. Ambiguous items such as plants, fruit and body parts were not used. Nonliving items were more varied, but were chosen to exclude highly functional/operational items.

5. *Word Length.* The final set of pictures consisted of 25 short picture names of one syllable and 25 longer picture names of 2, 3 or 4 syllables in length (mean 2.6).

Each of the above 5 subsets of items was matched on all of the above variables in addition to imageability and visual complexity (ratings of which were also taken from Morrison et al., 1997). All stimuli had a name agreement count of more than 80%. Table 6.2 shows the mean values of the variables in the 5 word sets. Seven other items were included in the final set of 134 stimuli in order to reduce the correlation between variables and so decrease the problems associated with multicollinearity in the regression analyses. The five subsets of picture names and their characteristics can be seen in full in Appendix 11.

The picture naming stimuli were presented in two randomised blocks of 67 items. One block was named in the first testing session and the other in the second testing session. The order of presentation of the blocks over the two sessions was counterbalanced over participants. Participants were given ten seconds to name each item, if they failed to produce a name in this time the item was marked as an error and the participant moved onto the next item. In the first testing session patients were also presented with the synonym judgement task and half of the word and nonword repetition task. In the second session they were given

	AoA	Freq'y	Fam'y	Anim'y	Length	Imag'y	VC
AoA							
Early	28.3 (7.2)	13.1 (11.8)	3.1 (0.9)	1.7 (0.7)	1.7 (0.7)	6.4 (0.2)	2.8 (0.7)
Late	75.9 (23.4)	14.3 (18.9)	3.0 (0.8)	1.7 (0.7)	1.6 (0.7)	6.1 (0.3)	2.9 (0.8)
Freq'y							
High	40.1 (20.0)	87.1 (92.8)	3.7 (0.7)	1.8 (0.4)	1.2 (0.5)	6.3 (0.3)	2.9 (0.7)
Low	43.5 (18.0)	6.5 (3.7)	3.4 (0.5)	1.8 (0.4)	1.5 (0.7)	6.2 (0.3)	2.7 (0.8)
Fam'y							
High	46.4 (21.1)	20.9 (20.1)	4.2 (0.4)	2.0 (0.0)	1.6 (0.7)	6.1 (0.2)	2.8 (0.7)
Low	48.6 (18.4)	18.5 (16.4)	2.5 (0.3)	2.0 (0.0)	1.7 (0.8)	6.2 (0.3)	2.6 (0.7)
Length							
Short	49.2 (21.2)	19.0 (22.2)	2.9 (0.8)	1.6 (0.5)	1.0(0.0)	6.2 (0.3)	2.9 (0.7)
Long	45.4 (22.1)	19.9 (29.3)	2.9 (1.0)	1.6 (0.5)	2.6 (0.7)	6.3 (0.3)	3.0 (0.9)
Anim'y							
Living	49.3 (27.3)	21.2 (44.7)	2.6 (0.7)	1.0(0.0)	1.5 (0.7)	6.3 (0.3)	3.3 (0.6)
Nonliving	48.8 (12.5)	21.3 (21.7)	2.6 (0.6)	2.0(0.0)	1.6 (0.8)	6.3 (0.3)	3.3 (0.7)

Note: AoA = age of acquisition, Freq'y = Celex combined frequency, Fam'y = concept familiarity, Anim'y = Animacy, Imag'y = imageability, VC = visual complexity.

Table 6.2 The mean values (and standard deviations) of the variables in the 5 subsets of the picture naming study.

the minimal pairs task, the word-picture matching task and the second half of the word and nonword repetition task.

6.2.2 Results - picture naming task

In the picture naming task, a response was classed as correct only if the initial response was the target name. Among the predictor variables in the regression analyses, the Celex combined frequency measure was subjected to a log transformation and the objective AoA and imageability measures were square root transformed in order to reduce the skew of these variables. All continuous variables were centred prior to being entered into the regression analyses. The present results will only analyse the naming success of the patient and control groups. Previous studies (e.g. Cuetos et al., submitted; Nickels & Howard, 1995) also report regression analyses in which error type (semantic, phonological or no response) was entered as the dependent variable. However, because the current study presented pictures only once, error rates for many items were too low to be included in an analysis of this type. When these items were removed from the analysis the inter-correlations between variables became too high for any conclusive results to be obtained.

6.2.2.1 Aphasic patients' group naming success

The mean picture naming accuracy for the group of aphasic patients was 59% correct, with a range of 34% to 81% correct.

Group naming performance was assessed using t-tests on the total naming performance on each of the five subsets, and a multiple regression analysis on the total picture naming set with group naming success as the dependent variable and the seven variables of AoA, frequency, familiarity, length, imageability, visual complexity and animacy entered as predictors. Table 6.3 shows the inter-correlations of the different predictor variables included in this analysis and the correlation of each of these predictors with the group naming score. As Table 6.3 shows, many of the predictor variables themselves correlate significantly, the highest of these correlations were between familiarity and frequency, familiarity and animacy, and between imageability and AoA. It is worth noting,

	1	2	3	4	5	6	7
1. AoA	-	-.31**	-.25**	.11	-.54**	.13	.07
2. Frequency		-	.45**	.24**	-.34**	-.21*	.24**
3. Familiarity			-	-.17*	-.16	-.39**	.45**
4. Length				-	.02	.11	-.03
5. Imageability					-	.01	-.20*
6. Visual complexity						-	-.39**
7. Animacy							-
Group naming accuracy	-.58**	.46**	.32**	-.32**	.36**	.19*	.28*

**p<0.01, *p<0.05

Table 6.3 The inter-correlations between predictor variables and the correlation between each predictor variable and group naming accuracy for the 134 items in the aphasic picture naming study.

however, that as a consequence of the matched subsets the inter-correlations among variables in the present study are generally far lower than in previous regression studies on aphasic picture naming (cf. Cuetos et al., submitted; Nickels & Howard, 1995; Lambon Ralph et al., 1998). Despite the lower inter-correlations, all seven of the predictor variables in the current analysis correlated significantly with group naming success; the highest correlation was with AoA, followed by frequency, imageability, word length, familiarity, animacy and finally visual complexity. The results of the multiple regression analysis are shown in Table 6.4. Together these seven variables were found to predict 47% of the variance in group naming accuracy. This level of prediction was highly significant, $F(7,126) = 17.89$, $p<0.01$. The variables that predicted

	B	SE	Beta coefficient	t-value
Word frequency	.861	.428	.163	2.01*
Familiarity	.084	.276	.027	0.31
Imageability	1.190	.803	.127	1.48
Word length	-.749	.253	-.203	-2.96**
Animacy	.768	.455	.128	1.69+
AoA	-.047	.009	-.418	-5.04**
Visual complexity	-.397	.248	-.111	-1.54

**p<0.01, *p<0.05, +0.10<p>0.05

Table 6.4 The results of the multiple regression analysis of aphasic patient's group naming performance in the aphasic picture naming study.

significant unique variance of naming success were AoA, frequency and word length. The effect of animacy approached significance ($p=0.06$). The effects of familiarity, imageability and visual complexity did not predict any unique variance of the groups naming success, however.

In addition to the multiple regression analysis, t-tests were completed on the groups naming success on each of the five item subsets. These analyses revealed very similar results to those of the multiple regression analysis, showing significant effects of both AoA, $t(1,24) = 4.14$, $p<0.01$, and of frequency $t(1,24) = 2.59$, $p<0.01$. The effect of length was very close to significance, $t(1,24) = 1.66$, $p=0.055$, and animacy also approached significance $t(1,24) = -1.42$ $p=0.09$ as it did in the regression analysis. As in the multiple regression analysis, familiarity was not significant, $t(1,24) = 0.65$, n.s.

6.2.2.2 Individual patient's naming success

Analysis of each patient's picture naming performance was completed by assessing each individual's performance on the five picture subsets, and by completing logistic regression analyses of each patient's naming score on the total 134 items. Logistic regression is the analysis of choice when the dependent variable is a dichotomy (0 = named incorrectly, or 1 = named correctly). This is because this form of analysis makes no assumptions about the normality of the distribution, assumptions that are difficult to satisfy when using a dichotomous dependent variable (cf. Ellis et al., 1996; Howell, 1997).

Table 6.5 shows the overall naming performance of each individual patient and also shows each patient's naming score on each of the five subsets that assessed AoA, frequency, length, animacy and familiarity whilst controlling all other variables. Any differences in the naming of the items of these subsets were analysed using chi-square. When expected values were less than 5, the alternative binomial test was employed.

This analysis revealed a significant AoA effect in 4 of the 13 patients (Cases 2, 3, 4 and 5), a frequency effect in 3 patients (Cases 1, 3 and 11), a length effect in one patient (Case 7), an animacy effect in one patient (Case 2) and a familiarity effect in one patient (Case 10). When patients whose effects approached significance in this analysis were also considered, a total of 7 patients showed an AoA effect (Cases 1, 2, 3, 4, 5, 10 and 13), 4 showed an effect of frequency (Cases 1, 3, 11 and 12), 2 patients showed an effect of length (Cases 3 and 7), two showed an effect of animacy (Cases 4 and 11) and two patients showed an effect of familiarity (Cases 7 and 10).

Patient Info		Naming Results of the Factorial Analysis				
Case	Naming	AoA E:L	Freq'y H:L	Length S:L	Anim'y L:NL	Fam'y H:L
1	40	12:6+	18:6**	9:7	12:9	13:8
2	81	23:17*	23:22	19:19	14:23**	24:23
3	43	15:6**	17:8*	13:7+	8:10	11:14
4	60	20:12*	20:17	16:11	11:16	18:18
5	74	22:16*	18:17	14:18	17:21	20:19
6	74	20:16	18:22	21:18	21:20	17:21
7	49	11:13	15:14	15:6**	12:12	9:15+
8	71	20:17	19:19	16:20	14:19	21:19
9	52	13:10	15:13	15:12	10:13	16:13
10	67	21:15+	20:21	16:14	14:16	23:14**
11	79	19:16	23:17*	19:18	18:23+	20:22
12	38	11:6	15:19+	7:7	10:11	10:6
13	34	12:6+	10:9	9:8	7:7	10:11

**p<0.01, *p<0.05, +.10>p>0.05

Note: AoA E:L = Objective age of acquisition, Early: Late, Freq'y H:L = Celex frequency, High: Low, Length S:L = Word length (number of syllables), Short: Long, Anim'y L:NL = Animacy, Living: Nonliving, Fam'y H:L = object familiarity, High: Low.

Table 6.5 The results of the factorial analyses of the 5 picture subsets for each individual aphasic patient in the picture naming study.

In order to assess each patient's naming success on all of the items, logistic regression analyses were completed for each patient over all 134 items, with the seven variables included as predictors. Table 6.6 shows the effects of each of the seven variables upon each patient's naming success. A more detailed table of this regression analysis, including the correlations between each patient's naming success and the predictor variables, and the Wald values of those correlations can be seen in Appendix 12.

The model chi-square in this logistic regression analysis was not significant for two of the patients (Cases 6 and 9) and, as a consequence, the logistic regression could not be completed for these patients. For the remaining eleven patients, this analysis revealed a significant AoA effect in 6 patients (Cases 2, 3, 4, 5, 10, and 11; while Cases 8 and 12 approached significance). These cases included 5 of the patients who showed an AoA effect in the factorial analysis. Frequency was significant for two patients (Cases 3 and 11; while Case 1 approached significance), these were the same patients that showed that effect in the frequency subset. Two patients showed an effect of length (Cases 4 and 7; while Case 3 approached significance), two of these patients (Cases 3 and 7) also showed the same effect in the factorial analysis. The same patient (Case 2) as in the factorial analysis showed an effect of animacy, whilst Case 4 also showed an animacy effect that approached significance in this analysis. One patient showed an effect of

Patient		Naming Results of 7 Variable Logistic Regression							
Case	Naming	Model Chi Sq	AoA	Freq'y	Length	Anim'y	Fam'y	Imag'y	VC
1	40	38.3**		+			*		
2	81	37.9**	**			**			
3	43	27.6**	*	*	+				+
4	60	35.8**	**		*	+			
5	74	24.6**	**						
6	74	4.4 n.s	-	-	-	-	-	-	-
7	49	17.0*			**				
8	71	15.2*	+						
9	52	8.8 n.s	-	-	-	-	-	-	-
10	67	28.0**	*				+		
11	79	16.0*	*	*					
12	38	24.6**	+					*	
13	34	14.9*						+	

**p<0.001, *p<0.05, +0.10>p>0.05

Note: AoA = age of acquisition, Freq'y = log frequency, Anim'y = animacy, Fam'y = object familiarity, Imag'y = imageability, VC = visual complexity

Table 6.6 The results of the 7 variable logistic regression analysis for each individual patient in the picture naming study.

familiarity (Case 1). This patient did not show an effect of familiarity in the factorial analysis, however, Case 10 who did show a familiarity effect in the factorial analysis had an effect that approached significance in this analysis. One patient showed a significant effect of imageability (Case 12) while another (Case 13) showed an imageability effect that approached significance, and one patient showed an effect of visual complexity that approached significance (Case 3).

A second logistic regression analysis was completed on each individual patient's naming performance with the variables of imageability and visual complexity removed from the analysis. These variables were removed in order to increase the power of the regression analysis as the smaller the number of predictors included in an analysis the greater the statistical power of the regression analysis (e.g. Howell, 1997). A second reason for removing these variables was because AoA and imageability correlated highly with one another (-0.54) and so it may have been the case that imageability was affecting the AoA effects reported in the seven variable analysis.

Table 6.7 shows the effects of these five predictors on each patient's naming success in the logistic regression analysis with imageability and visual complexity removed. A more detailed table of this regression analysis, including the correlations between each patient's naming success and the predictor variables and the Wald values of these correlations can be seen in Appendix 13.

Patient		Naming Results of 5 Variable Logistic Regression					
Case	Naming	Model Chi Sq	AoA	Freq'y	Length	Anim'y	Fam'y
1	40	35.5**	**	*			*
2	81	37.0**	**			**	
3	43	23.9**	*	*	+		
4	60	33.6**	**		**	*	
5	74	23.0**	**				
6	74	3.5 n.s	-	-	-	-	-
7	49	16.1**			**		
8	71	12.7*	*				
9	52	8.2 n.s	-	-	-	-	-
10	67	27.5**	**				*
11	79	14.8*	+	+			
12	38	20.1**	**				
13	34	9.6+	+				

**$p<0.01$, *$p<0.05$, +.10<p>0.05

Note: AoA = age of acquisition, Freq'y = log Celex frequency, Anim'y = animacy, Fam'y = object familiarity.

Table 6.7 The results of the 5 variable logistic regression analysis for each individual patient in the picture naming study.

As is clear from the model Chi-square values of this analysis, the removal of imageability and visual complexity does not dramatically affect the goodness of fit of the model Chi-square for any of the patients. It is clearly the case, therefore, that these two variables have very little effect upon the individual patient's naming performance. With these two variables removed, the model Chi-square for Cases 6 and 9 remained non-significant and so these patients were not included in this regression analysis. Ten of the 11 patients (all but Case 7) included in this analysis showed an effect of AoA (though Cases 11 and 13 showed effects that only approached significance). Aside from the increase in the number of patients showing an AoA effect, the other results were very similar to the seven variable logistic regression analysis: The same three patients (Cases 1, 3, and 11) showed an effect of frequency, Cases 3, 4, and 7 continued to show an effect of length, the same two patients (Cases 2 and 4) continued to show an animacy effect and Cases 1 and 10 continued to show an effect of familiarity. The most probable reason for an increase in the number of AoA effects found over patients in this analysis is the removal of imageability which correlated very highly with AoA (-0.54) in this study, and because of the better ratio of items to variables in this analysis that will have increased the statistical power of the logistic regression.

6.2.2.3 Comparison between the results of the factorial and regression analyses

Overall, the results of the factorial and regression analyses are very similar, although more patients showed effects of variables in the regression analyses than in the factorial analysis. One of the main reasons for this increase in the number of effects seen in the regression analyses is probably due to the fact that the statistical power in the factorial analysis was quite low. As a consequence, patients who revealed a strong trend towards an effect did not show a significant effect in the factorial analysis. This would appear to be particularly true for the AoA effect. Indeed, whilst the majority of patients showed a trend towards an AoA effect in the AoA subset - all but Case 7 successfully named more early than late acquired picture names - only 7 patients were found to have a significant effect (or an effect approaching significance) in the factorial analysis, whereas 10 patients showed a significant effect (or an effect approaching significance) in the five variable regression analysis.

Aside from this difference the other effects shown by patients were very similar over the two forms of analyses. This consistency over analyses would appear to allow more faith to be placed in the results of the present study wherein pictures were named only once (cf. Ellis et al., 1996). This overall consistency between the two forms of analyses also suggests that any serious problems associated with multicollinearity have been successfully addressed in the current regression analysis (aside, perhaps, from the high correlation between AoA and imageability, see below). The fact that the total picture naming set included matched subsets resulted in relatively low correlations between variables. On the whole, therefore, the present results would suggest that both the factorial and regression analyses in the current study are appropriate for assessing the picture naming performance of aphasic patients. However, the extra power associated with multiple regression analyses may make this method more reliable than factorial analyses in assessing the picture naming performance of aphasic patients - particularly for the AoA effect in the present study. Furthermore, although correlations between variables were relatively low, in the 7-variable analysis the high correlation between imageability and AoA does appear to have reduced the number of patients who showed a significant effect of the latter variable. Indeed, with imageability and visual complexity taken out of the analysis the number of patients showing a significant effect (or an effect approaching significance) of AoA increased from 8 to 10.

