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Deep dyslexia in bilingual aphasic patients

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Abstract

The present thesis concerns the acquired reading disorder of deep dyslexia. Semantic errors (semantic paralexias) in reading aloud (e.g. reading '*ring*' as '*wedding*' or '*ruler*' as '*rubber*') constitute the cardinal symptom of deep dyslexia. Semantic errors of oral reading by aphasic patients have been said to be comparatively rare in languages with a shallow (transparent) orthography (e.g. Spanish and Italian). Miceli et al. (1994) argued in relation to reading aloud and writing that '*transparent orthographies are relatively protected from the production of semantic paralexias and paragraphias*'(p.331). Thus the first part of the thesis reports a series of investigations of this claim in three bilingual readers of two orthographies, one deep, one shallow, namely English and Welsh.

On a picture naming task, each of the three brain damaged patients made a similar proportion of semantic errors in the two languages as expected. However, contrary to the predictions of Miceli et al. (1994), in oral reading of the corresponding words no patient produced proportionally more semantic errors in English than in Welsh. Indeed, two of the patients made proportionally more semantic errors in Welsh. Therefore the findings of this thesis do not support the view that semantic errors are rare in a shallow orthography. It was concluded from the data that the patients could be considered deep dyslexic in both Welsh and English.

Regression analyses revealed that age of acquisition influenced the production of semantic errors in Welsh reading for all three bilingual deep dyslexic patients and in English reading for two of the patients. This supports others findings (e.g. Gerhand & Barry 2000) that age of acquisition is the most salient factor that predicts a participant's response. The data were also in agreement with the viewpoint expressed by Morrison and Ellis (1995), among others, that a major component of what has been reported in the literature as frequency effects in lexical processing is in fact due to a confound with age of acquisition, as frequency was not found to exert an independent effect on the patients' responses. The semantic errors generated by the patients were earlier acquired, more frequent and were shorter in length than the target words to which the errors were made, supporting Gerhand and Barry's (2000) finding.

Studies of bilingual aphasia considering the cognate status of words are extremely rare. It was examined whether cognate status influenced the accuracy of the patients' naming and reading responses. However, when the cognate items were removed from the analysis, it had little effect on the findings from the multinomial regression. No cognate facilitation effect was found in either language.

The majority of theories of deep dyslexia attribute the occurrence of semantic errors to a lack of sub-lexical phonological ability. However, Katz and Lanzoni (1992) and Buchanan et al. (1994) claim that at least some deep dyslexics patients are sensitive to implicit phonological information. The second part of this thesis examined phonological decoding ability in deep dyslexia using pseudohomophones as stimuli.

Implicit phonological ability was found in terms of the Stroop effect (increased reaction times to incongruent stimuli compared to congruent stimuli) using pseudohomophones but no effect was found with orthographically controlled non-words. Patients were also significantly better at reading pseudohomophones than orthographic controls and showed the standard 'pseudohomophone effect' (extended reaction times) in lexical decision. However, no evidence of semantic priming using pseudohomophones was found in the three deep dyslexics, even though the control participants did show an effect with the same priming stimuli as was used with the patients.

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Prologue

"The brain is the organ of the mind; it is also an organ of the body and, as such, is susceptible to injury and illness"... (Ellis, 1993 p.39)

Fundamental insights can be gained into the way the human mind functions by studying brain injured patients. The most common cause of brain damage is a cerebrovascular accident (CVA), more commonly known as a stroke. The term stroke refers to a disruption of the blood supply produced by a haemorrhage or by an embolism restricting blood supply to parts of the brain. On average, strokes affect one person every five minutes in the United Kingdom, and are the biggest cause of disability world wide (Stroke Association, 2006). Insights gained from studying the effects of stroke or other brain injuries should feed back to provide a better understanding of the problems brain damaged individuals experience and should lead in turn to the development of better therapies.

At a theoretical level, studying the effects of brain damage can inform us as to the normal workings of the mind and of how the brain is organised to carry out cognitive and other functions. Reading is a meaningful interpretation of written or printed verbal symbols (Harris & Sipey, 1983). It is a skill that is highly valued and requires complex adaptation to be mastered. It involves a number of cognitive abilities which include visual skills, auditory factors and general speech co-ordination (Spache, 1981). Failure to learn to read, or acquired reading difficulties, may entail distressing consequences as literacy holds the key to education and communication. The ability to communicate with others by means of the printed word is vital in the modern world. When part of the language system is damaged after brain injury, affecting the ability to speak, read or write, it may have profound social and psychological effects on the individuals concerned.

Disorders which affect the comprehension of spoken language as a consequence of brain injury are known as *aphasias*. There are many different types of aphasias depending on which aspect of language processing has been impaired (Ellis & Young, 1988; McCarthy & Warrington, 1990). Aphasic patients often experience reading difficulties as part of a more general language impairment. However, in some instances, reading problems are the most salient symptom; in this case the individual is said to be suffering from an acquired dyslexia. This is the topic of this thesis.

Chapter 1

1.0 Acquired reading disorders: a review of the literature

Arguably, the most important brain regions related to acquired dyslexias are Broca's and Wernicke's areas located in the left hemisphere. Broca's area is adjacent to the section of the motor cortex that controls the movement of the muscles of the lips, jaw, tongue, soft palate and the vocal cords and incorporates programs for the coordination of these muscles in speech. Damage to Broca's area results in slow and laboured speech, but comprehension of language remains relatively intact. Wernicke's area lies between Heschl's gyrus, the primary auditory receiving area and the angular gyrus, which acts as a relay station between the auditory and the visual regions. When Wernicke's area is damaged, speech is fluent but has little content and comprehension is usually lost. Wernicke's and Broca's areas are joined by a nerve bundle called the arcuate fasciculus; when it is damaged speech is fluent but abnormal, and the patient can comprehend words but cannot repeat them.

The loss of the ability to read or to understand what one has read following a brain injury was commented upon by several researchers in the nineteenth century (e.g. Dejerine 1891, 1892). Berlin (1887), a German ophthalmologist was one of the first to describe the term 'dyslexia' when referring to reading difficulties caused by cerebral disease or injury. Kussmaul (1877) had earlier proposed the term 'word-blindness' to describe the reading difficulties of previously literate brain damaged patients. He suggested that a complete text-blindness may exist, although the power of sight, speech and the intellect are intact in such individuals. However, Sir Henry Broadbent (1872; 1896) president of the Neurological Society argued over whether it was actually he or Kussmaul who first coined the term of 'word-blindness'. Hinshelwood (1895), a Glasgow eye surgeon, also believed in word and 'letter-blindness' and published a series of papers (1895, 1896, 1898, 1899) describing individual acquired dyslexia case studies of word blindness in the absence of conspicuous speech difficulties.

Acquired disorders of reading are usually divided into two broad classes, peripheral and central dyslexias. Shallice and Warrington (1980) provided a useful distinction between the two types. Peripheral dyslexias affect early stages in the visual analysis of letters and words, resulting in a range of conditions in which the perception of letters in words is impaired. Peripheral dyslexias include pure alexia and neglect dyslexia. Pure alexia is argued to provide most information regarding the reading system as neglect dyslexia reflects deficits to attentional mechanisms. Pure alexia, or reading without agraphia, refers to the inability to read in the context of preserved writing and spelling, including material that the patient has written. The disorder arises from damage to posterior regions of the brain that disconnects the major pathways linking the visual areas involved in recognising written words with the more anterior language areas involved in comprehending and pronouncing words. Central dyslexias affect deeper processes such as grapheme-phoneme conversions or semantic access. The three central forms of acquired dyslexia are deep, phonological and surface dyslexia. These arise from impairment to language processes brought about by damage to the fronto-parietal-temporal areas of the hemisphere that is dominant for language, which is in most cases the left cerebral hemisphere.

Modern research on acquired dyslexias stems from the work of Lichtheim (1885) and Wernicke (1874) who produced simple diagramatic models of spoken word processing to represent their theories of how the brain processed language, although recent research on acquired dyslexia stems from the mid 1970s. It could be argued (Shallice, 1988) that this was due to the 1971 International Neuropsychological Society meeting in Engelberg, Switzerland, where Marshall and Newcombe reintroduced the cognitive neuropsychological study of reading by referring to three distinct forms of acquired dyslexia (see Marshall & Newcombe, 1973).

Traditionally, acquired dyslexia was defined in terms of its association with other disorders, such as dysgraphia (the inability to write) or dysphasia (the inability to speak); the primary aim was to correlate the impairment with the locus of brain damage. Over the past twenty years or so, cognitive neuropsychological analyses of the acquired dyslexias have led to the development of so-called 'box and arrow' models of a functional architecture that represents the state of affairs in adults who at one time were able to read (Beaton, 2004). It could be argued that the model building approach reflects the work of Hinshelwood (1900), who recognised that there were different types of reading disorders. He suggested that there were three types of reading disorders, namely letter blindness (referring to the inability to name letters) word blindness and sentence blindness. According to Kolb and Whishaw (1999) the Hinshelwood taxonomy has led to the hypothesis that reading is composed of a number of independent abilities each of which may have an independent anatomical basis. These cognitive neuropsychological models of word recognition attempt to characterise some of the mental processes that allow a reader to identify, comprehend and pronounce written words. They incorporate a number of different processes ranging from letter identification and visual word recognition to semantic comprehension and phonological appreciation of the sound of letter strings. Ellis (1993) claimed that the approach cognitive neuropsychologists take when investigating acquired dyslexias is not to ask which part of the brain is damaged in different forms of reading disorders, but to ask which part or parts of the 'normal' reading process have been impaired or lost. They therefore seek to explain different patterns of reading breakdown by reference to models of the 'normal' skilled reading process. In line with this approach, Coltheart (1982) argued that the most objective approach to the study of reading is 'model building', which differs from classic neurological approaches.

One of the most well-known cognitive neuropsychological approaches to reading is the dual route model (Coltheart, 1980). Coltheart used the term 'lexicon' to refer to a system of local mental representations. The elements in lexicon systems represent stimulus forms such as phonological, orthographic and pictorial. A phonological lexicon contains the phonology (sounds) of all the words a person knows, with one entry per word. An orthographic lexicon contains the orthographic forms of all the words with which a person is familiar. The pictorial (visual-object) lexicon contains the visual forms or structural descriptions of all the objects whose visual appearance a person knows. Models of word processing that explicitly posit the existence of phonological and orthographic lexicons include the dual route model (Coltheart, 1982; 1985); the dual route cascade model (Coltheart, Rastle, Perry, Langdon & Ziegler, 2001) and other models proposed by, for example, Ellis and Young (1986); Patterson and Shewell (1987); Southwood (2002); Rapp, Epstein & Tainturier, (2002) and Hillis (2001) among others. Models of visual object and picture naming proposing the existence of a pictorial lexicon include those of Seymour (1973); Warren and Morton (1982); Ellis and Young (1986); Rayner and Springer (1986); Smith et al. (2000) and Riddoch and Humphreys (2001).

Coltheart (2004) argued that the idea that mental lexicons are components of the human word and object processing systems is a venerable one dating back to Wernicke (1874) whose model included a component referred to as the '*Wortschatz*' meaning the treasury of words, which is, in today's terminology, a phonological lexicon. Lichtheim (1885) held the view that the language processing system is highly modular in structure; he described the architecture of the phonological components of such systems in a box and arrow notation. Henry Head (1926), a British neurologist, scorned the '*diagram makers*' when referring to the 'box and arrow' type models. However, Beaton (2004) proposed that '*something of the flavour of their endeavour survives to the present day*' (p. 25).

1.1 Theoretical approaches to reading

Funnell (2000) suggested that reading requires the ability to use three types of procedures. The first is a procedure for pronouncing novel words and nonwords using the most common mappings between letters and sounds. The second involves a procedure for mapping familiar written words directly onto their corresponding phonological forms, and third is a procedure for mapping a written word directly onto its meaning. At present, the main theoretical accounts of the normal reading system that have been proposed are the dual route model (Coltheart, 1980), the triangle model of reading (Plaut, 1997; Plaut, McClelland, Seidenberg & Patterson, 1996; Seidenberg & McClelland, 1989) and the dual route cascade (DRC) model (Coltheart et al., 2001). The dual route theory, the triangle model and the DRC model of reading offer different accounts of how the procedures identified by Funnell (2000) are aligned. Ellis (1993) argued that the idea behind such models is that word recognition is the product of orchestrated activity that occurs within a number of cognitive sub-systems which operate at least partially independently from one another. Fodor (1983) referred to these semi-independent cognitive sub-systems as 'modules'. Modularity is argued to be an important concept as it reflects the pattern of intact and impaired aspects of reading that may differ between individuals, resulting in the production of different illustrations of reading disorders.

According to Coltheart (1980), most theoretical accounts of reading at the time he wrote his paper were dominated by the idea of there being two routes, procedures or mechanisms in reading. One is the lexical (visual) route, used for reading words as wholes, and the other is the sub-lexical (phonological) route, used for linking grapheme to phoneme (letter-sound). Seidenberg and McClelland (1989) criticised the dual route theory, arguing that the putative processes were intuitive and under-specified. They proposed a connectionist approach to reading, by developing computer models. Seidenberg and McClelland argued that a single route suffices, there is no need for two or three. Zorzi, Houghton and Butterworth (1998) have also proposed a connectionist model which differs from previous theories by incorporating a sub-lexical pathway that assembles spelling-sound mappings from training on a word set that includes many irregular words. A definite conclusion as to which approach best explains reading development is still sought.

1.1.1 The dual route model

Coltheart's (1980) dual route model is shown below.

The dual route model of reading

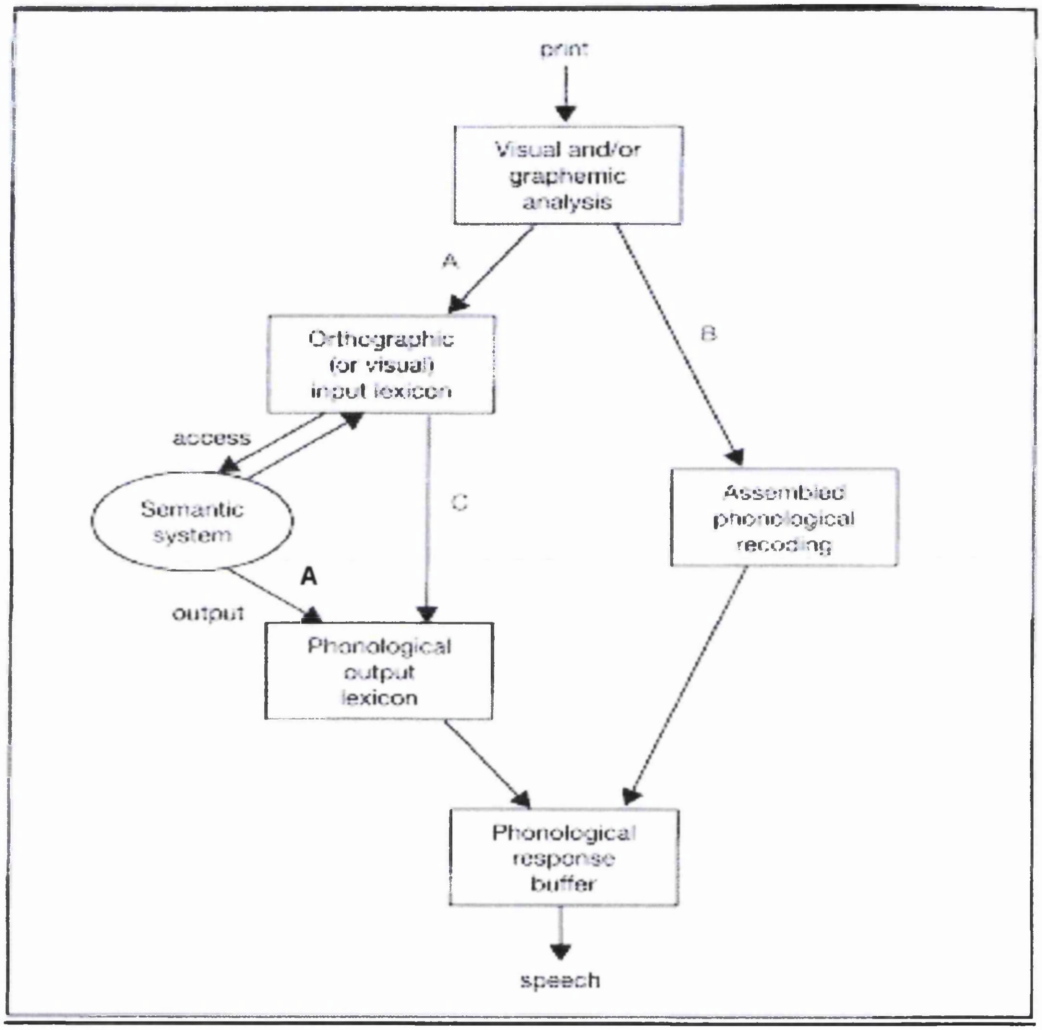


Figure 1. (Coltheart, 1980)

According to Coltheart (1980) the dual route model links two lexical processes together and separates these distinctly from sub-lexical processes. The first module is the *visual analysis system*. It has two main duties, namely to identify squiggles on a printed page as different letters of the alphabet and to note the position of each letter in its word. The visual analysis system encodes letter identities and positions before the reader can determine whether a word being fixated is familiar or unfamiliar. The system must then determine whether the string of letters on the page forms a highly familiar word, a real but visually unfamiliar word or an invented non-word.

The task of identifying letter strings as familiar words is the responsibility of the *orthographic input lexicon* (also known as the visual input lexicon). This lexicon contains word recognition units, which are representations of the written forms of all familiar words. Thus the orthographic input lexicon serves as a gateway to word meanings and pronunciations, but does not itself contain meanings or pronunciations. Ellis (1993) suggested that becoming familiar with new written words involves creating new recognition units for them in the orthographic input lexicon and forming associative connections between those units and the representations of meanings and pronunciations. He argued that this is an important part of learning to read. Some individuals have great difficulty with precisely this aspect of the acquisition of literacy skills.

The connection between the visual analysis system and the orthographic input system is bi-directional, meaning that not only can information flow inwards from the visual analysis system to the visual input system, but it can also flow back in the same direction. Thus, activity within recognition units can feed back down to letter identification and influence that process. Familiar words have recognition units in the orthographic input lexicon whereas nonwords do not. Therefore the visual analysis system will benefit from the assistance of 'top-down' support from the lexicon when the letter string is familiar but not when it constitutes a non-word (see Ellis, 1993).

Two separate lexical pathways link the visual input lexicon to the *phonological/speech output lexicon* and the *semantic system*. The phonological output lexicon stores the sounds of spoken word forms and the semantic system holds everything an individual knows about a word except how to spell or pronounce it. The knowledge of how to pronounce the particular word is contained in the phonological output lexicon. If a person sees a picture of a *bird* rather than the written word 'BIRD', they name the animal by first activating the semantic representation of the word held in their semantic system, and then by using the connections between the semantic system and the speech output lexicon, to come to the appropriate sound of the word. However, because a 'bird' is a familiar creature, people are less likely to struggle to remember the name of it than the name of an unfamiliar animal such as an 'aardvark or a platypus', although it could be argued that everyone experiences from time to time the frustration of not being able to recall the name of something the 'meaning' of which is known. The dual route model explains this phenomenon by suggesting that the problem arises when semantic information fails to activate the entry for the required word in the speech output lexicon.

The connection between the orthographic/visual input lexicon and the semantic system is again bi-directional, allowing top-down influences of word meanings on word identification. This helps to explain sentence context effects in word identification and semantic priming (Ellis, 1993). For example, participants are faster and more accurate in lexical decision in responding to words containing two semantically/associatively related words (e.g. bread and butter) than to words that are unrelated (e.g. rain and scissors). This is known as *semantic priming* (discussed later in this thesis).

According to the dual route model, once a word's entry has been accessed in the phonological output lexicon it must then be held in some short term store while the appropriate phonemes are run off from left to right; this store is known as the phonological response buffer. Long words like 'neuropsychology' are presumed to be retrieved in one go from the phonological output lexicon as a sequence of distinctive phonemes. However, the phonemes of 'neuropsychology' cannot be articulated all at once, they must initially be converted from first to last into a coordinated sequence according to the models articulated movements. Thus, the phonological response buffer acts as a short term store in which phonemes can be held in the interval between being retrieved from the phonological output lexicon and being pronounced.

The sub-lexical route (see route B on Figure 1) runs from the visual analysis system to the assembled phonological recoder then to the phonological response buffer. The phonological recoder is a store of grapheme-phoneme correspondences whose complexity develops with reading. The route is not word specific but consists of internalised rules of the English language and pronunciations. It allows a reader to fragment words into individual letters and then to blend them together in order to be able to read a word. It leads to the phonological response buffer. There must also be a route for performing the reverse operation, reading sounds as graphemes, in order to account for the ability to write non-words.

Coltheart's (1980) dual route model, then, proposes that there are two ways of pronouncing letter strings aloud, namely, a lexical (whole word) route (see route A on Figure 1) and a sub-lexical (phonological) route (see route B on Figure 1). The lexical route (also referred to as *'reading via meaning'*) enables a word to be read aloud through a mechanism that recognises the entire orthographic pattern, which then activates the appropriate semantic representation, which in turn is used to activate the appropriate sound entry in a phonological/speech output lexicon, a type of word dictionary. This route from print to sound passes through the visual input lexicon, the semantic system and the phonological output lexicon. An important feature of the lexical route is that it involves the semantic system, where written words activate their semantic representations. In the English language there are some words that can only be read aloud correctly via the activation of meaning. These are known as homographic heterophones, which are words that are spelled the same but are pronounced differently (e.g. the sentence... *the material of her dress had a large tear in it, and in the corner of her eye a tear was forming*. Ellis, 1993 p.29). These types of words can only be read aloud correctly by first activating the relevant meaning in the semantic system, then using the meaning (e.g. 'tear' in the dress or 'tear' in the eye) as a basis for selecting the correct pronunciation from the speech output lexicon. Because of the lexical route treating each word as an indivisible whole, it is also assumed to be required for the pronunciation of idiosyncratic or irregular words such as *pint, quay* and *yacht* which cannot be pronounced correctly by segmenting the word into separate constituent sounds according to grapheme-phoneme rules. Thus, the lexical route is used to read all irregular words by reading them as wholes.

Alternatively, a word may be pronounced by decomposing the letter string into its component letters, graphemes (e.g. '*th*') or other sized chunks (e.g. '*-tion*') and then matching these to the appropriate sound (see Shallice, Warrington & McCarthy, 1983). This is known as the sub-lexical (phonological) route. In terms of the model this route runs from the visual analysis system to the assembled phonological re-coder then to the phonological response buffer. The sub-lexical route enables letter strings to be pronounced by decoding a given word into smaller units and the phonology of each unit is assigned by means of context-dependent rules to provide the appropriate pronunciation. This way of reading is known as the phonological routine and can be used for reading familiar regular words as well as novel and non-words.

Coltheart, Curtis, Atkins and Haller (1993) argued that the two routes are necessary in order that two different classes of letter string can be pronounced correctly. One class consists of irregular exception words e.g. *leopard, colonel, pint* and the other of new words and non-words e.g. *bej, mird*. According to the model, irregular words would not be pronounced correctly using a sub-lexical route, while new or non-words could not be pronounced correctly using a lexical mechanism, since no orthographic visual entry exists for those types of words. On the other hand regular, consistent words can be read by both routes and lead to the same response in either case.

1.1.2 Two routes or three?

Although the term 'dual route theory' is used universally, the existence of a third route called the *'direct non-semantic route'* has been proposed. The third route to reading comes from the direct connection between the orthographic input lexicon and the phonological output lexicon. The orthographic input lexicon contains representations that are activated by familiar written words, while the phonological output lexicon contains the pronunciations of familiar words. The connections between the corresponding entries in both modules create a direct link between print and sound for familiar words, associations that bypass the representations of word meanings contained within the semantic system. In other words, a person using this route may be able to read the word out loud but will not understand the word's meaning as the direct route bypasses the semantic system.

The first indication of the direct route came from patient W.L.P of Schwartz, Saffran and Marin (1980) who suffered from dementia. W.L.P could read irregular words but did not understand any of their meanings. Further evidence in favour of the third route was provided by Coslett (1991) with patient W.T. It was found that W.T could read irregular words but was unable to read non-words, implying an impairment in the sub-lexical route. W.T. showed an imageability effect in repeating auditory presented words and in writing to dictation, suggesting that her performance on these tasks was semantically mediated. However, she showed no imageability effect in oral reading. Furthermore, her performance was impaired in comprehension tasks as well as in repetition and writing of the low-imageability words that she read correctly. Coslett (1991) argued that this pattern of results is consistent with the view that W.T's oral reading was accomplished through a lexical non-semantic route. In addition, Gerhand (2001) described the performance of patient E.W. who was diagnosed as a 'non-semantic reader'. E.W. had severely impaired comprehension of written words but could read aloud regular and exception words, non-words and sentences. Her results are therefore consistent with those models that propose three routes to reading (e.g. Morton & Patterson, 1980; Coslett, 1991). Gerhand (2001) argued that normal reading may be better conceptualised as a summation of the three routes rather than two. Cipolotti and Warrington (1995) favoured the view that a direct link exists between phonology and orthographic units of different size and that the co-occurrence of good but not perfect exception word reading with poor or non-existent definitions of these same words by their patient D.R.N. reflects the greater vulnerability of larger whole-word units compared with smaller units to the effects of progressive neurological disease. Thus, Cipolotti and Warrington supported the existence of the third 'lexical non-semantic route'.

In the light of the above findings, it would seem that the dual route model should be renamed the triple route model as there is now evidence of a third route to the pronunciation of letter strings. However, this remains a controversial issue as not all models of reading incorporate three possible routes in reading. Traditional dual route models argue that reading takes place via the semantic system or via the grapheme-phoneme conversion route (Ellis & Young, 1986; Coltheart, 1987). Thus a definite conclusion as to whether a triple route architecture to reading exists is still sought.

1.1.3 Neuropsychological support for the dual route theory

The dual route theory is supported by neuropsychological research. The principle of double dissociation (Jones, 1983; but see Plaut, 1995) has been invoked to support the view that there are two or three independent routes or procedures for reading. For example, damage to the lexical route (route A on figure 1) would lead to patients being unable to pronounce irregular words correctly and produce regularisation errors (irregular words are mispronounced using regular written to sound mappings e.g. *pint* may be pronounced to rhyme with *mint.*) They would have no difficulty in reading non-words since the sub-lexical route would still be intact. Such patients are said to show a pattern of ***surface*** dyslexia (see Marshall & Newcombe, 1973; Patterson, Marshall & Coltheart, 1985). Conversely, patients with damage to the sub-lexical route (route B on figure 1) and an intact lexical route would be able to read regular and irregular words but not non-words and are said to show *phonological dyslexia* (see Beauvois & Dérouesné, 1985; Dérouesné & Beauvois, 1979). In a special issue journal on the topic of phonological dyslexia (*Cognitive Neuropsychology,* 1996, 13, 6, edited by Coltheart) six different papers presented data from a total of 17 patients with the reading performance characteristic of phonological dyslexia; every one of the 17 had an associated phonological deficit. The inability of phonological dyslexics to read non-words (Coltheart, 1985; Marshall & Newcombe, 1980) contrasted with the ability of surface dyslexics to read regular but not irregular words (Marshall & Newcombe, 1973; Bub et al., 1985; Beauvois & Dérouesné, 1979) provides evidence for the conceptual and functional separation between the two routes. However, the dual route model has come under attack with the development of the concept of distributed representation and the introduction of computational modelling to the cognitive psychology of reading (Coltheart, 2006).

1.1.4 Connectionist models of reading

Coltheart et al. (1993) argued that various facts about skilled reading aloud cannot be explained by any model unless it possesses a 'dual-route' architecture, including lexical and sub-lexical routes from print to sound. However, as mentioned, this broad claim has been challenged by Seidenberg and McClelland (1989; 1990) and Zorzi et al. (1998) who proposed a connectionist type of reading model. Seidenberg and McClelland's (1989; 1990) model has but a single route from print to sound which they contend can account for all aspects of reading. Coltheart et al. (1993) identified six major questions about reading. Namely, how do skilled readers read exception words aloud? How do skilled readers read non-words aloud? How is the visual lexical decision task performed? How does surface dyslexia arise? How does phonological dyslexia arise? Finally, how does developmental dyslexia arise? Coltheart et al. (1993) argued that dual route theorists have offered answers to all six questions. However, they argue that the one-route model proposed by Seidenberg and McClelland only accounts for the first of these but not the remaining five. Thus Coltheart et al. (1993) argued that because models with dual route architectures can explain all six of these basic facts about reading, it is feasible to suggest that the dual route remains the core architecture for any tenable model of skilled reading and learning to read (see also Coltheart (2004) review in support of lexicons).

Coltheart (2006) argued that there were two crucial theoretical developments in the 1980s following the Marshall and Newcombe (1973) seminal paper which stimulated and reintroduced the study of acquired reading disorders. This was the development of the concept of distributed representation and the introduction of computational modelling which again provided essential theoretical questions to the cognitive neuropsychological study of reading. According to Hinton, McClelland and Rumelhart (1986) "*when in some cognitive system each entity is represented by a pattern of activity distributed over many computing elements, and each computing element is involved in representing many different entities... the entities are said to have 'distributed' representations' ... the alternative is to use one computing element for each entity. This is called 'local' representation*" (p.77). Prior to the concept of distributed representations, all of the models of reading used in cognitive neuropsychological work on acquired dyslexia posited 'local' representations, that is to say each word in a person's sight vocabulary was said to have a 'local representation'.

Hinton, McClelland and Rumelhart (1986) argued that the best psychological evidence for distributed representations was the degree to which their strengths and weaknesses match those of the human mind. Their view was that data from brain damaged patients provided verification that human mental representations were distributed rather than local (see McClelland & Rumelhart, 1986; Patterson, 1990). According to Seidenberg, Waters, Barnes and Tanenhaus (1984) this alternative perspective suggested that spelling regularities could be captured by the same system that represented lexical knowledge, eliminating the need for a separate rule-based system. Seidenberg and McClelland (1989) were among the first to incorporate distributed representations in a model of reading.

According to Coltheart et al. (2001) the psychology of reading has been revolutionised by the development of connectionist or computational models of visual word recognition and reading aloud. They are working simulations of computational processes and are designed to simulate 'normal' reading. All connectionist models have in common the fact that they are built up from simple processing units which are grouped into pools representing aspects of spelling, meaning or pronunciation. For example in reading, connectionist models are not only capable of generating some kind of phonological output representation from some kind of orthographic input representation but do so using the same processing mechanisms that are considered to be used by 'human readers' as they read aloud (Coltheart, 2006).

A connectionist model is composed of a network of interconnected units (comparable to neurones) that can learn about consistently occurring patterns available in the information to which it is exposed. In reading aloud, a stimulus is encoded by the input units (letter sequences) and a response is produced by the output units (phonology). The response to a given stimulus is provided by the output units taking the weighted sum of the activity of all input units. If the sum exceeds some predetermined threshold then an output is produced. This output can be compared with the correct response using a variety of algorithms; if incorrect, the weightings are adjusted and altered according to the frequency with which particular graphemic and phonemic sequences co–occur. This process can be repeated until the network produces the correct response. The input provided to the model during the 'training phase' enables the network to 'learn' the statistical regularities between orthography and phonology (see Seidenberg & McClelland, 1989, 1999; Coltheart et al., 2001).

Coltheart (2006) argued that computational modelling has many advantages over alternative ways of expressing theories about cognition. Models such as the original dual route theory are what Jacobs and Grainger (1994) referred to as '*verbal models*' that is, models that are described informally or in diagrammatic form as opposed to models that are described formally. Formal model description can be mathematical or computational. A computational model immediately reveals ways in which that theory is incomplete or underspecified, some of which the theorist will not have suspected. For example, a connectionist program will not run unless it is fully specified, therefore a theory cannot yield an executable program unless that theory is also specified (Coltheart et al., 2001).

1.1.5 The Seidenberg and McClelland (1989) model of reading

Following McClelland and Rummelhart (1981) model, an influential connectionist model of reading was introduced by Seidenberg and McClelland (1989). The general architecture of the model has come to be referred to as the '*triangle model*' and is one of the main competitors to the dual route model. Seidenberg and McClelland implemented the first components of the model as a computer program. It is a 'standard three layer feed forward network' based on 400 orthographic input units (where each unit represents a letter) connected to 200 hidden units (a total of 80,000 connections). All 200 hidden units are connected to all 460 phonological output units, giving a further 92,000 connections between the hidden units and the output units. The connections at first have random weights so that the network initially computes random pronunciations for orthographic inputs. The model is then trained using a back-propagation learning algorithm so that it gradually learns to produce appropriate phonological responses to orthographic inputs, in other words to read words aloud. Various versions (that differ somewhat from each other) have been developed (Coltheart, 2005)

The Seidenberg and McClelland Model (1989)

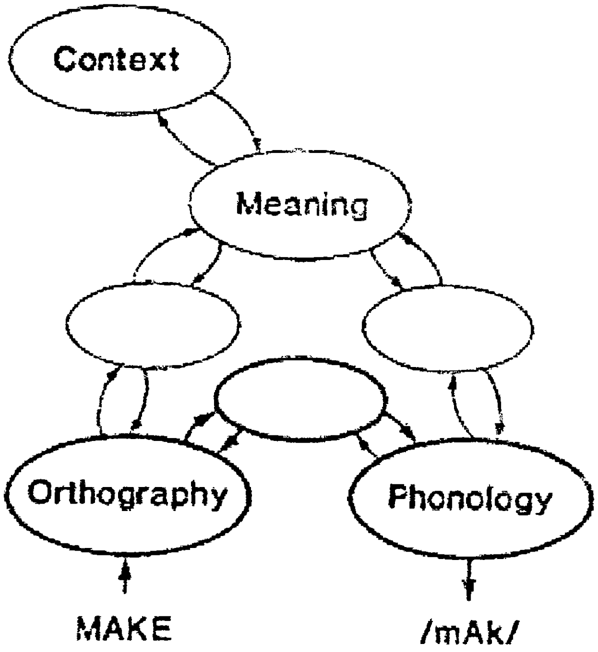


Figure 2. (Taken from Coltheart, 2006).

The central notion in dual route theories is that separate mechanisms are implicated in reading words and non-words. In contrast, the connectionist or neural network models exemplified by that of McClelland and Rummelhart (1981), Seidenberg and McClelland (1989) and its more recent modifications (Plaut, McClelland, Seidenberg & Patterson, 1996; Seidenberg, Petersen, MacDonald & Plaut, 1996) posit that the same mechanisms underlie the processing of words and non-words. Seidenberg and McClelland (1989) deny the idea that there are orthographic and phonological lexicons. Van Orden, Pennington and Stone, (1990) and Zorzi et al. (1998) also reject the existence of two separate lexicons. Unlike the dual route model there are no separate lexical components dedicated to the processing of familiar written and spoken word forms. Instead, an orthographic system processes representations of familiar and unfamiliar written words across sets of units representing graphemes, and a phonological system processes familiar and unfamiliar spoken words across sets of units representing phonemes.

Therefore lexical and sub-lexical processes are superimposed across a single hardware; this avoids the problem of integrating new words into the lexical system (Funnell, 2000). Connectionist models demonstrate that a single mechanism is sufficient to learn the correct pronunciation of both regular and irregular words and to work out pronunciations of non-words.

Funnell (2000) suggested that the connectionist model provides a computationally explicit account of reading, in that the 'behaviour' of the model can be compared with that of humans (to the extent that both 'behave' in the same way). The closer the correspondence between the behaviour of the model and the performance of humans the greater the plausibility of the psychological theory upon which the model is based. Funnell (2000) and Coltheart (2006) argued that the best way of evaluating any model of reading, whether it be dual route (diagrammatic form) or computational, is to consider how well the model can account for a body of empirical data collected from normal readers and from people with acquired disorders of reading. Using a computational model of reading to simulate data from acquired dyslexia involves seeking ways of damaging or 'lesioning' the model that not only makes its reading abnormal, but also creates specific patterns of atypical reading that are seen in particular cases of acquired dyslexia. Patterson, Seidenberg and McClelland (1989) attempted to lesion the Seidenberg and McClelland (1989) model to produce symptoms of surface dyslexia. That is, they sought some way of damaging the model so that it remained accurate at reading regular words and non-words whilst making regularisation errors when reading irregular words. However, Coltheart (2006) suggested that although the behaviour of the Seidenberg and McClelland (1989) model when lesioned in this way was intelligible, the model's reading behaviour did not specifically match the reading behaviour of patients with surface dyslexia. Patterson (1990) also displayed an unsuccessful attempt to simulate the reading of a surface dyslexic patient KT after lesioning the Seidenberg and McClelland (1989) model. Thus, it became clear that the model could not simulate all the facts about normal reading, that is, it was found to be far less accurate than 'human readers' at reading non-words, as noted by Plaut et al. (1996).

Plaut et al. (1996) and Plaut (1999) created three new triangle models aimed at remedying difficulties with the Seidenberg and McClelland model. However, the same problem occurred as noted by Patterson (1990) with respect to the Seidenberg and McClelland (1989) model. The third of the three models described by Plaut et al. (1996) also attempted to simulate surface dyslexia. They found that if they trained the model for 2000 training epochs then the reading of low frequency irregular words had come to depend very much on the 'semantic' input. Deletion of this input resulted in severe surface dyslexia. However, Plaut et al. (1996) were aware that this approach to simulating surface dyslexia depended upon the claim that acquired surface dyslexia is caused by damage to the semantic system. This was difficult to reconcile given the neuropsychological evidence, because not every patient with semantic impairment is surface dyslexic (e.g. see Schwartz et al., 1980, patient WLP).

The triangle model (Plaut, 1996)

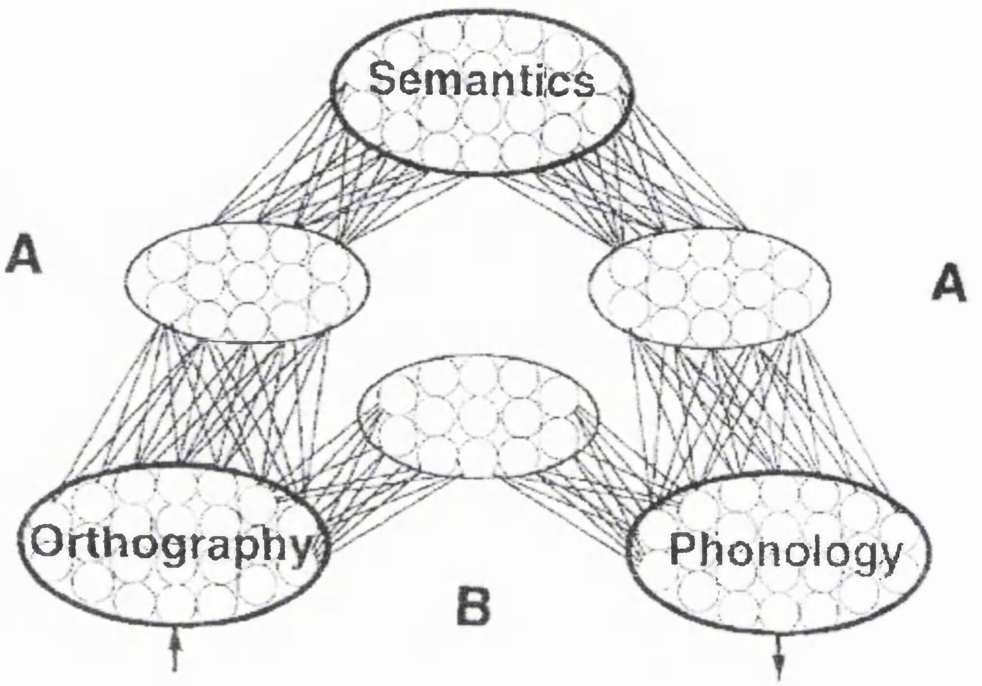


Figure 3. (Taken from Coltheart, 2006)

Harm and Seidenberg (1999) manipulated aspects of the Plaut et al. (1996) model so as to simulate a different pattern of acquired dyslexia, i.e. phonological dyslexia. However, the simulation did not lead to the pure case of phonological dyslexia, being very severely impaired in non-word reading. Therefore Harm and Seidenberg (2001) proposed another model. After training, the model was lesioned within the phonological representations themselves in an attempt to simulate phonological dyslexia. They used the results of the simulations to argue for what they referred to as the 'phonological impairment hypothesis', where acquired phonological dyslexia derives from impaired representation and use of phonology. However, Coltheart (2006) argued that if this is the correct explanation of acquired phonological dyslexia then all patients with this reading disorder will have impaired representation and use of phonology, and this is not so. For reported cases of phonological dyslexia in the absence of phonological impairment (see for example, Dérouesné and Beauvois, 1985; Bisiacchi et al., 1989; Patterson, 2000; Caccappolo et al., 2004).

1.1.6 The Dual Route Cascade (DRC) model

The dual route cascade (DRC) model (Coltheart et al. 1993; 2001) is a computational version of the dual-route theory and offers an alternative to the triangle model. The DRC models representations are local rather than distributed and Coltheart et al. specified the architecture of the model themselves rather than relying on back-propagation to do this. The DRC model of visual word recognition is argued by Coltheart et al. to be the only computational model of reading that can perform the two tasks most commonly used to study reading, namely, lexical decision and reading aloud. The computational version of the dual route theory is termed 'cascade' because as soon as activation begins at any one level it is assumed to flow on to subsequent levels; it is not necessary that a particular threshold must be reached in one component before being passed on to other components.

The DRC model is a generalisation of an early computational model of visual word recognition called the 'interactive activation and competition (IAC) model' introduced by McClelland and Rumelhart (1981) and Rumelhart and McClelland (1982). According to Coltheart et al. (2001) the reason for relying on the IAC was the success enjoyed by the model in accounting for the word superiority effect in human data in Reicher-Wheeler's recognition task (see Reicher, 1969; Wheeler, 1970) and because the IAC is a cascaded model. However, the IAC model only applied to four-letter words and the DRC generalised version applies to words from one to eight letters in length.

In the DRC model there are three routes, a lexical non-semantic route, a grapheme-phoneme correspondence (GPC) route and a lexical semantic route. However, the semantic part of the model has not yet been implemented. The DRC model uses a left-to right scan procedure across the letter string in order to decide which route could be used to pronounce the word aloud. Each of the three routes is composed of three different layers corresponding to visual letter features, abstract letter units and phoneme units. The abstract letter units layer is common to both the lexical non-semantic route and the GPC route. There are two ways in which the units of different layers interact. One is through inhibition, where the activation of a unit makes it more difficult for the activation of other units to rise. The other is through excitation, where the activation of a unit contributes to the activation of other units. According to Coltheart et al. (2001) '*whether a letter causes excitation or inhibition of a unit in the orthographic input lexicon is determined as follows: a letter in the Nth set of letter units excites all units in the orthographic lexicon for every word that contains that letter in the Nth letter position of the word and inhibits all other units in the orthographic lexicon*' (p.215). These units are frequency sensitive. If all other factors are held constant, the activation of high-frequency words rises more quickly than the activation of low-frequency words. To achieve this effect, a constant value is associated with each unit in the lexicon, as was done in the IAC model (Coltheart et al., 2001).

The Dual Route Cascade Model (Coltheart et al., 1993; 2001)

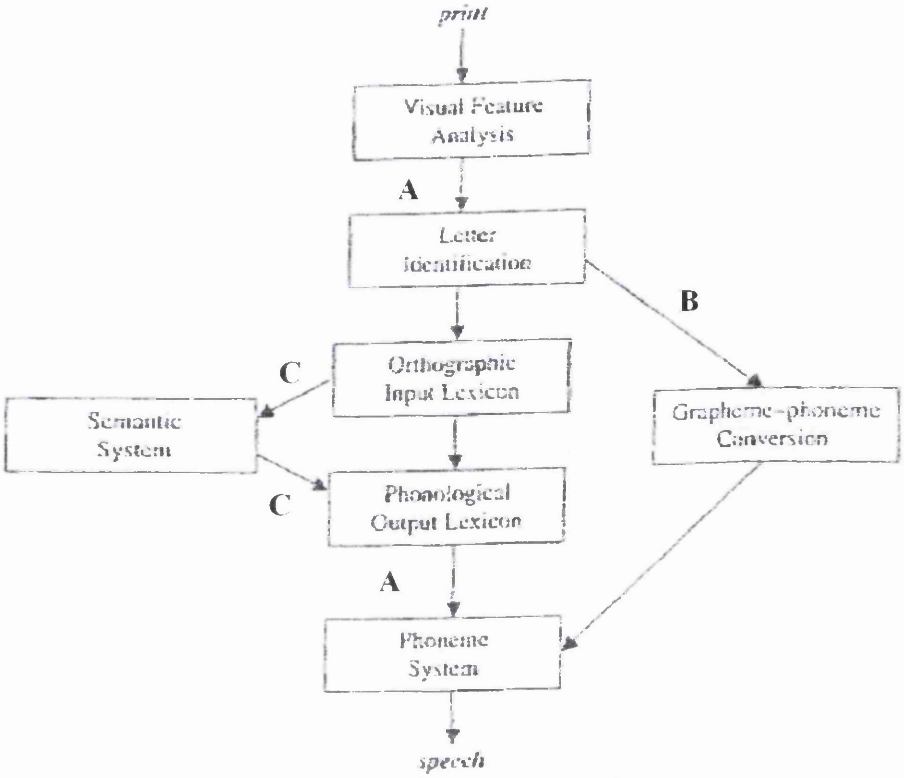


Figure 4. (Taken from Coltheart, 2006)

The lexical non-semantic route (see route A on figure above) of the DRC model generates the pronunciation of a word through a sequence of processes. The features of a given word's letters activate the word's letter units (in parallel across all letter positions), these letters then activate the word's entry in the orthographic input lexicon, which then activates the corresponding entry in a phonological lexicon, and that word's entry in the phonological lexicon then activates the word's phonemes in order to pronounce the word aloud (Coltheart et al., 2001).

The GPC route (see route B on Figure 4) converts a letter string into a phoneme string by using grapheme-phoneme correspondence rules. Visual features and corresponding letter units are activated just as with the lexical non-semantic route because the feature and letter levels are common to both routes. Coltheart et al. (1993) developed a rule discovery algorithm that learned a set of GPC rules from exposure to the database of approximately 3,000 word spellings and their pronunciations that was compiled by Seidenberg and McClelland (1989). This was done in order to show that there was enough information in the database for a procedure to be learned that would then be very accurate at reading non-words, as was the case with the learned set of GPC rules. However, the poor non-word reading of the Seidenberg and McClelland model could not be attributed to impoverishment of the database on which that model was trained. Thus, Coltheart et al. (1993) abandoned any more work on computational learning of GPC rules arguing that unless the learning procedure itself is known to be psychologically real, the model may not be able to learn what people learn and therefore not be of any use in computational models.

In the DRC model each word in a person's sight vocabulary has a local representation, whereas in other connectionist models (e.g. Seidenberg and McClelland, 1989) words are represented not as discrete entries in a lexicon but as patterns of activation distributed across a number of relevant units. Although the updated version of Seidenberg and McClelland's model proposed by Plaut et al. (1996) uses local representations of graphemes and phonemes, words are still represented as distributed patterns of activation across these units.

The DRC model is considered to have determined the pronunciation of a monosyllabic letter string (up to a given length) when it has activated all the phonemes of the letter string. It has a 99.987% accuracy of word reading and made 73 errors from 7,000 letter strings when reading three to seven monosyllabic non-words, giving an error rate of only 1.7%. Coltheart et al. (2001) argued that initial evaluation of the model's ability to translate words and non-words from orthography to phonology therefore yielded satisfactory results. They then went on to carry out more complex simulations by the DRC model, using two tasks that are commonly used to study reading, namely reading aloud and lexical decision. Coltheart et al. (2001) found for both tasks that a wide variety of variables that influence human response latencies also influence the DRC model's latencies in exactly the same way. For example, reading aloud is faster for high-frequency words than for low-frequency words, non-words with many orthographic neighbours are read aloud faster than non-words with few or no such neighbours and priming effects occur. Coltheart et al. (2001) argued that the DRC model can simulate a number of such effects that other computational models of reading can not. They also claim that there is no effect that any other current computational model of reading can simulate that the DRC cannot also simulate.

1.2 Acquired central dyslexia

1.2.1 Surface dyslexia

Modern studies of acquired dyslexia may be traced back to a single publication namely, Marshall and Newcombe's (1973) paper entitled 'pattern of paralexia', (paralexia refers to a reading error). Marshall and Newcombe used the errors made by their patients with acquired reading disorders following brain injuries to define three different forms of acquired dyslexia. These are surface, visual (referring to what is now called phonological dyslexia) and deep dyslexia. Surface dyslexia, a term coined by Marshall and Newcombe (1973), was represented by two patients, J.C and S.T. Surface dyslexics have little difficulty with the phonological code but are not able to use the lexical route, as they tend to read phonologically. They find regular words of varied length quite easy, although irregular and inconsistent ones cause serious difficulty. Patients with surface dyslexia have difficulty in reading irregular words aloud; they tend to pronounce irregular and inconsistent words as if they have applied a phonological recoding procedure, in other words they attempt to 'sound out letters', and make regularisation errors (e.g. pronouncing the word *quay* as 'kway' or misreading *island* as 'izland').

1.2.2. Phonological dyslexia

Acquired phonological dyslexia was first described by Beauvois and Dérouesné (1979) and is in some ways a mirror image of surface dyslexia. It refers to the difficulty experienced by those who apparently can not use the phonological code. They can pronounce familiar regular and irregular words, but can not read nonsense words and have difficulty with long and unfamiliar regular words. In terms of the dual route model this suggests that either some aspect of their sub-lexical (orthographic-phonological conversion) route is impaired or that there is a weakness or impairment in the representation of phonological information. Funnell

(1983) found that her patient W.B. could read ninety-three out of a set of one-hundred common nouns successfully, but could only manage two out of twenty simple non-words. Individuals with phonological dyslexia do not find regular words any easier than irregular ones. The reason often given for this is that they read regular and irregular words visually, and so whether the relationship between letters and sounds in any word is regular or not makes no difference. According to Lambon Ralph and Graham (2000) the critical feature of phonological dyslexia is the presence of a lexicality effect in reading accuracy. That is, patients read real words well (though not necessarily to a *fully* normal level of accuracy or speed) but are significantly and sometimes profoundly impaired at generating appropriate pronunciations of novel letter strings (non-words).

1.2.3. Deep dyslexia

As well as the varieties of acquired surface and phonological dyslexia, a distinctive pattern of symptoms has been given the name deep dyslexia. It is a relatively rare disorder and is argued by Shallice (1988) to have been of instrumental importance in cognitive neuropsychology as it highlighted a new way of examining and understanding existing models of 'normal' cognition. The lesion site is the same as that typically found in patients with phonological dyslexia except it is usually larger. It is commonly in the left fronto-temporo-parietal area. It encompasses at least the peri-Sylvian area and often extends to include much of the left hemisphere. In the forty-eight cases of deep dyslexia summarised by Lambon Ralph and Graham (2000) there were only four patients with a different lesion pattern: two right handed patients had a right hemisphere lesion (Nolan, Volpe & Burton, 1997; Sartori, Bruno, Serena & Bardin, 1984), the left hemispherectomy case of Patterson, Vargha-Khadem and Polkey (1989) and the patient of Michel, Henaff and Intrilligator (1996) with a posterior callosal lesion who displayed deep dyslexic symptoms only when words were presented to his left visual field.

Many features or symptoms in phonological dyslexia are found in patients with deep dyslexia. These include visual and derivational errors, function word substitutions, an almost complete inability to derive phonology from print (i.e. read non words or judge whether words rhyme); in addition, reading accuracy is affected by imageability and concreteness (these will be discussed in greater detail later in this review). Lambon Ralph and Graham (2000) argued that in effect the presence of semantic errors is the differential diagnostic between phonological and deep dyslexia. Deep dyslexia has been described most often in patients diagnosed with Broca's aphasia who have severe expressive aphasia but relatively good comprehension, poor short term memory and display an inability to manipulate phonological information. Writing is also impaired and some patients present with both deep dyslexia and deep dysgraphia, that is semantic errors in writing (e.g. Nolan & Caramazza, 1983) although the two can be dissociated (see Bub & Kertesz, 1982).

Lambon Ralph and Graham (2000) suggested that in the majority of cases the aetiology of deep dyslexia arises from various forms of cerebrovascular accident. However, there have also been nine reported cases with severe lesions following head injury, one case with an intracerebral abscess (Warrington & Shallice, 1979) and four individuals with missile or gunshot wounds (Marshall & Newcombe, 1973, 2 cases; Saffran, 1980; Caramazza et al., 1981). Lambon Ralph and Graham (2000) found no reported case of deep dyslexia in a patient with degenerative disease such as dementia in the 89 articles covered in their review of acquired dyslexias.

1.3 Deep dyslexia: a review

Marshall and Newcombe (1966) described two classic cases of deep dyslexia in patients G.R. and K.U. These were not the first cases to be reported in the literature; earlier ones were documented by Beringer and Stein (1930); Low (1931) and Goldstein (1948). However, it could be argued that G.R was the patient whose reading patterns sparked the revival of interest in deep dyslexia that began in the 1970s and has continued over more than three decades. The reports on G.R. appear at intervals over a period of thirty years, with different experiments in which he took part reflecting changing interest in theoretical questions directed towards deep dyslexia. The case of G.R has been discussed in detail by Barry (1996).

Marshall and Newcombe (1966) described the case of G.R. who had sustained a missile injury during the Second World War in 1944. He was 20 years old at the time and a soldier on active service, when he accidentally shot himself as he fell from a lorry. The bullet entered his brain at a point just in front of his left ear and passed up through the temporal and parietal lobes damaging the Sylvian fissure on the way, and emerging in the superior parietal region. G.R was found to have right-sided hemiplegia and severe language disorder as a result of his injuries. After his brain damage he was unable at first to produce words and could only make grunts with different inflections to communicate 'yes' and 'no'. After some time his spontaneous speech and comprehension improved, although severe reading and writing difficulties remained (Marshall & Newcombe, 1966).

More than twenty years after his injury Marshall and Newcombe (1966, 1973) re-assessed G.R's language abilities. They found that his spontaneous speech generally lacked function words, giving it the quality of a telegram (typical of Broca's aphasia). However, his articulation was good and he could repeat single words, including foreign words, single letters and numbers, but he found it difficult to recall series, for example, months of the year, and his digit span was only three items. G.R also had problems naming colours, although he was reported to name drawings of objects fairly well. Marshall and Newcombe (1966, 1973) reported that his comprehension was generally good, but he found it difficult to follow instructions which used complex sentence structure.

The most interesting feature of G.R's performance was the incidence of particular types of reading error. Among these, G.R. would read a word as one that was similar in meaning to the target word, but differed in orthographic (appearance) and phonological (sound) form. For example, G.R. read the word 'antique' as 'vase' and the word 'canary' as 'parrot'. These errors are known as *semantic paralexias* because there is a relationship in meaning between the stimulus and the response. These semantically related errors, which neither looked nor sounded like the target word, suggested that G.R's reading response was influenced by word meaning, rather than by the relationship between the written and spoken forms of the word.

Since G.R. was able to access an element of underlying meaning, Marshall and Newcombe (1966) thought in terms of the deep structure which Chomsky (1957) had first suggested underlies spoken language. They therefore called the reading syndrome shown by G.R. deep dyslexia. According to Temple (1993) scepticism initially greeted the description of the patient by Marshall and Newcombe (1966) but there have been many subsequent descriptions of similar patients and there is now no doubt that these error patterns occur. Temple (1993) argued that since the patients are able to access a word similar in meaning to the target, an element of the original word's meaning must have been processed correctly. Since the patient seems to have no access to the sound-based elements of the word, Temple (1993) suggested that it was as if deep dyslexics read with a semantic reading system in the absence of a phonological reading system.

1.3.1. Symptoms of deep dyslexia

Other errors in deep dyslexia are consistent with the idea of semantic route reading. Coltheart (1980) concluded after a review of twenty-one cases of deep dyslexia that there were twelve types of deficit that were typically observed in patients with this type of acquired reading disorder. The characteristic semantic error (semantic paralexia), in which the stimulus and response are semantically related, is the cardinal feature. Frequent visual errors are another feature of deep dyslexia, in which the response resembles the stimulus visually but in no other way, for example misreading 'signal' as 'single' or 'from' as 'form'. G.R was found to make a number of visual errors (e.g. he read 'perform' as 'perfume'). In the initial descriptions in the literature one type of error was called derivational paralexias. However, Temple (1993) argued that linguists highlighted the fact that the label was being used to include inflectional errors (e.g. reading 'sing' as 'singing'). Thus, in recent literature, the term morphological errors is more commonly used, where the stimulus and response has the same free morpheme but has a different bound morpheme, which changes the meaning of the word (e.g. reading 'edition' as 'editor' or 'governor' as 'governs'). Deep dyslexics tend to substitute the short grammatical function words for each other, for example, they may read 'in' as 'as'; these types of errors as known as function word substitutions. They make errors of phonological judgement (e.g. deciding whether words rhyme or not). They also have severe difficulty with reading novel and non-words. In addition, deep dyslexics' writing is usually impaired along with their auditory verbal short term memory.

Deep dyslexics usually display a concreteness or imageability effect. They find it easier to read words referring to things, such as concrete objects that are easily imaged, that is, words for which it is easy to imagine a picture, sound or a smell in the mind, than words referring to abstract concepts such as truth or unity. A 'part of speech' effect or syntactic effect is sometimes found where nouns are read more accurately than adjectives, which in turn are read more accurately than verbs. The ability to read a word is therefore dependent on its context within a sentence, for example, *'fly'* as a noun is easier to read than *'fly'* as a verb because it is easier to visualise. According to Temple (1993), concrete words have strong semantic representations, hence they trigger the semantic reading route more quickly than abstract words. Newton and Barry (1997) proposed that highly concrete concepts are more likely to specify an exact lexical representation than less concrete words and are more likely to specify a range of semantically related lexical representations, or synonyms, a number of which may be sufficiently activated to become candidates for response. Deep dyslexics also find it easier to read words that are of high rather than low frequency, that is, words that are very common although age of acquisition is a confounding variable (Gerhand and Barry, 2000).

Coltheart (1980) suggested that semantic errors in oral reading guarantee the occurrence of other deep dyslexic symptoms and hence deep dyslexia became known as a 'syndrome'. However, the description of deep dyslexia as a uniform syndrome has been challenged by various case studies. For example, patient A.R of Warrington et al. (1970), who made the characteristic semantic error, did not display a content word effect that is typically found in deep dyslexia (i.e. content words are read better than function words). Another deep dyslexic (patient C.A.V) reported by Warrington (1981) did not demonstrate an effect of word concreteness. More recent reports (e.g. Caramazza & Hillis, 1990) have shown other preservations in the presence of semantic errors. As with all such 'syndromes', there are individual differences between patients. Since the majority of patients tend to exhibit most of the twelve symptoms, those who do not could be viewed as exceptions rather than the rule.

1.3.2 Sub types of deep dyslexia

In order to explain the apparent heterogeneity in deep dyslexics' reading performance, Shallice and Warrington (1980) suggested that deep dyslexia is a 'multi-component syndrome' with three distinct sub-types, reflecting different loci of functional damage. It has commonly been assumed that semantic errors in reading aloud implicate damage to the semantic system itself or else reflect problems in accessing this system or in the output pathways from it. Functional lesions in each of these loci have given rise to what Shallice and Warrington (1980) and Shallice (1988) propose are three different sub-varieties of acquired deep dyslexia, respectively named input, central and output forms of deep dyslexia. They argue that the three sub-types could be theoretically distinguished according to their presumed primary impairment, at different levels of the semantically mediated route. An *input* problem is associated with difficulties in accessing a specific semantic representation, a *central* problem is related to a semantic deficit and a post-lexical *output* problem is connected to phonological retrieval. Shallice (1988) argued that these problems could all lead to the wrong, but semantically related, response being given to a stimulus word. Dickerson and Johnson (2004) argued that the division of deep dyslexia into sub-types may help account for the slightly different clinical profiles across different patients (for example, the variable rates of semantic substitutions when reading) but it cannot completely account for the different constellation of symptoms seen in deep dyslexia.

Shallice and Warrington (1980) suggested that 'input' type deep dyslexics have impairments which tend to affect the visual modality specifically, whereas the disorder is said to be modality independent in 'output type' deep dyslexics. Shallice and Warrington (1980) proposed that input deep dyslexics have specific difficulties in accessing precise semantic representations from written input. Their patient K.F. performed better on auditory synonym matching tasks than on equivalent visual tasks and was thus diagnosed as an input type deep dyslexic. However, eighty percent of the stimuli used with K.F. were abstract words, which are much harder for a deep dyslexic to read. Shallice and Coughlan's (1980) patient P.S. also showed superior auditory comprehension of words compared to visual comprehension. This was only on tasks involving the classification of words into abstract categories; performance was equally good on the auditory and visual version as on tasks that required classification into more concrete categories.

Shallice (1988) attempted to explain the difference in performance between patients K.F and P.S by suggesting that the semantic representations of words have an underlying structure and that this structure is perhaps more easily tapped by the 'concrete' tasks than by 'abstract' tasks. He concluded that the difficulties shown by K.F and P.S had to be specific to the more abstract words given their excellent performance on concrete words. Shallice argued that the failure of both patients to comprehend abstract words could be explained by assuming that within one subdivision of the semantic system (in this case referring to the abstractness of words) a semantic representation can not be efficiently obtained given visual input, despite the fact that the visual word form system is operating normally. This assumption is derived from theories that assume that the organisation of the semantic representations of words is categorical, that is, that there is some neurological differentiation between the representations of concrete and abstract words within the semantic system (Shallice & Warrington, 1975; Schwartz et al., 1977; Marcel & Patterson, 1978).

In contrast to 'input' deep dyslexia, 'central type' deep dyslexics show extreme impairments in comprehension in tasks such as word/picture matching or synonym judgements. Patient K.E. studied by Hillis, Rapp, Romani and Caramazza (1990) produced semantic errors in all processing tasks, reading, writing, naming and comprehension, implying that K.E. had suffered damage to the central lexical semantic system. Because central deep dyslexia is thought to arise as a result of degraded semantic knowledge, deficits should be evident across different modalities and different tasks. Patient M.G.K, of Beaton, Guest and Ved (1997) made semantic errors in reading aloud, writing to dictation, oral and written naming and in drawing, which suggested to the authors that she had a central semantic deficit. M.G.K seemed to comprehend the meanings of her semantic error, rather than the target word, as on some trials her drawings reflected her errors rather than the targets. On some stimulus items M.G.K could not respond at all in reading, writing or naming tasks. While permanent loss or destruction of the relevant semantic representations may account for this, Beaton et al. (1997) suggested that it was more probably due to factors affecting output mechanisms, since when M.K.G. was not able to respond orally she was usually able to provide appropriate drawings.

According to Dickerson and Johnson (2004) output type deep dyslexics are by far the most common type and there are several examples in the recent literature (Laine, Niemi, Niemi & Koivuselkä-Sallinen, 1990; Katz & Lanzoni, 1997; Buchanan, Kiss & Burges, 2000). Output types are believed to process words up to the level of the semantic system but can not accurately produce them as phonological output. Barry and Richardson (1988) suggest that output deep dyslexics should produce more semantic than visual errors and that they should show relatively well preserved lexical decision performance. Caramazza and Hillis (1990) reported two patients, R.B.G. and H.W, both of whom produced semantic errors in oral production only. Both patients were able to define words correctly, thereby demonstrating that they had access to intact semantic representations. Therefore, Caramazza and Hillis (1990) concluded that the only possible loci of impairment in R.B.G and H.W reading was at the phonological output level.

1.3.3 Different conceptualisations of deep dyslexia

There are four main approaches to explaining deep dyslexia. The first is that deep dyslexia results from a damaged left-hemisphere reading system that has lost the ability to read without reference to meaning (Morton & Patterson, 1980; Newcombe & Marshall, 1980; Patterson & Besner, 1984; Shallice & Warrington, 1980). An alternative explanation of deep dyslexia, proposed by Coltheart (1980), is that because of the atrophy of the left hemisphere, the preserved reading abilities of deep dyslexics reflect a subsidiary right hemisphere reading system. Third, is the continuum theory (Glosser & Friedman, 1990; Friedman et al., 1993). A forth, relatively recent approach is that of connectionism.

1.3.4. The right hemisphere hypothesis

Coltheart (1980) asked how it is that when a patient makes semantic errors all other characteristics of deep dyslexia, such as the inability to read function words, non-words and the presence of visual errors, also occur. Morton and Patterson (1980) attempted to explain the pattern of errors found in deep dyslexia within a functional model of normal reading by suggesting four possible 'lesions' to explain the effects of abstractness, derivational errors, failure to read non-words and semantic errors. However, Coltheart et al. (1987) argued that separable lesions suggest that, in principle, each lesion should be expected to occur independently, so that sometimes semantic errors should occur without the other characteristics. The mere fact that they do not raises problems for Morton and Patterson's explanation of deep dyslexia.