As a consequence of the low statistical power of the factorial analysis and the potential problem of high inter-correlations - particularly between AoA and imageability - in the 7-variable regression analysis, the proceeding analysis looking at possible relationships between each patient's level of impairment and the effects they show in the picture naming task will be completed by concentrating on the results of the 5-variable logistic regression analysis. This would appear to be a reasonable choice of the present results given that only one patient showed a significant effect of imageability and one an effect of visual complexity that approached significance. These two variables clearly have only a very small influence on the current group of patients. In addition, whilst the 5-variable regression resulted in a larger number of effects emerging in patients than did the factorial analysis, all those patients who showed an effect in this regression analysis showed a strong trend towards that effect in the factorial analysis.

Prior to completing the comparison between the effects that aphasic patients show in the picture naming task and their level of impairment it is first important to assess those variables that affect normal participant's picture naming success.

6.2.2.4 Control group's naming success

Analysis of the control participants' picture naming performance was only completed at a group level of analysis. This is because the naming of the control participants was almost at ceiling making any statistical analysis of individual naming on the predictor variables impossible. Similarly, on the group naming performance only a multiple regression analysis was completed on the results, as differences between the subsets were too small to allow a t-test analysis to be reliable. Appendix 14 shows the general characteristics of the individual control participants in addition to each participant's naming score.

The mean picture naming accuracy for the group of controls was 90% correct (SD 4.69), with a range of 83% to 98% correct. Group naming success on all 134 items was entered into a multiple regression analysis with the seven predictor variables of AoA, frequency, familiarity, length, animacy, imageability and visual complexity. The correlations between the predictor variables were the same as in the aphasic group analysis and thus can be observed in Table 6.3. The correlations between the control group's naming success and the predictor variables can be seen in Table 6.8. AoA correlated most highly with the control group's naming success, followed by imageability, visual complexity, frequency, familiarity and animacy. Length was the only variable that did not correlate significantly with the group's naming success.

	AoA	**Freq'y**	**Fam'y**	**Length**	**Imag'y**	**VC**	**Anim'y**
Group naming	-.55**	.23**	.22**	.02	.29**	.26**	.19*

**p<0.01, *p<0.05

Note: AoA = age of acquisition, Freq'y = Celex combined frequency, Fam'y = object familiarity, Imag'y = imageability, VC = visual complexity, Anim'y = animacy

Table 6.8 The correlation between the predictor variables and the control groups naming accuracy in the picture naming study.

The results of the multiple regression analysis for the control group's naming performance can be seen in Table 6.9. The seven predictor variables accounted for 34% of the unique variance of the control groups naming success. This level of prediction was significant F (7,126) = 10.59, p<0.01. Those variables that predicted significant unique variance of the control group's naming performance were AoA and animacy, while the effect of visual complexity approached significance (p=0.08). Frequency, familiarity, imageability and length did not predict any unique variance in naming performance. These results support those of Hodgson and Ellis (1998) who reported significant effects of AoA (and of word length) but not of frequency, familiarity, visual complexity or imageability on a group of normal elderly participant's naming performance.

	B	SE	Beta coefficient	t-value
Word frequency	.159	.378	.038	0.42
Familiarity	-.106	.244	-.042	-0.43
Imageability	.134	.711	.018	0.19
Word length	.300	.224	.102	1.34
Animacy	.801	.403	.168	1.99*
AoA	-.048	.008	-.537	-5.82**
Visual complexity	-.407	.228	-.143	-1.78+

**p<0.01, *p<0.05, +.10<p>0.05

Table 6.9 The results of the multiple regression analysis of the control groups naming performance in the picture naming study.

6.2.3 Does a patient's locus of impairment predict what factors will affect their naming success?

The classification of the patient's impairments was based upon their performance on each of the semantic and phonological tasks. If a patient's score on a task was 5% below the range of the control scores then the patient was judged to be impaired on that task. In the case of the synonym judgement task, patients were judged to be impaired if their score was 5% lower than the score achieved by 75% of Warrington et al.'s (1998) control participants[1]. Classification of the patient's impairment was also corroborated by the types of errors they made in the picture naming task. Thus, if the patient made a majority of semantic errors this would suggest a semantic impairment in that patient, whereas if a patient made a relatively equal number of semantic and phonological errors this would suggest problems in both semantics and phonology.

Table 6.10 shows, in percent, each patient's performance on the semantic and phonological tasks, their overall picture naming performance including the proportion of error types made, and the

[1] The range of scores for the 184 controls in Warrington et al.'s (1998) control group was very large, although the SD was low at just 5.9. The use of the 25th percentile score as a cut off point for the aphasic patients results in an impaired score beginning at less than 71% correct. This actually equates to the average score for a group of left temporal lobe patients in Warrington et al.'s (1998) validation study. Such patients are known to have comprehension deficits (Warrington et al.,1998).

level of impairment of each patient according to their performance on these tasks. The patients have been separated according to the type of impairment(s) that they showed.

These classifications lead to a total of 3 patients being judged as having a pure semantic deficit (Cases 5, 10 and 12) because their performance on the synonym judgement semantic task was poor, and the majority of their errors were semantic. One patient (Case 7) was judged to have a pure phonological deficit, as he was severely impaired on the phonological tasks and his errors were predominantly phonological. Two patients (Cases 2 and 4) were classified as having a category-specific semantic impairment that was judged to be present due to the significant animacy effect in the picture naming task. In addition to the category specific semantic impairment, Case 4 was judged to have a mild phonological deficit as her performance on all the phonological tasks was impaired. Case 3 was judged to have a mild phonological impairment as well as damage to the connections between semantics and phonology. This classification was based on the fact that his picture naming errors were mainly semantic yet he had no impairment to the semantic system itself, as evidenced by his normal scores on both of the semantic tasks. One patient (Case 9) was judged to have a semantic impairment and an impairment to input phonology, as his performance on the minimal pairs and nonword repetition tasks were impaired yet his performance on the

Case	Level of impairment	Semantic tasks		Phonological tasks			Naming score and error types			
		Synonym	WPM	Min Pairs	Wd Rep	Nwd Rep	Overall %	Semantic	Phon	NR
5	Semantics	64*	96	93	100	90	74	83	9	0
10		64*	96	93	100	78	67	50	7	16
12		54*	100	100	95	95	38	46	3	46
2	Semantics (CS)	82	96	100	80	88	81	48	24	24
4	Semantics (CS) & phonology	80	100	83*	70*	25*	60	30	53	11
9	Semantics & (In)phonology	66*	88	75*	93	55*	52	83	3	11
3	Connections & phonology	82	100	93	93	55*	43	66	2	21
7	Phonology	74	100	55*	20*	0*	49	15	69	9
1	Semantics & Phonology	56*	76*	68*	48*	25*	40	38	30	15
6		68*	80*	68*	98	58*	74	29	20	23
8		70*	96	58*	80	13*	71	51	43	0
11		66*	96	98	85	60*	79	29	25	46
13		68*	68*	68*	68*	15*	34	36	11	43

Note: * denotes impaired performance, (CS) = category specific, (In) = input phonology, WPM = word - picture matching, Min pairs = minimal pairs, Wd Rep = word repetition, Nwd Rep = nonword repetition, Phon = phonological, NR = no response.

Table **6.10** The aphasic patients' performance (in %) on the semantic, phonological and picture naming tasks, and their level of impairment(s). Patients have been grouped together in the table according to their level of impairment.

word repetition task was normal and the majority of his picture naming errors were semantic and not phonological in nature. The final 5 patients (Cases 1, 6, 8, 11 and 13) were judged to have impaired semantics and impaired phonology as performance was poor on both the synonym judgement semantic task (and on the word-picture matching task in Cases 1, 6 and 13) and the phonological nonword repetition task (and, in all but case 11, on the minimal pairs and/or word repetition tasks). Picture naming errors were also a mixture of both semantic and phonological errors in these 5 patients.

Table 6.11 shows the variables that predicted each patient's naming success. The patient's are again grouped according to their level of impairment so that comparisons can be made between patient's level of deficit and the effects that they show in the picture naming task. By observing which variables affect the picture naming success of patients with different levels of impairment, the locus of these effects within the picture naming system can be identified.

6.2.3.1 Which patients show effects of semantic variables?

The predictions made at the beginning of this Chapter were that patients with a semantic level of impairment might show effects of familiarity, imageability and animacy. However, as is clear from Table 6.11, not all patients with a semantic impairment showed such effects. In order to understand the reasons why this may be the case, each of the three semantic variables included in the current study (animacy,

Case	Level of impairment	Factors affecting naming success						
		AoA	Freq'y	Length	Anim'y	Fam'y	Imag'y	VC
5	Semantics	*						
10		*				*		
12		*					[*]	
2	Semantics (CS)	*			*			
4	Semantics (CS) & phonology	*		*	*			
9	Semantics & (In)phonology	n.s	n.s	n.s	n.s	n.s	n.s	n.s
3	Connections & phonology	*	*	+				
7	Phonology			*				
1	Semantics & Phonology	*	*			*		
6		n.s	n.s	n.s	n.s	n.s	n.s	n.s
8		*						
11		+[*]	+ [*]					
13		+						

*p<0.05, +.10>p>0.05 in 5-variable regression, [*] = p<0.05 in 7-variable regression

Note: AoA = age of acquisition, Freq'y = Celex frequency, Anim'y = Animacy, Fam'y = Object familiarity, Imag'y = imageability, VC = Visual complexity, (CS) = category specific, (In) = input phonology.

Table 6.11 The variables that predict individual picture naming performance. Patients have been grouped according to their level impairment.

familiarity, and imageability) will be now be discussed in turn in relation to the patients who showed these effects.

6.2.3.1.1 The animacy effect

Animacy was not predicted to affect all patients with a semantic level of impairment because this effect only occurs when there is a category-specific semantic deficit. Nevertheless, two patients (Cases 2 and 4) showed an effect of animacy in the current study, thereby suggesting a category-specific semantic impairment in these two patients. Both patients showed the effect in the more common direction with naming performance being impaired on living relative to nonliving items. It is worth noting here that although these two patients did not show any impairment on the two semantic tasks in the current study - despite having been judged as having a category-specific semantic impairment - the stimuli in these two tasks were predominantly inanimate. Consequently, any semantic impairment that is specific to living stimuli will not have been picked up by the semantic tasks employed here. However, both patients did produce a high proportion of semantic errors in the picture naming task (and, not surprisingly, the majority of these errors were to living stimuli) which supports the diagnosis of a category-specific semantic impairment in these two patients.

The occurrence of an animacy effect in the present study supports the report of an animacy effect in two patients in Cuetos et al.'s (submitted) study of aphasic patients' picture naming performance. The existence of this effect in the present study and in Cuetos et al.'s (submitted) study supports the claim made by Farah, Meyer, & McMullen (1996, see also Barbarotto, Capitani, & Laiacona, 1996; Funnell & De Mornay Davies, 1996) that the animacy effect is real and not simply a confound of a familiarity effect (with living items being less familiar than nonliving items) as has been suggested in the past (e.g., Funnell & Sheridan, 1992; Stewart, Parkin & Hunkin, 1992).

6.2.3.1.2 The familiarity effect

Familiarity is assumed to be a semantic variable that affects picture naming performance as a consequence of the quality of the semantic representations, with more familiar objects having more detailed semantic representations (e.g. Cuetos et al., submitted; Lambon Ralph et al., 1998; Morrison et al., 1997). Consequently, the prediction at the beginning of this Chapter was that a patient who has damage to the semantic system should show an effect of familiarity because the less detailed semantic representations for low familiarity objects will make those items more vulnerable to damage. However, in the present study, only two patients (Cases 1 and 10) showed a significant effect of familiarity in the 5-variable regression analysis. These two patients both had a semantic impairment, with Case 10 having a pure semantic deficit and Case 1 having both semantic and phonological deficits. None of the other patients with semantic problems showed a significant effect of familiarity in any of the three analyses.

The present results contrast with the report of a familiarity effect in 5 of the 16 aphasic patients in Cuetos et al.'s (submitted) study and, importantly, to the report of a significant effect of familiarity in 7 out of 8 of the semantic dementia patients studied by Lambon Ralph et al., (1998). Lambon Ralph et al.'s (1998) report of an apparently robust familiarity effect in patients with a pure semantic deficit suggests that all the patients with a pure semantic impairment in the current study should similarly have shown an effect of familiarity. However, Nickels & Howard's Study 2 (1995) found a familiarity effect in only 1 of their 15 patients, and Ellis et al. (1996) an effect in just 2 out of 6 of their patients. Nickels and Howard (1995) argued that the lack of a familiarity effect in their study was a consequence of the high inter-correlations of familiarity with other variables, and in particular its high inter-correlation with AoA. Yet in the present regression analysis the correlation between AoA and familiarity was relatively low (-0.25) (cf. -0.61 Nickels & Howard Study 2, 1995; -0.59 Cuetos et al., submitted; -0.43 Lambon Ralph et al., 1998), and the familiarity subset controlled for all other variables factorially. The argument of high inter-correlations reducing the emergence of a familiarity effect does not, therefore, uphold for the present study. An alternative reason for the lack of an effect here might be due to the small range of familiarity values in the present study. Indeed, the mean familiarity value for the total 134 items was 3.04 with a standard deviation of just 0.88. A value of 3.04 was higher than any of the items included in the low familiarity subset, and such a small standard deviation suggests that there were very few items in the present study that were of low familiarity. Consequently, any familiarity effects that may have been present in the patients in the current study would not have been detected by the values used here. This lack of spread of values may explain the differences between the results of the present study and the high number of familiarity effects in Cuetos et al.'s (submitted) patients and Lambon Ralph et al.'s (1998) semantic dementia patients. These studies may well have had a larger range of familiarity values.

An alternative/additional explanation for the differences between the number of patients showing a familiarity effect in the present study and in the studies of Cuetos et al. (submitted) and Lambon Ralph et al. (1998), may be to do with the severity of the semantic impairment in the different patients. Indeed, the patients in the current study are likely to have had far less severe comprehension difficulties than Lambon Ralph et al.'s (1998) semantic dementia patients. A part of the inclusion criteria for the present study was a level of comprehension suitable for the patient to fully understand the requirements of the study. Consequently, it may well be the case that while familiarity is a real enough effect, for it to emerge as a significant predictor of picture naming success the level of semantic damage in a patient must be quite severe. This level of severity argument could also apply to the aphasic patients in Cuetos et al.'s (submitted) study.

The lack of a familiarity effect in the present study where other variables were controlled factorially, and where familiarity had a much reduced correlation with other variables in the regression analyses, yet again highlights some of the potential problems associated with picture naming studies. By successfully reducing correlations and by controlling factorially different variables the range of some variables is also much reduced, thereby leading to null effects of familiarity in the present study. In addition, however, it may well be the case that the severity of the semantic impairment also plays a role in the emergence of this effect in aphasic patients.

6.2.3.1.3 The imageability effect

As has been discussed in previous Chapters of this thesis, imageability is widely viewed as a semantic variable that, like familiarity, affects the quality of semantic representations, with higher imageability items having more detailed semantic representations (e.g., Cuetos et al., submitted; Lambon Ralph et al., 1998; Morrison et al., 1997). However, this effect is not often studied in aphasic picture naming, and when it is, effects are not often reported. This is because, by the very nature of the task, all of the items in the picture naming task are highly imageable to the extent that they are picturable. As a consequence of the restricted range of imageability values, effects of imageability in aphasic picture naming are uncommon (cf. Cuetos et al., submitted; Ellis et al., 1996; Nickels & Howard, 1995). This is not to say, however, that given a wider range of values more aphasic patients with semantic deficits would show this effect. Nevertheless, it is not surprising that only one patient in the current study (Case 12) showed a significant effect of imageability in the 7-variable regression analysis. Nor is it surprising that this patient had a pure semantic deficit.

6.2.3.2 Which patients show effects of length?

The word length effect has long been assumed to be a phonological variable, and the prediction made at the beginning of the current Chapter was that patients who have phonological impairments would be the patients that show an effect of word length. Indeed, the results of the current analysis did show that those patients whose impairment was predominantly phonological (Cases 4 and 7), or whose impairment was both in phonology and accessing phonology (Case 3) showed significant effects of length. These three patients showed the effect in the predicted direction, with short picture names of one syllable being produced more successfully than longer names of more than one syllable in length. None of the patients that had both semantic as well as phonological problems showed an effect of length. This is presumably because the added problems in semantics in these patients means that any effect of length in phonology is confounded by the problems these patients have in successfully activating the correct phonological representations of items from weakened semantic output, regardless of the items word length. Nevertheless, the finding of an effect of length in those patients with predominantly phonological deficits supports the argument that this variable affects the retrieval and/or encoding of phonological representations ready for articulation (e.g. Cuetos et al., submitted; Nickels & Howard, 1995).

6.2.3.3 Which patients show effects of AoA?

The fact that the control group showed a significant effect of AoA on picture naming (cf. Hodgson & Ellis, 1998) suggests that AoA is an integrative part of adults' picture naming processes. The large AoA effect in the aphasic patient group and its significant effect on 10 of the 13 patients in the individual 5-variable analysis further suggests that this is the case. The fact that the AoA effect was seen in patients with pure semantic deficits, in patients with both semantic and phonological deficits, and in the patient with damage to the connection strengths, indicates that AoA must exert its effect at the level of the connections between semantics and phonology. No other locus could explain the finding of this effect in patients with all these different levels of impairment.

The reason that Case 7, the patient with a pure phonological impairment, did not show an effect of AoA may be because his phonological damage was so severe that any advantage in accessing phonological representations for early acquired words was lost because these phonological representations were so badly damaged. Indeed there is an indication of this in the types of errors that Case 7 made to early and to late acquired words. As Figure 6.2 shows, while the majority of errors Case 7 made to early acquired words were phonological nonwords (nonwords that shared more than 50% of their sounds with the target word), the errors to late acquired words were a mix of phonological nonwords, neologisms, semantic and no

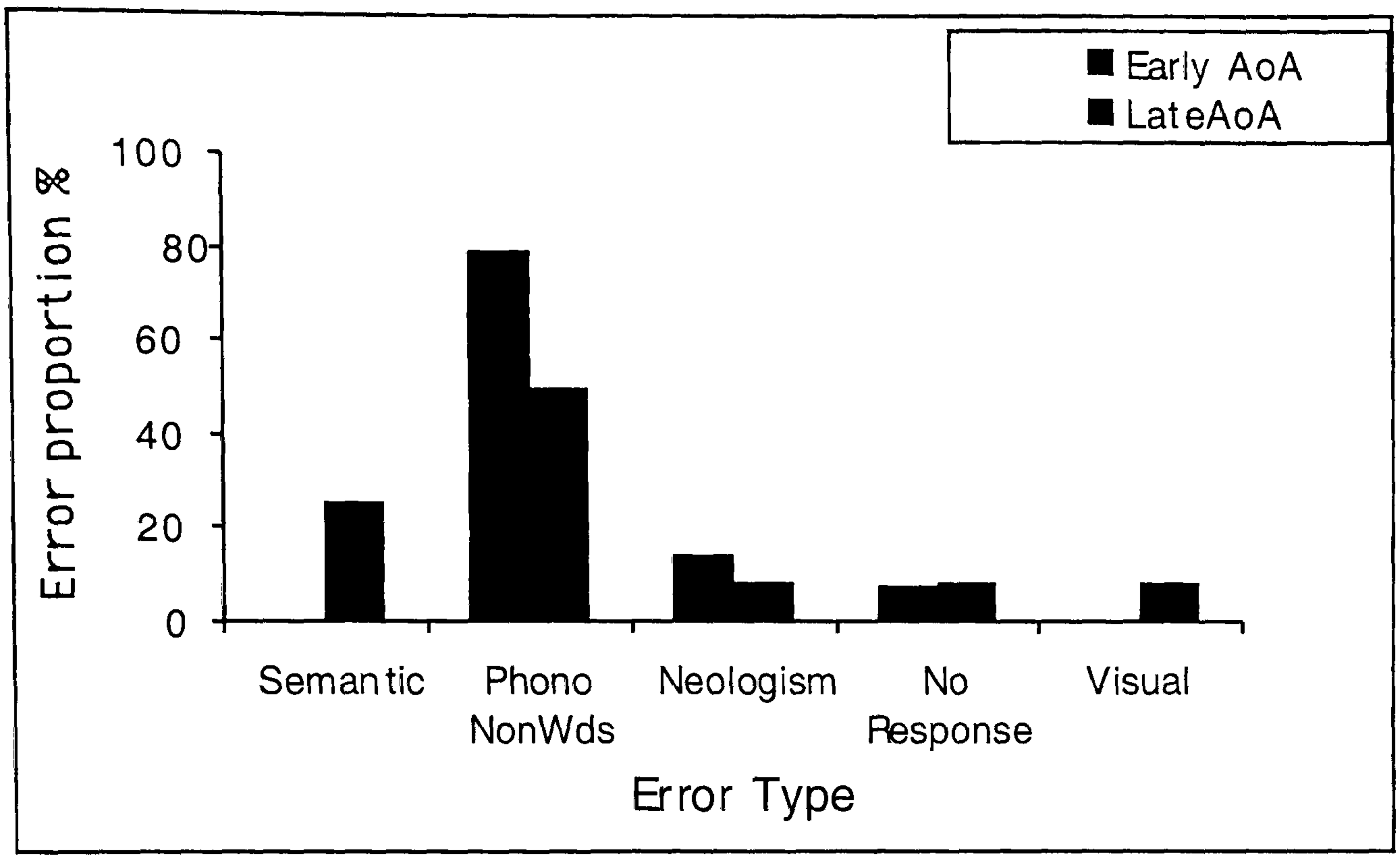

Figure 6.2 The proportion of each error type made by Case 7 on the early and late picture names in the AoA picture subset.

response errors. These different error types to early and late acquired items suggest that whilst early acquired words were successfully activating the correct phonological representations, these representations were too badly damaged for the word to be produced correctly. In contrast, the weaker connections into phonology for late acquired words meant that these connections failed to even successfully activate the appropriate representations, thereby causing more semantic, no response and neologistic errors to late acquired words.

A similar argument of severity of damage does not hold up for the other two patients (Cases 6 and 9) who failed to show a significant effect of AoA, however. Both of these patients appeared to have both semantic and phonological damage yet their level of performance on the semantic and phonological tasks and their performance on the picture naming task were higher than many of the other patients who did show an effect of AoA. However, the problems associated with picture naming performance in these two patients were not successfully identified by any of the variables included in the current analyses. It is, therefore, impossible to understand the characteristics of these patients' naming problems and so it is, unfortunately, difficult to provide any explanation of their pattern of results in the current study.

Nevertheless, the pattern for those patients whose picture naming performance was successfully predicted by the variables in the current study suggest that AoA is an integral part of the language processing system. The predicted locus of the AoA effect - in the connections between semantics and phonology - is supported by the results of the current study. Thus, picture naming in patients with a semantic impairment is predicted by AoA, with the stronger connections between semantics and phonology for early acquired words helping to successfully transmit weakened semantic output to the items correct phonological representations. Patients that have damage to the connections between semantics and phonology also show an AoA effect because the stronger connections for early acquired items means that these connections are more likely to have been preserved following damage. Finally, patients with phonological impairments are also more likely to successfully name early acquired words than late acquired words because of the stronger input from semantics for these items that then help to boost the activation of damaged phonological representations. Even when phonological representations are so severely damaged that an AoA effect is not observed in naming success, it is still the case that early acquired words more successfully activate their correct phonological representations, thereby producing errors that are more similar to the target name than the errors produced to late acquired words.

6.2.3.4 Which patients show an effect of frequency?

The previous work of this thesis has proposed that frequency affects the strength of the connections between semantics and phonology along with AoA. As a consequence, the predictions at the beginning of this Chapter were that frequency would exert an effect in those patients that have damage to these connections, and that frequency may also show an effect in patients with a semantic and/or phonological impairment due to the extra strength of the connections between semantics and phonology for high frequency words. In effect, that prediction also inferred that frequency will exert an effect whenever AoA does, because of the shared locus of effect for these two variables (cf. Ellis & Lambon Ralph, 2000). The first of these predictions - that frequency will affect picture naming success in patients that have damage to the connections - is supported by the strong frequency effect in Case 3 who was judged to have damage to the connections between semantics and phonology. However, a significant frequency effect was observed in just two other patients (Cases 1 and 11) that had both semantic and phonological damage. Frequency did not have a significant effect in patients that had purely semantic or purely phonological damage, nor did it have an effect in those other patients that had both semantic and phonological damage[2]. Consequently frequency was not present in all those patients that showed an AoA effect.

The most likely reason that frequency did not have a powerful effect upon individual patient's naming success in the present study is because this variable is not particularly robust in the picture naming task. Indeed, frequency did not affect the elderly control group's naming success (cf., Hodgson & Ellis, 1998). This suggests that, unlike AoA, frequency does not have a robust effect upon picture naming success in normal participants.

It may not, therefore, be particularly surprising to only observe a significant frequency effect on the picture naming success of 3 of the 13 patients in the present study. If frequency does not exert a strong effect on the normal processing of picture names then one would not expect this variable to be particularly influential in the damaged system. However, it may be the case that, when damage is incurred to the particular part of the picture naming system where

[2] As was noted in Section 6.2.1.2.3, the frequency count of some items did not correspond to the assumed everyday frequency of use of the item (e.g. Sandwich has a low frequency account, while Swing has a high frequency count), however, even when such items were removed from the regression analyses frequency remained significant only for the same 3 patients. The same was also true when the frequency measure entered into the analyses was the Celex spoken frequency rather than the combined written and spoken count - no other patients revealed an effect when this alternative measure was used.

frequency exerts its effect, the increased pressure on this part of the system causes the frequency effect to emerge as a significant predictor of picture naming success. Equivalent pressure on the normal system may occur when picture naming is speeded, thereby resulting in a significant frequency effect in picture naming speed (e.g., Barry et al., 1997; Cirrin, 1983; Ellis & Morrison, 1998; Lachman, 1973; Lachman et al., 1974; Snodgrass & Yuditsky, 1996).

Although the results of the present study cannot provide any insight into the locus of the frequency effect in picture naming, on the basis of the previous work of this thesis and the reliance on theoretical models of the frequency effect (e.g., Ellis & Lambon Ralph, 2000; Harm & Seidenberg, 1999; Plaut et al., 1996; Seidenberg & McClelland, 1989) it seems fair to assume that frequency affects the strength of the connections between semantics and phonology in picture naming.

However, in order to assume that frequency will only have an effect on an aphasic patient's picture naming success when there is damage to these connections, one has to presume that those patients who showed an effect of frequency in the present study have damage to these connections, while none of the other patients do. While Case 3 - the patient who had damage to the connections - supports such an assumption, there is no direct evidence in the current study to suggest that the other two patients who showed an effect of frequency (Cases 1 and 11) had damage at this level of processing.

Nevertheless, the results of the present study clearly indicate that the effect of frequency in the picture naming task is not particularly robust. It may be the case that, for frequency to exert a significant effect on picture naming success, the connections between semantics and phonology must suffer damage. Although there is no real evidence for such an assumption, this argument certainly makes some interesting predictions for further research into frequency effects in aphasic patients.

6.3 General Discussion

The present study has shown that the use of regression analyses to investigate the picture naming performance of aphasic patients produces similar results to those found using factorial analyses. The reason for this consistency over the different forms of analyses in the present study are most likely due to the use of the controlled subsets of items that clearly reduced the inter-correlations between variables in this study. Clearly, therefore, the issue of high inter-correlations in regression analyses in general remains and future studies should be aware of the potential confounds in regression analyses when variables are highly inter-correlated. In addition, however, the use of factorial analyses are not without their problems. By using such controlled subsets the variance associated with the familiarity variable was much reduced and likely caused the inability to detect familiarity effects in the patients of the current study. Furthermore, as the results of the present study demonstrate, such analyses have only weak statistical power and as such create the danger of Type II errors. Nevertheless, by taking into account the trends towards an effect as well as the significant effects in the factorial analysis the results of that form of analysis are quite similar to those of the regression analyses. The present study has, therefore, attempted to overcome some of the problems associated with both types of analyses and as such has produced results that have some reliability.

The present study revealed significant effects of AoA, frequency and length on a group of aphasic patients' picture naming performance. As evidenced from previous studies of this kind, however, the results of the group analysis do not accurately reflect the effects that predict individual patient's picture naming performance. The present study aimed to extend the findings of Nickels and Howard (1995) and Cuetos et al. (submitted) to demonstrate that the reason for such variability in predictors of picture naming success over individual patients is a consequence of the level of the patient's impairment. This was completed in an attempt to identify the locus of the AoA, frequency, and other effects, within picture name production.

As predicted, patients that had a semantic level of impairment showed effects of animacy, familiarity and imageability. However, not all patients with semantic impairments showed effects of these variables. In the case of animacy this is hardly surprising given that such an effect only occurs in patients with a category-specific semantic impairment. The existence of an animacy effect in two patients in the current study does, however, further support the claims of Farah et al. (1996; see also Barbarotto et al., 1996; Funnell & De Mornay Davies, 1996) that the animacy effect is not simply a confound of familiarity. The occurrence of a significant imageability effect in just one patient is not particularly surprising either. As was discussed in section 6.2.3.1.3 previously, the restricted range of imageability values in the picture naming task makes finding such effects in aphasic patients particularly difficult and as a consequence it is not surprising to observe this effect in only one patient in the present study.

The lack of a familiarity effect across patients with a semantic impairment was, however, a little more surprising. Only two patients in the current study showed a significant familiarity effect, despite many more patients demonstrating damage to the semantic system. The reason for the lack of this effect in the patients with a semantic deficit was explained as a consequence of the lack of variability in the range of the familiarity values in the present study. The second possible reason for a lack of a familiarity effect in the current results was that the level of semantic deficit in the patients in this study might have been quite mild relative to patients in previous studies (e.g. Lambon Ralph et al., 1998).

The second prediction made in the Introduction of this Chapter was that patients with a phonological impairment would show effects of the phonological variable of length in the picture naming task. As predicted, the length effect was present in those patients who had a phonological impairment (Cases 4 and 7), or damage to the connections accessing phonology (Case 3). This supports the widely evidenced belief that length affects the level of phonological retrieval or recoding (e.g. Cuetos et al., submitted; Nickels & Howard, 1995).

The two variables that were of primary concern in the current picture naming study were those of AoA and frequency. The locus of these effects have been confirmed in the word naming system in the current thesis, but their locus of effect in picture naming has remained unconfirmed. The opportunity to investigate whether patients with different levels of impairment showed these effects in the picture naming task was, therefore, of great interest to the current thesis.

AoA significantly predicted the control and aphasic group's naming success and also predicted 10 of the 13 aphasic patients' performance in the picture naming task. The results of the control participants suggest that AoA has a strong effect upon normal picture naming success and as such may be an integral part of the language processing system. The results of the aphasic patients' picture naming further support this argument. The fact that the AoA effect was observed in patients with different levels of impairment at semantics, and/or phonology, and/or in the connections themselves, suggests quite strongly that AoA does indeed exert its effect at the level of the connections between semantics and phonology. Placing the AoA effect in another location could not explain why AoA had an effect in so many patients with different levels of deficits.

The idea that AoA has a robust effect on picture naming success in both control participants and in aphasic patients makes perfect sense. This is because the AoA effect emerges as a consequence of the fact that early learnt items are the first to establish connections between semantics (and orthography) and phonology. If, as Ellis and Lambon Ralph (2000) argue, these early established connections actually determine the very structure of the processing network, then AoA will affect every naming attempt made by an individual throughout development and adulthood. Damage to any part of this processing system will accentuate the AoA effect because the stronger connections for early acquired words will make such connections less susceptible to damage and will help to transmit information from, and to, damaged representations.

In contrast to AoA, however, frequency did not have a strong effect on picture naming in the present study. Frequency did not influence the picture naming success of the control group and does not, therefore, appear to have an effect on normal picture naming success (cf., Hodgson & Ellis, 1998). In addition, while frequency had a significant effect on the naming success of the aphasic patient group, frequency only predicted the naming success of 3 of the 13 patients in the present study. This suggests that, for the frequency effect to emerge as a significant predictor of picture naming success, the picture naming system must have incurred damage at the level of processing wherein frequency exerts its effect. On the basis of current theories (e.g. Ellis & Lambon Ralph, 2000; Plaut et al., 1996) it was presumed that frequency affects the strength of the connections between semantics and phonology. One of the patients who showed an effect of frequency in the present study did have identified damage to the connections between semantics and phonology that supports placing the effect of frequency at that level. However, the other two patients who showed an effect of frequency had impairments to the semantic and phonological levels of processing. The conclusion that frequency only affects aphasic patients picture naming success when the connections between semantics and phonology are damaged, therefore, rests on the assumption that these two patients also had unidentified damage to these connections.

What is clear from the present results is that, in contrast to the AoA effect, frequency does not have a strong influence on the normal picture naming system. One possibility, therefore, is that while AoA has a fundamental influence on the picture naming system from early on in development, frequency has a much weaker effect and one that only influences processing in the mature system. Frequency, therefore, might be best construed as some form of a recency effect wherein frequently used words have stronger connections between semantics and phonology because these connections have recently been exercised. This would explain the lack of a frequency effect in normal picture naming success. When the connections between semantics and phonology in the established system are damaged, however, a significant frequency effect may be observed in some aphasic patients because recently used high frequency items are more likely to resist damage than are low frequency items. Similarly, in the normal system, whilst frequency does not affect naming success, the extra pressure placed upon the picture naming system when naming is speeded may result in a frequency effect upon naming RTs (e.g., Barry et al., 1997; Cirrin, 1983; Ellis & Morrison, 1998; Lachman, 1973; Lachman et al., 1974; Snodgrass & Yuditsky, 1996).

CHAPTER SEVEN

THE LOCI OF THE AoA EFFECT, THE FREQUENCY EFFECT, AND THE IMPLICATIONS FOR CURRENT MODELS OF WORD AND PICTURE NAMING

7.1 Introduction and summary of main findings

AoA has long been recognised as a robust and influential factor in word and picture naming, yet few theories have been developed that offer a comprehensive account of this effect (cf. Brown & Watson, 1987; Ellis & Lambon Ralph, 2000). Moreover, current influential models of word and picture production have failed to acknowledge the fundamental impact that AoA has upon these processes. Chapter One suggested that the lack of recognition of the AoA effect in these models might in part be due to a lack of experimental evidence regarding the exact locus/loci of this effect. The experiments of the present thesis set out to address this issue by examining the effects of AoA in the word and picture naming tasks and in a phonological segmentation task in order to provide some direct evidence as to the exact locus/loci of the AoA effect in the word and picture production systems.