Coltheart (1980) contrasted two possible ways to explain the pattern of symptoms shown by deep dyslexics. The first was to seek to show that some specific patterns of impairments of the components of the 'normal' reading system would generate all of the error types evident in the reading of a deep dyslexic. The other was to argue that deep dyslexics are reading, not with a damaged version of the 'normal' reading system, but with a completely different reading system. Since the co-occurring pattern of features of deep dyslexia did not appear to be accounted for readily within a model of normal reading, an alternative hypothesis was put forward (Coltheart, 1980; Marcel & Patterson, 1978; Saffran, Bogyo, Schwartz & Marin, 1980). This was that the characteristics of deep dyslexia arise from right hemisphere processing, a part of the brain generally thought not to be involved in 'normal' reading. Coltheart (1980) examined CT scans of five deep dyslexic patients whose lesions showed widespread damage to the language areas of the left hemisphere. Such large lesions suggested that it was highly unlikely that oral reading in deep dyslexia could be carried out by left hemisphere processes. Thus, the theory assumes that the residual reading abilities observed in deep dyslexia are underpinned by processes in the right hemisphere.

The large lesions typically found in deep dyslexics provide one of the motivations behind the 'right hemisphere hypothesis' proposed by Coltheart (1980) and supported by Saffran et al. (1980). The hypothesis describes the preserved reading abilities of a deep dyslexic patient in terms of a subsidiary reading system in the right hemisphere that is uncovered subsequent to devastation of the primary reading system in the left hemisphere. The hypothesis predicts that the inability of deep dyslexics to perform phonological decoding of non-words is due to their reliance on this less verbal hemisphere. Coltheart (1980) argued that independent support for the right hemisphere hypothesis was available from hemi-field studies using intact subjects and split brain patients. Coltheart reported that hemi-field studies at that time generally revealed a processing advantage for written abstract words in the left hemisphere compared to the right, with no difference between the two hemispheres for concrete words. Split brain studies, in which the patient's corpus callosum (separating the cortical connections between the cerebral hemispheres) had been sectioned, also showed an advantage for concrete words compared to abstract words when the words were presented to the right hemisphere.

Patterson et al. (1989) presented a case report of a thirteen year old patient N.I who following a complete left hemispherectomy presented with a pattern of dyslexia that was very similar to that seen in adult deep dyslexics. Given that the left hemispherectomy was complete and assuming that after thirteen years the neural functional components of the reading architecture closely resemble those found in adulthood, the case clearly provides evidence in support of the right hemisphere reading hypothesis. Michel et al. (1996) offered more support for the hypothesis with their patient, who suffered from a posterior callosal lesion. He was found to read normally if words were presented in his right visual field, but exhibited a deep dyslexic pattern when the words were presented in his left visual field. However, there are also claims against the right hemisphere hypothesis for reading. For example, Roeltgen's (1987) patient presented with symptoms of deep dyslexia after a first cerebrovascular accident. Following a second lesion to the left fronto-parietal region this patient had almost no residual reading ability. This supports the alternative hypothesis that the poor reading of deep dyslexics reflects the residual capacity of the left hemisphere.

Recently, attempts have been made to investigate the right hemisphere hypothesis of deep dyslexia using functional imaging techniques. Price, Howard, Patterson, Warburton, Friston & Frackowaik (1998) found that increases in cerebral blood flow during the oral reading of concrete words by two deep dyslexic patients occurred primarily in structures lying outside the Sylvian areas of the left temporal lobe. Price et al. demonstrated that reading by two deep dyslexics (C.J. and J.G) involved normal or enhanced activity in the spared left hemisphere regions associated with naming (Broca's area and the left posterior inferior temporal cortex) and with the meanings of words (the left posterior temporo-parietal cortex and the left anterior temporal cortex). An inconsistent activation within the control group and between the two deep dyslexics was also found in the right hemisphere homologues of these regions. Price et al. (1998) argued that although these differential right-hemisphere activations may have influenced the reading behaviour of the patients, their activation patterns primarily reflected semantic and phonological systems in spared regions of the left hemisphere. Their conclusions therefore go against the explanation of deep dyslexia in terms of purely right-hemisphere word processing. However, Weekes, Coltheart & Gordon (1997) found greater right than left hemisphere activation in a deep dyslexic patient during word recognition. Three other subjects (one a surface dyslexic) demonstrated greater right than left activation during word recognition but more left than right activation during word production. Weekes et al. concluded in favour of the right hemisphere hypothesis.

Cossu, da Prati and Marshall (1995) described a case study of a young Italian boy who sustained extensive left hemisphere damage after a massive sub-arachnoid haemorrhage at twelve years of age. Two years later, he was diagnosed with residual anomic aphasia, displaying word-finding difficulty in confrontational naming tasks. His reading aloud showed all the characteristics of deep dyslexia. Writing and spelling were severely impaired, although there were no qualitative signs of deep dysgraphia (semantic errors in writing). Cossu et al. argued that the patient's overall pattern of performance reflected the written language capacity of the non-dominant hemisphere and its contribution to normal reading. They concluded that in this case, and perhaps some other cases of acquired deep dyslexia, reading and writing may be mediated by a combination of left and right hemisphere sites.

The suggestion of Cossu et al. (1995) was supported by Patterson and Besner (1984) who also argued that deep dyslexia reflected the use of both left and right hemisphere processes. They came to this conclusion after reviewing the reading performance of two patients, reported by Zaidel (1982), whose left hemispheres had been surgically removed. Following the procedure both PW and DE demonstrated characteristics of deep dyslexia. To explain this effect, Patterson and Besner suggested that deep dyslexic subjects may have access to additional resources for reading beyond right hemisphere processes (e.g. sub-cortical mechanisms). Patterson et al. (1989) entertained a similar assumption, although other reasons, such as the effect of early hemispherectomy on the development of reading and the consequences of possible damage to right hemisphere processes from seizures, were considered too. Therefore, current evidence form both left hemispherectomy and brain imaging studies appears to favour an account of deep dyslexia in terms of the recruitment of both left and right hemisphere processes.

1.3.5. Continuum theory of phonological and deep dyslexia

It has been suggested that acquired phonological and deep dyslexia reflect points along a continuum (see Friedman, 1996; Lambon-Ralph & Graham, 2000; Crisp & Lambon-Ralph, 2006). At one end there is deep dyslexia, with a range of co-occurring symptoms; at the other end there is 'pure' phonological dyslexia with impoverished performance for non-words as the only reading deficit. In between the two are patients for whom the exact features of their phonological dyslexia are predictable on the basis of severity alone.

Glosser and Friedman (1990) and Friedman et al. (1993) proposed a continuum theory of deep dyslexia based on an analogy model of word recognition. In their model, there are two routes; connections from orthography to phonology, which are used by normal readers to pronounce both words and non-words, and a semantically mediated route from orthography to phonology. Both phonological and deep dyslexics are hypothesised to have a variable degree of impairment in the orthography to phonology connections. As this impairment becomes more severe, subjects are forced to rely on the semantically mediated route to a greater degree. The semantic errors observed in deep dyslexia are proposed to occur as a result of this severe impairment to orthography to phonology connections as well as an additional semantic impairment. Thus, an inability to process sub-lexical phonology is critical for the continuum theory.

1.3.6. Connectionist approaches to deep dyslexia

Connectionism suggests an alternative to the 'box and arrow' information approach to explaining deep dyslexia. According to Coltheart et al. (2001) '*computational cognitive neuropsychologists attempt to reproduce patterns of acquired dyslexia by lesioning specific components of their computational models and studying how closely the resultant acquired dyslexia in the computational model corresponds to the acquired dyslexia in the patient being simulated*' (p.241).

Hinton and Shallice (1991) were among the first to use a connectionist model to simulate the characteristic reading errors found in deep dyslexia, most notably the semantic error. They attempted to replicate deep dyslexia by producing lesions in various locations within their connectionist architectures. Their model consisted of a network composed of two sets of representations. These included a set of grapheme units which represented particular letters in particular positions in the word and a set of semantic units, which represented the meaningful characteristics of a word. The semantic representation units in the model were referred to as 'semene units' and these corresponded to basic semantic features of words that linked with five different categories, namely indoor object, outdoor object, body part, food and animal. These semantic units were then connected to each other by local connections between closely related semantic features (e.g. colour, shape and size). An important aspect of the model was the presence of 'clean up' units which received connections from some semantic units and sent connections to others. The clean up units build and organise more precise higher-order semantic relationships based upon consistently occurring feature sets in order to provide more global semantic descriptions in response to target words.

Hinton and Shallice's (1991) model was trained to identify and activate the precise semantic representation output for forty monosyllabic words drawn from the five semantic categories (mentioned above). The model was then lesioned by removing some units or connections at random or by introducing noise into the system. Subsequently, the model exhibited errors that were characteristic of deep dyslexia. Hinton and Shallice found that lesions at the sites produced semantic, visual and visual/semantic errors analogous to those of deep dyslexia; however, the location of the lesion displayed an important effect. The closer the lesion was to the semantic unit component of the model, the more likely it was that a semantic error was produced; visual errors were more likely to occur with damage closer to the grapheme units. A limitation of their model was that it did not have any phonological units, thus the examination of picture naming errors was impossible (Buchanan, Hildebrandt & MacKinnon, 1994).

Plaut and Shallice (1993) developed and refined their connectionist model further in order to examine the concreteness effect that occurs in deep dyslexia. They lesioned several architectures that included a phonological unit (that receives input from the semantic unit) and reported that a single lesion in various places within the system could produce errors such as those produced by deep dyslexics. However, Buchanan et al. (1994) argued that as none of the architectures lesioned by Plaut and Shallice could read non-words they were in some sense already dyslexic.

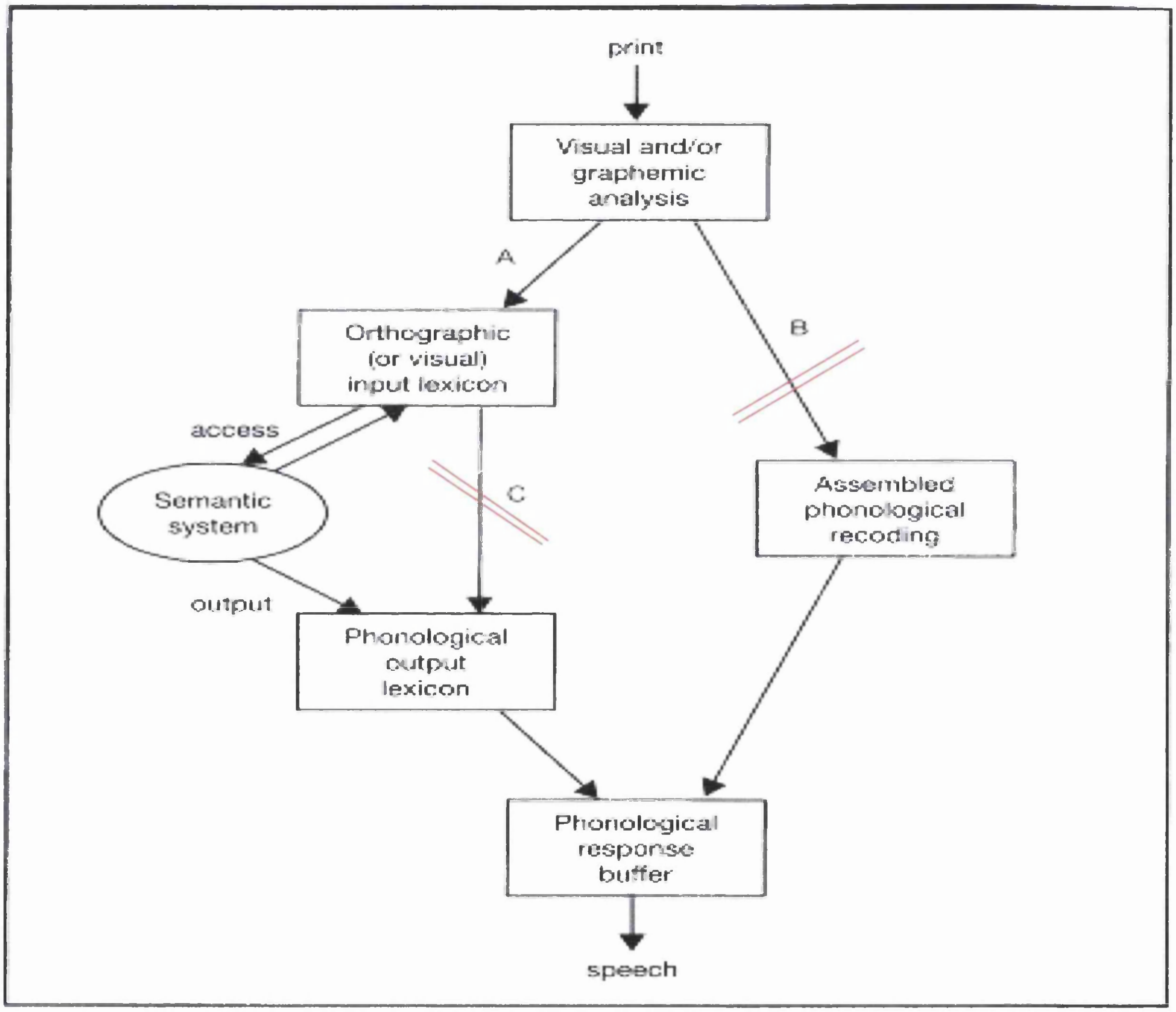
Coltheart et al. (2001) discussed in some detail the success achieved in lesioning their dual route cascade model of reading in a way that mades its reading resemble that of people with surface dyslexia (with selective impairment of the lexical route) and in a way that mades its reading resemble the reading of people with phonological dyslexia (selective impairment of the sub-lexical route). Coltheart (1998) has also shown how pure alexia might be explained within the context of interactive activation and competition (IAC) model (see McClelland & Rumelhart, 1981). However, the computational DRC approach has not been applied to deep dyslexia.

Coltheart et al. (2001) suggested that in the connectionist work on surface dyslexia, phonological dyslexia and pure alexia the idea has been that someone with acquired dyslexia is reading using a damaged form of the 'normal' reading system, located in the left hemisphere. This assumption appears to hold for patients with surface or phonological dyslexia and with pure alexia, but not for deep dyslexia. Coltheart et al. (2001) argued that "*...it is fruitless to seek to interpret deep dyslexia in relation to a model of the normal reading system and thus fruitless to seek to simulate it by lesioning the DRC model, even though this is a fruitful enterprise in relation to the other three forms of acquired dyslexia*" (p.246). The explanation of deep dyslexia therefore is outside the scope of the DRC model.

1.3.7. The dual route explanation of deep dyslexia

The damaged left hemisphere lexical system explanation refers to the dual route model and is arguably the most popular way of addressing and evaluating the performance of deep dyslexics. It has the advantage of allowing the experimenter to identify functional lesions within the dual route information processing model of 'normal' reading which could account for the patterns of impairment and preserved abilities displayed in acquired dyslexics' reading.

Figure 5. The dual route model of deep dyslexia (Coltheart, 1980)



The dual route model assumes that reading takes place via either or both of the lexical and or sub-lexical route (as discussed earlier). Triple route models argue for the existence of a third 'direct' route from the orthographic input lexicon directly to the phonological output lexicon. The symptom pattern in deep dyslexia is attributed to at least three functional lesions or impairments within the cognitive architecture outlined in the dual or triple route model. As deep dyslexics can read many irregular or exception words, and may not show a regularity effect, they must be using an intact whole-word route. However, since the target word has been understood at least partially, and many words are not read at all (i.e. function and abstract words), it is assumed that patients can not use the non-semantic route. Instead, they must be using a route through semantics. Therefore, one 'functional lesion' is assumed to impair the non-semantic route (route C on figure 5). A second functional lesion, accounting for the partial or total inability to read or write non-words, impairs or totally abolishes sub-lexical conversion procedures (route B on figure 5) (Miceli, Capasso & Caramazza, 1999). Third, there is assumed to be some impairment in, and or around, the semantic system, or else a 'fuzzy' normal semantic system (Newcombe & Marshall, 1980; Newton & Barry, 1997). However, the idea of a 'fuzzy' semantic mediated route is questionable. The same semantic system is used in speech and reading yet 'normal' people do not say things like *"an orange a week keeps the chemist close"* instead of *"an apple a day keeps the doctor away"* (an acknowledgement is made to an anonymous referee).

Deep dyslexics, then, are assumed to read via the lexical semantic route (route A on figure 5) which can account for the occurrence of semantic errors. Saffran et al. (1976) and Newcombe et al. (1980) have argued that this route is not damaged but merely unassisted by the grapheme-phoneme conversion route. Some authors have postulated an additional impairment (Morton & Patterson, 1980; Nolan & Caramazza, 1982; Shallice & Warrington, 1980).

However, it is generally agreed in the literature that the sub-lexical route is inoperative or severely impaired in deep dyslexia, which accounts for the inability to read novel or non-words or to derive any phonology from print. Thus, it is presumed that route B is not being used, at least for regular words and at least consciously. It is also assumed that the lexical non-semantic route is impaired (route C) in deep dyslexics or else why should the response not be correct?

An alternative view was introduced by Kay and Marcel (1981) and Friedman and Kohn (1990). These authors argued that an independent grapheme-phoneme mechanism was not necessary to account for some errors in deep dyslexia. They proposed that the retrieval of phonological entries for words and non-words occurs by analogy, where oral reading of both types of letter string utilises phonological entries in a phonological lexicon. It was hypothesised that non-words activate phonologically similar real words which help to provide the pronunciation of the target non-word. Impaired access to the phonological lexicon then affects the oral reading of both words and non-words. Thus, if reading of non-words does occur by analogy, then error responses should always be phonologically similar to real words and in the case of non-words the response should be a close approximation to the target item. However, Southwood and Chatterjee (1999) argued that deep dyslexics do not always produce phonologically related errors. Moreover, if reading words and non-words relies on being able to access the phonological output lexicon and this is impaired, then similar errors should be present during, naming, repetition and spontaneous speech as in reading but this is not (usually) the case. Thus Southwood and Chatterjee emphasised the fact that reading by analogy fails to explain dissociations in error responses across a variety of oral production tasks.

1.4 How do the error types arise in deep dyslexia?

In order to explain the principal symptom of deep dyslexia, the semantic error, many different theories have been proposed. Marshall and Newcombe (1973) suggested that a deficit of the sub-lexical route alone may give rise to semantic errors. They argued that the semantic system is by nature unstable unless it is corrected by various peripheral devices such as the phonological route. If a deep dyslexic had any phonological information available to them then this would act as a checking procedure and thus eliminate semantic errors. Morton (1964) provided evidence in support of this suggestion in that semantic errors have been reported in 'normal' readers in rapid reading experiments where the speed of reading is thought to impede grapheme-phoneme conversion procedures. However, one criticism is that phonological dyslexics are also poor at reading non-words and yet they make few semantic errors, nor do they show deficits for particular word classes.

Nolan and Caramazza (1982) argued that a simple deficit in the grapheme-phoneme conversion route combined with a 'fuzzy' semantic system was not adequate to explain the complex symptoms of deep dyslexia. Saffran (1984) proposed that the degree of intrinsic instability within the semantic system would have to be very great indeed to account for semantic errors. In relation to this suggestion, it may be argued that 'normal' participants who have not sustained a brain injury do not make semantic errors when naming objects, whereas deep dyslexics do. However, such errors may escape un-noticed in non-injured patients as one may expect the occasional 'oddity' (e.g. naming 'chair' as 'stool' or 'hand' as 'foot'). For Marshall and Newcombe (1973) to retain consistency in their argument they would be forced to suggest a phonological route to stabilise object naming as well as word reading.

A common assumption, then, has been that patients with deep dyslexia have both phonological and semantic access impairments (e.g. Morton & Patterson, 1980; Plaut & Shallice, 1993). However, according to Colangelo et al. (2003) the data supporting these claims are not convincing. They argued that the trademark feature of deep dyslexia, namely the semantic error, strongly implies that deep dyslexics *can* access semantic information from printed words. They tested the reliability of the semantic system in two deep dyslexic patients B.V. and J.O. through auditory and visual word association tasks. Colangelo et al. found that semantics remained intact and thus postulated that the disorders and associated errors arise through a selection impairment related to failure of inhibitory connections in the phonological lexicon. This, of course, may only apply to 'output' type deep dyslexics (i.e. with no semantic impairment or access problems). Other theories have argued that the critical disruption occurs subsequent to semantic processing and affects the retrieval or the production of the appropriate phonological form (Marshall & Newcombe, 1966; Marcel & Patterson, 1978; Patterson, 1978). However, theories positing a post semantic deficit encounter the problem of not being able to explain the occurrence of visual errors.

Shallice and Warrington (1975) argued that the obliteration of the sub-lexical route together with impaired semantics may account for certain other symptoms or errors. They suggested that low frequency words rely more than high frequency words on preliminary phonological recoding for lexical access and that abstract words rely more on phonological recoding than concrete words; this would explain the typical concreteness effect. Saffran et al. (1979) also proposed that the sub-lexical route is essential for reading certain classes of words aloud. They argued that the mechanisms that mediate oral reading performance in deep dyslexia are designed for the comprehension of written words and not their production. Saffran et al. suggested that concrete words have a core meaning that is little affected by context;

conversely, the meaning of abstract words is more vague and much more context dependent. Assuming abolition of the phonological route, deep dyslexics have no additional information about the stimulus word other than the semantic representation it evokes. This suggestion may account for deep dyslexics' problems in reading function words, as the latter have little meaning on their own.

Morphological (derivational) errors have been attributed to a consequence of phonological disability. Patterson (1977) proposed that words which are derivationally related to each other (sharing the same free morpheme but different bound morphemes) may in fact only have a lexical entry corresponding to this free morpheme. If this is the case, then accessing this entry would be insufficient to inform the patient of which word they are looking at. Patterson suggested that it is necessary to have a non-lexical representation of a word's bound morpheme in order to pronounce it aloud. If this non-lexical representation is phonological then again it is presumably unavailable to those suffering from deep dyslexia.

Patterson (1980) postulated that separate impairments in the orthographic visual input lexicon gave rise to visual errors and that derivational errors were due to a deficit in analysis of bound morphemes. Semantic errors were believed to arise either in the semantic system itself or in the phonological output system. Comparably, Morton and Patterson's (1980) model included impairments in grapheme to phoneme conversion and damage to the connections from the visual input to the output logogens. However, a possible criticism of such models is that they presume that the symptoms of deep dyslexia arise from numerous deficits. If these deficits are caused by damage to specific components of the reading system then arguably they are ultimately caused by lesions to different brain sites. If this suggestion is correct then patients should exist who exhibit some but not all of the 'standard' deficits in various combinations.

By and large most deep dyslexics show all the symptoms, although there are exceptions who exhibit 'some but not all standard symptoms' (e.g. see Warrington et al., 1970).

1.4.1 The NICE model

A general assumption in the literature appears to be that abstract words can not be read aloud because they are not completely understood. According to Crutch and Warrington (2007) most forms of spoken and written language processing require the integrated comprehension or production of both abstract and concrete words. Paivio et al. (1968) referred to concrete words as the extent to which a word's referent *"can be experienced by the senses"*. Crutch and Warrington (2007) suggest that concrete words are those which refer to items which can be experienced directly through their sensory properties, whereas abstract words refer to indirect, intangible concepts or affective states; however, there is no generally accepted criteria for distinguishing between abstract and concrete terms.

Do deep dyslexics understand the words that they cannot read? Newton and Barry (1997) discuss the relative lack of research into this question and suggested that this may be due to the difficulties of using comprehension tests with dysphasic patients. Most tests can only be applied to concrete words and studies on the comprehension of abstract words reflect the intrinsic difficulties of such tests with dysphasic patients, who may find it difficult, for example, to produce definitions. Many individuals with neuropsychological deficits (like healthy individuals) exhibit a processing advantage for concrete words in tasks such as word comprehension or reading (e.g. Marshall & Newcombe, 1973; Katz & Goodglass, 1990) (see also Strain, Patterson & Seidenberg, 1995). However, Klein et al. (1994) compared the comprehension of concrete and abstract words using a synonym judgement task with their deep dyslexic patient (R.L.). Although he exhibited the typical pattern of deep dyslexia, his comprehension of both concrete and abstract words in the synonym judgement tasks was good, thus the patient showed no impairment in the comprehension of abstract words.

Newton and Barry (1997) found that their deep dyslexic patient (L.W.) showed a substantial concreteness effect in oral reading, but no corresponding effect in lexical decision task or comprehension tests. According to Newton and Barry (1997), despite the three claimed sub-types of deep dyslexia (i.e. input, central and output), most accounts of the concreteness effect in deep dyslexia have leaned towards the assumption that some sort of semantic deficit exists. Newton and Barry (1997) suggest that the generally accepted proposal is that abstract words cannot be read aloud because they are not properly comprehended. They argued that L.W's impairment is at the level of lexicalisation, that is, where a semantic representation is used to select an appropriate word which then makes its phonological form available. This is similar to Morton and Patterson's (1980) proposal of a problem in the transmission from a semantic code to the output logogens.

Newton and Barry (1997) found that concreteness had much less of an effect on L.W's printed word recognition than on her reading aloud. As a result, they proposed that deep dyslexia is more informative of word production processes than of the normal reading process. Newton and Barry argued that the lexicalisation process is 'normally' sensitive to concreteness. They proposed that a concreteness effect is a feature of normal output from the semantic system and suggested that concrete concepts are easier (than abstract concepts) to lexicalise precisely as words in speech. This account assumes that L.W (and probably the majority of other deep dyslexics of the 'output' type) has qualitatively 'normal' semantic representations but that in oral reading these operate in 'isolation'. Newton and Barry argued that highly concrete concepts (with a high concreteness value) have a high degree of specificity in the lexical system; the semantic activation is strong and specific, producing only a small degree of spreading activation to only a few related concepts.

Thus the corresponding entry in the output lexicon will be readily activated and only a few entries of other words will be activated. Consequently, highly concrete words are very likely to be read correctly. Conversely, the semantic representations of moderately concrete words are less strong and specific, having a fair number of synonyms or related concepts to 'choose' from. There will therefore be more spreading activation to a larger number of concepts than with highly concrete items. Due to the high number of 'candidate' responses the selection process is prone to errors, especially semantic errors, in deep dyslexics who are reading 'by meaning only'. Newton and Barry (1997) refer to their model as the NICE model ('Normal Isolated Centrally Expressed' semantics).

Newton and Barry (1997) claim that the NICE model is supported by the finding that semantic errors are usually made to words whose concreteness values (see Quinlan, 1992) are intermediate between those read correctly and those to which the patient makes no response. This tendency has been demonstrated in patients G.R (Barry & Richardson, 1988), K.F. (Shallice & Warrington, 1975) and B.L (Nolan & Caramazza, 1982). According to the NICE model, the semantic representations of highly abstract concepts have little specificity in the lexicalisation process (especially when activated by a single word, isolated from any context). There will therefore be a great deal of spreading activation to many, perhaps more loosely related, concepts. The spread of such words is larger but the degree of activation for each candidate item will be far less than for any concrete word. Newton and Barry (1997) argue that this is why deep dyslexics find it nearly impossible to access a unique entry in the phonological output lexicon. In order to offer a complete explanation of the concreteness effect in the oral reading of deep dyslexics, Newton and Barry suggested a generally increased 'threshold' for spoken word production so that a dysphasic deep dyslexic patient requires more activation to produce any word than does a neurologically normal individual. Accordingly they argue that the 'pathological threshold' will be higher than the normal strength of activation of most highly abstract semantic representations compared to concrete words. This accounts for the typical pattern of omissions to abstract words rather than semantic errors. Thus, the NICE model posits an account of oral reading in deep dyslexia that concerns the central process by which semantic representations are assumed to address the phonological representation of words for production (i.e. lexicalisation). The NICE model predicts that deep dyslexics who read via the semantically mediated route, that is by using meaning alone, the differential nature of 'qualitatively normal but isolated semantics' and the pathologically increased 'dysphasic threshold' results in substantial concreteness effects whenever spoken output is required. However, differential thresholds will not affect word recognition or comprehension, which may remain virtually intact.

1.4.2 The summation hypothesis

The production of semantic errors in lexical processing tasks would seem, at first, to constitute evidence for damage to the semantic system. However, it has been shown that not all types of semantic errors can be attributed to such a cause (Miceli, Capasso & Caramazza, 1994). According to Hillis et al. (1990), there is strong evidence that whereas in some cases semantic errors can reasonably be assumed to result from damage to the lexical-semantic route, in other cases, they would seem to result from damage to the sub-lexical component of the reading system (Hillis & Caramaza, 1991). If it is assumed that a single semantic component mediates performance in all lexical tasks, then it would be expected that damage to the semantic system should lead to the production of semantic errors in all lexical tasks such as reading, writing and spelling. However, when semantic errors arise from selective damage to the phonological or orthographic lexicons, then they should only be present in the affected modality, for example, only in spelling. Hillis et al. (1990) confirmed these expectations with their patient K.E. who made semantic errors in roughly equal proportions in reading, writing, naming and comprehension tasks. By contrast, Caramazza and Hillis (1990) found that patients H.W and R.G.B only made semantic errors in oral production tasks, while Caramazza and Hillis's (1991) patient S.J.D made semantic errors only in written spelling tasks. These contrasting patterns of performance were interpreted as indicating damage to the semantic system in patient K.E, damage to the phonological output lexicon in patients H.W. and R.G.B, and damage to the orthographic output lexicon in patient S.J.D. Thus Caramazza and Hillis (1990) argue that the production of semantic errors in some lexical processing tasks does not necessarily imply damage to the semantic component itself. However, Miceli, Capasso & Caramazza (1994) suggested that the absence of semantic errors in one or more lexical processing tasks in a patient who produces semantic errors in other lexical tasks does not mean that the damage responsible for the semantic errors in the latter tasks cannot concern the lexical-semantic component. This claim is based on the assumption that in some tasks the activation of non-semantic components receives input from other processing components without the use of the semantic system. Miceli et al. (1994) argued that these non-semantic inputs to the modality specific lexicons could limit the production of semantic errors even if the semantic components were damaged.

A different explanation of semantic errors during naming and their absence when reading was proposed by Hillis and Caramazza (1991) in their 'summation hypothesis'. The summation hypothesis constitutes one of a class of theories which have in common the idea that a patient's output is jointly determined by the operation of one or more routes (see Patterson & Marcel, 1977; Newcombe & Marshall, 1980; Southwood & Chatterjee, 1999, 2000, 2001). However, the summation hypothesis differs from a similar premise suggested by Newcombe and Marshall (1980) to account for the production of semantic errors. Newcombe and Marshall argued that the semantic procedure for activating lexical phonological representations is ‘intrinsically noisy’, leading to semantic errors unless the response is constrained by phonological information provided by the sub-lexical orthography to phonology conversion procedure. However, Miceli et al. (1994) pointed out that one obvious prediction of this model was that ‘normal’ subjects should produce a significant number of semantic errors in tasks such as word-picture matching and picture naming, in which the response is produced solely on the basis of information activated in the semantic system. Since this pattern of performance is not observed, Miceli et al. preferred the summation hypothesis assuming that the semantic procedure, unless damaged or otherwise stressed, functions flawlessly.

The summation hypothesis suggests a relationship between lexical and non-lexical procedures in reading and spelling. It proposes that sub-lexical (grapheme-phoneme) and semantic procedures function jointly to activate a phonological entry. Hillis and Caramazza (1991) argued that semantic errors cannot occur with an intact grapheme-phoneme conversion route. This undamaged mechanism effectively ‘blocks’ the production of semantic errors because it provides additional information that facilitates selection of the appropriate phonological entry. The hypothesis argues for summation at the phonological output lexicon and entails the assumption that non-semantic information would only influence phonological lexical access when semantic information is inadequate. Therefore, the summation hypothesis assumes that errors occur at the level of the phonological output lexicon itself, rather than in gaining entry to the lexicon. Thus patients with partial damage to one or both of the lexical and sub-lexical routes may still be able to achieve relatively proficient performance at reading, even with irregular words. For example, if a patient is trying to read the irregular word ‘bear’, but the semantic specification for this words contains little more than ‘big animal’, the semantic system will activate a number of candidates with these properties including bear, horse, cow and so forth. However, the sub-lexical grapheme-phoneme conversion system will also activate, to differing degrees, a set of lexical candidates which are phonologically similar to the target (e.g. beer, bare, bar etc.) By combining these two sources of information, the patient should be able to arrive at the correct pronunciation of 'bear', even though neither route may be able to 'select' the correct entry by itself (Ward, Stott & Parkin, 2000). In short, semantic errors are considered to arise if the response from the semantic-lexical route is insufficiently constrained by information form the sub-lexical route.

In support of the summation hypothesis, Hillis and Caramazza (1991) reported the performance of a neurologically impaired patient, J.J, whose oral reading of words exceeded his naming and comprehension performance for the same words. He could correctly read aloud all regularly spelled words, but could only read irregular words for which he demonstrated some understanding. This is consistent with the notion that even very limited semantic knowledge can be sufficient to prevent the sub-lexical route operating in isolation, because otherwise J.J would have shown regularisation errors. Hillis and Caramazza (1991) explained J.J's performance by suggesting that he had a central semantic impairment, combined with intact sub-lexical phonological recoding. The activation of an entry in his phonological output lexicon was assumed to result from a summing of information derived from sub-lexical phonological recoding rules and the output of semantic processing. Therefore, whether an entry in the phonological output lexicon was correctly selected or not seemed to depend upon the relative degree of activation that it received from these two sources.