Chapter Two investigated the locus of the AoA and frequency effects in word naming by examining these variables relationship to the spelling-sound consistency effect. Chapter Three then investigated the locus of the consistency effect in detail in order to allow identification of the loci of the AoA and frequency effects in word naming.

Experiment 1 of Chapter Two demonstrated that frequency continues to affect word naming latencies and to interact with consistency even when AoA is controlled. Experiment 2 then demonstrated that AoA affects single word naming and also interacts with consistency such that late acquired exception words were named more slowly than early acquired exception words or consistent words of both early and late AoA. The interaction between AoA and consistency was replicated in the word naming task of Experiment 6b in Chapter Four, thereby providing an indication of the reliability of this finding.

Chapter Two concluded that, because AoA and frequency interact with consistency, these two variables must influence the same level of processing in single word naming as does the consistency effect. The most common explanation of the consistency effect in connectionist models of word naming is that it influences the strength of the connections between orthography and phonology (e.g., Harm & Seidenberg, 1999; simulations 1-3 of Plaut et al., 1996; Seidenberg & McClelland, 1989). However, in a final simulation of their model Plaut et al. (1996) implemented a contribution from a semantic pathway claiming that, because the semantic variable of imageability affects word naming latencies and interacts with consistency (for low frequency words) (e.g., Strain et al., 1995), the consistency effect must be a consequence of a required contribution from semantics in the successful reading of low frequency exception words. However, the experiments of Chapter Three demonstrated quite clearly that, once AoA is controlled, imageability does not influence single word naming, not even for the naming of low frequency exception words. Consequently, Chapter Three concluded that there is little in the way of evidence to support Plaut et al.'s (1996) implementation of a contribution from semantics to the successful reading of low frequency exception words. The results of Chapter Three, therefore, support the explanation of consistency offered in the earlier simulations of Plaut et al.'s (1996) model wherein consistency affects the strength of the connections between orthography and phonology (see also Harm & Seidenberg, 1999; Seidenberg & McClelland, 1989). Because AoA and frequency interact with consistency, the results of Chapter Three further suggest that in word naming AoA and frequency also influence the strength of the connections between orthography and phonology.

Chapter Four provided further evidence to suggest that AoA affects a level of processing prior to the level of the phonological output store. Chapter Four set out to test the claims of the phonological completeness hypothesis of Brown and Watson (1987) that states that AoA affects the quality of the phonological representations, with early acquired words having more holistic representations than do late acquired words.

The claims of this hypothesis were tested using a phonological segmentation task. According to the phonological completeness hypothesis late acquired words should be segmented more quickly than early acquired words because they are already stored in a fragmented form. The results of the segmentation task, however, provided no support for this hypothesis: over the three segmentation conditions, no effect of AoA was found. Although there was an effect of AoA in the consonant cluster segmentation condition, this effect was in the opposite direction to that predicted by the phonological completeness hypothesis, with early acquired words being segmented significantly faster than late acquired words.

In opposition to the phonological completeness hypothesis, the results of the segmentation experiment provide support for the lexical restructuring model of Metsala and Walley (1998). This model argues that early acquired words undergo more extensive segmental restructuring at an earlier stage than do late acquired words during vocabulary development. The finding of a significant effect of AoA in the consonant cluster segmentation task - the task requiring the finest level of segmentation (at the phoneme level) - suggests that early acquired words do achieve a better established and finer grained level of segmentation than do late acquired words.

The segmentation task, therefore, provides direct evidence against the phonological completeness hypothesis - the AoA effect is not a consequence of the fact that early acquired words are stored as more holistic phonological representations.

The second part of Chapter Four then set out to investigate the more general claim that AoA influences processing at the level of phonological output (e.g., Brown & Watson, 1987; Gilhooly & Watson, 1981; Metsala & Walley, 1998). This was tested by completing a comparison between individual's phonological skill and the size of the participant's AoA effect size in both the consonant cluster segmentation condition and in a word naming task. The size of each participant's consistency effect size in the word naming task was also assessed in relation to the individual's phonological skill.

This comparison found no relationship between individual's phonological skill and the size of their consistency effect in word naming, thereby reaffirming the conclusion that consistency influences processing prior to the level of phonological output. Similarly, phonological skill was not related to the size of participant's AoA effect size in the consonant cluster segmentation task. This suggests that like consistency, AoA exerts its effect prior to the level of explicit phonological processing. On the basis of the results of Chapters Two and Three it was assumed that AoA affects the strength of the connections between input (orthography and semantics) and phonological output.

Phonological skill did, however, correlate with the size of individuals' AoA effect size in the word naming task. This relationship suggested that while the AoA effect is not located in phonological output, phonological skill might influence the establishment of connections between input and phonological output during development, thereby influencing the strength of the emerging AoA effect.

The final study of this thesis investigated the locus of the AoA effect (and other variables' effects) in the picture naming task using a group of aphasic patients. Each patient's level of impairment was related to the variables that affected their picture naming success in the hope of identifying the locus of such effects within the picture naming system. This study demonstrated that the semantic variables of familiarity, imageability and animacy only influenced the naming success of (some) patients with a semantic level of impairment, and that the phonological effect of word length affected those patients whose level of impairment was primarily phonological.

The predicted locus of the AoA effect as being in the connections between semantics and phonology was also confirmed in this study. Indeed, AoA influenced the picture naming success of 10 of the 13 aphasic patients. These 10 patients had different levels of damage within the picture production system - at the semantic level, at both the semantic and phonological levels, and at the level of the connections between semantics and phonology. The fact that

AoA influenced the naming success of patients with these different levels of impairment suggests that AoA must exert its effect within the connections between semantics and phonology in picture naming. This is the only possible locus that could explain the occurrence of an AoA effect in patients with damage to the semantic system and/or to the phonological system and/or to the connections between the two. The reason that patients with a semantic impairment show an effect of AoA is because weakened semantic output will be transmitted more successfully through the stronger connections from semantics to phonology for early acquired words. Similarly, patients with a phonological impairment will show an AoA effect because the damaged phonological representations will receive stronger input from early acquired words and so will be more likely to achieve sufficient activation in order to retrieve those items. Patients with damage to the connections themselves will also show an AoA effect because the weaker connections of late acquired items means that these connections will be more susceptible to damage.

AoA was also found to influence both the elderly control participant's and the aphasic patient's picture naming success at the group level of analysis. Such a strong AoA effect in both the control and aphasic groups' picture naming success lead to the conclusion that AoA is an integral part of the speech processing system.

The present picture naming study, however, found only a weak effect of frequency: frequency did not affect the control participant's naming success and although it did influence the aphasic group's naming performance, it only influenced the naming success of 3 of the 13 patients. It was concluded that frequency does not have a particularly strong effect on normal picture naming and may only exert an effect when the picture naming system is placed under pressure. That is, perhaps, when naming is speeded in normals or when damage is incurred to the level of processing wherein frequency exerts its effect. On the basis of current theories of frequency (e.g., Ellis & Lambon Ralph, 2000; Plaut et al., 1996) it was assumed that frequency influences the strength of the connections between semantics and phonology and that, therefore, those patients who showed an effect of frequency had damage to these connections, though this was only confirmed in 1 of the 3 patients.

Together, the experiments of the current thesis have provided strong evidence that locates the AoA effect in the connections between orthography and phonology in word naming and between semantics and phonology in picture naming. The implications of these results for current theories of AoA and for the influential connectionist model of word and picture production offered by Plaut et al. (1996) will now be discussed in turn.

7.2 The locus and influence of the AoA effect in word and picture naming

Contrary to the phonological completeness hypothesis of Brown and Watson (1987), there is no support for the claim that AoA exerts its effect at the phonological level of processing. Instead, the results of the experiments in the current thesis point to the loci of AoA as being within the connection strengths between orthography and phonology in word naming and in the connections between semantics and phonology in picture naming.

This is in direct support of the model of AoA offered by Ellis and Lambon Ralph (2000). As Ellis and Lambon Ralph (2000) argue it would appear that early established words structure the configuration of the connections between input and phonological output so as to be most optimal for the retrieval of their phonological representations. By the time later learnt words are presented to the system for learning, the network will have lost much of its plasticity and, consequently, later established connections will struggle to become as entrenched in the network as are the earlier connections. As was discussed at the end of Chapter Three, however, later learnt items will only suffer if their connections are different to those already set up for early acquired words. In terms of the semantic - phonology pathway all late acquired connections will suffer relative to the early acquired connections because these connections are entirely arbitrary for all items. That is, there are no similar patterns of shared connections between early and late acquired picture concepts and their names. Consequently, the AoA effect in picture naming is robust across all items (cf. Ellis, Scarna, Monaghan & Lambon Ralph, 2000).

In contrast, late acquired words in the orthography - phonology pathway will only suffer when their connections are exceptional. Late acquired consistent words that share their orthographical and phonological word bodies with early acquired words can share the already established connections of these early acquired words and so be named as quickly as are their early acquired neighbours. Consequently, the AoA effect in single word naming is only apparent for late acquired exception words. The simulations completed by Lambon Ralph (cf., Monaghan & Ellis, in press) demonstrated that Ellis & Lambon Ralph's (2000) network does indeed simulate an AoA by consistency interaction in word naming.

The significant positive relationship between individual's phonological skill and the size of their AoA effect in the word naming task reported in Chapter Four suggests that the establishment of strong connections between input and phonological output for early acquired words is dependent upon the level of an individual's phonological skill during development. As vocabulary development theories argue, increasing vocabulary size during development forces the restructuring of representations in the phonological output store into increasingly fine-grained fragments (e.g. Ferguson, 1986; Fowler, 1991; Jusczyk, 1986; 1993;

Metsala & Walley, 1998; Walley, 1993). The accurate and efficient restructuring of the phonological output store will be facilitated by good phonological skill. A consequence of this fragmentation of phonological representations is the necessary establishment of connections between input and increasingly distributed phonological output. It follows that the better the individual's phonological skill, the more accurate and efficient this restructuring process will be and, therefore, the easier it will be to set up established and clear connections between input and phonological output. Clearly, therefore, this argument suggests that the better an individual's phonological skill, the easier it will be to establish strong and accurate connections between input and phonological output. According to Ellis and Lambon Ralph's (2000) theory, early established connections then configure the network in to a structure most advantageous for the activation of their phonology, thereby resulting in the AoA effect seen in adults.

The present thesis has provided strong support for the loci of the AoA effect in word and picture naming. These results have further provided direct support for the theory of AoA proposed by Ellis and Lambon Ralph's (2000) connectionist network. The challenge now, therefore, is for current models of word and picture naming to demonstrate that their models can simulate the robust AoA effect in both word and picture naming. The locus of this effect is in the same situation as the currently modelled effects of frequency and, as Ellis and Lambon Ralph (2000) have demonstrated, with the use of cumulative learning connectionist models can simulate this effect.

7.3 The locus and influence of the frequency effect in word and picture naming

The present thesis has demonstrated that frequency continues to affect word naming speed and to interact with spelling-sound consistency even when AoA is controlled. This supports the models of word reading which argue that both frequency and spelling-sound consistency influence the strength of the connections between orthography and phonology (e.g., Ellis & Lambon Ralph, 2000; Harm & Seidenberg, 1999; Plaut et al., 1996; Seidenberg & McClelland, 1989). However, the results of the present Chapter Six suggest that the effect of frequency upon picture naming success is not particularly robust, especially in comparison to the effect of AoA. Unlike AoA, frequency did not affect the control participant group's naming success, and although it did affect the aphasic patient group's naming success, it only had a significant effect on 3 of the 13 patients included in the picture naming study. It was concluded, therefore, that frequency might only have a significant effect upon picture naming success when damage occurs in the connections between semantics and phonology (where frequency is presumed to exert its effect). In the normal system, whilst frequency does not affect naming success, the extra pressure placed upon the picture naming system when naming is speeded may result in a frequency effect upon naming

RTs (e.g., Barry et al., 1997; Cirrin, 1983; Ellis & Morrison, 1998; Lachman, 1973; Lachman et al., 1974; Snodgrass & Yuditsky, 1996).

The weaker effect of frequency upon picture naming relative to the strong effect of AoA suggests that frequency may have a more transient role in the language processing system than does AoA. Chapter Six proposed that, because AoA emerges during the development of the language processing system its effect on every picture naming attempt will be robust. In contrast, frequency might be a variable that affects naming production in the mature system. Frequency may, therefore, be better construed as some form of a recency effect, wherein frequently used words have stronger connections between semantics and phonology because these connections have recently been exercised. This would explain the non-significant effect of frequency in normal picture naming success. When the connections between semantics and phonology in the established system are damaged, however, a significant frequency effect may be observed in aphasic patients because recently used high frequency items are more likely to resist damage than are low frequency items. Similarly, in the normal system, while the frequency effect is not powerful enough to influence naming success, when the picture production system is placed under pressure - when naming is speeded, the extra pressure on the connections may allow a frequency effect to emerge in the RT data. Thus whereas one can observe an AoA in both naming success and naming speed, one may only observe a frequency effect when naming is speeded in the normal system, or when damage occurs to the level of processing wherein frequency exerts its effect.

The models of Ellis and Lambon Ralph (2000) and Plaut et al. (1996) both offer explanations of the frequency effect in terms of the strength of the connections between input and phonological output, with high frequency items having stronger connections and, therefore, more accurate levels of output than do low frequency items. Consequently these models would predict a frequency effect in both word and picture naming. Such predictions are entirely valid. However, it may be the case that, as was argued in Chapter One, the effect of frequency is not as robust or as influential as is the AoA effect in both the word and the picture naming systems. Future work modelling the effects of frequency should take into account the fact that frequency can no longer be construed as the most important and influential variable in word and picture production. Instead, previous work and that of the present thesis indicate that a more robust and fundamental predictor of word and picture name production is the item's AoA.

7.4 Conclusions

The present thesis has demonstrated that AoA affects the strength of the connections between input and phonological output. This effect is an integral part of the language processing system that becomes established very early on in a child's language and reading development. As a consequence, AoA affects every naming attempt made in picture naming and affects the naming of arbitrary mappings in word naming.

The present thesis has also argued that frequency affects the strength of the connections between input and phonological output. However, whilst frequency certainly affects exception word naming, its effect in normal picture naming success is less reliable. The frequency effect is clearly far less influential in picture naming than is the AoA effect. For frequency to emerge as a significant predictor of picture naming the connections between semantics and phonology must be placed under considerable pressure, thus one might only observe an effect of frequency when naming is speeded or when these connections are damaged in aphasia. On the basis of the results of the present thesis, it was concluded that current models of word and picture naming should be modelling the AoA effect as a fundamental and integral part of the network's processing, thereby simulating a robust effect of AoA in both word and picture naming and placing less emphasis on the smaller, weaker effect of frequency.

7.5 Future directions

7.5.1 Modelling of the AoA effect in current models of word and picture naming

As was discussed in the Introduction to this thesis, current models of word reading and picture naming have failed to recognise the robust and fundamental influence of AoA in word and picture naming. The aim of this thesis was to provide conclusive evidence about the level of effect of this variable in terms of connectionist models. This thesis has successfully located the AoA effect within the connections between input and phonological output.

The challenge for the models of word and picture naming is to now incorporate the AoA effect into the programming of their models. Ellis and Lambon Ralph (2000) have demonstrated clearly that the AoA effect can be modelled in connectionist networks through the use of cumulative, interleaved training. The current work has also provided experimental support for the loci of the AoA effect postulated by Ellis and Lambon Ralph's (2000) model.

Advanced connectionist models such as those of Plaut et al. (1996) must now follow suit and demonstrate that their models are able to simulate the AoA effect. Plaut et al.'s (1996) model would appear to be perfectly capable of modelling the AoA effect given that its network is adaptive. In addition, by placing the AoA effect in the connections between orthography/semantics and phonology, Plaut et al.'s (1996) model should be able to easily explain the effects of AoA in picture naming, and its interaction with spelling-sound consistency in word naming. Until this model attempts to simulate these AoA effects, however, its applicability in terms of its ability to explain some of the most fundamental and robust of reading and picture naming phenomenon will remain undermined.

7.5.2 Further investigation of the frequency effect

The present thesis has argued that frequency may have more of a transient effect in the language processing system, thereby explaining its weak effect on picture naming success. However, conclusive evidence to support such suggestions about the frequency effect have been difficult in the present thesis given its small and sometimes elusive effect.

Future work clearly needs to investigate further the claim that frequency only affects aphasic patients' naming success when their level of damage is to the connections between semantics and phonology. The present thesis has proposed that, for frequency to exert an effect in the picture naming task, the connections must be either damaged or placed under pressure in a speeded naming task. However, these claims were not supported by any conclusive evidence in the present thesis. Consequently, further detailed investigation of aphasic patients that have identified damage to these connections could provide some very interesting and important insights into the true impact of frequency (and of AoA) on picture naming in both aphasic and normal adults. Similarly, further investigation of the true effects of frequency upon speeded picture naming in normal adults is needed. The debate as to whether frequency does indeed affect normal picture naming still continues - while the majority of recent regression studies have concluded that frequency does affect picture naming speed (e.g., Barry et al., 1997; Cirrin, 1983; Ellis & Morrison, 1998; Lachman, 1973; Lachman et al., 1974; Snodgrass & Yuditsky, 1996) recent studies using factorial methods have concluded that frequency does not influence picture naming speeds (e.g., Barry et al., 2001; Bonin et al., 2001). The arguments of the present thesis suggest that frequency will affect picture naming, but only when the task is speeded, thereby increasing the pressure placed upon the connections between semantics and phonology.