Despite being able to read single irregular words for which he demonstrated some understanding, the pattern of performance shown by patient J.J of Hillis and Caramazza

(1991) was initially presented as 'evidence' in support of a 'direct' non-semantic lexical route from input to output lexicons. J.J was found to read aloud narrative material fluently with very few errors, despite having impaired comprehension of what he was reading; he also correctly spelled words that he did not fully understand. However, Hillis and Caramazza (1991) subsequently revealed that after detailed analysis of J.J's reading and comprehension two specific results did not follow directly from the 'direct route' hypothesis. J.J. showed relatively preserved naming but his comprehension was restricted to the category of animals.

In contrast, another patient P.S. showed the opposite pattern of performance when the same stimuli as used with J.J. were presented. The dissociation between categories in J.J's naming and comprehension of animal words highlighted the selective impairment within the semantic system. However, the authors found one major problem with this proposal in that J.J's performance was not equivalent across all tasks assumed to involve the semantic system. For example, he demonstrated better results in oral reading compared to oral naming, such that all categories of words were correct in oral reading and in spelling to dictation despite persisting category-specific oral and written naming deficits. Hillis and Caramazza (1991) argued that the results were problematic because the category-specific effects shown by J.J arise at a specific level of processing; these should then appear in all tasks that involve that particular processing component and should not appear in tasks that do not. They suggested that in cases of damage to the semantic system, tasks that normally require the impaired component (reading, spelling, naming and comprehension) all require accurate semantic processing for the correct response to be selected.

Hillis and Caramazza (1991) argued that the data reported on J.J was consistent with the hypothesis of selective impairment of the semantic system, only by postulating that oral reading could still be successful without having access to semantic information. They pointed to at least two types of processing procedures for reading without having access to semantics: first, by the application of sub-lexical conversion procedures (Coltheart, 1978). Second, the application of procedures for accessing entries in the phonological output lexicon directly from the orthographic input lexicon (a non-semantic route). Hillis and Caramazza (1991) stressed that in order to maintain the hypothesis that J.J's semantic errors resulted from damage to the semantic system, it would have to be assumed that one or both of the non-semantic procedures for pronunciation (sub-lexical conversion processes or non-semantic whole word reading) could support J.J's oral reading performance. In order to explain J.J's level of accuracy in writing to dictation, they suggested that sub-lexical conversion procedures and non-semantic lexical access to orthographic representations were intact.

Hillis and Caramazza (1991) suggested an account of J.J's observed results that did not require the assumption of direct connections between the input and output lexicons. Their theory consisted of a set of related hypotheses about the organisation and processing structure of the reading and spelling systems. The first premise concerned the nature of the representations that were computed in these two tasks, in particular reading. They proposed (as a central assumption) that semantic representations consist of functional, perceptual and other descriptive features of the item. For example, the semantic representation of 'car' may consist of meaningful features such as motor, wheels, it moves, on the road and so forth. They also assumed that each semantic feature activates, to some degree, all the representations in the output lexicon to items whose meaning also contains that particular attribute. For example, in the context of reading, the semantic element of *'motor'* would partly activate phonological representations of 'motorbike', 'train', 'aeroplane', while *'wheels'* would activate 'tyres', 'air', 'rubber' and so on. However, Caramazza and Hillis (1990) suggested that if, as a consequence of brain damage, normal processing of a particular lexical representation were impeded, then other more available and meaningfully related lexical entries could receive sufficient activation to reach the desired threshold for output. Under normal conditions semantic representations activate in parallel all items that are semantically related (lexical versions) to the target word. This leads to the production of the correct response, which is the lexical item with the greatest degree of activation. Under conditions of brain damage, no lexical representations may receive enough stimulation, resulting in the default production of the most readily available representation, which is usually the most frequent item from the set of activated responses.

The second major idea proposed by Hillis and Caramazza (1991) was that lexical phonological representations could be activated not only by semantic information, but also by sub-lexical information that is generated by orthography to phonology conversion procedures. More specifically, the hypothesis suggested that the string of phonemes produced by the orthography to phonology conversion procedures from the input orthographic representations activates entries in the phonological output lexicon to an extent proportional to their degree of phonological similarity to the input string. Hillis and Caramazza (1991) suggested that they did not wish to argue that the phoneme string generated by the orthography to phonology conversion procedures can only be pronounced via reference to the phonological output lexicon. They proposed that the orthography to phonology conversion procedures can also be used to activate phonological representations for output.

Saffran (1985) suggested similarly that phonologically plausible errors from either words or non-words should result whenever semantic information is insufficient to activate the target item. However, this proposal alone cannot account for fluent and accurate reading without comprehension as was found in patient W.L.P of Schwartz et al. (1980). In order to explain the absence of reading errors, despite very impaired comprehension, in this case Hillis & Caramazza (1991) proposed that input from the sub-lexical conversion mechanism summates with partial information from the semantic system to select correct entries in the phonological output lexicon. This has since become known as the '*summation hypothesis*'. It assumes that the output of the lexical-semantic route summates with that from the sub-lexical route such that production of a particular response by the patient is constrained by the phonology of the target word. Even limited phonological information may be sufficient to restrict the choice of response to the correct alternative.

Hillis and Caramazza's (1991) account of accurate reading with impaired semantics has several suppositions. Firstly, lexical phonological representations in the output lexicon are activated in parallel. Secondly, activation comes from two sources, the semantic system and the sub-lexical conversion system. Thirdly, the level of activation of each entry depends on both the degree of similarity to the target semantic representation and the degree of this similarity to the phonological strings assembled by the orthography to phonology procedures. Finally, selection of a particular lexical representation for production depends on the total activation from the two sources of input and on the threshold of activation for that entry. All of these assumptions underlie the proposal that accurate oral reading results from the summation of (even partial) information from sub-lexical procedures and (even partial) semantic information, which together activate corresponding entries in the phonological output lexicon to threshold levels (Hillis & Caramazza, 1991).

According to Miceli et al. (1994) the summation hypothesis allows specific predictions about the form that damage to the cognitive system has to take in order for it to result in the production of semantic errors in tasks such as reading aloud, writing to dictation and repetition. These all involve the interaction between semantic and sub-lexical mechanism in lexical production. Given that lexical forms for output receive activation from both the semantic component and from sub-lexical procedures, semantic errors in a specific modality (e.g. reading, writing and repetition) cannot be produced unless, in addition to damage to the semantic system, the corresponding sub-lexical procedure is also damaged. This prediction is consistent with observations in the neuropsychological literature. For example, Coltheart (1980) found that patients who produce semantic errors in reading aloud have been shown to have severe difficulty in reading pseudohomophones i.e. non-words that sound like real words when read aloud, for example, '*seet*' or '*taybul*'. Furthermore, patients who produce semantic errors in writing to dictation (semantic paragraphias) have also been shown to have difficulties in spelling pseudo-words.

1.4.3 The simultaneous activation hypothesis

Southwood and Chatterjee (1999) argued that the concept of supportive mechanisms during oral reading has the benefit of accounting for differences in error patterns across different lexical tasks and allows alternative sources to compensate for an impaired mechanism. However, this type of model can account for dissociations between naming and oral reading only when the other non-semantic mechanisms are intact. For example, the summation hypothesis (Hillis & Caramazza, 1991) cannot account for dissociation in semantic errors between oral reading and picture naming if the grapheme-phoneme conversion route is totally impaired. If the damaged sub-lexical route accompanied an impaired lexical semantic system then semantic errors cannot be blocked effectively under those circumstances. Southwood and Chatterjee (1999) predict that semantic errors should occur with the same frequency in both oral reading and picture naming (see also Beaton & Davies, 2007). They suggested that another problem with the summation hypothesis is that it predicts a regularity effect. If the grapheme-phoneme conversion procedure activates a phonological entry, then the hypothesis suggests that the 'least summation' occurs for irregular words. However, Southwood and Chatterjee argued that not all patients with deep dyslexia demonstrate a regularity effect. Thus a modification of such models is necessary to account for possible dissociations in error performance when several reading mechanisms are impaired.

In order to account for the inability of current models to clarify these dissociations Southwood and Chatterjee (1999; 2001) proposed two hypotheses that were related to the organisation and processing structure of the reading system. Their first assertion involved the 'simultaneous activation' of reading mechanisms, and the second premise related to weightings given to each mechanism. Southwood and Chatterjee (1999) agreed with other standard models that there was a triple route architecture underlying the pronunciation of words, with three functionally and conceptually independent mechanisms available for word reading, namely, the semantic mechanism, the direct orthographic input to phonological output route and sub-lexical grapheme-phoneme procedures. However, they proposed that a letter string simultaneously activates all three routes; information from the three mechanisms converges and amalgamates at the phonological output lexicon to constrain activation of an appropriate phonological entry. Thus according to their hypothesis sub-lexical information is said to combine with semantic and direct non-semantic information to select the correct phonological entry. The significant information from each mechanism then dictates its influence on the phonological selection, where the system that has the most salient information has the strongest influence on the output chosen. This principle became known as the *simultaneous activation hypothesis* of reading (Southwood and Chatterjee, 1999). It could be argued that this theory has clear similarities to the summation hypothesis. Each argues that the output of the lexical-semantic route comes together with that from the sub-lexical route such that production of a particular response by the patient is constrained by the phonology of the target word. Even limited phonological information may be sufficient to restrict the choice of response to the correct alternative.

Southwood & Chatterjee's (1999) second hypothesis concerned the impact that each of the reading mechanisms has on phonological selection with changes in tasks demands and the nature of the stimuli. As suggested, the system with the most significant information will have the greatest influence or weighting, which in most cases is the semantic route. However, additional information that is supplied by the direct and sub-lexical route further constrains the selection process. For example, when reading irregular words the weightings of the semantic and direct route may be stronger than those of the sub-lexical route. Southwood & Chatterjee (1999) argued that brain damage may alter the weightings of these different reading mechanisms and that the changes in weights for each mechanism may explain dissociations in error patterns across different kinds of words in deep dyslexics. Normal readers on the other hand are able to switch between reliance on lexical and sub-lexical reading mechanisms, consistent with an alternative of weightings based on the nature of the stimuli and task demands (see Baulch & Besner, 1991; Monsell, Patterson, Graham, Hughes & Milroy).

Southwood and Chatterjee (1999) reported the findings of L.C. in an attempt to test the adequacy of serial models of reading and to examine the relative influence of all three reading routes on the phonological output lexicon. L.C. was deep dyslexic and was classified as having anomic aphasia. After initial evaluation of her reading it was argued that she had impaired access to the phonological output lexicon, an impaired grapheme-phoneme conversion route and that her semantic errors in reading suggested that she read via an impoverished semantic mechanism. However, Southwood and Chatterjee (1999) argued that a serial model of oral reading could not explain the error differences in reading, picture naming, spontaneous speech and repetition. For example, L.C. produced neologisms in reading but not in speech or repetition. To account for these different error patterns it was proposed that the semantic route, the direct route and the grapheme-phoneme conversion route are all activated simultaneously during reading, and that the activation from each of these converge at the phonological output lexicon to constrain phonological selection.

1.4.4 The failure of inhibition hypothesis

Buchanan Hildebrandt and MacKinnon (1994, 1999) suggested that the deficit in deep dyslexia is not related to the integrity of the semantic system, as postulated by dual-route models, but rather with explicitly accessing phonological representations in the output lexicon (when the phonological representation is accessed via print). Buchanan et al. (1999) and more recently Buchanan, McEwen, Westbury and Libben (2003) proposed that selection impairment in the phonological output lexicon alone accounted for the various types of reading errors observed in deep dyslexia. According to this formulation, errors during reading evolve from a failure of inhibition caused by slowed or reduced inhibitory connections or 'spuriously' activated candidate representations. The failure of inhibition view suggests intact processing via the orthographic and phonological reading routes as well as normal activation in the semantic system. Through the spread of activation, neighbouring semantic representations are excited and their corresponding phonological representation subsequently activated in the phonological output lexicon. Neighbourhood representations can be defined in terms of orthography, semantics or phonology. For example, the neighbourhood for '*rose*' defined in terms of semantic features may include '*flower*' or '*red*'; in terms of phonological features '*hose*' or '*dose*' might be activated. The failure of inhibition hypothesis holds that semantic errors occur because deep dyslexics are unable to correctly determine the most highly activated candidate representations for selection in output, that is, responses are not pruned through inhibition. The reduced inhibitionary connections results in decreased sensitivity to the activation levels of semantic neighbours. This reduced sensitivity increases the likelihood that neighbours are incorrectly selected and therefore causes semantic and phonological errors in reading.

Buchanan et al. (1999) argued that the selection impairment view not only provides an explanation for the occurrence of semantic errors in deep dyslexia but can also accommodate the fact that these patients are unable to read non-words in that non-words provide no semantic lexical activation to 'boost' activation levels of phonological representations. Buchanan, Kiss and Burgess's (2000) finding that deep dyslexics read pseudohomophones better than orthographically controlled non-words is consistent with this view. The finding implies that the semantic content available through the word-like phonological information in the pseudohomophones can act (presumably through feedback to semantics and then feed forward to phonology) to constrain the response selection process in comparison to orthographically controlled non-word equivalents that provide no semantic lexical activation.

Phonological input during oral reading, for example, by supplying the initial phoneme (Buchanan et al., 2000; Katz & Lanzoni, 1997) or by priming (Colangelo et al., 2003), has been shown to provide strong facilitatory effects in oral reading for some deep dyslexics. The findings of such studies propose several testable hypotheses regarding deep dyslexics' performance. If the semantic system is intact in deep dyslexia, then patients should perform normally in a standard word association task when they are presented with a spoken cue and asked to respond with the first word that comes to mind. However, when that presentation is visual (that is when patients are asked to *read* a cue and say the first word that comes to mind) their phonological output system cannot benefit from the initial phonological codes available through auditory presentation. Thus, deep dyslexic performance on word association should be more vulnerable to the effects of the selection impairment in the phonological output system when the target is presented visually than when the target is presented auditorily.

Other theories that posit a selectional deficit in deep dyslexia include the ‘random noise’ account of Hildebrandt and Sokol (1993), which suggests that interference creates ‘spurious’ potential candidate representations, and the rapid decay hypothesis of Martin et al. (1994) which holds that the activation of appropriate representations decays too quickly to support production. Both theories accommodate the host of error types found in aphasics without resorting to a ‘multiple loci of damage’ account (e.g. Morton & Patterson 1980; Coltheart, 1980).

1.5 Deep dyslexia across languages

Funnell (2000) suggested that the study of the breakdown of reading alphabetic scripts in languages other than English and in languages with non-alphabetic scripts such as Chinese and Japanese has considerably broadened our understanding of the role of lexical and sub-lexical processes involved in reading. Funnell (2000) argued "*the study of acquired reading disorders across languages is an important area of research that regrettably cannot be done justice to*" (p.3). Yet little research across different orthographies has been reported in the literature on deep dyslexia.

One of the earliest studies of reading problems in different languages appears to have been that of Stevenson, Stigler, Lucker, Lee, Hsu and Kitamura (1982), who devised reading tests in Chinese, Japanese and English. Contrary to the general view that reading difficulties were not found in readers of non-alphabetical languages, Stevenson et al. found that a proportion of Chinese and Japanese children also experienced severe problems. Yin and Butterworth (1992) argued that because Chinese script is non-alphabetic, it is widely assumed that characters contain no sub-lexical information as to their pronunciation; however, this is not the case. Most Chinese characters, including the vast majority of common characters, contain a '*phonetic radical*' which can indicate how the character is to be pronounced. A phonetic radical, in isolation, is like a normal character that stands for a word or morpheme (Sampson, 1985). Yin and Butterworth (1992) suggested that although this way of phonological encoding in Chinese language is very different from alphabetic scripts it is nevertheless possible that a sub-lexical route to phonology is available to 'normal' Chinese which makes use of clues from phonetic radicals. It should therefore be possible to find different types of dyslexia in this language. Yin and Butterworth (1992) tested this hypothesis with 11 brain injured patients who were all native speakers of Mandarin Chinese and found cases of surface and of deep dyslexia in Chinese.

Deep dyslexia has also been found in Japanese (e.g. Hayashi, Ulatowska & Sasanuma, 1985; Yamada, 1995). The Japanese writing system consists of two qualitatively different scripts: logographic, morphographic Kanji, derived from Chinese characters, and two forms of syllabic Kana, Hiragana and Katakana which are derived from Kanji characters (Wydell et al., 1993). Both forms of Kana have an almost perfect one-to-one relationship between character and pronunciation, it is a transparent, (shallow) orthography. In contrast, the relationship between character and pronunciation in Kanji is very opaque (a deep orthography).

1.6 The orthographic depth hypothesis

The orthographic depth hypothesis (Feldman & Turvey, 1983; Katz & Frost, 1992; Lukatela & Turvey, 1998) proposes that languages that differ in their orthographic depth are read using lexical and sub-lexical strategies to differing degrees. The hypothesis states that shallow orthographies are more easily able to support a phonological word recognition process. Italian and Spanish, for example, are composed almost entirely of regular words that can be pronounced phonically, so that in principle, a Spanish or Italian reader could read text aloud without establishing a lexical system. In contrast, deep orthographies encourage a reader to process printed words by referring to their morphology via the printed word's visual orthographic structure (Katz and Frost, 1992). A strong version of the orthographic depth hypothesis (ODH) would propose that an orthographically shallow (transparent) language is always read using only the sub-lexical route (Turvey et al., 1984) as this will provide a correct pronunciation for any word or non-word. Since there is no need for a lexical route, no such route develops (Bridgeman, 1987). If this hypothesis were true, then it should not be possible to find an individual who can read or write words in a shallow orthography but not non-words since according to this hypothesis both words and non-words are read using the same process. It should therefore not be possible to observe acquired phonological or deep dyslexia in an orthographically shallow language. However, cases of acquired phonological dyslexia have been reported for Italian by DeBastiani, Barry and Carreras (1988) while deep dyslexia (Sartori, Bruno, Serena & Bardin, 1984; Valiani, Spitaleri & Fasanaro, 1988), and deep dysgraphia (Cappa, Miozzo, Monastero, Aboutalebi, 1998), have been reported in Italian and Spanish (Ruiz, Ansaldo & Lecours, 1994; Ferreres & Miravalles, 1995; Cuetos, Valle-Arroyo & Suarez, 1996; Basso & Paulin, 2003; Davies & Cuetos, 2005). These findings provide evidence against any strong version of the ODH (unless it is argued that a lexical route develops after the onset of illness).

Further evidence against the view that readers of orthographically shallow languages fail to develop a lexical processing route comes from demonstrations in such languages of lexical priming effects on non-word spelling (Barry, 1992) and pronunciation (Job, Peresotti & Cusinato, 1998) and on lexical decision tasks (Sebastian-Gallès, 1991). While a strong version of the orthographic depth hypothesis is thus not tenable (see also Besner & Smith, 1992), it is possible that children learning to read languages that differ in orthographic depth tend to adopt lexical (whole word) and sub-lexical strategies to differing extents. This weaker version of the orthographic depth hypothesis has been investigated in a series of studies by Wimmer and his colleagues. Wimmer and Goswami (1994) compared English children learning to read English with Austrian children learning to read German. The children were presented with real words that were numbers (e.g. *five, seven, fünf, sieben*), and with non-words derived from these real words in such a way that the onset-rime segments were preserved. The children were also presented with the numerals (5, 7, and so on) corresponding to the written words. The results showed that whereas reading time and accuracy were very similar for the English and German words and numerals, many more errors were made by the English children attempting to read non-words derived from English than by the German children reading non-words derived from German. There were also differences between the two languages in the nature of the errors that were made. Similarly, Ognjenovic et al. (1983) noted different error patterns made by beginning readers of English and Serbo-Croatian. All these findings are consistent with the view that children learn to read deep and shallow languages using different strategies, the strategy for a shallow orthography being more analytic or phonically based than for a deep orthography.

In a partial replication of the Wimmer and Goswami (1994) study, Beaton et al. (2001) studied English-Welsh bilingual and monolingual English speaking children. The results of Wimmer and Goswami (1994) with regard to non-word reading were confirmed. More recently, Spencer & Hanley (2003) examined reading in English and Welsh speaking monolingual children who were "*in their second year of formal reading instruction*". Spencer and Hanley included among their stimuli the non-word set used by Wimmer and Goswami (1994). Welsh children read these items (and non-words derived from Welsh) more accurately than the English children. Welsh children also read real words more accurately than did English children. This advantage for Welsh children was maintained one year later and attributed by Spencer and Hanley to the greater orthographic transparency of Welsh compared to English. On the basis of these findings and error analyses, Spencer and Hanley concluded that Welsh children "*are much more likely to use-letter-sound associations to read aloud words with which they are not familiar*" (p.14). Consistent with the view that Welsh-speaking readers use a phonological recoding (sub-lexical) strategy, Ellis and Hooper (2001) reported that they show stronger length effects than readers of English (see Ziegler et al. (2001) for comparable findings in German versus English).

Discussions concerning the relative frequency of occurrence of semantic errors of reading in deep and shallow orthographies have been very largely based upon comparisons between monolingual brain damaged readers of these orthographies. This inevitably confounds differences between patients in the severity and nature of their disorder as well as by differences in test protocols and time of testing relative to the onset of brain injury. It has been argued that deep dyslexia, characterised by the presence of semantic errors, and acquired phonological dyslexia, in which semantic errors are absent, lie on a single continuum (Laine et al., 1990; Glosser & Friedman, 1990; Friedman, 1996). In both conditions there is an inability to read non-words; the difference lies in the presence versus the absence of semantic errors. If, in some but not all cases (e.g. patient GR, the "prime" deep dyslexic discussed by Barry, 1996) deep dyslexia "resolves" into phonological dyslexia, as suggested by Friedman and others (e.g. Klein, Behrmann & Doctor, 1994; Southwood & Chatterjee, 2001; Nolan, Volpe & Burton, 1997), then any apparent difference in frequency of semantic errors between orthographies might reflect different stages in the process of recovery from initial deep dyslexia.

1.7 Summary of review

Historically deep dyslexia may be considered the most interesting of the acquired dyslexias. It is observed in brain damaged patients, especially Broca's aphasics with large lesions of the left hemisphere. Many features or symptoms in phonological dyslexia are found in patients with deep dyslexia. These include visual and morphological (derivational) errors, function word substitutions and an almost complete inability to derive phonology from print (i.e. read non-words or judge whether words rhyme); in addition, reading accuracy is affected by imageability or concreteness, and writing is usually impaired along with auditory verbal short term memory. However, the cardinal symptom of deep dyslexia is the presence of semantic errors and this is the differential diagnostic between phonological and deep dyslexia. The continuum theory, based on the analogy model of word recognition (Glosser & Friedman, 1990; Friedman 1993), sees deep dyslexia as a 'special case' of phonological dyslexia.

In order to explain the principal symptoms of deep dyslexia, different theories have been proposed. Most of these have been formulated within the general framework of dual-route theory. Marshall and Newcombe (1973) suggested that a deficit of the sub-lexical route alone may give rise to semantic errors but most theories of deep dyslexia postulate some impairment of, or access to, the semantic system as well as impairment or damage to the sub-lexical phonological conversion route. The summation hypothesis (Hillis & Caramazza, 1990) and the simultaneous activation hypothesis (Southwood & Chaterjee), in particular, both emphasise the integration of output from the lexical-semantic and the sub-lexical route in producing a patient's response . Shallice and Warrington (1980) and Shallice (1988) proposed three different sub-varieties of deep dyslexia, named *input*, *central* and *output* forms of deep dyslexia. They argue that the three sub-types can be theoretically distinguished according to their presumed primary impairment at different levels of the semantically mediated route. A relatively recent approach is that of connectionism. One influential connectionist model (e.g. Seidenberg & McClelland, 1989; Plaut, 1999) rejects the idea of two different ways of reading letter strings while another (the dual route cascade model, Coltheart et al., 2001) implements a dual route approach.

The conventional view of deep dyslexia is that it results from a damaged left-hemisphere reading system that has lost the ability to read without reference to meaning (dual route models) (e.g. Morton & Patterson, 1980; Newcombe & Marshall, 1980; Patterson & Besner, 1984; Shallice & Warrington, 1980). An alternative explanation of deep dyslexia, proposed by Coltheart (1980) is that because of the atrophy of the left hemisphere, the preserved reading abilities of deep dyslexics reflect the use of a subsidiary right hemisphere reading system.

Chapter 2

Introduction to the present investigations

It is clear from the review that deep dyslexia manifests in different ways; not everyone shows all the "classic" symptoms. Nor is there universal agreement as to how particular symptoms arise or should be explained when they do occur. As mentioned in the review, there has been limited research conducted on deep dyslexia across different languages. Funnell (2000) argued that "*the study of acquired reading disorders across languages is an important area of research*" (p. 3). It is true that deep dyslexia has been reported for Japanese (e.g. Hayashi et al., 1985; Yamada, 1995), Chinese (Yin & Butterworth, 1992), Spanish (e.g. Ardilla, 1991) and Italian (Cossu et al., 1995) but by far the greatest amount of research has been carried out on English speaking patients. But does what we learn from English reflect a universal cognitive architecture of reading? What applies to reading in one language may not apply to another. Languages differ in the nature of the relationship between their spoken and written forms (some of the world's languages, indeed, are not represented in writing!). Some languages have a deep or opaque orthography while others have a more transparent orthography. It can not be automatically assumed that depth of orthography is irrelevant to the symptoms that are seen after brain injury. Investigation of acquired dyslexia in different orthographies is a fundamental step towards a better understanding of how written language is represented in the brain.

A limitation of existing research into deep dyslexia, then, is that it has concentrated almost exclusively on monolingual speakers (readers) of English. Yet English is thought to be spoken as a second or third language by more people than speak (and read) it as their only language. There is a pressing need to examine not only acquired dyslexia in different orthographies but also acquired dyslexia in bilingual (or multilingual) speakers. The first part of this thesis reports therefore a series of investigations of bilingual readers of two orthographies, one deep and one shallow, namely English and Welsh

The following chapter of this thesis **(Chapter 3)** reports the results of investigations conducted on three bilingual aphasic patients. Each patient had suffered from a left sided CVA from two to eight years post stroke. The tests attempt to characterise the acquired reading difficulties of the three patients and in particular examine whether deep dyslexia occurs in Welsh.

Semantic errors of oral reading by aphasic patients have been said to be comparatively rare in languages with a shallow (transparent) orthography (e.g. Spanish and Italian). Miceli et al. (1994) argued in relation to reading aloud and writing that transparent orthographies are relatively 'protected' from the production of semantic errors. In **Chapter 4** a comparison of the three bilingual patients' picture naming and reading ability is carried out; even if semantic errors are comparatively rare in reading, there is no reason to suppose that they should be infrequent in picture naming. The results of this chapter have been published and are based on Beaton, A.A. & Davies, N.W. (2007). Semantic errors in deep dyslexia: does orthographic depth matter? *Cognitive Neuropsychology*, 2007, 24 (3), 312-323.

With regard to bilingual aphasics it is of interest to ask whether the same psycholinguistic variables, such as, age of acquisition, frequency, imageability and length, influence picture naming and word reading in the same way for the patients' two languages. **Chapter 5** reports the results of multinomial logistic regression analyses conducted on the picture naming and reading scores obtained from the three participants in Chapter 4. Other questions (for example, what factors predict reading and naming accuracy in deep dyslexia? when do deep dyslexics make semantic errors? does cognate status affect responses in both languages?) are also examined in this section of the thesis.

The second part of this thesis examines phonological decoding ability in deep dyslexia. As discussed in the review, the majority of theories attribute the occurrence of semantic errors, the cardinal symptom of the disorder, to a lack of sub-lexical phonological processing ability. However, Katz and Lanzoni (1992) and Buchanan et al. (1994) claim that at least some deep dyslexic patients are sensitive to implicit phonological information. Given the centrality of arguments concerning impairment of phonological decoding ability to explanations of deep dyslexia, it was decided to examine further the claim that deep dyslexics have available to them some level of preserved sub-lexical phonological processing ability. Given the potential importance of this claim for theories of deep dyslexia, **Chapter 6** reports the results of experiments carried out to examine whether the current deep dyslexic patients have available to them some level of preserved sub-lexical phonological processing ability.

The results of the experiments reported in this thesis are summarised in **Chapter 7** and their implications discussed.

Chapter 3

3.0 A note concerning the Welsh Orthography

According to Brown (1976) orthographies such as English and Welsh have descended from the Roman alphabet and are therefore examples of alphabetic writing systems, which apply grapheme to phoneme conversion rules. All alphabetic orthographies can be classified according to the transparency of their letter to phoneme correspondence, a factor that has been referred to as orthographic depth (Liberman et al., 1980). English and Welsh share a relatively large number of letters (graphemes) and have almost the same sounds (phonemes). However, there are differences in the consistency of grapheme-phoneme rules between the two. In English, the mappings from graphemes to phonemes are inconsistent in that correspondences between graphemes and phonemes are not always one to one. For example 'c' can represent more than one phoneme. For example, it can be pronounced hard as in 'cat' or soft as in 'ceiling'. The result of this lack of one to one correspondence is that the English language contains both regular and irregular (exception) words e.g. *island, knight* and *debt*. English and French are therefore referred to as opaque (deep) orthographies. Conversely, Welsh and other languages such as Italian and Spanish are considered to have consistent grapheme to phoneme correspondences and are therefore referred to as transparent (shallow) languages.

There are 29 graphemes in the Welsh alphabet (see appendix 6). Some graphemes which are found in the English alphabet are omitted from the Welsh alphabet; these are the letters 'k', 'q', 'v', 'x' and 'z'. However, there are 8 additional graphemes in the Welsh alphabet – ('ch', 'dd', 'ff', 'ng', 'll', 'ph', 'rh' and 'th') (where 'll' is the only phoneme to which there is no English equivalent). These additional digraphs are explicitly taught as single units (e.g. 'ng' is taught as the sound /ng/, /n/ and /g/ are also taught separately). Apart from when they appear in the very rare exception words of 'dangos' (show) and 'Bangor', 'ng' is always pronounced as 'ng'. Barry (1992) pointed out that other features of the Welsh language which obscure the level of transparency include the vowels 'y', 'i' and 'w'. The vowel 'y' is pronounced differently depending on its position in a word. Evans and Thomas (1953) found that 'y' could be pronounced either as a long clear sound as in 'dyn' or as a short clear sound as in 'plentyn'. They suggested that as a general rule, the clear sound of 'y' occurs in the last syllable of a word and in monosyllables. However, stress patterns in Welsh words are much more consistent than they are in English (see Evans and Thomas, 1953).

There are seven vowels in the Welsh alphabet (a, e, i, o, u, w, y). The pronunciation of these may be short, long or medium resulting in approximately fifteen vowel phoneme units. Pronunciation of some vowels (especially 'i', 'u' and 'y') can vary (e.g. '*adeiladu*' (building), '*achosi*' (cause) and '*ty*' (house') all end in the sound 'e'. North Walians pronounce '*u*' like French 'u' or German 'ü' without rounding the lips, whereas South Walians pronounce '*u*' as 'I'. North and South Wales also have different dialects of Spoken Welsh (e.g. North Walian for '*out*' is '*allan*' whereas for a South Walian it is '*mas*'). However, no problems exist with written Welsh as the same correspondences are used throughout Wales. Spencer and Hanley (2003) argued that although the relationship between letters and phonemes is not always one to one in Welsh, there are context-sensitive rules (e.g. associated with the position of the letter in a word) that indicate with a high degree of accuracy how ambiguities are to be resolved. Consequently, it is clear that Welsh is a very much more transparent orthography than English. Spencer and Hanley (2003) proposed that one reason for this is that, unlike English, there is no tradition of retaining morphological information in a word's spelling at the expense of phonology. For example, Welsh has a rule-governed mutation system in which the first consonant of a word changes in different contexts without affecting its meaning. A second reason is that whereas English spelling has not been reformed for centuries (despite alterations in the ways that words are spoken) the current spellings of Welsh words were standardised in 1928 and again in 1977 when a number of irregular words were reformed. Furthermore, there is a Welsh Academy ('Academi Gymreig') that controls new words entering the language (including foreign words) and ensures that their spelling reflects Welsh grapheme-phoneme rules.

The geographical features of Wales have historically meant that some areas have been 'protected' more from the influence of the English language than others. Gwynedd and Ceredigion are two areas, on the North and West coast of Wales respectively, that are said to have the highest number of Welsh speakers according to the 1991 Census. Based on the 1991 report it was estimated that 72.1% of the population in Gwynedd, 59.1% of the population in Ceredigion and 54.8% in Carmarthenshire, spoke Welsh.

It could be argued that Welsh is used today for a wider variety of purposes than ever before. Several factors could account for this, including an increase since the 1950s in the use of Welsh as a medium of education, a diversification in the range of Welsh books published, recognition of the language as an official language in business and services (Welsh Language Act, 1993), plus the establishment of Welsh radio and television channels including, for example, BBC radio Cymru and the Welsh language television programmes S4C and S4C digital respectively.

3.1 Introduction

Reports of deep dyslexia/dysgraphia in shallow languages are relatively rare. According to Beaton and Davies (2007) this may be because semantic errors of reading occur infrequently in orthographically shallow languages and/or because they are, for what ever reason, reported relatively infrequently. Discussions concerning the relative frequency of occurrence of semantic errors of reading in deep and shallow orthographies have been largely based upon comparisons between monolingual brain-damaged readers of these orthographies.

Two well-known published papers on the relative frequency of semantic errors in Spanish and Italian are those by Ardila (1991) and Basso and Corno (1994) respectively. Ardila's data came from 41 monolingual Spanish speaking aphasics who were given tests of reading which included a list of 13 single words. Ardila reported that no semantic errors were made by any of the patients. Basso and Corno (1994) retrospectively examined the records of 502 brain-damaged Italian patients who were each given a reading test consisting of 10 words. The number of semantic errors was very low. It needs to be appreciated, however, that deep dyslexic patients do not make errors on every experimental trial. Consequently, 10-13 is far too low a number of trials with which to elicit a reasonable number of semantic paralexias. Furthermore, the implied comparison between the proportion of semantic errors of reading made by English speaking deep dyslexics and the number made by aphasic speakers of Italian or Spanish is somewhat misleading. This is because English deep dyslexics, studied intensively precisely *because* they were so diagnosed, principally on the basis of their semantic paralexias, are being compared with aphasic speakers of shallow languages who may very well not have been deep dyslexic at all. Indeed, Basso and Corno (1994) begin their discussion with the following statement: "*The small number of stimuli in our test precludes any possibility of making a diagnosis of deep dyslexia*" (p. 154).

There are, relatively few studies of acquired reading disorders in bilingual (biscriptal) readers (Paradis, 1994; Ratnavalli, Murthy, Nagaraja, Veerendrakumar, Jayaram, Jayakumar, 2000). The first report of a bilingual deep dyslexic person appears to be that of Byng et al. (1984); the patient was deep dyslexic in English while reading was said to be almost impossible in the (syllabic) Devanagari script. More recently, Béland and Mimouni (2001) tested an Arabic/French bilingual patient, ZT. Arabic script is of two kinds, one of which has been called shallow, the other deep. ZT was reported to be deep dyslexic in both French and (deep) Arabic but showed more semantic errors in French. Karanth (2002) reported on a bilingual English-Hindi speaking aphasic patient who showed the pattern of deep dyslexia in English but made no semantic errors in Hindi, described as having *"high gpc [grapheme-phoneme correspondence]"* and *"nearly always regular"* (p.144). Reading was said to be poorer overall in Hindi but no quantitative data are provided – perhaps there was insufficient opportunity for semantic errors to arise in Hindi. Raman and Weekes (2005) report the case of a bilingual Turkish-English reader who was deep dysphasic (that is, made semantic errors of repetition) but surface dyslexic in both languages (though given Turkish words to read some of his responses were semantic errors given in English).

The summation hypothesis (Caramazza & Hillis, 1990; Hillis & Caramazza, 1991; Miceli et al., 1999) (reviewed in chapter 1 of this thesis) offers an explanation of the apparent rarity of semantic errors of reading, and hence deep dyslexia, in shallow languages. The hypothesis suggests a relationship between lexical and non-lexical procedures in reading and spelling. It proposes that sub-lexical and semantic procedures function jointly to activate a phonological entry. Thus, the summation hypothesis suggests that semantic errors cannot occur in the presence of an intact grapheme-phoneme conversion route. This undamaged mechanism effectively 'blocks' the production of semantic errors because it provides additional information that facilitates selection of the appropriate phonological entry. The grapheme-phoneme conversion procedure, in effect, generates at least an approximation to the pronunciation of the word. Miceli et al. (1994) argued that in cases of deep dyslexia, if the production of semantic errors of reading involves damage to the semantic system together with an impaired sub-lexical conversion system, then the nature of the relationship between orthography and phonology may be crucial in determining the extent to which a deep dyslexic patient's responses are constrained by sub-lexical information about the target word. Therefore, in shallow languages it should not (according to the summation hypothesis) be possible to be deep dyslexic in a transparent orthography, as for example, Welsh, Italian, Turkish, German and Spanish, which have highly consistent grapheme-phoneme conversion rules. However, deep dyslexia has been reported in Spanish (see Ardila, 1991; Davies & Cuetos, 2005) and Italian (see Cossu et al., 1995).

The aim of the following investigation was to see whether deep dyslexia would occur in Welsh, another very highly regular orthography. In particular in English/Welsh bilinguals, there maybe a difference between the manifestation of reading deficits in the two languages, one of which is highly transparent (Welsh) and one highly opaque (English) (see orthographic depth hypothesis, Feldman & Turvey, 1983, discussed in Chapter 1).

3.2 Case histories

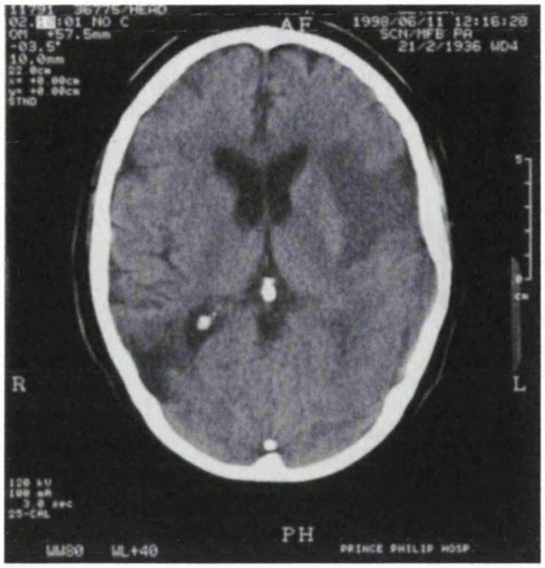
The opportunity arose to study three English/Welsh bilingual individuals all of whom had suffered a left sided CVA and experienced reading and writing difficulties. The patients were tested from 2 to 8 years after their strokes during which time their medical condition and cognitive status were stable. Although fluent speakers and readers of English and Welsh prior to their CVA, two of the patients (PD and JWT) considered English to be their dominant language while the third (MJ) considered Welsh to be her dominant language. Post-stroke all patients were dysphasic. Speech was effortful and dysfluent with some difficulty in articulation. Aphasia quotients as determined by the Western Aphasia Battery (Kertesz, 1982) are given below for each patient. There is no comparable aphasia battery for use with Welsh-speaking patients.

Patient **PD** was a bilingual, 48 year old right handed male. Prior to his injury he was a carpenter, who embarked on an apprenticeship after leaving school with GCSEs. He was diagnosed with epilepsy at an early age (after 3 months). He suffered a left CVA in August, 1997. His CT scan shortly after admission to hospital showed a large area of infarction in the territory of the left middle cerebral artery with no haemorrhage (Figure 6). Post stroke, PD was diagnosed with right sided hemiplegia and dysphasia. The Minnesota Test for Differential Diagnosis of Aphasia (shortened form) revealed severe difficulties in both receptive and expressive language skills mixed with a degree of verbal dyspraxia. At the time of testing PD's WAB aphasia quotient was 36.

Figure 6. **PD. (male, at the age 40 years).**

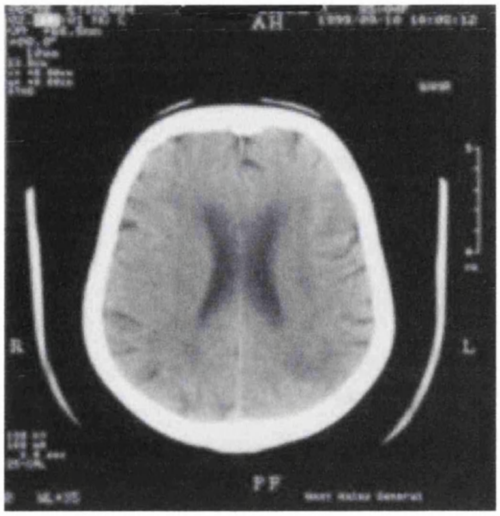
Patient **JWT** was a bilingual, 68 year old, right-handed male at the time of testing. Prior to his injury he was a laboratory technician in industry. He was taught through the medium of English and Welsh at Grammar school and technical college. His previous medical history indicated that he was hypertensive and suffered from a TIA in 1988. He suffered a left ischaemic CVA in June 1998. His CT scan (Figure 7) on the day of admission revealed a moderately sized area of infarction involving the left parietal region (left middle cerebral artery territory). According to the radiologist's report *"there was also another smaller area of infarction at the right posterior parietal region- the latter maybe on old one. No other focal endocranial lesions or midline shift."* Post stroke he suffered from right sided hemiplegia, and was characterised as a Broca's aphasic and as having dyspraxia. JWT's WAB aphasia quotient was 40. JWT died suddenly in July 2006.

Figure 7. **J.W.T. (male, at the age of 61 years).**



Patient **MJ** was a bilingual, 70 year old, right handed female at the time of testing. She was a graduate and a Welsh primary school teacher; after retiring she took up farming. MJ suffered a left CVA in September 1999. Her CT scan (Figure 8) two days after her stroke showed a small left parietal infarct. Post stroke she was diagnosed as a non insulin dependent diabetic and suffered from right sided paralysis. MJ was also diagnosed as dysphasic. Her WAB aphasia quotient was 64. MJ died in January, 2006.

Figure 8. **M.J. (female, at age 64 years).**



Each of the three brain injured patients were given a number of background assessments over a series of sessions from September 2004 to December 2006 in order to assess language abilities. These included the Western Aphasia Battery (Kertesz, 1982) and a number of sub-tests from PALPA (Psycholinguistic Assessments of Language Processing in Aphasia) (Kay et al., 1992).

The patients' scores on subtests of the Western Aphasia Battery (Kertesz, 1982) and on the National Adult Reading Test (Nelson, 1982, 1991) are shown in Table 1.

Table 1.Patient's scores on the Western Aphasia Battery and the National Adult Reading test

WAB sub-test	**P.D. scores**	**J.W.T scores**	**M.J. scores**
Spontaneous speech			
(a) Information content	5 (max = 10)	4 (max = 10)	8 (max = 10)
(b) Fluency	2 (max = 10)	2 (max = 10)	6 (max = 10)
Comprehension			
(a) Auditory verbal comprehension	51 (max = 60)	57 (max = 60)	54 (max = 60)
(b) Auditory word recognition	45 (max = 60)	55 (max = 60)	54 (max = 60)
(c) Sequential commands	11 (max = 80)	40 (max = 80)	50 (max = 80)
Repetition	17 (max =100)	24 (max =100)	44 (max =100)
Object naming	26 (max = 60)	27 (max = 60)	36 (max = 60)
(a) Word fluency	1 (max = 20)	5 (max = 20)	5 (max = 20)
(b) Sentence completion	2 (max = 10)	6 (max = 10)	8 (max = 10)
(c) Responsive speech	4 (max = 10)	5 (max = 10)	8 (max = 10)
Reading			
(a) Reading comprehension	14 (max = 40)	22 (max = 40)	22 (max = 40)
(b) Reading commands	6 (max = 20)	8 (max = 20)	8 (max = 20)
(c) Written word-object matching	6 (max = 6)	6 (max = 6)	6 (max = 6)
(d) Written word-picture matching	6 (max = 6)	6 (max = 6)	6 (max = 6)
(e) Picture stimuli-word matching	6 (max = 6)	6 (max = 6)	6 (max = 6)
(f) Spoken word-visual word match	3 (max = 4)	4 (max = 4)	3 (max = 4)
(g) Spoken word-visual letter name	4 (max = 6)	5 (max = 6)	5 (max = 6)
(h) Oral spelling *(by examiner patient says word spelled)*:	0 (max = 6)	1 (max = 6)	1 (max = 6)
Spelling	0 (max = 6)	0 (max = 6)	2 (max = 6)
Writing			
(a) On request (e.g. name & address)	3 (max = 6)	4 (max = 6)	3 (max = 6)
(b) Written output from pics stimuli	1 (max = 34)	0 (max = 34)	6 (max = 34)
(c) Writing to dictation	0 (max = 10)	2 (max = 10)	2 (max = 10)
(d) Writing words from visual stimuli	0 (max = 10)	2 (max = 10)	4 (max = 10)
(e) Writing the alphabet	4 (max =12.5)	6 (max =12.5)	9 (max =12.5)
(f) Writing numbers 0-20	10 (max = 10)	10 (max = 10)	9.5 (max = 10)
(g) Dictated letter names	1 (max = 2.5)	2 (max = 2.5)	2 (max = 2.5)
(h) Dictated numbers	2 (max = 5)	4 (max = 5)	4 (max = 5)
(i) Copying a sentence from a card	8 (max = 10)	7 (max = 10)	8 (max = 10)
TOTAL	29 / 100	37 / 100	47.5 / 100
Apraxia			
Carrying out oral commands	40 (max = 60)	60 (max = 60)	60 (max = 60)
Constructional and calculation			
(a) Construction – drawing	10 (max = 30)	14.5(max =30)	**********
(b) Calculation	16 (max = 24)	24 (max = 24)	
NART Score	0 / 50	6 / 50	**********

Note: WAB = Western Aphasia Battery (Kertesz, 1982). NART = National Adult Reading Test (Nelson, 1982, 1991).

According to the cut-off scores provided in the WAB administration and scoring manual, spontaneous speech, auditory comprehension, writing ability, repetition, object naming and spelling of all participants was impaired. PD could not pronounce any of the words on NART, while JWT only managed 6 / 50 (12%). MJ could not be tested on the NART.

A number of sub-tests from PALPA (Kay, Lesser & Coltheart, 1992) were administered to further probe participants' visual word recognition, oral reading, semantic processing, non-word reading, repetition and letter-sound abilities. Some of the PALPA tests were adapted for testing in Welsh, usually by translating the relevant English word into Welsh. Occasionally, however, the Welsh word was different in length to the English equivalent in which case a Welsh word of the same number of syllables and of equivalent imageability and frequency (see Fear, 1997) was substituted. There are no irregularly spelled words in Welsh so all Welsh words were regular. Non-words were devised so as to be equivalent to the corresponding English non-words, while retaining the relevant orthotactic features of Welsh.

3.3 Visual word recognition

Each participant's visual word recognition was tested using visual lexical decision tasks taken from PALPA 24 and 25. On each sub-test a set of 60 items was presented and participants were asked to indicate whether the items were real words or not by marking the words that they recognised on the paper, ignoring the 'made up' items. In PALPA 24 there are 15 regular words, 15 irregular words and 30 non-words (which were made up of letter-pairings that do not occur in written English and are almost impossible to pronounce). In this case, a decision about whether a string of letters is a word can be based purely on orthotactic characteristics. PALPA 25 looks for effects of imageability and frequency in deciding whether a letter string is a real word or not; 30 of the words were high in imageability and 30 were low in imageability. Thirty of the words were high in frequency and thirty were low in frequency. Sixty non-words were derived from these words by changing one or more letters, while preserving orthotactic and phonotactic regularity.

The scores obtained by each patient on PALPA 24 and 25 are displayed in Table 2

Table 2. Visual lexical decision scores for each participant

Visual word recognition tests	**P.D**	**J.W.T**	**M.J**
PALPA 24 (Visual lexical decision)			
Regular words:	14 / 15	15 / 15	15 / 15
Irregular words:	14 / 15	13 / 15	14 / 15
Non-words:	30 / 30	30 / 30	30 / 30
PALPA 25 (imageability & frequency: visual lexical decision)	HI/HF = 14 / 15 HI/LF = 13 / 15 LI/HF = 9 / 15 LI/LF = 8 / 15	HI/HF = 15 / 15 HI/LF = 15 / 15 LI/HF = 13 / 15 LI/LF = 13 / 15	HI/HF = 15 / 15 HI/LF = 15 / 15 LI/HF = 15 / 15 LI/LF = 15 / 15
Real words identified:	44 / 60	56 / 60	60 / 60
Non-words identified:	44 / 60	49 / 60	52 / 60

Note: HI = high imageability. LI = low imageability. HF = high frequency. LF = low frequency.

All participants performed well on PALPA 24 (PD 97% correct; JWT 97% correct; and MJ 98% correct) and were within the range of PALPA control scores (see Kay et al., 1992). Control participants would be expected to correctly distinguish 28 out of 30 real words and 30 out of 30 non-words. Thus all patients presented visual word recognition abilities within the 'normal' range. On PALPA 25 PD, JWT and MJ all performed well with high imageability and frequent words but PD's scores dropped below the PALPA 25 control range data when words were low in imageability. The scores of JWT and MJ remained high. The difference between the accuracy of PD's scores on low imageability versus high imageability words was significant ($\chi^2 = 6.90$, $p<0.05$)*. A significant effect of imageability in visual lexical decision may imply that the person is using the semantic system on which to base a decision. However, acquired dyslexics who show imageability effects in oral reading can perform within the 'normal' range on visual lexical decision task like PALPA 25, as did JWT and MJ. This suggests that visual lexical decisions need not be based on semantic information, but can be based on orthographic criteria. In any event, good lexical decision performance implies that the letter string is represented within the visual input lexicon (Kay et al., 1992).

** Although Chi Square (χ^2) is not strictly appropriate (as its assumption of independence is not met) it is widely used in the literature on single case studies and is therefore used as required throughout this thesis. In all 2X2 chi squares reported the degrees of freedom = 1 (unless otherwise stated).*

3.4 Reading aloud

PALPA 31 looks for effects of imageability and frequency in reading aloud. Coltheart et al. (1987) argued that imageability effects in oral reading implicate the semantic system. Frequency effects may indicate reliance on lexical, but not necessarily semantic, processing (Bub et al., 1985). PALPA 32 was given to each participant to examine effects of grammatical class in reading aloud. Participants were instructed to read aloud a set of 80 words; 20 nouns, 20 adjective, 20 verbs and 20 function words. Translated versions of PALPA 31 and 32 were devised in Welsh (see appendix 1 and 2). Words were matched across languages as far as possible for word frequency and number of letters and syllables (see Fear, 1997). The patients' oral reading scores are shown in Table 3.

Table 3. Oral reading scores for each patient

Reading aloud tests	**P.D**	**J.W.T**	**M.J**
PALPA 31 (word reading aloud: imageability & freq)	HI/HF = 16 / 20	HI/HF = 14 / 20	HI/HF = 18 / 20
	HI/LF = 10 / 20	HI/LF = 13 / 20	HI/LF = 17 / 20
	LI/HF = 2 / 20	LI/HF = 9 / 20	LI/HF = 13 / 20
	LI/LF = 0 / 20	LI/LF = 6 / 20	LI/LF = 11 / 20
WELSH (translated version)	HI/HF = 15 / 20	HI/HF = 17 / 20	**********
	HI/LF = 9 / 20	HI/LF = 13 / 20	
	LI/HF = 5 / 20	LI/HF = 5 / 20	
	LI/LF = 1 / 20	LI/LF = 2 / 20	
PALPA 32 (grammatical class reading)			
Nouns:	8 / 20	12 / 20	13 / 20
Adjectives:	7 / 20	12 / 20	15 / 20
Verbs:	4 / 20	11 / 20	12 / 20
Function:	0 / 20	4 / 20	4 / 20
WELSH (translated version)			
Nouns:	9 / 20	10 / 20	**********
Adjectives:	5 / 20	8 / 20	
Verbs:	2 / 20	4 / 20	
Function:	1 / 20	3 / 20	
PALPA 35 (Regularity of reading English) :			
Regular words:	17 / 30	21 / 30	**********
Irregular (exception) words:	16 / 30	18 / 30	

Note: HI = high imageability. LI = low imageability. HF = high frequency. LF = low frequency.

On PALPA 31 after collapsing across high and low frequency and imageability respectively, PD read 26 / 40 high imageability words and 18 / 40 high frequency words. He read only 2 / 40 low imageability words and 10 / 40 low frequency words. (PD imageability: $\chi^2 = 29.07$, $p<0.01$; frequency was not significant: $\chi^2 = 2.69$, $p > 0.05$). JWT read 27 / 40 high imageability and 23 / 40 high frequency words, and he scored 15 / 40 for low imageability and 19 / 40 for low frequency words. (JWT imageability: $\chi^2 = 6.07$, $p < 0.01$; frequency was not significant: $\chi^2 = < 1$). MJ correctly read 35 / 40 high imageability, 31 / 40 high frequency, 24 / 40 low imageability and 28 / 40 low frequency words. (MJ imageability: $\chi^2 = 6.46$, $p < 0.01$; frequency was not significant: $\chi^2 < 1$). However, all three patients' results of PALPA 31 were below PALPA control subject means (HI mean = 39.88; LI mean = 39.52; HF = 39.94; LF = 39.46).

On the Welsh version of PALPA 31, PD read 24 / 40 high imageability words and 20 / 40 high frequency words. He read only 6 / 40 low imageability words and 10 / 40 low frequency words (PD imageability: $\chi^2 = 15.41$, $p < 0.01$; frequency was not significant: $\chi^2 = 1.63$, $p > 0.05$). While JWT read 30 / 40 high imageability and 22 / 40 high frequency words, he scored 7 / 40 for low imageability and 15 / 40 for low frequency words. (JWT imageability: $\chi^2 = 24.34$, $p < 0.01$; frequency was not significant: $\chi^2 = 1.81$, $p > 0.05$. MJ was not available to complete the Welsh version of PALPA 31.

In order to check that the Welsh versions of PALPA 31 and 32 were equivalent to the English versions, data was collected from a small group of non-brain injured bilingual Welsh participants. Three of these were individually matched to PD, JWT and MJ for sex, age and education. A further two neurologically normal participants were matched to two other brain injured patients referred to later in this thesis (see appendix 3). On the Welsh version of PALPA 31 and PALPA 32 each control participant achieved a maximum score of 40. It can be concluded that PD and JWT showed impairment on the Welsh version as well as in the English versions (see appendix 3 for control data).

On PALPA 32 both PD and JWT read nouns better than adjectives (but MJ read adjectives better than nouns), all three participants read adjectives better than verbs and all were poor at reading function words. Furthermore, the same effect was found with PD and JWT's reading on the Welsh version of PALPA 32; they both read more nouns than adjectives, more adjectives than verbs, and were impaired at reading functors. The patients' scores on the Welsh version of PALPA 32 were below the Welsh control data for PALPA 32. All control participants' scores ranged from 39-40 (see appendix 3).

Interestingly, on the English version of PALPA 32, PD seemed to make a visual error followed by a semantic error to the word '*shrink*' as he replied '*ship*' ('*shrink*' – '*sink*' > '*ship*'). He also made several visual / morphological / derivational errors, for example reading '*proper*' as '*property*' ; '*write*' as '*writing*'; '*hang*' as '*hanging*' and '*run*' as '*running*'. JWT made a number of visual / morphological / derivational errors (e.g. reading '*career*' as '*care*'; '*build*' as '*building*' and '*amount*' as '*mount*'). In addition, he made semantic errors, for example reading '*wisdom*' as '*teeth*' and '*happy*' as '*smile*'. MJ made several visual / morphological / derivational errors (e.g. reading '*somehow*' as '*someone*'; '*speak*' as '*speech*' and '*image*' as '*imagine*'). Intriguingly, MJ made a cross linguistic semantic error (e.g. reading '*bell*' as '*cloch*' (clock). Similarly, on the Welsh version of PALPA 32, PD and JWT made visual / morphological / derivational and semantic errors (e.g. JWT read '*adeiladu*' (building) as '*cartref*' (house) and '*tyfu*' (grow) as '*lan*' (up). PD read '*ceg*' (mouth) as '*clust*' (ear) and '*ysgrifennu*' (writing) as '*pen*' (pen).

Thus PD and JWT displayed imageability/concreteness* and frequency effects in oral reading in both English and Welsh. MJ was not available to complete the Welsh version of PALPA 32; however, she did display an imageability/concreteness and frequency effect in English.

3.5 Non-word reading

PALPA 36 was administered to probe patients' ability to read non-words aloud (see Table 4). All 24 non-words were pronounceable, monosyllabic and varied in letter length from 3 to 6 letters.

Table 4. Non-word reading scores

Non-word reading tests	**P.D**	**J.W.T**	**M.J**
PALPA 36 (Non word reading in English)	0 / 24	3 / 24	9 / 24
WELSH (non word reading version)	1 / 24	3 / 24	6 / 24

PD did not read aloud any of the 24 words correctly. However, PD did make 6 lexicalisation errors (e.g. reading '*ked*' as '*key*', '*boak*' as '*book*', '*birl*' as '*bird*' and '*shoave*' as '*shaver*'). He also read one first phoneme correctly (e.g. of '<u>b</u>em'). JWT managed 3 out of the 24. He gave the correct pronunciation to 3 of the three letter words which is below the PALPA mean control score of 6 for these words (Kay et al., 1992).

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* *It is important to note at this point that imageability/concreteness effects are confounded and may in fact be reducible to an effect of age of acquisition (see chapter 5)*

JWT made 7 lexicalisation errors (e.g. reading ‘*boak*’ as ‘*boat*’ and ‘*churse*’ as ‘*church*’). He also read 1 first phoneme correctly (e.g. of ‘smode’). MJ scored 9 / 24. She gave 4 / 6 correct pronunciations for the three letter non-words, 2 / 6 for four letters, 2 / 6 for five letters and 1 / 6 six letter non-words. However, her scores were still below the PALPA mean control score (see Kay et al., 1992). In addition, MJ made 8 lexicalisation errors (e.g. reading ‘*doop*’ as ‘*door*’; ‘*glope*’ as ‘*globe*’; ‘*smode*’ as ‘*smudge*’). MJ also read 2 of the first phonemes correctly on ‘ked’ and ‘soaf’.

A Welsh version of PAPLA 36 (see appendix 4) was constructed; all items were monosyllabic and varied in length from 3 to 6 letters. PD read 1 / 24; JWT correctly read 3 / 24 and MJ scored 6 / 24. PD read one of the 3 letter words (‘*peb*’) correctly, but could not pronounce any of the other non-words. JWT made 5 lexicalisation errors to the Welsh non-words (e.g. reading ‘*dwff*’ as ‘*dwt*’ (small)). He also read another first phoneme correctly (e.g. ‘hoffs’). MJ made 5 lexicalisation errors (e.g. reading ‘*cun*’ as ‘*cwch*’ (boat) and ‘*lar*’ as ‘*iar*’ (hen)) and read 3 first phonemes correct (e.g. of ‘nas’). Each participant’s scores were still below the control mean score obtained of 24 / 24.

The results demonstrate a severe impairment of non-word reading in both English and Welsh suggesting that PD, JWT and MJ’s orthographic-phonological conversion routes were impaired for both languages.

3.6 Word and non-word repetition

All three participants had word finding difficulties in spoken production. PD, JWT and MJ's output phonology in tasks that did not entail semantic processing was examined by testing their ability to repeat spoken words. Participants were instructed to listen to the target word said aloud and then to repeat it. Lip reading was prevented by not letting participants seeing the experimenter's mouth while she read aloud the letter-strings. PALPA 8 is a non-word repetition task and tests the integrity of sub-lexical acoustic – phonological conversion and PALPA 9 examines the influence of imageability and frequency on word repetition. The participants' scores on PALPA 8 and 9 are shown in Table 5.

Table 5. Patient's scores on tests of real word and non-word repetition

Test	P.D	J.W.T	M.J
PALPA 8 (Non word repetition in English)	0 / 30	1 / 30	2 / 30
PALPA 8 (non word rep) (**WELSH** version)	0 / 30	0 / 30	2 / 30
PALPA 9 (imageability & frequency real-word repetition)	HI/HF = 17 / 20 HI/LF = 14 / 20 LI/HF = 10 / 20 LI/LF = 9 / 20	HI/HF = 16 / 20 HI/LF = 15 / 20 LI/HF = 5 / 20 LI/LF = 3 / 20	********** **********
WELSH (translated version)	HI/HF = 18 / 20 HI/LF = 14 / 20 LI/HF = 12 / 20 LI/LF = 5 / 20	HI/HF = 19 / 20 HI/LF = 15 / 20 LI/HF = 14 / 20 LI/LF = 5 / 20	**********

Note: HI = high imageability. LI = low imageability. HF = high frequency. LF = low frequency.

On PALPA 8 PD failed to repeat any non-word while JWT only pronounced 1 / 30 and MJ managed only 2 / 30. Each patient displayed a tendency to make lexicalisation errors, particularly in the repetition of the more lengthy letter strings (e.g. JWT pronounced '*drange*' as '*strange*' and '*ipical*' as '*typical*'). There are no control data available from PALPA;

however a control group of non-brain injured participants scored 30/30 (100%) on this task, indicating that the three patients were severely impaired. A Welsh version of PALPA 8 was also administered. The Welsh non-words were devised so as to be equivalent to the corresponding English non-words by substituting one phoneme in each of the words (e.g. changing '*splant*' to '*sblant*'). Neither PD nor JWT could repeat any of the Welsh non-words and MJ only managed 2 / 30. Each member of the control group scored 30/30 (100%) on the Welsh version of PALPA 8. Thus the patients were considered to be impaired in Welsh non-word repetition.

The results on PALPA 9 showed that words high in imageability and frequency were easier to repeat than words low in imageability and frequency in both languages (see appendix 5 for Welsh version of PALPA 9).

All three patients' performance suggests an impairment of their capacity to create phonological forms for output. In order to test sub-lexical conversion procedures, a letter-sound conversion task was given to each participant. Here, a letter of the English alphabet was presented to each participant who was asked '*what sound does the letter make?*' (e.g. the letter 'B' makes the sound /b/). The same procedure was used for Welsh. A sound-letter conversion task was also administered to each participant. Here, the sound of a letter from the English alphabet was said aloud by the experimenter and participants were required to indicate which of the written letters presented matched the particular sound. This was only possible in English as the sound of the letter is the same as its name in Welsh (e.g. the letter 'a' is /a/) (see appendix 6 for Welsh alphabet).

Table 6 shows each of the participant's scores on letter-sound and sound-letter conversion.

Table 6. Patient's scores on letter-sound and sound-letter conversion

Test	P.D	J.W.T	M.J
Letter-sound conversion (Written letter- spoken sound)			
ENGLISH:	4 / 26	5 / 26	10 / 26
WELSH:	7 / 28	8 / 28	8 / 18
Sound-letter conversion (Spoken sound – written letter)			
ENGLISH:	3 / 26	5 / 26	8 / 26

Table 6 shows that PD scored 15% correct, JWT scored 19%, while MJ achieved 38% on English letter-sound conversion. While PD scored 25% correct, JWT managed 29% and MJ scored 44% correct on the Welsh letter-sound conversion task. The sound-letter conversion scores also indicated an impairment with all 3 patients.

A further test of phonological ability examined whether PD, JWT and MJ demonstrated an ability to perform a rhyme matching test. PALPA 14 (word-rhyme judgement using picture selection) and PALPA 15 (written word-rhyme judgement) tests were administered. The tasks aim to find out whether participants can detect whether a pair of words rhyme. In PALPA 14 the task assesses whether a subject can select a picture whose name rhymes with a given stimulus picture. In PALPA 15 the written word version is used. There is also an auditory version which was administered to PD and JWT in separate sessions. Thirty of the word-pairs rhyme and 30 do not rhyme. Kay et al. (1992) argued that the way in which the material has been designed will cause particular difficulty if the patient bases their decision on the way a word looks rather than how it is pronounced. On PALPA 15 half of the rhyming pairs have the same orthographic ending (e.g. *yard – hard*). In this case, a correct decision does not have to be made on the basis of a phonological match, but can be made on the basis of visual similarity alone. However, half of the non-rhyming pairs also have the same orthographic ending (e.g. *down – flown*) so that, for this set, visual similarity is misleading. Moreover, half of the rhyming pairs have different orthographic endings (e.g. *bait – skate*) and a correct decision for these pairs can only be based on knowing the way each word sounds. In order that the set of words do not stand out as having visually dissimilar rhymes, half of the non-rhyming pairs have the same endings as the rhyming pairs (e.g. *sort – part*). The patients' scores on both PALPA 14 and 15 are shown in Table 7. A Welsh rhyme judgment test was also used see Table 7 (see appendix 7 for the Welsh rhyme judgment test).