7.5.3 Modelling of the frequency effect in current models of word and picture naming

Should future work on the frequency effect support the claims of the current Chapter, then this would cause a further challenge to current models of word and picture naming that would have to re-assess their explanation of the frequency effect. At the moment this effect emerges during training in connectionist networks with higher frequency items being exposed more often to the model (e.g., Ellis & Lambon Ralph, 2000; Plaut et al., 1996; Seidenberg & McClelland, 1989). However, this is by no means logical given that reported frequency effects are those based upon the frequency of usage in adult language, that is, frequency affects processing in the fully trained mature network. The present thesis has argued that frequency may be more appropriately viewed as a temporary effect that helps word production when that word has recently been used.

A more applicable way of modelling the frequency effect might, therefore, be to vary the exposure of items in the model once the model is fully trained and able to read and produce words. If such training can simulate a frequency effect it will likely simulate an effect far more alike to that observed in human processing; it will be a smaller, more volatile effect that is most prominent when the model is placed under pressure - when naming is speeded, or attempted following damage to the connection strengths themselves.

Such modelling of the frequency effect would appear to be far more valid and applicable on the basis of the present results. It may also allow a greater understanding of how the frequency effect truly influences skilled adult's word and picture naming. This is, however, a different explanation of the frequency effect to that currently offered in the connectionist models of word and picture naming (e.g. Ellis & Lambon Ralph, 2000; Plaut et al., 1996).

7.5.4 Does AoA affect word and picture naming in participants with poor phonological skill?

The results of Chapter Four suggested that an individual's phonological skill influences the extent to which connections between input and phonological output are successfully established. This suggestion was based upon the finding of a significant relationship between phonological skill and the size of the AoA effect in word naming with larger effect sizes being related to better phonological skill. One prediction that extends itself from this is that adults with poor phonological skill, and even, perhaps, developmental dyslexics, will show even smaller effects of AoA. In addition, if this was the case, one would also expect to see a reduced interaction between AoA and consistency in participants with poor phonological skill. That is, exception words will be named more slowly than consistent words regardless of the items AoA. The usual interaction between AoA and consistency is such that exception words are only at a disadvantage if they are also late acquired. This is because the strength of the connections for early acquired words allows early acquired exception words to be produced quickly and efficiently. However, if poor phonological skill reduces the strength of the connections of early acquired words, exception words may struggle in the network regardless of their AoA. Further studies assessing the size of the AoA effect and its interaction with consistency in developmental dyslexics and/or groups of adults with varying levels of phonological ability could provide some interesting insights into the claims of Chapter Four and may also allow further understanding of the emergence of the AoA effect during development.

7.5.5 Implications of the AoA effect in aphasic naming success

The results of Chapter Six highlighted the fact that a majority of aphasic patients retain early acquired words more successfully than late acquired words. Such a finding may have implications for therapy with aphasic patients. That is, if one wanted to increase the successful word production of a patient during therapy, it may be better to start training on early acquired items because they have the best chance of being produced correctly given the greater strength of the connections of such items. Therapy studies that compared the success rate of re-learning vocabulary/word production should demonstrate quicker and more successful performance on early acquired items relative to late acquired items. Such a result could have some very interesting and potentially quite important implications for therapy with many aphasic patients.

7.5.6 Future research on the emergence of the AoA effect

A large amount of research has demonstrated the robustness of the AoA effect in word and picture naming. The present thesis has provided experimental support for Ellis and Lambon Ralph's (2000) theory that places the AoA effect in the connections between input and phonological output. However, little is understood about the actual emergence of the AoA effect. That is, what makes some words easier to learn and so be early acquired, and others later learnt? Understanding the properties that make early acquired words easy to learn - such as, for example, their phonetic or orthographic make up - could allow some very interesting and important insights into the language processing system and the mechanism underlying the AoA effect. Such work should be considered as both interesting and imperative to a clear and rounded understanding of the emergence and influence of the AoA effect.

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Appendix 1 Words Used in Experiment 1

Word	Celex	K-F	AoA	Imag	N	Le	RT
	High frequency, consistent words						
block	33	66	2.58	5.52	7	5	487
bridge	58	98	2.25	6.92	3	6	479
claim	45	98	4.25	2.20	1	5	522
deal	144	142	3.96	3.68	24	4	501
deck	19	23	3.79	5.56	13	4	469
drink	79	82	1.21	6.32	4	5	499
fight	47	98	2.46	5.92	12	5	504
male	86	37	3.08	6.32	27	4	470
mile	35	48	4.00	3.36	24	4	468
pond	14	25	2.63	6.72	13	4	506
rate	141	209	4.21	2.88	26	4	483
risk	59	54	4.04	2.52	7	4	463
trust	43	52	3.79	2.24	5	5	530
scheme	45	98	4.25	2.20	1	6	613
sex	124	84	4.25	6.24	13	3	531
shape	63	85	2.50	4.46	10	5	522
shirt	45	27	2.13	6.80	8	5	546
spoke	29	87	3.00	3.54	7	5	582
wage	24	56	4.58	4.56	14	4	473
whole	421	309	3.42	3.56	4	5	497
M	77.7	88.9	3.32	4.58	11.2	4.6	507
SD	89.3	67.6	0.93	1.71	8.3	0.8	39.31
	Low frequency, consistent words						
dip	5	6	2.96	3.64	22	3	503
dump	5	4	4.00	5.08	9	4	495
crane	2	5	2.92	6.68	14	5	514
ditch	6	10	3.63	5.60	7	5	484
dent	1	2	3.75	5.32	19	6	484
grape	2	3	2.54	6.88	15	5	483
speck	3	7	4.92	3.92	6	5	583
moan	3	1	3.67	3.21	6	4	474
jolt	0	2	4.71	4.08	11	4	508
pet	13	8	1.75	6.28	26	3	502
rhyme	2	3	3.13	2.76	2	5	492
rung	8	3	4.46	4.36	10	4	497
peep	1	2	2.58	4.48	12	4	506
hump	3	2	3.92	5.24	12	4	480
greed	8	3	3.71	3.28	6	5	495
rust	4	10	3.58	5.48	17	4	493
jade	2	1	4.38	4.48	13	4	520
hop	4	2	2.17	5.60	26	3	490
whoop	0	1	4.75	2.48	1	5	561
whack	0	1	3.00	4.50	4	5	491
M	3.6	3.8	3.53	4.67	12	4.4	503
SD	3.3	2.9	0.89	1.25	7.3	0.8	26.62

Appendix 1 (Continued)

	Celex	K-F	AoA	Imag	N	Le	RT
	High frequency, exception words						
bomb	29	36	3.92	6.56	4	4	529
break	46	88	2.58	4.60	8	5	482
touch	65	87	2.38	3.96	6	5	501
bowl	27	23	2.00	6.56	13	4	507
gone	252	195	1.96	2.16	19	4	490
threat	61	42	4.00	3.24	3	6	529
sweat	26	26	3.83	5.52	5	5	575
move	87	171	1.83	3.64	19	4	468
gross	22	66	5.21	3.00	4	5	516
warm	84	67	1.79	3.88	11	4	465
aunt	30	22	1.92	6.44	8	4	524
prove	15	53	4.25	1.88	8	5	478
whom	180	146	5.08	1.36	4	4	558
ward	25	25	3.75	5.52	19	4	492
lose	20	58	2.50	2.44	16	4	527
none	121	108	2.04	2.48	19	4	477
whose	223	252	2.83	1.36	5	5	519
height	34	35	2.75	4.32	1	6	501
worth	87	94	4.38	2.00	2	5	481
youth	65	82	5.17	4.75	3	5	498
M	74.9	83.8	3.21	3.78	8.9	4.6	506
SD	69.0	63.2	1.20	1.72	6.4	0.7	29.1
	Low frequency, exception words						
brooch	2	0	3.83	5.44	1	6	540
glove	5	9	2.00	7.00	7	5	479
caste	5	3	5.63	2.00	7	5	578
vase	4	4	3.46	6.52	11	4	540
comb	4	6	2.13	6.96	5	4	510
thou	13	13	4.83	1.32	2	4	571
swan	5	3	2.29	6.84	9	4	564
lure	5	7	5.46	2.96	20	4	530
wand	2	1	2.50	6.28	13	4	491
wan	2	2	6.08	1.80	27	3	510
sew	1	6	3.21	4.76	20	3	586
wolf	6	6	2.38	6.96	4	4	474
worm	7	4	1.75	6.76	9	4	504
warn	3	11	3.70	3.04	15	4	508
shove	2	2	3.50	4.20	6	5	559
swarm	2	3	5.63	2.00	5	5	572
swear	4	10	3.92	3.96	5	5	549
spook	0	0	3.63	4.40	5	5	580
swat	0	0	4.29	3.92	10	4	580
swap	1	2	3.00	4.40	12	4	543
M	3.7	4.6	3.66	4.58	9.7	4.3	538
SD	3.0	3.8	1.32	1.95	6.7	0.7	36.0

Note: Celex = Celex word frequency, K-F = Kucera and Francis (1967) word frequency, AoA = age of acquisition, Imag = imageability, N = number of orthographic neighbours, Le = word length in letters, RT = word naming reaction time.

Appendix 2 Words Used in Experiment 2

Word	Celex	K-F	AoA	Imag	N	Le	RT
Early AoA, consistent words							
grape	2	3	2.54	6.88	15	5	524
swim	13	15	2.21	6.16	6	4	569
stump	4	2	3.30	5.70	2	5	613
snort	2	3	3.30	4.95	4	5	603
whack	0	1	3.00	4.50	4	5	523
drink	79	82	1.21	6.32	4	5	508
spoke	29	87	3.00	3.54	7	5	604
shirt	45	27	2.13	6.80	8	5	590
shape	63	85	2.50	4.46	10	5	563
groan	2	1	2.85	3.50	3	5	538
peck	2	5	2.65	4.35	15	4	509
boast	2	8	3.40	2.65	9	5	535
yelp	1	2	3.35	3.90	7	4	514
nip	1	3	3.25	3.10	18	3	530
hurt	7	37	1.58	3.54	9	4	520
whirl	1	3	3.25	4.55	2	5	509
stripe	2	4	2.25	6.35	6	6	631
rhyme	2	3	3.13	2.76	2	5	521
rust	4	10	3.58	5.48	17	4	483
half	329	275	2.50	4.00	18	4	512
M	29.5	32.8	2.75	4.67	8.3	4.7	545
SD	74.1	64.2	0.63	1.34	5.5	0.7	42.4
Late AoA, consistent words							
deal	144	142	3.96	3.68	24	4	521
swell	5	7	4.71	4.08	10	5	570
sex	124	84	4.25	6.24	13	3	576
shrub	4	1	4.04	6.28	2	5	632
weep	2	14	4.13	5.64	13	4	497
gleam	4	4	4.63	4.44	5	5	538
shawl	5	3	3.88	6.52	3	5	607
sigh	12	11	4.38	4.00	8	4	577
scheme	65	33	5.33	2.20	1	6	652
gig	1	1	5.71	4.50	21	3	523
trance	5	4	5.42	4.40	2	6	556
brawl	1	1	4.71	5.40	5	5	532
rye	5	4	5.05	2.95	12	3	534
nerve	14	12	4.32	3.85	5	5	524
hail	4	10	3.65	4.55	20	4	528
whoop	0	1	4.75	2.48	1	5	558
shield	7	8	4.00	6.46	1	6	566
ranch	6	27	4.67	5.40	5	5	526
rate	141	209	4.21	2.88	26	4	505
hump	3	2	3.92	5.24	12	4	507
M	27.6	28.9	4.49	4.56	9.5	4.6	551
SD	49.0	54.7	0.56	1.32	8.0	0.9	41.8

Word	Celex	K-F	AoA	Imag	N	Le	RT
			Early AoA, exception words				
deaf	11	12	3.10	3.15	9	4	521
swap	1	2	3.00	4.40	12	4	591
shove	2	2	3.50	4.20	6	5	589
steak	8	10	3.58	6.80	7	5	628
wolf	6	6	2.38	6.96	4	4	502
vase	4	4	3.46	6.52	11	4	581
squash	7	2	2.63	5.64	1	6	622
scarf	8	4	2.33	6.92	5	5	606
swan	5	3	2.29	6.84	9	4	582
glove	5	9	2.00	7.00	7	5	529
touch	65	87	2.38	3.96	6	5	556
bead	2	1	3.21	6.00	15	4	579
wear	23	26	1.90	2.35	18	4	499
lose	20	58	2.50	2.44	16	4	515
height	34	35	2.75	4.32	1	6	542
wash	14	37	1.63	5.36	14	4	494
shoe	14	14	1.33	6.92	7	4	596
wool	21	10	2.67	5.68	9	4	527
none	121	108	2.04	2.48	19	4	499
whose	223	252	2.83	1.36	5	5	560
M	29.7	34.1	2.58	4.97	9.1	4.5	556
SD	53.4	59.3	0.62	1.85	5.2	0.7	43.4
			Late AoA, exception words				
drought	1	1	4.21	6.04	3	7	590
swarm	2	3	4.83	5.12	5	5	603
swat	0	0	4.29	3.92	10	4	641
squad	9	18	5.13	4.52	4	5	651
wart	1	11	4.25	5.75	23	4	558
ghoul	1	1	4.21	6.04	0	5	612
sweat	26	26	3.83	5.52	5	5	587
suite	11	27	5.05	4.15	5	5	661
foul	9	4	3.70	3.25	9	4	560
brooch	2	0	3.83	5.44	1	6	625
pint	10	13	3.60	6.70	19	4	535
bomb	29	36	3.92	6.56	3	4	533
wreath	2	8	5.42	5.68	1	6	643
lure	5	7	5.46	2.96	20	4	552
hearth	4	4	4.79	5.36	3	6	635
wad	3	0	5.33	3.40	18	3	520
swear	4	10	3.92	3.96	5	5	591
worth	87	94	4.38	2.00	2	5	538
youth	65	82	5.17	4.75	3	5	520
whom	180	146	5.08	1.36	4	4	576
M	22.6	24.6	4.52	4.62	7.2	4.8	587
SD	43.5	38.7	0.63	1.48	7.1	1.0	45.9

Note: Celex = Celex word frequency, K-F = Kucera and Francis (1967) word frequency, AoA = age of acquisition, Imag = imageability, N = number of orthographic neighbours, Le = word length in letters, RT = word naming reaction time.

Appendix 3 Words Used in Experiment 3

Word	Celex	K-F	AoA	Imag	N	Le	RT
	High imageability, consistent words						
weep	2	14	4.13	5.64	13	4	481
hump	3	2	3.92	5.24	12	4	489
shrug	3	2	4.13	4.88	2	5	591
brim	3	4	4.75	4.6	11	4	499
rust	4	10	3.58	5.48	17	4	488
shrub	4	1	4.04	6.28	2	5	571
cube	5	1	3.67	6.32	7	4	558
shawl	5	3	3.88	6.52	3	5	574
dump	5	4	4.00	5.08	9	4	496
shield	7	8	4.00	6.46	1	6	568
heap	10	14	3.75	5.24	10	4	500
ridge	12	18	5.08	4.68	2	5	487
cliff	15	11	3.25	6.56	3	5	534
grief	15	10	4.42	5.08	2	5	499
core	17	37	3.96	4.8	30	4	527
deck	19	23	3.79	5.56	13	4	491
wage	24	56	4.58	4.56	14	4	496
text	28	60	4.38	5.48	5	4	518
male	86	37	3.08	6.32	27	4	492
sex	124	84	4.25	6.24	13	3	538
M	19.55	19.95	4.03	5.55	9.8	4.35	520
SD	30.8	23.23	0.48	0.70	8.13	0.67	35.08
	Low imageability, consistent words						
whack	0	1	3.00	4.5	4	5	487
whoop	0	1	4.75	2.48	1	5	510
peep	1	2	2.58	4.48	12	4	514
rhyme	2	3	3.13	2.76	2	5	498
jade	2	1	4.38	4.48	13	4	505
dell	2	5	5.58	2.16	15	4	509
moan	3	1	3.67	3.21	6	4	465
speck	3	7	4.92	3.92	6	5	610
gleam	4	4	4.63	4.44	5	5	528
squire	4	5	6.25	3.8	3	6	594
dip	5	6	2.96	3.64	22	3	488
swell	5	7	4.71	4.08	10	5	560
starch	5	4	5.92	2.72	2	6	583
greed	8	3	3.71	3.28	6	5	504
rung	8	3	4.46	4.36	10	4	488
grade	12	35	4.08	3.36	11	5	504
mile	35	48	4.00	3.36	24	4	484
trust	43	52	3.79	2.24	5	5	533
risk	59	54	4.04	2.52	7	4	469
cold	181	171	1.46	4.44	18	4	502
M	19.1	20.65	4.10	3.49	9.1	4.6	517
SD	41.31	39.81	1.15	0.80	6.60	0.75	40.42

Word	Celex	K-F	AoA	Imag	N	Le	RT
	High imageability, exception words						
font	1	0	5.21	5.2	3	4	544
swarm	2	3	4.83	5.12	5	5	593
wreath	2	8	5.42	5.68	1	6	559
quay	3	0	5.04	5.04	1	4	768
vase	4	4	3.46	6.52	11	4	551
swamp	4	5	3.58	5.76	3	5	544
hearth	4	4	4.79	5.36	3	6	572
drought	5	5	5.08	4.72	3	7	561
steak	8	10	3.58	6.8	7	5	605
squad	9	18	5.13	4.52	4	5	595
wool	21	10	2.67	5.68	9	4	477
beard	22	26	2.75	6.6	12	5	531
ward	25	25	3.75	5.52	19	4	494
sweat	26	26	3.83	5.52	5	5	579
bowl	27	23	2.00	6.56	13	4	519
bomb	29	36	3.92	6.56	4	4	504
aunt	30	22	1.92	6.44	8	4	512
breast	43	11	4.54	6.52	0	6	514
break	46	88	2.58	4.6	8	5	497
youth	65	82	5.17	4.75	3	5	519
M	18.8	20.3	3.96	5.67	6.1	4.85	552
SD	17.85	24.4	1.13	0.76	4.80	0.88	62.54
	Low imageability, exception words						
spook	0	0	3.63	4.4	5	5	598
swat	0	0	4.29	3.92	10	4	598
grieve	0	0	5.13	4.2	0	6	512
swatch	0	0	5.38	3.44	2	6	590
swap	1	2	3.00	4.4	12	4	581
plead	1	5	4.88	4.12	3	5	507
fiend	1	3	5.25	4.2	1	5	570
wan	2	2	6.08	1.8	27	3	556
shove	2	2	3.50	4.2	6	5	563
warp	2	4	5.00	2.92	10	4	491
warn	3	11	3.70	3.04	15	4	531
wad	3	0	5.33	3.4	18	3	504
swear	4	10	3.92	3.96	5	5	580
lure	5	7	5.46	2.96	20	4	524
thou	13	14	4.83	1.32	2	4	543
height	34	35	2.75	4.32	1	6	502
threat	61	42	4.00	3.24	3	6	551
touch	65	87	2.38	3.96	6	5	512
warm	84	67	1.79	3.88	11	4	472
none	121	108	2.04	2.48	19	4	490
M	20.1	19.95	4.12	3.51	8.8	4.6	539
SD	34.76	31.85	1.25	0.87	7.63	0.94	39.36

Note: Celex = Celex frequency, K-F = Kucera and Francis (1967) word frequency, AoA = age of acquisition, Imag = imageability, Le = word length in letters, RT = word naming reaction time.