Table 7. Patient's scores on rhyme judgement in both languages

Test	P.D	J.W.T	M.J
PALPA 14 (Rhyme judgement):			
Picture version: -	23 (max = 40)	26 (max = 40)	**********
Auditory version: -	2 / 10 test discontinued	34 (max = 40)	
PALPA 15 (Word rhyme judgement):			
Auditory version –	16/30 discontin'd	50 / 60	
Spelling & sound similar -	8 / 9	15 / 15	
Spelling same, sound diff -	1 / 6	11 / 15	
Spelling diff, sound same -	5 / 6	9 / 15	**********
Spelling diff, sound diff -	2 / 9	15 / 15	
Written version –	11/30 discontin'd	33 / 60	
Spelling & sound similar -	6 / 7	11 / 15	
Spelling same, sound diff -	1 / 8	7 / 15	
Spelling diff, sound same -	3 / 8	5 / 15	
Spelling diff, sound diff –	1 / 7	10 / 15	
Welsh Rhyme Judgement test			
Auditory version:	Testing discontinued	18 / 40	**********
Written version:		7 / 40	

According to Monsell (1987), PALPA 14 and 15 test the integrity of phonological short-term storage systems as well as input processing abilities and segmentation skills. Testing of PD on PALPA 15 was discontinued after 30 trials as he found the task very difficult. He scored 53% correct on the auditory version, with most of his correct answers given on the 'spelling and sound similar' word pairs. JWT on the other hand performed well (83% accuracy rate) on the auditory version but his score dropped to 55% on the written version. On the latter, his performance was worse for the '*spelling different, sound the same*' word pairs compared to the rest. The results again suggest reliance on the visual orthographic form of the word-pairs and not on the phonology. JWT performed significantly better on the auditory than on the written version of PALPA 15 ($\chi^2 = 18.34$, $p<0.01$) suggesting that JWT had problems in deriving sound from print.

PD's results did not differ significantly between the auditory and written versions of PALPA 15 ($\chi^2 = 1.07$, $p>0.05$); however, the mere fact that he could not complete the tests highlights that he had severe difficulty deriving phonology (sound) from print.

Rhyming in Welsh was examined. The English rhyming tests (PALPA 14 and 15) were given to PD first, then on a separate occasion the Welsh rhyming task was administered. However, due to PD's severe difficulty in English rhyming only a few words in Welsh were given as he became distressed and wanted to stop. JWT, on the other hand, was given the Welsh rhyming test first. He found the auditory version of the task easier than the written version ($\chi^2 = 5.82$, $p<0.05$). This suggests that he had severe difficulty deriving phonology from printed words. The results indicate that both patients were poor at rhyming in both languages.

3.7 Semantic processing

The Pyramids and Palm Trees Test (Howard & Patterson, 1992) was administered to each participant. A target picture is presented and the patient is asked to point out which one of the two other pictured concepts could be associated in meaning to the target, for example, whether a picture of an APPLE or an ONION is semantically related to a picture of a TREE. There is also a word-word version, in which instead of pictures the corresponding written words are presented. The participants' scores are shown in Table 8.

Table 8. Results for each participant on the Pyramid & Palm Trees Test

Semantic processing tests	**P.D**	**J.W.T**	**M.J**
Pyramid & Palm Trees			
(a) picture-picture version	49 / 52	49 / 52	50 / 52
(b) word-word version	47 / 52	49 / 52	49 / 52

Scores on the Pyramid and Palm Trees Test suggest that the semantic system of each patient was largely intact. However, it could be argued that the Pyramid and Palm Trees Test is relatively simple. More semantic processing tasks were therefore administered to further probe the integrity of the semantic system.

PALPA 47 and 48 are spoken and written forms of word-picture matching. On PALPA 47 a target picture along with four distractor pictures, namely, a close semantic distractor from the same category, a more distant semantic distractor, a visually similar distractor and an unrelated distractor, are presented to the participant. For example, the spoken word 'HAT' is given and the target pictures consist of a picture of a hat among four distractor pictures, namely a coat, sock, iron and an ironing table. Participants must point to the picture which matches the word spoken by the experimenter. In PALPA 48 the written word rather than the spoken word has to be matched to a target picture.

The scores of each patient on PALPA 47 and 48 are shown in Table 9.

Table 9. Results for each participant on semantic processing tests

Semantic processing tests	P.D	J.W.T	M.J
PALPA 47 (spoken word-picture matching)	37 / 40	38 / 40	**********
PALPA 48 (written word-picture matching)	34 / 40	37 / 40	32 / 40

On PALPA 47 both PD and JWT scores were inside the control PALPA range of 35-40. All PD's and JWT's errors on this task were close semantic distractors. MJ was not administered this test as she became too ill. In PALPA 48 a word written in the centre of the page is presented with five pictures around it. On this task PD and JWT's performance fell to 34 / 40 (85%) and 37 / 40 (93%) respectively, while MJ scored 32 / 40 (80%). However, PD's scores on the auditory and written version were not significantly different ($\chi^2 < 1$). His errors included 3 close semantic errors and 3 distant semantic distractors. All of JWT's and MJ's errors were close semantic distractors. The mean PALPA control score was 39 / 40 (range 35-40). The results of PD and MJ were therefore below the range of the PALPA control scores. The results on PALPA 48 indicate some degree of difficulty either in deriving the meaning of written words or for associating their meanings. However, neither patient showed any significant difference ($p > 0.05$) between performance on the written and auditory version. This suggests that differences on the written version were due to a semantic impairment per se rather than to a failure to comprehend specifically written input.

In order to investigate semantic ability further, PALPA 49, an auditory synonym judgment task was given to each participant. This tests the participant's ability to judge whether two spoken words are close in meaning (e.g. '*marriage – wedding*'). Sixty pairs of words were read aloud to each patient. Half the pairs were very similar semantically (e.g. '*ocean – sea*') and half the pairs were semantically unrelated (e.g. '*tool – crowd*'). The pairs were formed of words that were of either low or high imageability, with words matched on frequency across imageability conditions. Each patient had to say '*yes*' or '*no*' to indicate whether the stimulus pairs consisted of words that were approximately of the same meaning. PALPA 50 (written synonym judgement version of PALPA 49) was administered in a different session. Participants were instructed to read the word pairs silently to themselves and to put a tick if they thought the word pairs meant nearly the same thing or to put a cross if they had different meanings (e.g. '***battle – fight***'; '***marriage – lamp***'). Patients' scores on PALPA 49 and 50 are shown in Table 10.

Table 10. Results for each participant on synonym judgements tests

Semantic processing tests	**P.D**	**J.W.T**	**M.J**
PALPA 49 (Auditory synonym judgement)			**********
Synonym pairs =	14 / 15 High I 12 / 15 Low I	15 / 15 High I 14 / 15 Low I	
Control pairs =	6 / 15 High I 5 / 15 Low I	14 / 15 High I 14 / 15 Low I	
TOTAL =	20 / 30 Hi image 17 / 30 Lo image	29 / 30 Hi image 28 / 30 Lo image	
PALPA 50 (Written synonym judgement)			**********
Synonym pairs =	10 / 15 High I 13 / 15 Low I	12 / 15 High I 4 / 15 Low I	
Control pairs =	4 / 15 High I 4 / 15 Low I	15 / 15 High I 15 / 15 Low I	
TOTAL =	14 / 30 Hi image 17 / 30 Lo image	27 / 30 Hi image 19 / 30 Lo image	

On PALPA 49 high imageability word pairs PD scored 20 / 30 (67%) and JWT was correct on 29 / 30 trials (97%). On low imageability word pairs PD scored 17 / 30 (57%) and JWT scored 28 / 30 (93%). On PALPA 50, PD scored 31 / 60 (51%) and JWT 46 / 60 (77%). Performance by both patients was below that of the PALPA control group data range 58-60, implying an impairment of this task. The difference between the auditory and visual written version was only significant on McNemars test for JWT ($\chi^2 = 6.28$, $p < 0.05$).

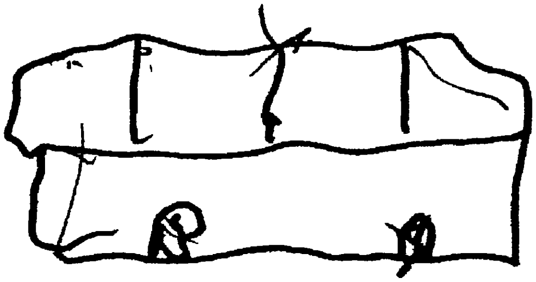
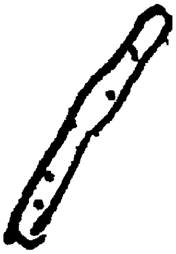
No Welsh versions of the semantic processing tasks were administered as the patients became too ill to participate. However, no difference would be expected as 'semantics' should be similar for both languages.

3.8 Further tests of semantic processing: drawing ability

Results of the tests of semantic processing suggested that all three patients had a mild central semantic deficit. Each patient was unable to write legibly, thus writing ability could not be assessed. However, it was possible to investigate comprehension ability further by asking participants to draw certain items. It was predicted that they would show semantic errors in all lexical processing tasks whatever the modality of input or response. Beaton et al. (1997) and Laine et al. (1990) have examined the drawing performance of deep dyslexics. They found that their patients (M.G.K of Beaton et al., 1997 & V.J of Laine et al., 1990) produced semantic errors of drawing.

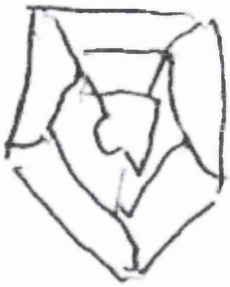
Each patient was asked to repeat a stimulus word aloud after the experimenter and then to draw it. The tables below show examples of JWT, PD and MJ's semantic errors of drawing. Both PD and JWT made semantic errors of drawing in both English and Welsh (see Tables 11-14). All three patients' repetition responses to the target words were correct.

Table 11. Examples of PD's semantic errors of drawing in English

Target Word	P.D drew...	Semantic error?
Truck		Bus?
Dress		Suit?
Trumpet		Flute?

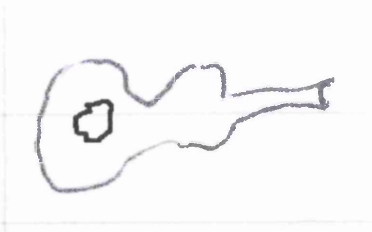
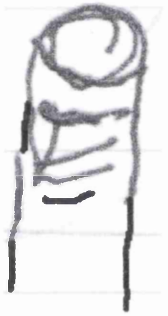
(Drawing in response to a target word spoken in English)

Table 12. Examples of PD's semantic errors of drawing in Welsh

Target Word	PD drew…	Semantic error?
Corryn (*spider*)		Web?
Cloch (*bell*)		Watch?

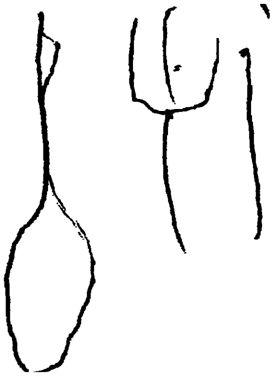
(Drawing in response to a target word spoken in Welsh)

Table 13. Examples of JWT's semantic errors of drawing in English

Target Word	JWT drew...	Semantic error?
Violin		Guitar?
Foot		Hand?
Thumb		Finger?
Fork		Spade?

(Drawing in response to a target word spoken in English)

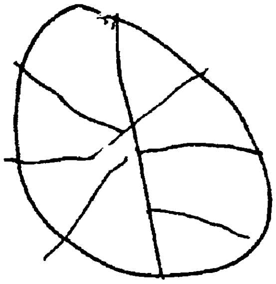
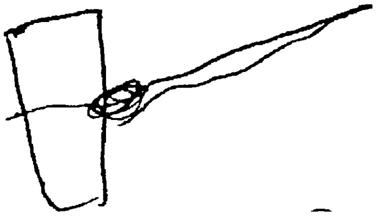
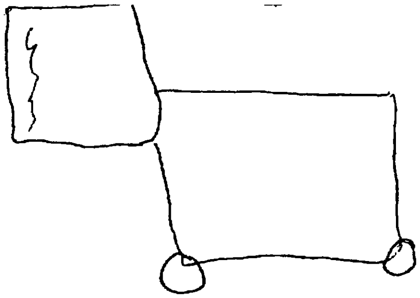
Table 14. **Examples of JWT's semantic errors of drawing in Welsh**

Target Word	**JWT drew...**	**Semantic error?**
Pin-afal (*pineapple*)		Grapes?
Cyllell (*knife*)		Cutlery?

(Drawing in response to a target word spoken in Welsh)

Table 15. **Examples of MJ's semantic errors of drawing in English and in Welsh**

M.J's drawing ability was limited. Most pictures drawn were incomprehensible.

Target Word	**M.J drew...**	**?**
Clock		?
Bwyall (axe)		Mallet?
Lorry		Dumper truck?

(Drawing in response to a target word spoken in English and in Welsh)

PD and JWT made several semantic errors of drawing in both languages. However, MJ's drawing ability was difficult to comprehend, and there were several occasions on which it was impossible to tell whether certain drawings were correct or represented semantic errors. In conclusion, the semantic errors of drawing are consistent with a central semantic deficit.

3.9 Summary and discussion of the performance on tests of language processing

The tests above indicate that PD, JWT and MJ had little or no deficit in visual word recognition (see PALPA 24 and 25). The results shown in Tables 1-10 suggest that each patient showed an effect of imageability in reading words aloud and displayed poorer performance in reading function than content words. Each patient demonstrated an impairment in reading, writing and repeating non-words in both languages. Letter-sound and sound-letter conversion was impaired in all three patients in both English and Welsh and all demonstrated problems with rhyming in both languages. These findings suggest that all three patients' orthographic-phonological and phonological–orthographic conversion routes were severely impaired. Patient MJ could not be tested so extensively but the pattern of her performance was similar (imageability effect in reading English words; poor non-word reading and non-word repetition in English and Welsh; poor function word reading in English). In addition, all three participants made semantic errors of reading in both languages. For example, they all made semantic errors on PALPA 31 and 32 (e.g. PD read '*summer*' as '*spring*' and '*treason*' as '*prison*'; JWT read '*hotel*' as '*doors*' and '*battle*' as '*armies*'; MJ read '*student*' as '*teacher*' and '*night*' as '*sky*'). (More extensive data on semantic errors can be found in chapter 4). Furthermore, PD and JWT made semantic errors of drawing in both languages.

In short, the data show that PD, JWT, MJ were deep dyslexic in *both* English and Welsh. This is an important finding as reports of deep dyslexia in shallow orthographies are scarce. Furthermore, there have been relatively few studies of acquired reading disorders in bilingual readers, most of which find deep dyslexia in only one of the two orthographies. For example, Karanth (2002) reported on a bilingual patient who showed deep dyslexia in English (deep orthography) but not in Hindi (a shallow orthography). Béland and Mimouni (2001) tested an Arabic/French bilingual patient and found deep dyslexia in French and in the deep script of Arabic but not the shallow Arabic script. Wydell and Butterworth (1999) reported a case of developmental phonological dyslexia in an English/Japanese bilingual subject (A.S). They found dyslexia in English but not in Japanese. In order to account for the dissociation between A.S's ability to read English and Japanese Wydell and Butterworth (1999) put forward the '*hypothesis of granularity and transparency*'. They postulated that any language where orthography-to-phonology mapping is transparent, or even opaque, or any language whose orthographic unit representing sound is coarse (i.e. at a whole character or word level) should *not* produce a high incidence of developmental dyslexia. Although their hypothesis applies to developmental phonological dyslexia it may apply also to acquired dyslexia. Thus, arguing from an acquired phonological dyslexia perspective, the hypothesis of granularity and transparency would predict '*little*' phonological dyslexia (and by the same token, deep dyslexia) in Welsh and more in English. The present findings go against this hypothesis.

Chapter 4

4.0 Introduction

There has been relatively little investigation on the effects of brain damage on reading and writing in languages of different orthographic depth. In particular, reports of deep dyslexia in a shallow language are relatively rare (see below). This may be because semantic errors of reading are rarely seen in orthographically shallow languages. For example, semantic errors in aphasic patients' reading of Spanish (see Ardila, 1991) or Italian (see Cossu et al., 1995) have been said to occur infrequently in comparison with their frequency of occurrence in English (see Ferreres & Miravalles, 1995).

Given the belief that semantic errors are rare in Spanish and Italian, Miceli et al. (1994) attempted to account for the apparent difference in frequency of semantic errors in oral reading between readers of deep and shallow orthographies in terms of the summation hypothesis (Hillis & Caramazza, 1991; 1995; Hillis et al., 1999; Miceli et al., 1994; 1999). According to this hypothesis semantic errors in deep dyslexia are considered to arise if the response from the semantic-lexical route is insufficiently constrained by information from the sub-lexical route. Miceli et al. (1994) suggest that in orthographically transparent languages, such as Italian and Spanish, these two sources of information are more or less identical. By contrast, in an orthographically deep or opaque language, such as English, the two sources of information will on occasion conflict. For example, the word *yacht* may be pronounced in one of two ways (yot versus yæt/t) depending on whether it is read as a whole word or decomposed using grapheme-phoneme conversion rules. Damage to a sub-lexical conversion route would be expected to limit the ability of this route to contribute to correct reading aloud.

Miceli et al. (1994) argue that *"the same cognitive damage to sub-lexical conversion mechanisms in a language with transparent and in one with opaque orthography might result in vastly different consequences in reading and writing performance: in opaque languages, it could lead to a severe functional deficit of sub-lexical conversion; whereas in transparent languages it would interfere only minimally with sub-lexical conversion. Thus in a language with opaque orthography, damage to a sub-lexical conversion procedure would result in a situation where the output of the damaged component would consist of relatively unusable information in constraining the activation of lexical entries in the relevant output lexicon. By contrast, in a language with transparent orthography the comparable amount of damage to a sub-lexical conversion procedure would have relatively minor effects on the information value of the output of the damaged process, at least with respect to its role in constraining the activation of lexical forms in the relevant output lexicon. The obvious consequences of these contrasting situations is that transparent orthography languages are relatively "protected" from the production of semantic paralexias and paragraphias because the sub-lexical conversion mechanisms even when damaged continue to provide information that is useful in constraining the activation of phonological and orthographic lexical forms"* (p. 331).

As noted at the beginning of Chapter 3, Welsh is a shallow orthography. It is spoken as a first language by approximately 250,000 people in Wales, or by about 19% of the population over the age of 20 (Welsh Language Board, pers.com). However, there are no monolingual Welsh adult speakers since everyone learns English (although many people are more proficient in Welsh). This means that bilingual Welsh speakers grow up reading one orthographically shallow language (Welsh) and another orthographically deep language (English). Thus, adult Welsh speakers potentially provide an ideal opportunity to test the prediction of the summation hypothesis as applied by Miceli et al. (1994) to reading of shallow and deep orthographies.

A clear prediction from the argument put forward by Miceli et al. (1994) is that a bilingual English-Welsh deep dyslexic patient will make proportionally more semantic errors in oral reading of English (orthographically deep) than Welsh (orthographically shallow) words. There should not, however, be any difference in the frequency of semantic errors made in picture naming in the two languages. Although picture naming is generally assumed to rely on the same semantic-phonological pathway to spoken output as irregular word reading (see Funnell, 1996), it does not engage the sub-lexical reading route which therefore can not contribute to the patient's performance on this task. These predictions were tested with the three patients described in Chapter 3.

4.1 Picture Naming and Oral Reading

The stimulus items for picture naming and oral reading were taken from the original Snodgrass & Vanderwart (1980) set. Rossion and Pourtois (2004) found that the Snodgrass and Vanderwart object pictorial set were named better when the items were in colour compared to when they were in black and white. This advantage was increased for objects with a diagnostic colour and structurally similar shapes such as fruit and vegetables. Therefore the Snodgrass and Vanderwart picture set used in the present experiment were in colour. However, certain items are named differently in American and British English, for example '*sailboat*' as '*yacht*'; '*truck*' as '*lorry*' and '*sweater*' as '*jumper*'. A Cardiff (British) version of the Snodgrass items was compiled by Barry et al. (1997). Thus, the 'British' version of the Snodgrass items was used as the stimuli in this experiment (see Barry et al., 1997).

Dual-word items (such as 'lamp shade' and 'light bulb') were removed from the stimulus set prior to administration of the tasks. Pictures that had a name agreement in English of less than 60% according to Bates et al. (2003) were also removed leaving 222 items from the Snodgrass and Vanderwart (1980) set. These 222 items were shown to a panel of 18 native Welsh speakers who were asked to provide the Welsh name for each item.

The name with the highest agreement between members of the panel was taken as the 'correct' name; name agreement was greater than 70% for all items. These stimuli were subsequently presented one at a time to each of the three patients who was asked to provide its name in English or in Welsh or to read the corresponding English or Welsh word depending upon condition.

The stimuli were presented in pseudo-random order to each patient across a number of test sessions, with the constraint that the same item was not presented for reading and naming within the same session. Within each session, items were blocked according to language of response. That is, participants responded to a set of items in English only or in Welsh only throughout a session. If the patient gave the plural rather than singular form of a stimulus item it was accepted as correct.

4.2 Picture naming results

The data for picture naming from the Snodgrass items in English and Welsh are shown in Table 16. Examples of errors referred to as naming visually similar objects are giving the response *wheel* to the stimulus item *button* or *screw* to *needle* (see Kellenbach et al., 2000 referring to visually similar objects with the same global shape). See Appendix 8 for all errors produced.

Table 16. Picture naming in English and Welsh

Picture Naming	**P.D.**		**J.W.T.**		**M.J.**	
	English	*Welsh*	*English*	*Welsh*	*English*	*Welsh*
Correct-	99	71	124	104	124	132
Omission-	40	39	39	36	22	19
Semantic error-	46	46	26	36	39	38
Name of visually similar object-	3	2	0	0	4	3
Circumlocution-	26	12	19	4	19	5
Cross-linguistic semantic error-	3	16	6	6	6	9
Phonemic error-	2	0	2	0	0	0
Morphological error-	0	0	1	0	0	0
Name correct language incorrect-	3	36	5	36	8	16
TOTAL-	222	222	222	222	222	222

A 'cross linguistic semantic error' (see Table 16) is a semantic error given in a non-target language e.g. (P.D. saw a picture of a '*barrel*' and was asked to name it in English. He replied '*cwrw*' in Welsh (which is Beer in English). P.D. also named '*pig*' as '*bywch*' (cow in Welsh). 'Name correct language incorrect' (see Table 16) refers to when the participant gave the correct name but in the non-target language e.g. P.D. picture naming in English saw '*spider*' and named it as '*corryn*' (which is spider in Welsh).

McNemar's test showed that for patient PD, picture naming was significantly better in English than in Welsh ($\chi^2 = 9.12$, $p<0.01$). The same was true for JWT ($\chi^2 = 4.76$, $p<0.05$). For patient MJ, naming was slightly but not significantly better in Welsh ($\chi^2 = 1.33$, $p>0.05$).

(For all tests reported in this thesis degrees of freedom = 1 and the direction is two-tailed, unless otherwise stated).

Chi-square comparison of semantic errors relative to all other errors of naming (excluding omissions) in English compared with Welsh showed no significant effect for any of the three patients ($p > 0.05$). This was also the case when the analyses were repeated taking account of failures to respond (omissions) as well as errors.

4.3 Reading aloud results

The data for reading in English and Welsh are shown in Table 17. An example of a visual then semantic error was given by PD when he made a probable visual error to the target word '*hanger*' ⟶ *harbour* and replied '*anchor*'; however, it is impossible to state unequivocally that errors described as visual are not instead (or additionally) phonological.

Table 17. Reading aloud in English and Welsh

Reading	**P.D.**		**J.W.T.**		**M.J.**	
	English	*Welsh*	*English*	*Welsh*	*English*	*Welsh*
Correct-	147	83	152	121	151	159
Omission-	30	65	17	37	21	31
Semantic error-	15	30	12	21	14	16
Cross-linguistic semantic error-	1	6	2	7	6	2
Visual then semantic error-	1	0	0	0	0	0
Name of visually similar object-	15	21	26	27	21	7
Circumlocution-	10	7	10	9	8	5
Phonemic error-	1	0	0	0	0	0
Morphological error-	2	1	1	0	0	0
Name correct language incorrect-	0	9	2	0	1	2
TOTAL-	222	222	222	222	222	222

McNemar tests showed that for patients PD ($\chi^2 = 42.67$, $p<0.01$) and JWT ($\chi^2 = 10.80$ $p<0.01$) reading was significantly better in English than in Welsh. For patient MJ reading was slightly but not significantly better in Welsh than in English ($\chi^2 <1$).

Chi-square tests comparing semantic errors relative to all other errors (excluding omissions) of reading in Welsh versus English gave the following results: for PD, $\chi^2 = <1$, for JWT, $\chi^2 = 1.02$; for MJ, $\chi^2 = 3.18$ ($p>0.05$ in each case). Equivalent results were obtained when the analyses were repeated taking into account of failures to respond (omissions) as well as errors. Thus semantic errors were not proportionally more frequent in one language than the other.

4.4 Reading versus Picture Naming

Reading was compared with naming performance in each of the two languages of the patients. McNemar tests showed that for PD, reading in English was significantly more accurate than picture naming ($\chi^2 = 28.10$; $p< 0.001$) but not in Welsh ($\chi^2 = 1.90$, $p> 0.05$). For JWT, too, reading in English was significantly better than naming ($\chi^2 = 9.33$, $p <0.01$); the difference between the two tasks narrowly failed to reach significance in Welsh ($\chi^2 = 3.48$, $p> 0.05$). For patient MJ, reading was significantly better than naming in both English ($\chi^2 = 10.57$, $p< 0.01$) and Welsh ($\chi^2 = 9.72$, $p< 0.01$).

For responses given in English, comparison of semantic and other errors in picture naming versus reading (see Tables 16 and 17) gave the following results. For PD, $\chi^2 = 1.36$ ($p>0.05$); for JWT, $\chi^2 = 4.80$ ($p<0.05$); for MJ, $\chi^2 = 5.80$ ($p <0.05$). Thus, in English the latter two patients made proportionally more semantic errors, relative to other types of error, in naming compared with reading.

For responses given in Welsh, the corresponding chi-square values for semantic errors in naming versus reading were not significant for any of the three patients ($p>0.05$ in each case). The chi-square analyses comparing semantic errors in picture naming versus reading in each of the two languages were repeated taking account of failures to respond (omissions) as well as errors. In English, PD, but not the other two patients, showed significantly more semantic errors in picture naming than reading ($\chi^2 = 5.83$, $p< 0.05$). In Welsh, only MJ showed a significantly greater proportion of semantic errors in picture naming ($\chi^2 = 3.89$, $p< 0.05$).

4.5 Discussion

It has been argued that the summation hypothesis can account for an apparent difference between transparent and opaque orthographies in the frequency of semantic errors of reading made by brain-damaged subjects. According to Miceli et al. (1994), a transparent orthography is relatively protected from the production of semantic paralexias. Reading in English and Welsh by bilingual deep dyslexic participants was therefore compared. If Miceli et al. are correct, the results should have shown relatively more semantic paralexias in English than in Welsh. The data provide a clear refutation of this prediction; there were *not* more semantic errors made by the patients in reading English compared with the corresponding Welsh words.

The production of semantic errors of reading and/or writing has been held to require the presence of impaired sub-lexical conversion mechanisms, since otherwise intact conversion procedures would "block" the output of semantic errors (Patterson & Marcel, 1977; see papers in Coltheart et al., 1980; Caramazza & Hillis, 1990; Hillis & Caramazza, 1991; Nickels, 1992; Friedman, 1996; Miceli et al., 1999; Southwood & Chatterjee, 2000). If this is true, then there would be no reason to expect any difference in semantic paralexias between deep and shallow orthographies when the orthographic-phonological sub-lexical conversion route is *totally* abolished since the means of "blocking" semantic errors would be unavailable for both languages. All else being equal, semantic errors in the two languages would be "free" to arise with approximately equal frequency in reading (as in picture naming).

All of the patients had a severely impaired sub-lexical conversion route, in common with other deep dyslexics (see Chapter 3). None could read or spell more than a few simple non-words in either English or Welsh. Nor could they name or give the sound of more than a few letters (letter-sound conversion), or point to the correct letter on hearing its sound spoken by the experimenter (sound-letter conversion) in either language. However, some residual capacity for converting from letter to sound remained available; all three patients performed poorly but at above chance level on letter-sound conversion in both languages. Thus there is little or no reason to argue that the patients did not provide a suitable test of the summation hypothesis as applied to reading in a shallow (transparent) and a deep (opaque) orthography.

Failure to confirm the prediction of the summation hypothesis concerning semantic errors argues against any straightforward version of its application to languages differing in orthographic depth as outlined by Miceli et al. (1994). These authors did not spell out in any detail how they saw the sub-lexical route constraining the output of the lexical route but presumably it runs somewhat as follows. Imagine that the information delivered to the phonological output lexicon (POL) by the lexical-semantic route activates a number of (semantically related) candidate responses. These might, for example, relate to the concept of a four-legged furry animal with a tail – such as *dog, cat, rat* and so on. Even minimal phonemic information, for example that the initial phoneme is /d/, would be sufficient to constrain the response to that of *dog*. But what if only information regarding the final phoneme were available, for example, that it is /t/? This would be sufficient to "block" the potential response *dog* but there would remain a choice between *cat* and *rat* and the patient might make the incorrect choice – that is, a semantic error. If the semantic activation concerned, say, farm animals, and if one of the response alternatives was *lamb*, information regarding the initial phoneme /l/ would serve to distinguish between *lamb* and *sheep*. On the other hand, knowing that the final phoneme was /b/ - which is what the print-sound conversion mechanism would produce - would not be helpful since the 'b' in *lamb* is silent. Similarly, with regard to silent initial letters, knowing, for example, that the initial letter of *'pterodactyl'* is pronounced /p/ would not be helpful as it is not pronounced. Such inconsistencies between spelling and pronunciation are what characterise an orthographically deep (or opaque) language as opposed to a shallow (transparent) language. This, presumably, is why Miceli et al. (1994) argued that "*in a language with opaque orthography, damage to a sub-lexical conversion procedure would result in a situation where the output of the damaged component would consist of relatively unusable information in constraining the activation of lexical entries in the relevant output lexicon*" whereas in a shallow orthography the information might be rather more helpful.

If one assumes with Rastle & Coltheart (1998; 1999, a,b; 2000 a,b) that the sub-lexical conversion route operates in a serial left-to-right manner, how might this be affected in cases of brain damage? Conceivably, the normal left-to-right "scan" is interfered with, or slowed down, such that the leftmost grapheme is converted into its corresponding phoneme but that the further to the right the grapheme in a letter string occurs, the greater is the chance of "failure" (due, for example, to loss of the relevant memory trace). Such a view would predict that the earlier the occurrence in the letter string of a phoneme that is able to remove ambiguity as to the correct one of a number of candidate responses (and thereby block a semantic error), the better the chance of a correct response. Conversely, the later the occurrence of a disambiguating phoneme, the greater the probability that the response blocking effect will fail, and therefore the greater the probability of a semantic error.

In languages that have a deep or opaque orthography, the presence of an irregularly or inconsistently pronounced grapheme ("irregularity") in the target word must be positively unhelpful in contributing to the choice of response, at least in some proportion of cases (as with silent initial letters). Consequently, in deep (opaque) orthographies, an early point of irregularity might be more inimical than a later one if, in fact, later ones are “unavailable” due to some pathological process. A prediction from this view, then, is that there will be more semantic errors made in response to target words with early points of irregularity than with later ones. With this in mind, the patients’ data was examined in relation to the position within irregular/inconsistent stimulus words of an irregularity or inconsistency in pronunciation of its constituent phonemes. For example, in words such as *celery* or *giraffe* the initial phoneme has an irregular/inconsistent pronunciation but in the words *glove* or *anchor* the inconsistency comes at the third phoneme. Unfortunately, there were too few semantic errors to carry out a formal analysis but there were no trends evident to simple inspection. Each of the patients was as likely to make a semantic error in response to irregular/inconsistent words with an initial irregularity/inconsistency (phoneme positions 1 and 2) as to words with a later irregularity/inconsistency (phoneme positions 3, 4 or 5).

The arguments put forward by Miceli et al. (1994) based on the summation hypothesis can be applied not only to the case of two languages differing in orthographic depth but also to reading by deep dyslexics of irregular or exception words compared with regular words within a single language, such as English. If Miceli et al. (1994) are correct, then one would expect to see more semantic errors made in response to irregular than to regular words (see also Southwood & Chatterjee, 1999).

When all is said and done concerning the irregularity of the English language, it remains improbable that phonological recoding of irregular words (which would produce regularisation errors in reading) would not provide *some* useful information. Between the correct pronunciation and a regularized pronunciation there will always be considerable phonemic overlap except in the case of very few irregular or exception words such as *yacht* or *colonel*. This being so, it is highly likely that there will be only very few occasions on which a damaged conversion procedure will provide less useful information in a deep orthography than in a shallow one. Even if Miceli et al. (1994) are correct that, following brain damage, more sub-lexical information will be preserved in a transparent (shallow) than an opaque (deep) orthography, almost always sufficient information from each orthography would survive to block the output of many semantic errors. If this is so, then arguably there is no basis for the prediction that there will be fewer semantic errors made in reading a shallow than a deep orthography.

The interpretation of results obtained from bilingual patients is not without a number of potential problems. These include the level of competence achieved in each language, the relative age and order of acquisition of the two languages and so on (see Paradis, 2004 for discussion). Of the three patients, two considered themselves to be dominant in English (and named and read more items correctly in English than Welsh) while MJ considered Welsh to be her dominant language (and named and read more items correctly in Welsh than English). However, in all three cases there is no evidence of proportionally more semantic errors of reading in one language than in the other. Neither language dominance nor orthographic depth therefore appears to have influenced the relative frequency of production of semantic errors in the patients.

For all patients, reading accuracy was better than picture naming performance in both languages (significantly so for English but in Welsh significant only for MJ). This is consistent with the availability of some sub-lexical support in reading. Furthermore, it is possible that some degree of *implicit* phonological processing was also available to each of the patients. Buchanan and colleagues have argued that (at least in some deep dyslexic patients) the capacity for implicit phonological processing remains even if explicit phonological processing (as in reading aloud of non-words) is impaired (Buchanan, Hildebrandt & MacKinnon, 1994; 1996; Buchanan, McEwen, Westbury & Libben, 2003). This will be discussed in Chapter 6. An alternative explanation of the better reading than naming accuracy in the patients draws on the notion that the semantic system is not unimodal (or supramodal) but is organised by 'modality' of input (Beavois, 1982; Shallice, 1988). On this account, information presented via the spoken or written word enters a verbal semantic system whereas (non-verbal) information received through vision enters a visual semantic system. The verbal semantic system has direct access to the speech output mechanisms while the visual non-verbal system has only indirect access via communication with the verbal system. These two systems are assumed to be in contact but in certain cases of brain damage there may be some impediment to transfer of information between the two systems. Direct access to speech output mechanisms from the verbal semantic system would explain better reading than naming performance for corresponding items. However this would not explain the fact that their reading was better than naming in English but not in Welsh for PD. The actual reason for this is not understood.

Turning now to another feature of the results, all three patients made proportionally more semantic errors, relative to other types of error, in naming compared with reading when tested in English. The effect was statistically significant for JWT and MJ but not for PD. When tested in Welsh, however, none of the patients showed statistically more semantic errors in naming than in reading. A greater relative proportion of semantic errors in naming target pictures, compared with reading the corresponding names, is consistent with the idea that production of semantic errors in word reading is reduced by the availability of some information from sub-lexical processing. In Welsh, however, there were *not* proportionally more semantic errors in naming than in reading. It is possible that the patients were more phonologically impaired in Welsh than in English, thus reducing a discrepancy between the proportion of semantic errors made in naming, compared with reading. However, the data shown in Tables 16 and 17 do not support this idea.

In addition to errors within each language, a number of cross-linguistic semantic errors was noted (i.e. semantically related responses to the target item were given in the non-target language). For example, PD named '*pig*' as '*buwch*' *(cow)*; JWT read '*dress*' as '*sgyrt*' (*skirt*); MJ read '*pumpkin*' as '*pasc*' (*easter*). These were observed in both reading and picture naming in both languages. They are readily explained by the hypothesis that lexico-semantic activation occurs simultaneously for both languages of bilingual participants (see e.g. Colomé, 2001). Cross-linguistic errors of this type were produced by the patients described by Byng et al. (1984) and Béland et al. (2001). The latter (see their p. 108) distinguished four different types of "translinguistic" errors and found them to be more frequent in Arabic than in French (p. 117). An insufficient number of cross-linguistic errors were made by the patients to make a formal comparison of their relative frequency in English and Welsh.

Finally, in contrast to the dual-route account of reading, the so-called triangle model (Seidenberg & McClelland, 1989; Patterson & Lambon-Ralph, 1999) does not include separate lexical and sub-lexical routes. Instead a single route is used for reading both familiar words and unfamiliar letter strings. In this model, there are connections between orthography and phonology, and between each of these and the semantic system. Differences in orthographic depth are captured by differences in degree of consistency in the mapping between spelling (orthography) and pronunciation (phonology) which are picked up by the learning algorithm and encoded by the strength of the connections (Seidenberg, 1992). The computation of phonology is constrained by semantic processing: the weaker the connections between orthography and phonology, the greater the influence of semantics. Damage to phonological processing mechanisms would produce increased reliance on semantic processing.

An impairment of semantic processing, a feature of dual-route accounts of at least some (central) types of deep dyslexia (Dickerson and Johnson, 2004), in addition to impaired phonological processing mechanisms implies that semantic errors will be produced in response to some target words, even in the context of some degree of preserved phonological processing. The triangle model might therefore predict that inherently weaker connections between orthography and phonology for an orthographically deep than for a shallow language, combined with a given degree of semantic impairment, would lead to a greater likelihood of semantic errors being made by a deep dyslexic patient reading an opaque (deep) than a transparent (shallow) language. That is, both the triangle model and the 'summation version' of the dual-route model at first glance might be thought to make the same prediction namely that more semantic errors will be made in reading a deep compared with a transparent language. However, for the reasons outlined above, such a prediction may not in fact, be appropriate. Certainly, the findings of this study do not support such a prediction though, of course, they do not constitute evidence against the summation (or triangle) hypotheses as such.

Chapter 5

5.0 Introduction

As mentioned else where in this thesis, the cardinal feature of deep dyslexia is the semantic reading error. Patients may also make semantic errors in speech (Caramazza & Hillis, 1990), writing (Bub & Kertesz, 1982; Hillis et al., 1999), drawing (Beaton et al., 1997) and in picture naming (e.g. Beaton & Davies, 2007). Rather similar theoretical accounts have been offered for the production of semantic errors in reading and picture naming (e.g. Morton & Patterson, 1980; Plaut & Shallice, 1993). This is not surprising as the same semantic system and output lexicon are involved in lexical processing and picture naming.

The main assumption of the processing framework involved in picture naming suggests a sequence of stages (e.g. see Morton, 1985; Lesser, 1989). The common argument is that once a picture is recognised, the semantic system is accessed, and output from the semantic system is used to address entries in the phonological output system (but see Kremin, 1986; Kremin et al., 1998). Successful picture naming is presumed to depend upon prior activation of the appropriate semantic representation, and any impairment to this system should result in naming difficulties. The same should apply to retrieval of a printed word's phonology from the phonological output lexicon (but not if a non-semantic reading route is used). It might be expected, therefore, that many of the same (semantic and post-semantic) factors (such as imageability or word frequency) would determine the outcome of attempts to name a picture and to read aloud the corresponding word.

Morrison et al. (1997) argued that certain word attributes, for example, word frequency and concreteness, are important determinants of speed of processing in word and picture recognition tasks. For instance, Morton and Patterson (1980) proposed that visual errors are more likely to be produced in response to abstract words than to concrete words and tend to be more concrete than the stimulus words to which the error was made (see also Shallice & Warrington, 1975; Gerhand & Barry, 2000). However, traditional accounts of word and picture recognition (e.g. see Forster & Chambers, 1973) postulate that the most important among these word attributes is word frequency, that is, the number of occurrences a word has in written or spoken language. Since Oldfield and Wingfield's (1965) suggestion that high frequency words are more readily accessible for speech production than are low frequency words, there has been much debate as to the exact locus of the apparent word frequency effect. Some argue its locus is in orthographic recognition (Monsell et al., 1989), others believe it may be located in the link between orthography and semantics (Borowsky & Besner, 1993) or in the links between semantics and phonology (Vitkovitch & Humphreys, 1991), while Levelt (1983) and Jescheniak and Levelt (1994) suggest that word frequency effects occur during the retrieval of phonological forms.

Gerhand and Barry (2000) claim that a mounting body of evidence on the effect of the age at which words are first learned (their age of acquisition, AoA) questions the status of putative frequency effects, arguing that they reflect the confounding effect of AoA. According to Morrison et al. (1997), frequency and AoA are highly correlated; high frequency words tend to be learned earlier in life than low frequency words. Morrison et al. argue that this confound has resulted in AoA effects being misattributed to frequency; in the absence of AoA as a predictor variable, frequency emerges as an important predictor largely because of the variance it shares with AoA. Morrison et al. (1992) reanalysed Oldfield and Windfield's (1965) data and found that the frequency effect disappeared entirely when AoA was included as an independent variable, and that there was a marked AoA effect on naming latency when the frequency effect was removed.

In 'normal' subjects AoA effects have been found in picture naming (Barry et al., 1997), oral reading (Gerhand & Barry, 1998), lexical decision (Gerhand & Barry, 1999) and in face naming (Moore & Valentine, 1998). An age of acquisition effect is not found in semantic categorisation tasks (Morrison et al., 1992) nor in visual recognition threshold tasks (Gilhooly & Logie, 1981). Gerhand and Barry (2000) therefore argued that the locus of the age of acquisition effect is at the level of phonological retrieval (but see Johnston & Barry, 2005). They further argued that the apparent role of word frequency at this stage of processing is in fact mainly due to the effect of AoA, a conclusion also drawn by Hirsh and Ellis (1994).

Age of acquisition (AoA) effects have been found in brain injured participants as well as in neurologically normal subjects. Rochford and Williams (1962) compared a number of dysphasic patients with a group of 'healthy' children aged 2-11 years. They found that the age at which an item was correctly named by 80% of the children was also a good predictor of the proportion of dysphasic subjects to name the particular item.

Gerhand and Barry (2000) examined the effect of age of acquisition with a deep dyslexic patient (L.W). Using a multinomial logistic regression, they found that the words to which she produced semantic errors were less concrete, later-acquired and shorter than those words she read correctly (providing evidence for Newton and Barry's 1997 NICE model). L.W produced as semantic errors words that on average were earlier acquired, more frequent and shorter than the target words (contrary to what is stated in their abstract but consistent with their text). The latter age of acquisition effect was independent of word frequency (which did not emerge as a significant independent predictor of type of response); thus Gerhand and Barry (2000) suggested that AoA is an important factor in the process that leads to the production of semantic errors.

Age of acquisition effects have been found in the naming accuracy of healthy adult participants (Hodgson & Ellis, 1998) and in patients with semantic dementia (Lambon Ralph et al., 1998). A number of studies have also shown that, in English, word frequency and word length (as well as other factors) predict naming success (e.g. Hirsh & Funnell, 1995; Lambon Ralph et al., 1998; Nickels & Howard, 1994; 1995). Do word length and frequency, and/or age of acquisition, influence picture naming performance in other languages, in particular, orthographically shallow languages?

Cuetos, Ellis & Alvarez (1999) reported that, as a group, young Spanish adults showed significant independent effects of age of acquisition, word frequency, object familiarity and number of syllables on naming times for items from the Snodgrass and Vanderwart (1980) picture set. Even though word length has tended not to be a significant predictor in studies of English naming, it was found in Spanish when measured in terms of the number of syllables. Cuetos et al. (1999) suggested that this may be due to the fact that Spanish is a 'syllable-timed' language whereas English is 'stress-timed'. It may also be that Spanish object names cover a wider range of syllable lengths in a more even manner, making an effect of letter length easier to detect.

Participants in the studies by Cuetos et al. (1999) were neurologically normal. Picture naming is a straightforward task for such people. For brain-damaged participants, however, picture naming is more difficult. Indeed, for left-brain damaged patients with aphasia some difficulty in picture naming is extremely common. Cuetos, Aguado, Izura and Ellis (2002) investigated picture naming in 16 aphasic patients. Naming accuracy was significantly predicted by age of acquisition, word frequency, object familiarity and visual complexity but neither imageability nor word length (nor animacy) was a significant independent predictor of success at the level of the group. Analyses of the data from individual patients, however, showed that for 3 of the 16 patients word length was statistically significant as a predictor of unique variance in the proportion of items correctly named. Cuetos et al. suggested that for these patients "*effects of word length independent of frequency, age of acquisition, etc., presumably reflect problems at the level of output problems or articulation*" (p.358). Clearly, they do not consider length effects to be an integral contributor under ordinary circumstances to picture naming performance in Spanish.

Other research on neurologically 'normal' individuals suggests that word length has little effect on picture naming latency. Bates, Burani, D'Amico & Barca (2001) compared oral reading in Italian (another shallow language) by 30 university students with naming of the corresponding pictures by 50 other Italian students. With response latency as the dependent variable and factor scores resulting from a factor analysis as the independent variable, these authors found that scores on factors loading on age of acquisition (frequency, familiarity and word length) all influenced reading latencies. For picture naming, the same variables except word length, plus imageability and neighbourhood size, affected naming latency. Thus, word naming was unaffected by semantic factors (imageability/concreteness) but affected by length whereas picture naming was affected by semantic factors but not by length.

In a subsequent study, Bates et al. (2003) reported that although name agreement and frequency were important variables across all seven languages they studied, different additional factors affected picture naming latency in different languages. In particular, after other variables had been statistically controlled for in a regression analysis, word length (number of syllables) predicted unique variance in Spanish, Italian and Hungarian but not in English, German, Bulgarian or Chinese. However, length in number of characters predicted unique variance in all languages except German (and was not examined for Chinese). Bates et al. (2003) argued from these and additional findings that "...*the main message to take away from these analyses is that every language shows a unique pattern of word structure contributions to picture naming*" (p.373/374). Bates et al. (2001) pointed out that recent studies of reading in English have shown that imageability effects are normally not observed for short, regular consistent words; instead, the primary influence of imageability is on low frequency exception words (e.g. Cortese et al., 1997; Zelvin & Balota, 2000). Bates et al. argue that these results suggest that the semantic system is recruited *only* when the speaker finds it difficult to generate a pronunciation using the sub-lexical system. Burani et al. (2000) (cited in Bates et al., 2001) reported lexical effects such as frequency and semantic priming for pronunciation of words in a lexical decision experiment in Italian, despite the transparency of the orthography, thus implying that Italian readers make use of the semantic system and output lexicon during oral word reading. However, as postulated by the orthographic depth hypothesis, reliance on lexical reading may be weaker for shallow orthographies relative to languages with deep orthographies. Frost (1994) conducted experiments with 'normal' participants in Hebrew; he found that in naming and lexical decision studies, subjects behaved differently in naming tasks depending on whether stimuli were written in deep or shallow print. Frost (1994) also observed larger frequency and semantic priming effects when the participants were presented with a deep orthography compared with a shallow orthography.

With regard to bilingual aphasics, it is of interest to ask whether the same factors (i.e. frequency, age of acquisition, length, imageability/concreteness) influence picture naming and word reading in the same way for both their languages. It could be argued that lexical variables, such as frequency and age of acquisition, should have relatively little if any effect on reading transparent languages, since the dominant route used for these languages is said to be the sub-lexical route. On the other hand, reading should be affected by word length. Weekes (1997) suggested that "*the effect of number of letters on non-word naming reflects a sequential, non-lexical reading* *mechanism*" (p.439). This mechanism will show an effect of number of letters because the more letters there are to process, the longer it will take to generate the phonological code for a letter string. This will be reflected in the latency to read non-words. A similar argument would apply to reading in a shallow orthography if, in fact, such an orthography is read using a sequential reading mechanism. By the same token, it might be argued that lexical variables, such as word frequency and age of acquisition which are considered to exert their effects post semantically, might be greater for a deep orthography than for a transparent orthography.

In contrast to a possible differential effect of word length on reading in a shallow and a deep orthography, there is little reason to suppose that word length would have any greater effect on picture naming in one kind of orthography compared with the other, if any effect at all. However, both would be expected to show the effect of lexical variables.

As discussed above, word length has generally been found to show little effect on picture naming latency in neurologically unimpaired individuals. However, a similar conclusion might not apply to patients with brain damage, for whom the more appropriate dependent variable is success in naming. For some patients, regardless of depth of orthography, length might affect naming success, as found by Cuetos et al. (2002), in which case the effect presumably relates to factors involved at the output stage of word articulation (as argued by Cuetos et al.).

If variation in latency to name pictures and read the corresponding words by neurologically unimpaired individuals can be taken as in some sense a reflection of relative difficulty, then one would expect to see the same factors influencing reading and picture naming success in brain damaged participants as affect reading and picture naming latency in 'normals'. With regard to languages differing in orthographic depth, therefore, the pattern of findings that can be anticipated in brain-damaged bilingual Welsh-English patients is as follows.

If Welsh is more likely than English to be read using sub-lexical orthography-phonology conversion rules, then an effect of word length is more likely to be found in reading Welsh than English. Conversely, an effect of lexical variables is more likely to be seen for reading English than Welsh. With regard to picture naming success, there is little reason to expect an effect of word length in either language, but if such an effect does emerge it will be equivalent for both languages. The same lexical variables as influence reading in English would be expected to influence picture naming in both English and Welsh.

The data generated by presentation of the Snodgrass and Vanderwart (1980) set of pictures and the corresponding words to the deep dyslexic patients discussed in the previous chapters of this thesis were therefore examined with these predictions in mind. This required that there be measures of the relevant variables in Welsh as well as English.

Morrison, Chappell and Ellis (1997) derived a set of English norms in a large scale study of children's naming of pictured objects. Data were obtained on measures of rated age of acquisition, frequency, imageability, object familiarity, picture-name agreement and name agreement for 297 words, including 232 from the Snodgrass and Vanderwart, (1980) set. The latter included 204 words presented to the deep dyslexic participants discussed in Chapter 3 and 4. Fear (1995, 1997) obtained ratings for Welsh words and their English equivalents from bilingual final year pupils at two Welsh medium high schools plus young adult Welsh-English bilinguals in the community. He examined familiarity/frequency, age of acquisition, concreteness and imageability ratings for 705 Welsh words and their English equivalents. Of these, 87 corresponded to items rated in the study by Morrison et al. (1997). It was therefore necessary to collect ratings for a further set of Welsh words so as to have ratings in Welsh to match the ratings in English for the 204 English words used with the deep dyslexic participants. Fear (1997) provides ratings for 87 words. Ratings in Welsh were therefore acquired for the remaining 117 items in a manner strictly comparable to that employed by Fear (1997), as described below. Thus, the initial part of this study was an extension of Fear's (1997) analysis. This enabled the reading and picture naming data obtained from the deep dyslexic patients to be analysed to determine which variables influenced their performance in each language.

5.1 Method

5.1.1 Participants

Forty bilingual participants from a 6th form school in West Wales took part in rating 117 Welsh words. All were fluent Welsh/English speakers and were aged between 16-18 years.

5.1.2 Materials & Procedure

Three rating questionnaires were devised, one questionnaire on *imageability*; one on *age of acquisition* and one on *frequency* (see appendix 9 for the three questionnaires).

In addition to obtaining ratings for 117 Welsh words for which Fear (1997) does not provide ratings, a random selection of 30 words from Fear's list was also used. This was for the purposes of checking the comparability of Fear's (1997) ratings and those of the present study. Therefore, two separate questionnaires were given to each participant, one with 117 words and another with 30 of Fear's words that were randomly chosen (see appendix 10).

The questionnaires were distributed in the form of stapled A4 size booklets to the 40 bilingual participants. The first 20 participants (8 males, 12 females; mean age 16 years, 7 months) completed both imageability and age of acquisition ratings; the other 20 participants (12 males, 8 females; mean age 16 years, 3 months) completed the frequency ratings. There was a rating scale at the top of each page of each questionnaire to remind raters of the scale being used. Instructions closely followed those of Fear (1997), which were based on those of Gillhooly and Logie (1980), and requested participants to circle the appropriate number on each scale. A 'Likert-type' scale ranging from 1 to 7 was used. Instructions were written in English and in Welsh.

The first 20 participants (8 male, 12 female; mean age 16 years 7months) completed **both** imageability and age of acquisition ratings; the other 20 participants (12 male, 8 female; mean age 16 years 3 months) completed the frequency ratings.

The **imageability** questionnaire asked how easy a particular Welsh word was to imagine; participants were requested to circle 7 if they thought the word was '*very easy to imagine*', 1 if they found the word '*very difficult to imagine*' and to give an intermediate value (e.g. 4) if they thought the word was '*neither very easy nor very difficult to imagine*'.

The **age of acquisition** (AoA) questionnaire asked participants to estimate the age at which they believed they had learned each of the words on the list (in either its spoken or written form). Participants were requested to circle 7 if they believed that they had learned the particular Welsh word at the '*age of 13 or after*' or to circle 1 if they thought they had learned the word at the '*age of 0-2 years*'. Any word that a participant did not know had to be rated as 7.

The **frequency** questionnaire asked participants to rate how often they read, heard, wrote or said each Welsh word on the list. Circling 7 on the scale indicated that the participant read, heard, wrote or said the word '*several times a day*', while circling 1 implied that the subject '*never*' read, heard, wrote or said the word.

5.2 Results

Mean ratings for each item on each questionnaire were determined by averaging the ratings for each item across 20 participants. For the first part of the study a grand mean was calculated for each questionnaire by averaging the mean ratings across all 117 newly rated items (averaged across subjects then across all words). The additional 30 words used for the inter-reliability measure were not included in this analysis. The values thus calculated and their standard deviations are shown in Table 18.

Table 18. Means and standard deviations of ratings on 117 Welsh words

n = 117	**Age of Acquisition**	**Frequency**	**Imageability**
Grand mean score & Standard deviation (SD):	3.64 (1.12 SD)	3.65 (1.62 SD)	5.79 (1.32 SD)

The data of Table 18 imply that on average the rated age of acquisition for the 117 Welsh items was between the ages of 5-6 and 7-8 years. The frequency mean suggests that on average the items were heard, read, written or said '*once a week*', and the imageability measure that the items were on average '*easy to evoke a mental image*'.

For comparison purposes, the grand means and standard deviations values of the 87 other words rated by Fear's (1997) participants are shown in Table 19.

Table 19. Means and standard deviations of Fear's ratings of 87 Welsh words

n = 87	**Age of Acquisition**	**Frequency**	**Imageability**
Grand mean score & Standard deviation (SD):	2.48 (0.77 SD)	5.94 (1.05 SD)	6.31 (0.59 SD)

The data of Table 19 shows that on average the rated age of acquisition for Fear's 87 Welsh rated items was between the ages of 3-4 years. The frequency mean suggests that on average the items were heard, read, written or said '*once a day*', and the imageability measure that the items were on average '*easy to evoke a mental image*'. This suggests that the 87 items used by Fear were on average earlier acquired, more frequent and higher in imageability than the additional 117 words compiled by the present author (Davies).

T-tests were carried out to test the difference between Davies's 117 items and Fear's 87 items. The independent t-tests found that age of acquisition, frequency and imageability measures all differed significantly (**AoA**: t (202) = 8.297; $p<0.01$; **frequency**: t (202) =11.45; $p<0.01$; **imageability**: t (202) = 3.40; $p<0.01$). Thus Fear's and Davies's data ratings were statistically different.

A reliability check was conducted on a random selection of 30 words from Fear's list. This was for the purpose of checking the comparability of Fear's (1997) ratings and those of the present study. The participants who rated the 117 Welsh words were also given 30 of Fear's words (chosen at random) to rate.

The means for Davies's subjects' ratings and Fear's (1997) ratings for the 30 words are shown in Table 20.

Table 20. Mean and standard deviation for Davies's ratings & Fear's ratings for 30 Welsh words

n = 30	**Age of Acquisition**	**Frequency**	**Imageability**
Davies mean & SD:	2.27 (0.89 SD)	5.49 (1.23 SD)	6.19 (0.72 SD)
Fear's mean & SD:	2.66 (0.88 SD)	5.66 (1.08 SD)	6.18 (0.72 SD)

Table 20 shows that the means for Davies's participants' ratings of Fear's 30 words and the mean for Fear's participants' ratings of the same items were very similar. T-tests showed that there was no significant difference for any scale (p >0.05 in each case).

Davies's ratings were correlated with Fear's (1997) ratings of age of acquisition, frequency and imageability. The correlations are shown below in Table 21.

Table 21. Correlations between Fear's ratings and Davies's ratings

n = 30	Fear's Age of Acquisitio ratings	Fear's Frequency ratings	Fear's Imageability ratings
Davies Age of Acquisition ratings	.953**		
Davies Frequency ratings		.966**	
Davies Imageability ratings			.923**

** Correlation significant at p <0.01

The data from Table 21 show that Davies's ratings for the 30 words correlated highly with Fear's ratings and thus that Davies' participants had rated the Welsh items in a similar manner to Fear's subjects. The fact that the 117 words rated in the present study were rated on average as later acquired, less frequent and lower in imageability than the 87 words from Fear's study can therefore be attributed to the particular set of words that were compared, rather than to a difference in the behaviour of the raters in the two studies. This being so, the additional 117 newly rated items were added to the 87 items rated by Fear's participants to give a total of 204 Welsh items. Of these 204 words, 14 were exact cognates in English and Welsh (e.g. piano, banana and lamp) and were removed from the list of stimuli to leave 190 items for subsequent analysis.

5.2.1 Characteristics of stimulus items used

The mean and standard deviation for the 190 English words are shown in Table 22.

Table 22. Mean and standard deviation for the English stimulus words used (Morrison et al. (1997)

n = 190	**Letter Length English**	**Age of Acquisition English**	**Imageability English**	**Frequency English**
Mean:	5.38	2.44	6.22	2.86
Standard deviation:	1.79	.71	.34	.85

The mean score for English age of acquisition suggests that the items were acquired between the ages of '*3-4 and 5-6 years*'. The average score for imageability in English showed that items were '*easy to evoke a mental image*' and the frequency score revealed that the items were heard, read or said '*more than once a month but less than once a week*'. The average word length was approximately 5 letters. Word length can be measured in terms of number of syllables or in terms of the number of letters. In this investigation the term word length is used interchangeably with letter length and refers to the number of letters in a letter string.

Table 23 shows the correlations between the different variables for the English words.

Table 23. Correlations between predictor variables for the stimulus words used in English (Morrison et al. (1997)

n = 190	**Letter Length English**	**Age of Acquisition English**	**Imageability English**	**Frequency English**
Letter Length English	-	.422**	-.089	-.275**
Age of Acquisition English		-	-.514**	-.625**
Imageability English			-	.158*

** Correlation is significant at the 0.01 level.
* Correlation is significant at the 0.05 level.

Table 23 shows that all of the variables for English (except letter length and imageability) significantly correlated with one another. The highest correlation in English was between AoA and frequency, that is, higher frequency words tended to be learned earlier in life. A significant frequency and AoA correlation has been reported extensively in the literature in English (e.g. see Morrison et al., 1997; Gerhand and Barry, 2000).

The mean and standard deviation for the 190 Welsh words are shown in Table 24.

Table 24. Mean and standard deviation for the Welsh stimulus words used

n = 190	**Letter Length Welsh**	**Age of Acquisition Welsh**	**Imageability Welsh**	**Frequency Welsh**
Mean	5.57	3.11	6.04	4.69
Standard deviation	1.53	1.12	1.05	1.79

The mean score for age of acquisition of the Welsh words suggests that words were acquired between the ages of '*5-6 years*', thus on average the items were acquired around the same age in English and in Welsh. The average score for imageability was similar in English and Welsh and showed that items were '*easy to evoke a mental image*' in both languages. The mean Welsh frequency rating suggested that the items were heard, read or said '*once a* week' and the average letter length in Welsh was approximately 5 letters.

Table 25 shows the correlations between the different variables for the Welsh words.

Table 25. Correlations between predictor variables for the stimulus words used in Welsh

n = 190	**Letter Length Welsh**	**Age of Acquisition Welsh**	**Imageability Welsh**	**Frequency Welsh**
Letter Length Welsh	-	.390**	-.221**	-.309**
Age of Acquisition Welsh		-	-.787**	-.814**
Imageability Welsh			-	.668**

** Correlation is significant at the 0.01 level.

* Correlation is significant at the 0.05 level.

Table 25 showed that all of the variables for Welsh significantly correlated with one another. The highest correlation was between AoA and frequency, that is, higher frequency words tended to be learned earlier in life.

The original frequency ratings across languages would be expected to differ due to the difference in the rating scales used to rate English (5 point scale) and Welsh (7 point scale) words. In order to express the data in the same metric across languages, the data for each variable and each language was transformed into Z scores. This procedure also homogenised the variance which for some variables differed considerably between the languages. The transformed scores for English and Welsh were compared by means of a t-test. However, none of the differences was significant at the 5% level. Therefore, the scores were comparable between languages.

Correlations were then computed between the English and Welsh variables using the Z scores for all of the variables. The results are shown in Table 26.

Table 26. Correlations across languages for each variable in English and Welsh using Z scores

n = 190 (Z scores)	**L.Length English**	**AoA English**	**Image English**	**Freq English**	**L.Length Welsh**	**AoA Welsh**	**Image Welsh**	**Freq Welsh**
L.Length English	-	.427**	-.089	-.275**	.492**			
AoA English		-	-.514**	-.625**		.740**		
Image English			-	.158*			.399**	
Freq English				-				.71**
L.Length Welsh					-	.39**	-.221**	-.309**
AoA Welsh						-	-.787**	-.814**
Image Welsh							-	.668**
Freq Welsh								-

** Correlation is significant at the 0.01 level.

* Correlation is significant at the 0.05 level.

All English and Welsh variables significantly correlated with each other (most at $p < 0.01$), the highest correlations being for age of acquisition and frequency.

In order to determine whether there was a significant independent effect of any of these variables (i.e. letter length, age of acquisition, frequency and imageability) on responses, separate analyses were conducted within each language using logistic regression. As there were more than two categories of response (correct, omissions, semantic errors and all other errors) multinomial logistic regression was conducted (Howell, 1997) using all 190 items, with correct scores as the reference category. The results are described below for each individual patient.

5.3 Multinomial logistic regression analysis:

PD

For picture naming in English the final regression model was highly significant ($p < 0.01$) with a Nagelkerke R^2 score of .237, suggesting that the null hypothesis that all effects of the independent variables (i.e. letter length, AoA, frequency and imageability) are zero can be rejected. The variable which significantly predicted type of response was letter length ($\chi^2 = 15.76$, $p < 0.01$). From the model parameter estimates, it was concluded that relative to the reference category (i.e. correct scores) there was a significant effect of letter length on omissions ($p< 0.02$) and on all other errors ($p < 0.02$) for PD's picture naming in English.

In reading English the final regression model was highly significant ($p < 0.01$) with a Nagelkerke R^2 score of .277. Letter length ($\chi^2 = 17.62$, $p < 0.01$) and frequency ($\chi^2 = 11.44$, $p < 0.05$) predicted type of response. From the model parameter estimates, it was concluded that relative to the reference category (correct scores) there was a significant effect of letter length on omissions ($p < 0.01$), imageability on omission ($p < 0.05$) and frequency on omissions ($p < 0.05$). There was also a significant effect of age of acquisition on semantic errors ($p < 0.05$) for PD' reading in English.

In naming in Welsh the final regression model was not significant ($p > 0.05$) therefore there were no significant predictors of PD's picture naming in Welsh. However, in reading Welsh the regression model was found to be significant ($p < 0.01$) with a Nagelkerke R^2 score of .263. The variables which significantly predicted type of response were letter length ($\chi^2 = 8.44$, $p < 0.05$) and age of acquisition ($\chi^2 = 11.32$, $p< 0.05$). From the model parameter estimates, it was concluded that relative to the reference category (correct scores) both letter length and AoA had a significant effect on PD's omissions ($p < 0.05$). Furthermore, age of acquisition had a significant effect on all other errors ($p <0.05$) in reading Welsh words.

JWT

For picture naming in English the final regression model was significant ($p < 0.01$) with a Nagelkerke R^2 score of .240. The variable which significantly predicted type of response was letter length ($\chi^2 = 22.75$, $p < 0.05$). From the model parameter estimates, it was concluded that relative to the reference category (correct scores) letter length had a significant effect on JWT's omissions ($p <0.01$) and on all other errors ($p <0.04$) in English picture naming.

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* *Because of the skew found with distributions of word frequency in both languages, frequency ratings were transformed using log (x + 1). This made no difference to the results of the regression analyses, thus only the results using mean frequency are reported.*

* *Cuetos et al. (1999) reported that the number of syllables predicted naming success in Spanish. Furthermore, Bates et al. (2003) found that syllable number predicted variance in Spanish, Italian and Hungarian. However, the number of syllables made no difference to the outcome of the present regression analyses. Only the results based on letter length are therefore reported.*

In reading English the final regression model was significant ($p < 0.01$) with a Nagelkerke R^2 score of .226. Letter length ($\chi^2 = 8.98$, $p < 0.03$) and age of acquisition ($\chi^2 = 9.31$, $p < 0.03$) predicted type of response. From the model parameter estimates, it was concluded that relative to the reference category (correct scores) there were significant effects of letter length and age ofacquisition on omissions ($p < 0.02$). Age of acquisition was a significant predictor for semantic errors ($p < 0.03$) and letter length had a significant effect on all other errors ($p < 0.03$).