Appendix 4 Words Used in Experiment 4

Word	Celex	K-F	AoA	Imag	N	Le	RT
	High imageability, low frequency consistent words						
brawl	1	1	4.71	5.40	5	5	541
brim	3	4	4.75	4.60	11	4	530
fawn	1	1	4.58	5.32	10	4	590
sneer	1	1	5.21	4.56	3	5	615
thong	1	1	5.92	6.40	1	5	554
peep	1	2	2.58	4.48	12	4	522
rake	1	11	3.50	6.52	20	4	510
wick	2	4	3.90	5.50	11	4	508
crane	2	5	2.92	6.68	14	5	569
mast	3	6	3.88	5.84	22	4	510
shrub	4	1	4.04	6.28	2	5	599
cube	5	1	3.67	6.32	7	4	560
jade	2	1	4.38	4.48	15	4	541
urn	3	2	5.00	5.00	3	3	523
vine	3	4	4.30	5.45	21	4	551
elm	7	3	3.70	5.10	6	3	513
hump	3	2	3.92	5.24	12	4	518
cock	6	5	2.85	5.90	19	4	563
M	2.7	3.1	4.10	5.50	10.8	4.2	545
SD	1.8	2.6	0.86	0.73	6.8	0.6	32.4
	Low imageability, low frequency consistent words						
dell	2	5	5.58	2.16	15	4	562
dip	5	6	2.96	3.64	22	3	529
spurt	1	2	4.35	4.35	5	5	630
slit	3	6	3.45	4.30	13	4	610
thaw	1	6	3.95	3.60	6	4	587
peck	2	5	2.65	4.35	15	4	498
rhyme	2	3	3.13	2.76	2	5	531
whoop	0	1	4.75	2.48	1	5	564
tuck	1	2	2.95	2.90	13	4	536
moan	3	1	3.67	3.21	6	4	521
speck	3	7	4.92	3.92	6	5	640
trance	5	4	5.42	4.40	2	6	568
gleam	4	4	4.63	4.44	5	5	545
yelp	1	2	3.35	3.9	7	4	510
tack	2	4	4.70	4.10	16	4	532
rung	8	3	4.46	4.36	10	4	532
rye	5	4	5.05	2.95	12	3	528
keel	2	6	5.10	3.75	12	4	571
M	2.8	3.9	4.17	3.64	9.3	4.3	555
SD	2.0	1.9	0.92	0.73	5.8	0.8	40.0

Word	Celex	K-F	AoA	Imag	N	Le	RT
High imageability, low frequency exception words							
brooch	2	0	3.83	5.44	1	6	616
bead	2	1	3.21	6.00	15	4	570
font	1	0	5.21	5.20	3	4	567
sew	1	6	3.21	4.76	20	3	609
soot	2	1	3.00	5.50	19	4	648
swamp	4	5	3.58	5.76	3	5	580
wart	1	11	4.25	5.75	23	4	526
wand	2	1	2.50	6.28	13	4	541
sheath	3	4	5.92	4.48	2	6	613
mould	0	1	4.29	5.32	5	5	530
swarm	2	3	4.83	5.12	5	5	609
drought	5	5	5.08	4.72	3	7	574
ghoul	1	1	4.21	6.04	0	5	605
wreath	2	8	5.42	5.68	1	6	588
vase	4	4	3.46	6.52	11	4	575
steak	8	10	3.58	6.80	7	5	613
hearth	4	4	4.79	5.36	3	6	609
quay	3	0	5.04	5.04	1	4	700
M	2.6	3.6	4.19	5.54	7.5	4.8	593
SD	1.9	3.4	0.95	0.63	7.4	1.0	42.0
Low imageability, low frequency exception words							
draught	0	1	4.30	3.10	2	7	644
deaf	11	12	3.10	3.15	9	4	522
foul	9	4	3.70	3.25	9	4	539
shove	2	2	3.50	4.20	6	5	587
spook	0	0	3.63	4.40	5	5	614
swat	0	0	4.29	3.92	10	4	605
warp	2	4	5.00	2.92	10	4	525
wad	3	0	5.33	3.40	18	3	557
swap	1	2	3.00	4.40	9	4	601
knead	0	1	4.00	4.40	2	5	590
swatch	0	0	5.38	3.44	2	5	619
plead	1	5	4.88	4.12	3	5	524
grieve	0	0	5.13	4.20	0	6	538
warn	3	11	3.70	3.04	15	4	577
caste	5	3	5.63	2.00	7	5	638
swear	4	10	3.92	3.96	5	5	575
sewn	3	1	4.46	3.12	4	4	629
squat	4	7	4.79	4.33	3	5	655
M	2.7	3.5	4.32	3.63	6.6	4.7	585
SD	3.14	4.0	0.80	0.68	4.8	0.9	43.7

Note: Celex = Celex word frequency, K-F = Kucera and Francis (1967) word frequency, AoA = age of acquisition, Imag = imageability, N = number of orthographic neighbours, Le = word length in letters, RT = word naming reaction time.

Appendix 5 Words Used in Experiment 5

Word	Celex	K-F	AoA	N	Le	Expt 5RT	Expt 5 Reg	SSM RT	SSM Reg
High imageability, low frequency consistent words									
banner	7	8	3.85	7	6	511	0	496	0
cliff	17	11	3.35	3	5	537	0	509	0
coffin	8	7	3.70	1	6	528	0	513	0
corpse	10	7	4.95	0	6	555	0	548	0
duck	4	9	1.55	15	4	502	0	483	0
groin	3	4	5.25	3	5	533	0	533	0
mattress	9	5	3.00	0	8	517	0	501	0
sandal	1	1	2.80	1	6	626	0	546	0
scarlet	15	3	4.35	1	7	613	0	609	0
snail	3	1	2.05	3	5	597	0	570	0
spike	2	2	3.85	8	5	599	0	580	0
straw	22	15	2.80	7	5	634	0	606	0
trout	16	4	4.55	4	5	559	0	539	0
trumpet	5	7	3.20	1	7	538	0	531	0
witch	16	5	2.15	8	5	518	0	503	0
wreck	7	8	3.95	4	5	502	0	493	0
M	9.1	6.1	3.45	4.1	5.6	554	0	535	0
SD	6.3	3.8	1.04	4.0	1.0	45.1	0	39.5	0
Low imageability, low frequency consistent words									
blessing	11	10	4.80	0	8	505	0	502	0
clause	7	9	5.90	0	6	561	0	529	0
cleft	3	2	6.35	3	5	567	0	533	0
custom	16	14	5.57	1	6	529	0	513	0
deed	5	8	4.95	13	4	521	0	501	0
figment	1	2	6.00	2	7	586	0	569	0
fraud	7	8	5.80	0	5	584	0	546	0
gait	3	8	6.75	80	4	563	0	506	0
madness	13	2	3.70	1	7	518	0	504	0
scorn	6	4	5.30	4	5	618	0	598	0
scribe	1	4	6.25	1	6	637	0	598	0
stanza	1	7	6.75	0	6	646	0	614	0
traitor	6	2	5.10	1	7	559	0	538	0
truce	3	5	5.50	3	5	621	0	559	0
whence	5	3	6.45	1	6	562	0	547	0
wrest	0	1	6.00	6	5	542	0	512	0
M	5.5	5.6	5.70	2.8	5.8	570	0	542	0
SD	4.6	4.6	0.80	3.6	1.1	43.1	0	37.0	0

Word	Celex	K-F	AoA	N	Le	Expt 5 RT	Expt 5 Reg	SSM RT	SSM Reg
		High imageability, low frequency exception words							
boulder	5	10	4.40	5	7	544	0	532	0
climb	19	12	2.15	1	5	540	0	509	0
comb	4	6	2.25	5	4	541	0	523	0
croquet	2	0	5.25	0	7	608	3	582	1
dove	3	4	3.20	18	4	519	0	511	2
fatigue	9	11	5.95	0	7	586	3	589	0
ghost	20	11	2.20	2	5	516	0	502	0
meadow	10	17	3.55	0	6	521	0	494	0
pear	2	6	1.90	20	4	537	3	518	0
shovel	3	5	3.15	1	6	570	0	556	0
soot	2	1	3.20	19	4	631	15	572	2
swamp	4	5	4.15	3	5	598	0	578	0
sword	13	7	3.05	3	5	586	0	573	1
treasure	9	4	2.75	0	8	536	0	534	0
wand	2	1	2.75	13	4	513	0	514	1
worm	7	4	2.00	9	4	515	3	498	6
M	7.1	6.5	3.24	6.2	5.3	554	1.69	537	0.81
SD	5.9	4.6	1.18	7.3	1.4	37.5	3.79	33.1	1.56
		Low imageability, low frequency exception words							
broader	8	19	4.60	2	7	551	0	569	0
cache	1	1	6.80	4	5	631	10	602	3
caste	5	3	6.65	7	5	585	5	589	4
chasm	2	2	6.25	4	5	654	8	634	9
dose	6	11	4.25	16	4	564	6	539	8
guise	4	6	6.45	5	5	533	3	544	0
mischief	4	5	3.60	0	8	508	20	518	11
scarce	10	6	5.25	1	6	677	6	597	2
sleight	0	1	6.50	1	7	614	18	627	16
soften	1	4	3.70	1	6	574	3	564	3
stingy	1	1	4.35	1	6	658	13	605	17
suave	1	2	6.55	6	5	681	4	635	5
toughnes	2	6	4.30	1	9	587	0	550	0
trough	3	3	4.25	1	6	625	10	607	2
warn	3	11	3.90	15	4	509	0	505	0
wrath	7	9	5.60	1	5	580	23	576	10
M	3.6	5.6	5.19	4.1	5.8	596	8.06	579	5.63
SD	2.9	4.9	1.19	4.9	1.4	55.8	7.20	40.1	5.61

Note: Celex = Celex word frequency, K-F = Kucera and Francis (1967) word frequency, AoA = age of acquisition, Imag = imageability, N = number of orthographic neighbours, Le = word length in letters, Expt 5 RT = word naming reaction time from the present Experiment 5, Expt 5 Reg = regularisation errors from the present Experiment 5, SSM RT = word naming reaction time from Experiment 2 of Strain et al. (1995), SSM Reg = Regularisation error rates from Experiment 2 of Strain et al. (1995).

Appendix 6 The adjusted means for each word type in the covariate analysis of Experiment 5 and of Strain et al.'s Experiment 2.

	Consistent	**Exception**
High imageability		
Expt 5 Mean RT	554	552
Expt 5 Adjusted Mean RT	569	572
Strain et al. Mean RT	*535*	*537*
Strain et al. Adjusted RT	*551*	*556*
Low imageability		
Expt 5 Mean RT	570	595
Expt 5 Adjusted Mean RT	549	583
Strain et al. Mean RT	*542*	*579*
Strain et al. Adjusted RT	*520*	*565*

Appendix 7 Words used in Experiment 6a

Word	Length	AoA	Image	Freq	N	RT
		Consonant Cluster Condition - Early AoA				
sting	5	2.20	4.65	4	7	850
spell	5	2.92	4.29	15	9	736
trunk	5	2.35	5.60	20	4	787
skirt	5	2.58	5.73	20	4	854
sleep	5	1.40	5.20	86	5	778
plug	4	2.70	5.65	6	3	741
groan	5	2.85	3.50	2	2	758
crawl	5	1.85	6.05	3	5	774
scare	5	2.97	4.71	4	11	860
slip	4	2.70	4.35	14	11	730
brick	5	2.35	6.10	28	9	768
speak	5	2.35	4.60	32	6	781
frog	4	2.58	6.17	4	8	765
stew	4	2.83	5.87	3	9	865
drew	4	3.00	3.00	15	9	742
trip	4	2.50	3.45	55	6	710
frost	5	2.64	5.95	8	3	772
steal	5	3.00	4.15	3	7	862
flash	5	2.45	5.28	19	7	775
sweep	5	2.81	5.13	7	5	766
M	4.70	2.55	4.97	17.40	6.50	784
SD	0.47	0.40	0.96	20.79	2.65	48
		Consonant Cluster Condition - Late AoA				
starch	6	5.92	2.72	5	2	937
spurt	5	4.06	4.91	1	5	808
troop	5	4.06	4.98	4	1	790
sketch	6	4.11	5.10	7	1	939
slave	4	3.86	4.11	16	11	780
plead	5	4.88	4.12	1	3	776
grove	5	4.83	4.70	8	8	757
crypt	5	5.39	5.53	1	1	861
scout	5	3.72	5.78	3	6	871
slot	4	3.85	4.15	4	16	736
brass	5	4.35	5.00	19	5	749
spear	5	3.85	6.05	8	5	819
frame	5	3.94	5.08	26	5	782
staff	5	4.03	4.78	117	2	886
drove	5	4.06	3.53	17	7	721
trout	5	3.94	6.17	16	4	763
fraud	5	5.19	3.81	7	0	808
stump	5	3.79	4.90	4	2	875
flesh	5	4.11	5.67	52	4	793
swell	5	4.28	4.10	4	10	729
M	5.00	4.31	4.76	16.00	4.90	809
SD	0.46	0.61	0.88	26.59	3.99	65

Word	Length	AoA	Image	Freq	N	RT
		Onset - Rime Condition - Early AoA				
bin	3	1.90	5.95	5	21	653
keep	4	2.45	2.15	87	12	651
sip	3	2.45	4.40	4	21	616
fix	3	2.95	3.20	6	14	617
fork	4	1.60	6.25	12	10	653
spoon	5	1.65	6.35	11	7	671
flat	4	3.05	5.20	110	13	743
sell	4	2.85	3.90	14	17	656
hop	3	2.89	5.54	4	26	643
hen	3	1.60	5.90	6	23	652
ham	3	2.50	5.95	7	29	673
mask	4	2.65	5.90	13	14	665
nod	3	2.00	5.20	8	22	620
nut	3	2.15	5.80	7	15	633
rub	3	2.35	4.40	4	18	610
swap	4	3.00	4.40	1	12	868
rusk	4	2.20	3.15	1	9	635
slid	4	2.95	4.10	3	8	710
tap	3	2.05	5.55	19	25	618
warm	4	2.10	3.60	24	11	681
M	3.55	2.37	4.85	17.3	16.35	663
SD	0.61	0.48	1.20	28.62	6.46	58
		Onset - Rime Condition - Late AoA				
bill	4	4.05	4.55	54	24	656
keen	4	4.10	2.90	26	9	649
sin	3	4.65	3.00	24	24	613
fig	3	4.42	4.40	4	22	638
fort	4	3.95	4.80	23	13	627
spool	5	5.80	3.60	3	5	684
flan	4	4.05	4.80	1	11	715
sex	3	4.35	6.30	124	13	611
hob	3	4.55	5.25	0	27	663
hem	3	4.60	4.10	2	15	667
hag	3	4.45	4.60	1	19	638
mast	4	4.30	5.10	3	22	684
nob	3	4.15	4.35	0	26	629
nun	3	4.10	6.35	5	14	637
rum	3	4.84	5.25	6	20	631
swat	4	4.45	4.25	0	13	835
rust	4	3.90	5.00	4	17	658
slim	4	3.80	5.50	11	11	716
tan	3	3.95	5.55	13	27	624
ward	4	4.45	3.70	25	9	745
M	3.55	4.35	4.67	16.45	17.05	666
SD	0.61	0.44	0.94	28.74	6.68	54

Word	Length	AoA	Image	Freq	N	RT
Syllable Juncture Condition - Early AoA						
magic	5	2.81	4.58	37	1	808
stable	6	2.92	5.37	26	3	875
pedal	5	3.06	5.56	1	4	776
merry	5	2.95	4.85	8	10	793
worker	6	3.08	4.86	36	4	836
ribbon	6	2.86	5.63	6	1	873
ruler	5	3.11	5.43	8	0	795
insect	6	2.83	5.86	14	4	850
ticket	6	2.94	5.74	21	8	934
basin	5	2.50	5.42	15	8	852
swallow	7	3.08	5.54	4	1	885
whisper	7	2.56	5.67	12	3	844
berry	5	2.89	5.51	2	13	808
fairy	5	2.42	5.36	11	4	845
cotton	6	3.06	5.62	28	0	898
fifteen	7	2.89	4.91	65	0	838
rattle	6	2.61	5.54	4	6	932
finish	6	3.00	4.37	11	4	967
heaven	6	2.72	4.48	37	3	831
pepper	6	2.69	5.87	7	3	893
M	5.80	2.85	5.31	17.65	4.00	857
SD	0.70	0.21	0.46	16.2	3.49	51
Syllable Juncture Condition - Late AoA						
margin	6	4.03	4.94	9	1	784
slumber	7	4.19	5.00	2	5	809
produce	7	4.31	3.96	32	1	886
merit	5	4.44	3.80	10	0	784
wicket	6	4.45	4.95	6	6	992
rebel	5	4.61	4.97	5	5	779
relief	6	4.43	4.32	57	2	814
insight	7	5.46	3.29	22	1	847
thicket	7	4.69	5.11	1	1	975
blessing	8	3.92	4.22	11	0	972
scarlet	7	4.35	5.87	3	1	779
weapon	6	3.75	5.46	24	0	754
baron	5	4.72	4.98	6	5	751
ferry	5	3.78	5.92	7	12	790
canteen	7	4.36	5.40	6	0	806
fountain	8	3.89	6.02	9	1	836
rector	6	5.61	4.94	2	4	830
finance	7	5.22	4.05	26	0	1024
havoc	5	4.69	5.05	4	0	784
purpose	7	4.28	2.80	92	0	833
M	6.35	4.46	4.75	16.7	2.25	841
SD	0.99	0.51	0.86	22.35	3.08	84

Note: AoA = age of acquisition, Image = imageability, Freq = Celex word frequency, N = number of orthographic neighbours, RT = mean segmentation reaction time.

Appendix 8 Words used in Experiment 6b

Word	Le	AoA	Image	Celex	K-F	N	RT
			Early AoA, consistent words				
peach	5	2.42	6.48	3	3	8	564
swim	4	2.21	6.16	13	15	6	595
stain	5	2.85	5.50	6	6	6	644
whack	5	3.00	4.50	0	1	4	568
drink	5	1.21	6.32	79	82	4	562
spoke	5	3.00	3.54	29	87	7	611
shirt	5	2.13	6.80	45	27	8	593
shed	4	2.45	6.40	11	11	8	588
girl	4	1.50	6.52	276	220	10	548
tuck	4	2.95	2.90	1	2	13	571
boast	5	3.40	2.65	2	8	9	576
yelp	4	3.35	3.90	1	2	7	550
nip	3	3.25	3.10	1	3	18	563
hurt	4	1.58	3.54	7	37	9	537
whirl	5	3.25	4.55	1	3	2	555
stripe	6	2.25	6.35	2	4	6	636
rhyme	5	3.13	2.76	2	3	2	571
hide	4	1.95	4.35	10		16	554
M	4.56	2.55	4.80	27.0	30.2	7.9	577
SD	0.71	0.68	1.51	65.3	55.8	4.3	29
			Late AoA, consistent words				
deal	4	3.96	3.68	144	142	24	547
shrug	5	4.13	4.88	3	2	2	616
set	3	3.70	1.95	141		23	584
wick	4	4.85	5.50	2	4	11	548
gleam	5	4.63	4.44	4	4	5	570
shrub	5	4.04	6.28	4	1	2	641
shawl	5	3.88	6.52	5	3	3	613
sneer	6	5.21	4.56	1	1	3	616
greed	5	3.71	3.28	8	3	6	560
trance	6	5.42	4.40	5	4	2	593
brawl	5	4.71	5.40	1	1	5	559
whoop	5	4.75	2.48	0	1	1	614
nerve	5	4.32	3.85	14	12	5	553
hail	5	3.65	4.55	4	10	20	571
ranch	5	4.67	5.40	6	27	5	553
shield	6	4.00	6.46	7	8	1	603
rate	4	4.21	2.88	141	209	26	530
hump	4	3.92	5.24	3	2	12	543
M	4.8	4.32	4.54	27.39	25.5	8.67	579
SD	0.8	0.53	1.33	52.84	58.03	8.62	32

Word	Le	AoA	Image	Celex	K-F	N	RT
			Early AoA, exception words				
deaf	4	3.10	3.15	11	12	9	547
shove	5	3.50	4.20	2	2	6	615
swamp	5	3.58	5.76	4	5	3	613
worm	4	1.75	6.76	7	4	9	563
vase	4	3.46	6.52	4	4	11	632
squash	6	2.63	5.64	7	2	1	644
soot	4	3.00	5.50	2	1	19	659
swan	4	2.29	6.84	5	3	9	642
glove	5	2.00	7.00	5	9	7	542
touch	5	2.38	3.96	65	87	6	543
break	5	2.58	4.60	46	88	8	562
wear	4	1.90	2.35	23	26	18	550
lose	4	2.50	2.44	20	58	16	555
height	6	2.75	4.32	34	35	1	577
wash	4	1.63	5.36	14	37	14	504
shoe	4	1.33	6.92	14	14	7	608
wool	4	2.67	5.68	21	10	9	548
whose	5	2.83	1.36	223	252	5	580
M	4.56	2.55	4.91	28.0	36.1	8.8	582
SD	0.71	0.65	1.73	51.5	60.7	5.2	44
			Late AoA, exception words				
pint	4	3.60	6.70	10	13	19	568
swarm	5	4.83	5.12	2	3	5	619
squad	5	5.13	4.52	9	18	4	646
wart	4	4.25	5.75	1	11	23	600
ghoul	5	4.21	6.04	1	1	0	659
sweat	5	3.83	5.52	26	26	5	609
suite	5	5.05	4.15	11	27	5	645
foul	4	3.70	3.25	9	4	9	593
breast	6	4.54	6.52	43	11	0	587
threat	6	4.00	3.24	61	42	3	572
bomb	4	3.92	6.56	29	36	3	559
wreath	6	5.42	5.68	2	8	1	632
lure	4	5.46	2.96	5	7	20	556
hearth	6	4.79	5.36	4	4	3	680
wan	3	6.08	1.80	2	2	27	637
swear	5	3.92	3.96	4	10	5	604
youth	5	5.17	4.75	65	82	3	551
whom	4	5.08	1.36	180	146	4	601
M	4.8	4.61	4.62	25.78	25.1	7.72	607
SD	0.9	0.72	1.6	43.52	36.14	8.39	38

Note: Le = word length in letters, AoA = age of acquisition, Image = imageability, Celex = Celex word frequency, K-F = Kucera and Francis word frequency, N = number of orthographic neighbours, RT = word naming reaction time.

Appendix 9 Items used in Experiment 6c

Nonword	Syllable Length
bape	1
burge	1
dength	1
dest	1
dilt	1
dounce	1
kice	1
pake	1
tealth	1
toat	1
barden	2
bingle	2
buddle	2
cranite	2
datient	2
dutter	2
grother	2
potel	2
tolice	2
tourage	2
becimal	3
bialect	3
diberate	3
dortify	3
kulletin	3
padiate	3
pattery	3
pelicate	3
predible	3
tapital	3

Appendix 10 Items used in the word - picture matching task in the aphasia picture naming study, Chapter Six.

Target	Distracters		
eagle	pigeon	owl	heron
plane	helicopter	blimp	hot air balloon
cigar	cigarette	pipe	match
donkey	horse	cow	pig
car	Bus	lorry	motorbike
apple	lemon	banana	pear
panther	tiger	lion	zebra
fly	bee	ladybird	butterfly
grapes	cherries	strawberry	pineapple
triangle	square	circle	diamond
eye	nose	tongue	ear
arm	leg	foot	finger
harp	piano	guitar	drum
bath	shower	sink	tap
devil	nun	angel	witch
shorts	trousers	skirt	jumper
saw	screwdriver	hammer	pliers
bridge	tunnel	road	crossing
chair	stool	table	bed
chicken	duck	goose	turkey
flower	leaf	plant	tree
arrow	bow	axe	sword
king	queen	crown	castle
thread	needle	thimble	wool
kettle	teapot	pan	cup

Appendix 11 Picture names of the five subsets used in the picture naming task, Experiment 7

Word	Le	Anim'y	AoA	Image	Celex	K-F Freq	Fam'y	VC
			Early AoA					
balloon	2	2	22.1	6.55	3	10	2.86	1.25
basket	2	2	38.5	6.20	18	17	2.27	3.85
boot	1	2	23.4	6.05	8	13	4.23	2.05
butterfly	3	1	23.4	6.25	5	2	2.73	4.05
button	2	2	38.5	6.40	15	10	4.09	2.02
cake	1	2	23.4	6.40	21	13	3.32	2.80
clock	1	2	22.1	6.25	36	20	4.18	2.60
frog	1	1	23.4	6.35	4	1	2.38	3.60
hammer	2	2	25.1	6.10	9	9	2.82	2.55
hat	1	2	23.4	6.60	53	56	2.59	2.15
jigsaw	2	2	38.5	6.25	2	0	3.00	2.35
ladybird	3	1	38.5	6.50	0	0	3.00	2.35
lion	2	1	23.4	6.55	8	17	1.91	3.25
monkey	2	1	25.1	6.45	9	9	2.09	3.20
pencil	2	2	38.5	6.35	15	34	4.00	2.05
pig	1	1	23.4	6.75	18	8	2.36	2.70
pram	1	2	38.5	5.80	5	2	2.40	3.55
rabbit	2	1	22.1	6.60	11	11	2.81	2.65
sandwich	2	2	38.5	6.45	10	10	4.36	3.15
snake	1	1	25.1	6.70	14	44	2.05	3.55
sock	1	2	23.4	6.20	3	4	4.73	1.80
towel	1	2	38.5	5.85	15	6	4.70	3.50
tractor	2	2	23.4	6.15	7	24	2.80	3.60
umbrella	3	2	23.4	6.60	11	8	3.41	2.95
wheel	1	2	25.1	6.45	28	56	2.68	3.35
M	1.68	1.68	28.3	6.35	13.12	15.4	3.11	2.84
SD	0.69	0.48	7.1	0.24	11.75	16.00	0.86	0.72

Appendix 11 (Continued)

Word	Le	Anim'y	AoA	Image	Celex	K-F Freq	Fam'y	VC
				Late AoA				
beetle	2	1	86.5	5.90	5	0	2.95	3.05
belt	1	2	50.5	5.80	20	29	3.81	1.70
camel	2	1	68.5	6.40	8	1	1.73	3.00
camera	2	2	50.5	6.00	24	36	3.95	2.70
caravan	3	2	56.5	6.40	7	8	2.85	3.20
cigarette	3	2	86.5	6.25	49	25	3.86	2.10
crab	1	1	50.5	6.40	4	2	2.55	3.75
desk	1	2	86.5	6.15	82	65	4.60	3.30
envelope	3	2	68.5	5.80	19	21	4.30	1.40
guitar	2	2	62.5	6.35	6	19	3.00	3.10
lamp	1	2	74.5	6.00	21	24	3.73	1.90
lobster	2	1	86.5	5.95	2	1	1.77	4.25
mountain	2	2	62.5	6.65	46	33	2.41	2.30
needle	2	2	86.5	6.05	9	15	2.77	1.55
peacock	2	1	92.5	6.25	3	2	1.91	4.25
plug	1	2	68.5	5.70	6	23	3.59	2.50
scales	1	2	86.5	5.60	9	0	3.20	3.10
screw	1	2	80.5	5.80	7	21	2.77	2.90
skunk	1	1	140.0	5.55	0	1	1.55	4.72
swan	1	1	62.5	6.55	5	3	2.23	2.65
syringe	2	2	140.0	6.25	2	1	2.50	3.00
tights	1	2	74.5	5.75	4	0	3.70	3.50
torch	1	2	56.5	5.90	9	4	3.45	2.65
vase	1	2	62.5	6.55	4	4	2.50	3.40
whale	1	1	56.5	6.35	6	0	3.15	2.85
M	1.60	1.68	75.9	6.09	14.3	13.5	2.99	2.91
SD	0.71	0.48	23.4	0.32	18.9	16.1	0.83	0.83

Appendix 11 (Continued)

Word	Le	Anim'y	AoA	Image	Celex	K-F Freq	Fam'y	VC
			High Frequency					
bell	1	2	44.5	6.30	27	37	2.27	2.55
bottle	2	2	38.5	6.35	82	76	4.41	1.40
boy	1	1	56.5	6.25	207	242	4.50	3.85
bus	1	2	23.4	6.55	64	34	3.95	4.15
camera	2	2	50.5	6.00	24	36	3.95	2.70
cat	1	1	23.4	6.40	41	23	4.00	2.60
chain	1	2	56.5	5.85	33	50	2.57	2.50
church	1	2	44.5	6.50	159	348	3.09	3.75
cigarette	3	2	86.5	6.25	49	25	3.86	2.10
clock	1	2	22.1	6.25	36	20	4.18	2.60
coat	1	2	68.5	5.75	50	43	3.77	2.45
desk	1	2	86.5	6.15	82	65	4.60	3.30
dog	1	1	22.1	6.65	69	75	4.05	2.70
dress	1	2	38.5	6.10	74	67	3.14	3.45
fish	1	1	22.1	6.75	80	35	3.09	2.95
glass	1	2	44.5	6.00	125	99	4.45	1.95
glasses	2	2	23.4	6.25	32	29	3.82	2.60
hat	1	2	23.4	6.60	53	56	2.59	2.15
horse	1	1	23.4	6.70	85	117	2.82	3.45
house	1	2	22.1	6.65	479	591	3.77	2.40
shirt	1	2	56.5	6.30	45	27	4.09	2.95
train	1	2	25.1	6.25	68	82	3.64	3.45
van	1	2	50.5	6.05	54	33	3.65	3.60
wheel	1	2	25.1	6.45	28	56	2.68	3.35
window	2	2	25.1	6.15	132	119	4.64	3.40
M	1.24	1.8	40.1	6.30	87.1	95.4	3.66	2.89
SD	0.52	0.41	20.0	0.26	92.8	127.0	0.69	0.67

Word	Le	Anim'y	AoA	Image	Celex	K-F Freq	Fam'y	VC
			Low Frequency					
balloon	2	2	22.1	6.55	3	10	2.86	1.25
bee	1	1	56.5	6.30	7	11	2.82	4.75
boot	1	2	23.4	6.05	8	13	4.23	2.05
brush	1	2	23.4	6.20	12	4	3.68	2.60
button	2	2	38.5	6.40	15	10	4.09	2.02
candle	2	2	38.5	6.10	8	18	3.32	2.25
comb	1	2	38.5	6.15	4	6	3.68	2.00
dice	1	2	56.5	6.65	2	14	3.00	2.65
glove	1	2	44.5	5.95	5	9	2.91	2.70
jug	1	2	56.5	6.30	8	6	3.23	1.85
microwave	3	2	68.5	5.85	2	2	4.55	3.60
motorbike	3	2	38.5	6.20	0	0	3.32	4.15
mouse	1	1	23.4	6.65	8	10	2.59	3.00
peg	1	2	44.5	5.60	4	5	3.35	2.40
purse	1	2	44.5	5.60	9	14	4.05	2.40
rabbit	2	1	22.1	6.60	11	11	2.81	2.65
scales	1	2	86.5	5.60	9	0	3.20	3.10
scissors	2	2	23.4	6.20	4	1	3.91	2.20
spider	2	1	25.1	6.45	4	2	3.09	3.15
stool	1	2	50.5	5.90	9	8	3.50	2.35
tights	1	2	74.5	5.75	4	0	3.70	3.50
toaster	2	2	50.5	6.00	1	0	3.86	3.50
torch	1	2	56.5	5.90	9	4	3.45	2.65
umbrella	3	2	23.4	6.60	11	8	3.41	2.95
whale	1	1	56.5	6.35	6	0	3.15	2.85
M	1.52	1.8	43.5	6.16	6.52	6.64	3.43	2.74
SD	0.71	0.41	18.0	0.33	3.74	5.29	0.50	0.76

Word	Le	Anim'y	AoA	Image	Celex	K-F Freq	Fam'y	VC
			Short (One syllable)					
ant	1	1	62.5	5.90	4	6	2.75	3.70
axe	1	2	62.5	6.20	0	12	2.14	1.85
belt	1	2	50.5	5.80	20	29	3.81	1.70
cake	1	2	23.4	6.40	21	13	3.32	2.80
cap	1	2	68.5	5.90	27	27	2.91	2.18
cup	1	2	25.1	6.50	59	45	4.59	2.05
desk	1	2	86.5	6.15	82	65	4.60	3.30
flute	1	2	92.5	6.10	2	1	1.91	4.15
fork	1	2	23.4	6.35	12	14	4.55	2.20
frog	1	1	23.4	6.35	4	1	2.38	3.60
goat	1	1	56.5	6.30	12	6	2.00	2.80
gun	1	2	44.5	6.50	63	118	2.00	2.75
owl	1	1	38.5	6.10	3	2	2.18	3.70
pig	1	1	23.4	6.75	18	8	2.36	2.70
pram	1	2	38.5	5.80	5	2	2.40	3.55
screw	1	2	80.5	5.80	7	21	2.77	2.90
sheep	1	1	44.5	6.40	20	23	2.86	3.30
duck	1	1	22.1	6.55	4	9	2.59	3.05
snail	1	1	44.5	6.25	3	1	2.45	2.70
swan	1	1	62.5	6.55	5	3	2.23	2.65
sword	1	2	50.5	6.35	13	7	2.55	1.75
tights	1	2	74.5	5.75	4	0	3.70	3.50
van	1	2	50.5	6.05	54	33	3.65	3.60
whale	1	1	56.5	6.35	6	0	3.15	2.85
wheel	1	2	25.1	6.45	28	56	2.68	3.35
M	1.00	1.60	49.2	6.22	19.0	20.1	2.90	2.91
SD	0.00	0.50	21.2	0.28	22.2	27.1	0.82	0.68

Word	Le	Anim'y	AoA	Image	Celex	K-F Freq	Fam'y	VC
			Long (>One syllable)					
barrel	2	2	74.5	6.10	14	24	2.14	3.05
bottle	2	2	38.5	6.35	82	76	4.41	1.40
castle	2	2	38.5	6.50	24	7	3.45	3.45
jacket	2	2	56.5	5.95	34	33	4.12	3.85
ladder	2	2	25.1	6.70	13	19	2.64	2.55
lion	2	1	23.4	6.55	8	17	1.91	3.25
monkey	2	1	25.1	6.45	9	9	2.09	3.20
mountain	2	2	62.5	6.65	46	33	2.41	2.30
pencil	2	2	38.5	6.35	15	34	4.00	2.05
rabbit	2	1	22.1	6.60	11	11	2.81	2.65
tiger	2	1	44.5	6.60	4	7	1.77	4.35
trousers	2	2	25.1	6.20	28	7	4.90	2.30
window	2	2	25.1	6.15	132	119	4.64	3.40
butterfly	3	1	23.4	6.25	5	2	2.73	4.05
caravan	3	2	56.5	6.40	7	8	2.85	3.20
elephant	3	1	23.4	6.70	12	7	2.20	4.12
envelope	3	2	68.5	5.80	19	21	4.30	1.40
gorilla	3	1	62.5	6.10	2	0	1.64	3.20
kangaroo	3	1	44.5	6.45	1	0	1.41	3.70
ladybird	3	1	38.5	6.50	0	0	3.00	2.35
microphone	3	2	102.5	6.10	6	4	2.85	1.55
typewriter	3	2	86.5	5.85	9	10	3.65	3.30
violin	3	2	62.5	6.40	4	11	2.14	3.75
caterpillar	4	1	44.5	6.40	2	1	1.95	3.00
helicopter	4	2	23.4	6.35	11	1	2.00	4.20
M	2.6	1.6	45.4	6.34	19.9	18.4	2.88	3.03
SD	0.7	0.5	22.1	0.25	29.3	26.7	1.03	0.86

Word	Le	Anim'y	AoA	Image	Celex	K-F Freq	Fam'y	VC
				Living				
gorilla	3	1	62.5	6.10	2	0	1.64	3.20
seahorse	2	1	86.5	5.45	0	0	1.70	3.75
camel	2	1	68.5	6.40	8	1	1.73	3.00
raccoon	2	1	140	5.40	0	1	1.75	4.40
goat	1	1	56.5	6.30	12	6	2.00	2.80
tortoise	2	1	38.5	6.10	4	4	2.10	3.10
owl	1	1	38.5	6.10	3	2	2.18	3.70
swan	1	1	62.5	6.55	5	3	2.23	2.65
frog	1	1	23.4	6.35	4	1	2.38	3.60
snail	1	1	44.5	6.25	3	1	2.45	2.70
fox	1	1	38.5	6.55	10	13	2.50	4.02
squirrel	2	1	25.1	6.30	4	1	2.55	2.75
crab	1	1	50.5	6.40	4	2	2.55	3.75
ant	1	1	62.5	5.90	4	6	2.75	3.70
rabbit	2	1	22.1	6.60	11	11	2.81	2.65
horse	1	1	23.4	6.70	85	117	2.82	3.45
bee	1	1	56.5	6.30	7	11	2.82	4.75
beetle	2	1	86.5	5.90	5	0	2.95	3.05
ladybird	3	1	38.5	6.50	0	0	3.00	2.35
fish	1	1	22.1	6.75	80	35	3.09	2.95
spider	2	1	25.1	6.45	4	2	3.09	3.15
whale	1	1	56.5	6.35	6	0	3.15	2.85
cow	1	1	23.4	6.55	22	29	3.18	3.85
cat	1	1	23.4	6.40	41	23	4.00	2.60
boy	1	1	56.5	6.25	207	242	4.50	3.85
M	1.5	1.0	49.3	6.28	21.2	20.4	2.64	3.31
SD	0.7	0.0	27.3	0.34	44.7	52.0	0.69	0.61

Word	Le	Anim'y	AoA	Image	Celex	K-F Freq	Fam'y	VC
			Non-Living					
windmill	2	2	50.5	6.50	7	1	1.59	4.60
crown	1	2	56.5	6.40	23	19	1.68	3.75
gun	1	2	44.5	6.50	63	118	2.00	2.75
helicopter	4	2	23.4	6.35	11	1	2.00	4.20
trumpet	2	2	56.5	6.40	5	7	2.05	3.15
kite	1	2	38.5	6.65	3	1	2.14	2.70
barrel	2	2	74.5	6.10	14	24	2.14	3.05
violin	3	2	62.5	6.40	4	11	2.14	3.75
basket	2	2	38.5	6.20	18	17	2.27	3.85
pram	1	2	38.5	5.80	5	2	2.40	3.55
drum	1	2	50.5	6.45	7	11	2.41	2.65
vase	1	2	62.5	6.55	4	4	2.50	3.40
chain	1	2	56.5	5.85	33	50	2.57	2.50
wheelbarrow	3	2	44.5	5.85	1	0	2.80	2.40
cap	1	2	68.5	5.90	27	27	2.91	2.18
tie	1	2	56.5	6.10	19	23	2.91	2.65
glove	1	2	44.5	5.95	5	9	2.91	2.70
piano	2	2	44.5	6.35	0	38	2.91	4.60
guitar	2	2	62.5	6.35	6	19	3.00	3.10
dress	1	2	38.5	6.10	74	67	3.14	3.45
tent	1	2	44.5	6.35	37	20	3.15	2.95
castle	2	2	38.5	6.50	24	7	3.45	3.45
camera	2	2	50.5	6.50	24	36	3.45	3.45
van	1	2	50.5	6.05	54	33	3.65	3.60
bus	1	2	23.4	6.55	64	34	3.95	4.15
M	1.6	2.0	48.8	6.27	21.3	23.2	2.64	3.30
SD	0.8	0.0	12.5	0.26	21.7	26.0	0.62	0.67

Word	Le	Anim'y	AoA	Image	Celex	K-F Freq	Fam'y	VC
			High Familiarity					
toaster	2	2	50.5	6.00	1	0	3.86	3.50
microwave	3	2	68.5	5.85	2	2	4.55	3.60
sock	1	2	23.4	6.20	3	4	4.73	1.80
comb	1	2	38.5	6.15	4	6	3.68	2.00
scissors	2	2	23.4	6.20	4	1	3.91	2.20
biscuit	2	2	68.5	6.10	5	2	4.05	3.80
boot	1	2	23.4	6.05	8	13	4.23	2.05
button	2	2	38.5	6.40	15	10	4.09	2.02
sandwich	2	2	38.5	6.45	10	10	4.36	3.15
spoon	1	2	22.1	6.30	11	6	4.64	1.90
brush	1	2	23.4	6.20	12	4	3.68	2.60
fork	1	2	23.4	6.35	12	14	4.55	2.20
shoe	1	2	22.1	6.40	14	14	4.68	3.20
pencil	2	2	38.5	6.35	15	34	4.00	2.05
towel	1	2	38.5	5.85	15	6	4.70	3.50
envelope	3	2	68.5	5.80	19	21	4.30	1.40
belt	1	2	50.5	5.80	20	29	3.81	1.70
lamp	1	2	74.5	6.00	21	24	3.73	1.90
camera	2	2	50.5	6.00	24	36	3.95	2.70
trousers	2	2	25.1	6.20	28	7	4.90	2.30
cigarette	3	2	86.5	6.25	49	25	3.86	2.10
shirt	1	2	56.5	6.30	45	27	4.09	2.95
coat	1	2	68.5	5.75	50	43	3.77	2.45
van	1	2	50.5	6.05	54	33	3.65	3.60
desk	1	2	86.5	6.15	82	65	4.60	3.30
M	1.6	2.0	46.4	6.10	20.9	17.4	4.20	2.60
SD	0.7	0.0	21.1	0.20	20.1	16.0	0.40	0.70

Word	Le	Anim'y	AoA	Image	Celex	K-F Freq	Fam'y	VC
			Low Familiarity					
pram	1	2	38.5	5.80	5	2	2.40	3.55
balloon	2	2	22.1	6.55	3	10	2.86	1.25
guitar	2	2	62.5	6.35	6	19	3.00	3.10
tractor	2	2	23.4	6.15	7	24	2.80	3.60
windmill	2	2	50.5	6.50	7	1	1.59	4.60
wheelbarrow	3	2	44.5	5.85	1	0	2.80	2.40
drum	1	2	50.5	6.45	7	11	2.41	2.65
caravan	3	2	56.5	6.40	7	8	2.85	3.20
screw	1	2	80.5	5.80	7	21	2.77	2.90
rocket	2	2	56.5	6.55	8	22	2.95	2.85
hammer	2	2	25.1	6.10	9	9	2.82	2.55
needle	2	2	86.5	6.05	9	15	2.77	1.55
helicopter	4	2	23.4	6.35	11	1	2.00	4.20
sword	1	2	50.5	6.35	13	7	2.55	1.75
barrel	2	2	74.5	6.10	14	24	2.14	3.05
basket	2	2	38.5	6.20	18	17	2.27	3.85
crown	1	2	56.5	6.40	23	19	1.68	3.75
bell	1	2	44.5	6.60	27	18	2.50	2.55
cap	1	2	68.5	5.90	27	27	2.91	2.18
wheel	1	2	25.1	6.45	28	56	2.68	3.35
swing	1	2	50.5	6.30	30	24	2.27	2.72
chain	1	2	56.5	5.85	33	50	2.57	2.50
mountain	2	2	62.5	6.65	46	33	2.41	2.30
hat	1	2	23.4	6.60	53	56	2.59	2.15
gun	1	2	44.5	6.50	63	118	2.00	2.75
M	1.7	2.0	48.6	6.30	18.5	23.7	2.50	2.90
SD	0.8	0.0	18.4	0.30	16.4	25.1	0.40	0.80

Note: Le = word length, Anim'y = animacy, AoA = age of acquisition, Image = imageability. Celex = Celex combined frequency, K-F Freq = Kucera and Francis (1967) word frequency, Fam'y = object familiarity, VC = visual complexity.

Appendix 12 The results of the 7 variable logistic regression in Chapter Six

Patient Case	Naming	Model Chi Sq		Naming Results of 7 Variable Logistic Regression AoA	Freq'y	Length	Anim'y	Fam'y	Imag'y	VC
1	40		Corr:	-.34**	.37**	-.18*	-.01	.30**	.25**	-.12+
		38.3**	Wald:	2.17	3.31+	0.45		5.28*	2.51	0.18
2	81		Corr:	-.37**	.31**	-.18*	.34**	.28**	.13+	-.14+
		37.9**	Wald:	7.71**	1.22	0.82	9.58**	0.00	0.01	0.88
3	43		Corr:	-.26**	.30**	-.24**	.10	.10	.14+	-.21**
		27.6**	Wald:	4.94*	5.17*	2.59			0.13	3.42+
4	60		Corr:	-.34**	.29**	-.30**	.17*	.18*	.17*	-.24**
		35.8**	Wald:	7.20**	0.98	6.20*	2.96+	0.59	.10	2.09
5	74		Corr:	-.38**	.08	-.11	.00	-.02	.27**	-.11+
		24.6**	Wald:	9.45**					0.39	1.21
6	74		Corr:	-.12+	-.04	-.03	.04	.02	.07	-.09
		4.4 n.s	Wald:	-	-	-	-	-	-	-
7	49		Corr:	-.09	.18*	-.32**	.02	.03	.08	-.10
		17.0*	Wald:		0.82	9.24**				
8	71		Corr:	-.28**	.17*	-.05	.10	.17*	.15*	-.21**
		15.2*	Wald:	3.46+	0.10			0.23	0.20	2.23
9	52		Corr:	-.16*	.14*	-.09	.16*	.14*	.09	-.06
		8.8 n.s	Wald:	-	-	-	-	-	-	-
10	67		Corr:	-.36**	.27**	-.16*	.11	.31**	.16*	-.17*
		28.0**	Wald:	5.07*	0.30	0.55		3.80+	0.33	0.16
11	79		Corr:	-.26**	.27**	-.10	.13+	.17*	.08	-.07
		16.0*	Wald:	4.33*	4.10*		0.82	0.09		
12	38		Corr:	-.32**	.20**	-.16*	-.03	.13+	.30**	-.02
		24.6**	Wald:	3.14+	0.03	1.84		1.19	4.02*	
13	34		Corr:	-.21**	.20*	-.05	.04	.10	.23**	-.16*
		14.9*	Wald:	0.70	1.12				2.77+	2.04

**p<0.01, *p<0.05, +0.10<p>005. Note: AoA = age of acquisition, Freq'y = log frequency, Anim'y = animacy, Fam'y = object familiarity, Imag'y = imageability, VC = visual complexity, Corr = correlation of the predictor variables and each patient's naming accuracy, Wald = the value of the Wald statistic in the logistic regression analysis for those variables that correlated significantly with that patient's naming accuracy.

Appendix 13 The results of the 5 variable logistic regression in Chapter Six

Patient Case	Naming	Naming Results of 5 Variable Logistic Regression: Model Chi Sq		AoA	Freq'y	Length	Anim'y	Fam'y
1	40	35.5**	Corr:	-.34**	.37**	-.18*	-.01	.30**
			Wald:	6.74**	5.52*	0.25		4.04*
2	81	37.0**	Corr:	-.37**	.31**	-.18*	.34**	.28**
			Wald:	9.99**	1.12	0.97	9.26**	0.00
3	43	23.9**	Corr:	-.26**	.30**	-.24**	.10	.10
			Wald:	5.87*	4.58*	3.41+		
4	60	33.6**	Corr:	-.34**	.29**	-.30**	.17*	.18*
			Wald:	10.6**	1.30	6.73**	4.39*	0.47
5	74	23.0**	Corr:	-.38**	.08	-.11	.00	-.02
			Wald:	16.3**				
6	74	3.5 n.s	Corr:	-.12+	-.04	-.03	.04	.02
			Wald:	-	-	-	-	-
7	49	16.1**	Corr:	-.09	.18*	-.32**	.02	.03
			Wald:		1.05	9.48**		
8	71	12.7*	Corr:	-.28**	.17*	-.05	.10	.17*
			Wald:	6.32*	0.28			0.36
9	52	8.2 n.s	Corr:	-.16*	.14*	-.09	.16*	.14*
			Wald:	-	-	-	-	-
10	67	27.5**	Corr:	-.36**	.27**	-.16*	.11	.31**
			Wald:	8.35**	0.57	0.49		3.96*
11	79	14.8*	Corr:	-.26**	.27**	-.10	.13+	.17*
			Wald:	3.59+	3.26+		0.64	0.00
12	38	20.1**	Corr:	-.32**	.20**	-.16*	-.03	.13+
			Wald:	9.32**	0.72	1.21		0.04
13	34	9.6+	Corr:	-.21**	.20*	-.05	.04	.10
			Wald:	3.73+	2.38			

**p<0.01, *p<0.05, +0.10<p>005. Note: AoA = age of acquisition, Freq'y = log frequency, Anim'y = animacy, Fam'y = object familiarity, Corr = correlation of the predictor variables and each patient's naming accuracy, Wald = the value of the Wald statistic in the logistic regression analysis for those variables that correlated significantly with that patient's naming accuracy.

Appendix 14 Information and overall picture naming performance of the control participants in the aphasia picture naming study

Control Information Control	Age	Sex	Naming Score %
1	74	F	90
2	80	F	87
3	60	F	96
4	88	M	87
5	79	M	92
6	72	F	83
7	73	F	84
8	63	F	88
9	72	F	90
10	75	M	85
11	44	M	98
12	53	M	95
13	48	M	92