For picture naming in Welsh the final regression model was significant ($p < 0.01$) with a Nagelkerke R^2 score of .274. The variable which significantly predicted type of response was age of acquisition ($\chi^2 = 7.68$, $p < 0.05$). The model parameter estimates found that relative to the reference category (correct scores) age of acquisition had a significant effect on JWT's omissions ($p <0.05$) and on semantic errors ($p < 0.05$). Letter length also had a significant effect on JWT's semantic errors ($p < 0.05$).

In reading Welsh the final regression model was significant ($p < 0.01$) with a Nagelkerke R^2 score of .304. Imageability significantly predicted type of response ($\chi^2 = 15.57$, $p < 0.01$). The model parameter estimates found that relative to the reference category (correct scores) imageability had a significant effect on JWT's omissions ($p <0.01$) and age of acquisition had a significant effect on all other errors ($p < 0.02$).

MJ

For picture naming in English the final regression model was significant ($p < 0.01$) with a Nagelkerke R^2 score of .257. The variables which significantly predicted type of response were letter length ($\chi^2 = 8.95$; $p < 0.03$) and imageability ($\chi^2 = 8.86$; $p < 0.03$). From the model parameter estimates, it was concluded that relative to the reference category of correct scores, letter length had a significant effect on MJ's omissions ($p < 0.05$). Imageability had a significant effect on semantic errors ($p < 0.02$) and on all other errors ($p < 0.05$).

In reading English the final regression model for MJ was significant ($p < 0.01$) with a Nagelkerke R^2 score of .223. Letter length significantly predicted type of response ($\chi^2 = 9.22$; $p<0.05$). From the parameter estimates, it was concluded relative to the reference category (correct scores) that letter length had a significant effect on omissions ($p< 0.05$) and on all other errors ($p < 0.05$).

For picture naming in Welsh the final regression model was significant ($p < 0.01$) with a Nagelkerke R^2 score of .335. The variables which significantly predicted type of response were letter length ($\chi^2 = 11.95$; $p < 0.05$) and age of acquisition ($\chi^2 = 14.06$; $p < 0.03$). From the parameter estimates, it was concluded, relative to the reference category (correct scores), that letter length had a significant effect on omissions ($p < 0.05$) and age of acquisition had a significant effect on semantic errors ($p < 0.05$) and on all other errors ($p < 0.01$).

In reading Welsh the final regression model was significant ($p < 0.01$) with a Nagelkerke R^2 score of .225, but there were no significant chi square values. Thus it is unwise to place any reliance on the model parameter estimates. However, for heuristic purposes it can be noted that the model parameter estimates found that relative to the reference category (correct scores), age of acquisition had a significant effect on MJ's semantic errors ($p < 0.05$).

A summary of all significant chi square results for the multinomial logistic regressions are shown in Tables 27 and 28 below:

Table 27. Factors that predict distributions of response categories in reading

n = 190	**Reading English**	**Reading Welsh**
P.D	Letter length Frequency	Letter length Age of Acquisition
J.W.T	Letter length Age of Acquisition	Imageability
M.J	Letter length	No significant predictors

Table 28. Factors that predict distributions of response categories in picture naming

n = 190	**Picture Naming English**	**Picture Naming Welsh**
P.D	Letter length	No significant predictors
J.W.T	Letter length	Age of Acquisition
M.J	Letter length Imageability	Letter length Age of acquisition

5.4 Discussion

It might be argued in line with the orthographic depth hypothesis that lexical variables, such as frequency and age of acquisition, should have relatively little if any effect on reading shallow orthographies, since the dominant route used for these languages is said to be the sub-lexical route. On the other hand, reading in a shallow orthography should be affected by letter length. However, the data from Tables 27 and 28 show that a letter length effect was not more apparent in Welsh than in English. Furthermore, the results show that letter length significantly predicted type of response for reading and picture naming in English for all three deep dyslexics.

Superior performance with shorter than longer words (i.e. a word length effect) is a widely reported phenomenon in the literature on aphasia (e.g. Ellis, Miller & Sin, 1983). Gerhand and Barry (2000) noted that it is very common to interpret a word-length effect as some kind of limitation in the output of aphasic patients. According to these authors the most commonly accepted explanation of the word-length effect is that it operates at a post lexical-access level of processing. If, as suggested by Gerhand and Barry (2000) and Cuetos et al. (2002), a length effect reflects output difficulties in aphasic patients' naming performance, why is the effect not seen for JWT's and MJ's reading of Welsh nor for naming in Welsh by PD and JWT?

Age of acquisition was found to predict reading responses for PD in Welsh and JWT in English; it was also a significant predictor of picture naming responses in Welsh for JWT and MJ. The earlier a word was acquired, the more likely the patient was to read it correctly or name its referent. This is in accordance with findings of studies of picture naming, where age of acquisition has emerged consistently as a significant predictor (e.g. see Rochford and Williams, 1962; Hirsh and Ellis, 1994; Gerhand and Barry, 2000). The data is also consistent with the viewpoint expressed by Morrison and Ellis (1995), among others, that a major component of what has been reported as a frequency effect in lexical processing is in fact due to a confound with age of acquisition, as frequency was not found to exert an independent effect (except for PD's reading in English).

To some extent, the results of the present study showing an effect of AoA on JWT's reading of English and on PD's reading of Welsh support Gerhand and Barry's (2000) findings. They found that AoA, concreteness (which correlates with imageability) and word length were all significant predictors of L.W's responses (log x +1 frequency was not significant). Gerhand and Barry (2000) argued that their results indicate that AoA was an important contributor to LW's reading accuracy as were concreteness and letter length. No current model of deep dyslexia predicts this effect. The present data show that the effect reported by Gerhand and Barry (2000) is not found for all patients (MJ did not show an effect of AoA in her reading) nor for both languages of bilingual patients.

In reading Welsh, imageability was a significant predictor of JWT's reading responses. Imageability is generally seen as a property of the semantic system, thus the question arises as to whether JWT's semantic ability was any different from that of PD or MJ. However, when referring back to the language assessments (see Chapter 3) JWT's semantic ability did not differ substantially from that of PD or MJ. Therefore, there is no obvious reason why imageability affected JWT's reading of Welsh, nor why it did not also predict his reading in English.

5.5 Factors that influence the production of semantic errors

An important question to ask was what factors influenced the production of semantic errors in the three patients?

The tables below provide a summary of the variables shown by the multinomial regression parameter estimates to be significantly associated with membership of the category 'semantic errors' relative to the reference category (correct scores).

Table 29. Factors that were shown by the multinomial regression parameter estimates to be significantly associated with membership of the category 'semantic errors' relative to the reference category (correct scores) in reading

n = 190	**Reading English** Semantic errors predictors:	**Reading Welsh** Semantic errors predictors:
P.D	Age of Acquisition	None
J.W.T	Age of Acquisition	Age of Acquisition
M.J	None	Age of Acquisition

Table 30. Factors that were shown by the multinomial regression parameter estimates to be significantly associated with membership of the category 'semantic errors' relative to the reference category (correct scores) in picture naming

n = 190	**Picture Naming English** Semantic error predictors:	**Picture Naming Welsh** Semantic errors predictors:
P.D	None	None
J.W.T	None	Age of Acquisition Letter length
M.J	Imageability	Age of Acquisition

The multinomial regression parameter estimates show that age of acquisition was significantly associated with semantic errors, relative to the reference category (correct scores), made by JWT and MJ in Welsh reading and just missed significance (p = 0.06) for PD. Age of acquisition also predicted semantic errors in English reading by two patients (PD and JWT). Apart from age of acquisition, the only other significant influences on semantic errors were imageability in English picture naming and letter length and age of acquisition in Welsh picture naming for JWT.

It is difficult to know what else to make of the parameter estimate results other than to note (a) that age of acquisition appears to be a more salient predictor of inclusion of a response in the category ‘semantic error’ compared with the category ‘correct’ than frequency, imageability or word length; (b) that not all patients show the same effects in reading and in picture naming; and (c) that different effects may be seen for the same task carried out in different languages.

5.6 The effect of cognate status

Languages that share a common parent language or have a history of borrowing due to contact between each other have pairs of words known as cognates. Cognates are words pairs with similar form and the same meaning in two languages (e.g. the English – Welsh pairs: '*drum – drwm*'; '*flute – ffliwt*'; '*boot – bwt*'). Although there is no single accepted definition of a cognate, many studies have found that cognate status influences performance on a number of lexical tasks. For example, de Groot and Nas (1991) found that cognate nouns are recognised by bilingual adults more rapidly than non-cognate nouns in lexical decision tasks. Furthermore, cognate nouns are translated more quickly than non-cognates (de Groot, 1992).

Studies of bilingual aphasia considering cognate status are very rare. According to Roberts and Deslauriers (1999) only two investigations have been reported, those by Stadie et al. (1995) (using picture naming) and by Ferrand and Humphreys (1996) (using a word-matching task). Roberts and Deslauriers (1999) looked at picture naming of cognate and non-cognate nouns in bilingual (English/French) aphasics. They examined whether cognate status influenced naming accuracy and error types on a confrontation naming task. Their results showed that cognate status increased the likelihood of correct picture naming by aphasic patients and that cognate nouns were more often correctly read in both languages than were non-cognates.

The following analyses assessed whether cognate status influenced the outcome of the regression analyses by repeating the multinomial regression analyses but excluding cognate words. This reduced the number of items available for analysis to 127. The analyses were carried out using multinomial logistic regression, with correct, semantic errors, omissions, and all other errors as the categories.

The results are described below for each individual patient.

PD

For picture naming in English the final regression model was significant ($p < 0.01$) with a Nagelkerke R^2 score of .271, suggesting that the null hypothesis that all effects of the independent variables (i.e. letter length, AoA, Frequency and Imageability) are zero can be rejected. The variable which significantly predicted type of response was letter length ($\chi^2 = 15.17$, $p < 0.02$). From the model parameter estimates, it was concluded that relative to the reference category (i.e. correct scores) there was a significant effect of letter length on omissions ($p< 0.05$) and on all other errors ($p < 0.05$) for PD's picture naming in English.

In reading English the final regression model was significant ($p < 0.01$) with a Nagelkerke R^2 score of .332. Letter length predicted type of response ($\chi^2 = 17.52$, $p < 0.01$). From the model parameter estimates it was concluded that, relative to the reference category (correct scores), there was a significant effect of letter length on omissions ($p < 0.01$) and on semantic errors ($p<0.05$) for PD's reading in English.

In naming Welsh the final regression model was not significant ($p > 0.05$) therefore there were no significant predictors of PD's picture naming in Welsh. However, in reading Welsh the regression model was found to be significant ($p < 0.01$) with a Nagelkerke R^2 score of .31. The variables which significantly predicted type of response were letter length ($\chi^2 = 8.04$, $p < 0.05$) and age of acquisition ($\chi^2 = 8.71$, $p< 0.05$). From the model parameter estimates it was concluded that, relative to the reference category (correct scores), both letter length and AoA had a significant effect on PD's omissions in reading Welsh words.

JWT

For picture naming in English the final regression model was significant ($p < 0.02$) with a Nagelkerke R^2 score of .246. The variable which significantly predicted type of response was age of acquisition ($\chi^2 = 9.41$, $p < 0.05$). From the model parameter estimates it was concluded that, relative to the reference category (correct scores), letter length and age of acquisition had a significant effect on JWT's omissions in English picture naming.

In reading English the final regression model was significant ($p < 0.02$) with a Nagelkerke R^2 score of .256. Letter length predicted type of response ($\chi^2 = 14.08$, $p < 0.03$). From the model parameter estimates it was concluded that, relative to the reference category (correct scores), there was a significant effect of letter length on omissions ($p < 0.02$) and on all other errors ($p < 0.05$).

For picture naming in Welsh the final regression model was significant ($p < 0.01$) with a Nagelkerke R^2 score of .281. There were no significant chi square results. Thus it is unwise to place any reliance on the model parameter estimates. However, for heuristic purposes it can be noted that the model parameter estimates showed that, relative to the reference category (correct scores), letter length had a significant effect on JWT's semantic errors ($p < 0.05$).

In reading Welsh the final regression model was significant ($p < 0.05$) with a Nagelkerke R^2 score of .324. The variable which significantly predicted type of response was imageability ($\chi^2 = 10.25$; $p < 0.05$). From the model parameter estimates it was concluded relative to the reference category (correct) that imageability had a significant effect on JWT's reading omissions.

MJ

For picture naming in English the final regression model was significant ($p < 0.01$) with a Nagelkerke R^2 score of .386. The variable which significantly predicted type of response was imageability ($\chi^2 = 14.58$; $p < 0.02$). From the model parameter estimates it was concluded that, relative to the reference category of correct scores, imageability had a significant effect on MJ's omissions ($p < 0.05$), semantic errors ($p < 0.01$) and on all other errors ($p < 0.05$).

In reading English the final regression model for MJ was significant ($p < 0.01$) with a Nagelkerke R^2 score of .323. Letter length significantly predicted type of response ($\chi^2 = 12.31$; $p<0.05$). From the parameter estimates it was concluded that, relative to the reference category (correct scores), letter length had a significant effect on omissions ($p< 0.03$) and on all other errors ($p < 0.05$).

For picture naming in Welsh the final regression model was significant ($p < 0.01$) with a Nagelkerke R^2 score of .460. The variable which significantly predicted type of response was age of acquisition ($\chi^2 = 21.69$; $p < 0.01$). From the parameter estimates it was concluded that, relative to the reference category of correct scores, letter length had a significant effect on omissions ($p < 0.05$), age of acquisition had a significant effect on semantic errors ($p < 0.05$) and on all other errors ($p < 0.01$); furthermore, frequency had a significant effect on all other errors ($p < 0.05$) of MJ's.

In reading Welsh the final regression model was significant ($p < 0.01$) with a Nagelkerke R^2 score of .302. There were no significant chi square results. However, for heuristic purposes it can be noted that the model parameter estimates found that relative to the reference category (correct scores), letter length had a significant effect on MJ's semantic errors ($p < 0.05$).

A summary of the results of the multinomial regression analyses carried out on the data for stimuli excluding cognate items is shown in Tables 31 and 32 below. For comparison purposes, the findings relating to the full list of stimuli are also shown (in blue).

Summary of cognates versus non-cognates

Table 31 Factors that predict responses in reading

	Reading English		**Reading Welsh**	
	With Cognates	**Without Cognates**	**With Cognates**	**Without Cognates**
P.D	Letter length Frequency	Letter length	Letter length AoA	Letter length
J.W.T	Letter length AoA	Letter length	Imageability	Imageability
M.J	Letter length	Letter length	No predictors	No predictors

Table 32 Factors that predict responses in picture naming

	Picture Naming English		**Picture Naming Welsh**	
	With Cognates	**Without Cognates**	**With Cognates**	**Without Cognates**
P.D	Letter length	Letter length	No predictors	No predictors
J.W.T	Letter length	AoA	AoA	No predictors
M.J	Letter length Imageability	Imageability	Letter length AoA	AoA

**With cognates included (n = 190)*
**Without cognates included (n = 127)*

The results of the multinomial logistic regression analyses without the cognates (n = 127) revealed that letter length was still the main independent predictor of all three patients' responses in English reading. Age of acquisition was also found to be a significant predictor in English picture naming for JWT and in Welsh picture naming for MJ. Frequency was again found not to exert any independent influence on responses.

It can be seen from the tables 31 and 32 that the removal of cognate items had little effect on the results of the multinomial regression analyses. Some effects that were significant when cognates were included were no longer significant when the data for the cognates were removed from the data set. As this reduced the number of items available for analysis it is not surprising that some effects were nullified (no longer significant). The only other difference between the analyses with and without cognates was for patient JWT's picture naming in English.

Cognates have the same meaning in the two languages of a bilingual, therefore it might be supposed that they both reach high levels of activation in the course of producing one of them. It should therefore be easier to name a cognate word rather than a non-cognate. Costa, Caramazza and Sebastian-Gallès (2000) suggested that according to some models of speech production cognates and non-cognates have a differential influence in different tasks. Costa et al. (2000) suggested that when a bilingual person names a cognate in their non-dominant language, the large activation received by its translation in the dominant language helps the retrieval of the target's phonological units in the non-dominant language. Alternatively, when the naming task is conducted in the dominant language, the activation that is sent to the phonological units of its translation in the non-dominant language is not as great as the activation that is sent in the dominant language. Costa et al. (2000) argued that this is because the strength of the connection between semantic representations and their corresponding lexical nodes is stronger for the dominant language than it is for the non-dominant language. Therefore the effects of having a cognate translation should be larger when naming in the weaker language.

Costa et al. (2000) found that the cognate status of picture names affected the performance of bilingual 'normal' speakers more when they were naming in their non-dominant language than when they were naming in their dominant language. Costa et al. also found that cognate items were named more quickly than non-cognates.

Picture naming is a straightforward task for healthy, 'normal' participants; however, for aphasics it is much more difficult and the use of reaction times with such patients is problematic. Arguably accuracy scores are a more appropriate measure. Applying the arguments of Costa et al. (2000) to the case of aphasic patients leads to the prediction that they will be more successful in naming cognates items than non-cognate items. Indeed, Roberts and Deslauriers (1999) showed that cognate status increased the likelihood of correct picture naming by bilingual (English/ French) aphasic patients and that cognate nouns were more often correctly read in both languages than were non-cognates. On the basis of Roberts and Deslauriers's (1999) finding it was hypothesised that there would be more correct answers given to cognates than non-cognates. This was examined with the cognate and non-cognate data obtained from the present study (see Tables 35 and 36 for results).

The number and percentage of cognate items responded to correctly by each patient in a reading and naming task in English and Welsh are shown in Table 33. Corresponding data for non-cognate items are shown in Table 34.

Table 33 The number (and percentage) of correct scores and semantic errors made by each patient to the **63 cognate** items

	English						**Welsh**					
	Reading			*Naming*			*Reading*			*Naming*		
(n = 63)	**PD**	**JWT**	**MJ**	**PD**	**JWT**	**MJ**	**PD**	**JWT**	**MJ**	**PD**	**JWT**	**MJ**
Correct Scores:	42 (66%)	42 (66%)	41 (65%)	21 (33%)	34 (54%)	34 (54%)	21 (33%)	31 (49%)	41 (65%)	26 (41%)	31 (49%)	41 (65%)
Semantic Errors: (% of errors) *	5 (45%)	5 (31%)	4 (24%)	12 (50%)	9 (45%)	10 (46%)	11 (52%)	9 (39%)	7 (58%)	9 (36%)	14 (63%)	12 (66%)
All other Errors ** (excl. omissions)	6	11	13	12	11	12	10	14	5	16	8	6

Table 34 The number (and percentage) of correct scores and semantic errors made by each patient to the **127 non-cognate** items.

	English						**Welsh**					
	Reading			*Naming*			*Reading*			*Naming*		
(n = 127)	**PD**	**JWT**	**MJ**	**PD**	**JWT**	**MJ**	**PD**	**JWT**	**MJ**	**PD**	**JWT**	**MJ**
Correct Scores:	87 (68%)	86 (67%)	90 (71%)	69 (54%)	72 (56%)	74 (58%)	44 (34%)	67 (52%)	94 (74%)	37 (29%)	56 (44%)	71 (56%)
Semantic Errors: (% of errors) *	8 (32%)	5 (17%)	8 (32%)	26 (62%)	15 (52%)	24 (57%)	17 (38%)	12 (34%)	8 (42%)	29 (41%)	18 (34%)	22 (50%)
All other Errors** (excl. omissions	17	24	17	16	14	18	27	23	11	41	34	22

* *The proportion of semantic errors is expressed as a percentage of total errors (excluding omissions)*

** *All other errors do not include omissions*

The number of cognate and non-cognate items responded to correctly were compared for each task, patient and language separately by means of chi square. In no case did the difference reach statistical significance at the 5 % level. There was thus no evidence of a cognate facilitation effect in either task or language. Furthermore, the proportion of semantic errors were examined between cognates and non-cognates for each task, patient and language separately by means of chi square. Only one result was found to be statistically significant, which was JWT's Welsh naming of cognate and non-cognate items ($\chi^2 = 4.19$; $p < 0.05$). However, given the multiple chi square tests completed and no consistent findings, this results will be regarded as a chance finding.

The present investigation has failed to replicate the findings of Roberts and Deslauriers (1999) as no cognate facilitation effect was found. One reason may be that the cognate and non-cognate items differed in terms of the psycholinguistic variables and that this nullified any cognate advantage. To examine this possibility the characteristics of each variable (in each language) were compared. The data are shown in Tables 35 and 36.

Table 35. Mean and standard deviation for cognate and non-cognate words in English

English	Letter length	Age of Acquisition	Frequency	Imageability
Cognate (n=63)				
Mean	**5.75***	**2.67***	2.76	6.18
SD	1.63	.71	.89	.34
Non Cognate				
(n=127) Mean	**5.20***	**2.32***	2.91	6.24
SD	1.84	.68	.80	.34

Table 36. Mean and standard deviation for cognate and non-cognate words in Welsh

Welsh	Letter length	Age of Acquisition	Frequency	Imageability
Cognate (n=63)				
Mean	**5.19***	3.11	4.65	6.20
SD	1.52	.96	1.78	.72
Non Cognate (n=127)				
Mean	**5.76***	3.11	4.71	5.97
SD	1.51	1.20	1.80	1.17

* *Significant difference found between cognates and non-cognates ($p < 0.05$)*

Independent t-tests were conducted on the data from tables 35 and 36. In English (Table 35) a significant difference was found for letter length (i.e. word length) between cognate and non-cognate items (t (188) = 2.00; $p < 0.05$) and for age of acquisition between cognate and non-cognate items (t (188) = 3.33; $p < 0.05$). The cognates were longer and later acquired than the non-cognate items. In Welsh (see Table 36) a significant difference between cognate and non-cognate items was found for letter length (t (188) = 2.45; $p < 0.05$) cognates were shorter than non-cognates. The opposite direction of the difference in letter/word length between cognate and non-cognate items in English and Welsh does not suggest that a potential cognate facilitation effect was 'masked' by an associated letter length effect in either language. Similarly, if later age of acquisition of cognate than non-cognate items mitigated or offset a potential cognate facilitation effect in English, it clearly could not have done so for Welsh (for which the mean age of acquisition of cognate and non-cognate items was identical).

Roberts and Deslauriers (1999) do not provide full details of the psycholinguistic characteristics of their stimuli and admit that '*while the cognate and non-cognate stimuli were similar...we cannot be certain that they were comparable on all levels*' (p. 14/15). However the information they do provide plus inspection of their stimuli suggest their stimuli were well controlled. The fact that only 50 stimuli were used in their analysis, 25 cognates and 25 non-cognates in comparison with the much larger number of the current study, may have allowed some unforeseen advantage for cognate items to have arisen in relation to only a few individual items. Roberts and Deslauriers (1999) presented their results in terms of the number of participants showing a cognate facilitation effect, rather than in terms of the number of items correctly reported as was done in the present study. A small but consistent advantage across participants for certain cognate items could lead to a significant effect being observed when the data are analysed for participants as a group. Whatever the reason for the discrepancies in findings between Roberts and Deslauriers

(1999) and the present study, the issue of cognate status (especially in relation to language dominance) clearly merits further investigation.

5.7 Characteristics of the semantic errors produced by PD, JWT and MJ

For all the words to which single word semantic errors were produced by each of the three patients, a comparison was made between the target items and the semantic error responses given. Only those responses for which ratings were available could be used. There were too few items for the stimuli to be separated into responses to cognate and non-cognate words. In any case there is no reason to expect that the features of semantic errors should differ as between cognate and non-cognate target words.

Gerhand and Barry (2000) analysed the semantic errors produced by their patient L.W. They found that, in comparison to the target word, the semantic errors given by L.W were earlier acquired, shorter in length and were higher in frequency. They were not any more concrete than the target words. Do the same semantic error characteristics arise with PD, JWT and MJ's in the current study? Gerhand and Barry (2000) only looked at semantic errors of reading. The following analyses were carried out on both reading and naming data. The results for the individual patients are given below.

5.8 Individual patient results:

PD

Table 37 shows the means and standard deviations (in parentheses) of characteristics of the target word that elicited single-word semantic errors and of the semantic errors produced by PD in English picture naming.

Table 37. Means and standard deviations of ratings of age of acquisition, imageability, frequency and letter length of target words and semantic error responses for English picture naming by patient PD.

(n = 17) Variable	Target word	Semantic error Response
Age of Acquisition	2.50 (.77)	1.89 * (.76)
Imageability	6.18 (.28)	6.32 (.21)
Frequency	2.75 (.92)	3.24 * (.83)
Letter length	5.82 (1.77)	4.47 * (1.12)

* Significant ($p < 0.05$)

T-tests conducted on PD's picture naming data in English showed significant differences between the target word and the semantic error response for each variable. Thus in comparison to the target words, the semantic errors produced by PD in English naming were earlier acquired ($t(16) = 3.57$, $p < 0.05$), more imageable ($t(16) = 2.07$, $p = 0.05$), more frequent ($t(16) = 2.74$, $p < 0.05$) and were shorter in length ($t(16) = 2.38$, $p < 0.05$).

For English reading, only three of the semantic errors produced had ratings from Morrison et al. (1997). Therefore, due to the small number of items no analysis was carried out.

Table 38 shows the means and standard deviations (in parentheses) of characteristics of the target word that elicited single-word semantic errors and of the semantic errors produced by PD in Welsh picture naming.

Table 38. Means and standard deviations of ratings of age of acquisition, imageability, frequency and letter length of target words and semantic error responses for Welsh picture naming by patient PD.

(n = 18) **Variable**	**Target word**	**Semantic error Response**
Age of Acquisition	3.08 (1.03)	2.31 * (.46)
Imageability	6.13 (.82)	6.27 (.46)
Frequency	5.10 (1.64)	6.15 * (.75)
Letter length	5.44 (1.54)	4.66 (1.45)

* Significant ($p < 0.05$)

T-tests on PD's Welsh picture naming found significant differences between the target word and the semantic error response for age of acquisition ($t(17) = 2.92$, $p < 0.05$) and frequency ($t(17) = 2.35$, $p < 0.05$). The semantic error responses made by PD were earlier acquired and were higher in frequency than the target words. Even though the mean ratings in Table 38 suggest that semantic errors were shorter and slightly more imageable, the difference between the target items versus semantic errors was not statistically significant for either letter length or imageability ($p > 0.05$).

Table 39 shows the means and standard deviations (in parentheses) of characteristics of the target word that elicited single-word semantic errors and of the semantic errors produced by PD in Welsh reading.

Table 39. Means and standard deviations of ratings of age of acquisition, imageability, frequency and letter length of target words and semantic error responses for Welsh reading by patient PD.

(n = 14) **Variable**	**Target word**	**Semantic error Response**
Age of Acquisition	3.08 (1.03)	2.31 * (.46)
Imageability	6.13 (.82)	6.27 (.46)
Frequency	5.10 (1.64)	6.15 * (.75)
Letter length	5.44 (1.54)	4.66 * (1.45)

* Significant ($p < 0.05$)

T-tests on PD's Welsh reading found significant differences between the target word and the semantic error response for age of acquisition ($t(13) = 2.29$, $p < 0.05$), frequency ($t(13) = 2.75$, $p < 0.05$) and letter length ($t(13) = 2.35$, $p < 0.05$). There was no significant difference between the imageability of target words versus semantic errors. The semantic error responses made by PD in Welsh reading were earlier acquired, higher in frequency and were shorter in length than the target words.

In summary the semantic errors produced by PD in Welsh naming and reading had similar characteristics, that is, they were words which were earlier acquired, more frequent and were shorter in length than the target items to which the errors were made. The same applies to PD's English picture naming semantic errors.

JWT

Table 40 shows the means and standard deviations (in parentheses) of characteristics of the target word that elicited single-word semantic errors and of the semantic errors produced by JWT in English picture naming.

Table 40. Means and standard deviations of ratings of age of acquisition, imageability, frequency and letter length of target words and semantic error responses for English picture naming by patient JWT

(n = 12) **Variable**	**Target word**	**Semantic error response**
Age of Acquisition	2.46 (.76)	2.11 (.38)
Imageability	6.25 (.32)	6.25 (.23)
Frequency	3.09 (1.00)	2.93 (.78)
Letter length	5.41 (.90)	4.33 * (1.15)

* Significant ($p < 0.05$)

At first glance at the mean and standard deviations of Table 40 it appears that the semantic errors produced by JWT in English picture naming were slightly earlier acquired and higher in frequency than the target words; however, this impression was not confirmed statistically. A t-test on JWT's English picture naming found that the only significant difference between the target word and the semantic error response was for letter length ($t(11) = 2.31$, $p < 0.05$), showing that the semantic errors produced by JWT were shorter in length.

In English reading, only 2 out of the 10 semantic errors produced by JWT had ratings from Morrison et al. (1997). Therefore, due to the small number of cases no analysis was carried out.

Table 41 shows the means and standard deviations (in parentheses) of characteristics of the target word that elicited single-word semantic errors and the actual semantic errors produced by JWT in Welsh picture naming.

Table 41 . Means and standard deviations of ratings of age of acquisition, imageability, frequency and letter length of target words and semantic error responses for Welsh picture naming by patient JWT.

(n = 14) **Variable**	**Target word**	**Semantic error response**
Age of Acquisition	3.38 (1.16)	2.30 * (.52)
Imageability	6.01 (.98)	6.54 (.26)
Frequency	4.26 (1.85)	6.28 * (.76)
Letter length	6.35 (1.69)	4.35 ** (1.21)

* Significant ($p < 0.05$) ** Significant ($p < 0.01$)

T-tests on JWT's picture naming in Welsh found significant differences between the target word and the semantic error response for age of acquisition ($t(13) = 3.71$, $p < 0.03$), frequency ($t(13) = 3.45$, $p < 0.04$) and letter length ($t(13) = 4.77$, $p < 0.01$). The semantic error responses made by JWT when naming in Welsh were earlier acquired, higher in frequency and shorter in length compared to the target words. The difference between target words and semantic errors in terms of imageability marginally failed to reach statistical significance ($p < 0.06$).

Table 42 shows the means and standard deviations (in parentheses) of characteristics of the target word that elicited single-word semantic errors and the actual semantic errors produced by JWT in Welsh reading.

Table 42. Means and standard deviations of ratings of age of acquisition, imageability, frequency and letter length of target words and semantic error responses for Welsh reading by patient JWT.

(n = 10) **Variable**	**Target word**	**Semantic error response**
Age of Acquisition	2.96 (.89)	2.11 * (.66)
Imageability	6.29 (.50)	6.61 (.30)
Frequency	5.12 (1.71)	6.36 * (.69)
Letter length	6.30 (1.05)	4.10 ** (1.10)

* Significant ($p < 0.05$) ** Significant ($p < 0.01$)

T-tests on JWT's reading in Welsh found significant differences between the target word and the semantic error response for age of acquisition ($t(9) = 2.17$, $p = 0.05$), frequency ($t(9) = 2.23$, $p = 0.05$) and letter length ($t(9) = 5.66$, $p < 0.01$). No significant difference was found for imageability. The semantic errors produced by JWT in Welsh naming and reading had the same characteristics, that is, they were words which were earlier acquired, more frequent and were shorter in length than the target items.

MJ

Table 43 shows the means and standard deviations (in parentheses) of characteristics of the target word that elicited single-word semantic errors and of the semantic errors produced by MJ in English picture naming.

Table 43. Means and standard deviations of ratings of age of acquisition, imageability, frequency and letter length of target words and semantic error responses for English picture naming by patient MJ.

(n = 23) Variable	Target word	Semantic error response
Age of Acquisition	2.75 (.73)	2.29 * (.70)
Imageability	6.13 (.24)	6.28 (.28)
Frequency	2.49 (.80)	2.91 * (.91)
Letter length	5.56 (1.92)	5.17 (1.80)

* Significant ($p < 0.05$)

T-tests on MJ's English picture naming in English found significant differences between the target word and the semantic error response for age of acquisition ($t(22) = 2.95$, $p < 0.05$) and frequency ($t(22) = 2.35$, $p < 0.05$). There was no significant difference between the target items and the semantic errors in terms of imageability or letter length.

In English reading, only 5 out of the 12 semantic errors produced by MJ had ratings from Morrison et al. (1997). Therefore, no analysis was carried out.

Table 44 shows the means and standard deviations (in parentheses) of characteristics of the target word that elicited single-word semantic errors and of the semantic errors produced by MJ in Welsh picture naming.

Table 44. Means and standard deviations of ratings of age of acquisition, imageability, frequency and letter length of target words and semantic error responses for Welsh picture naming by patient MJ

(n = 15) **Variable**	**Target word**	**Semantic error response**
Age of Acquisition	3.67 (1.25)	2.27 ** (.45)
Imageability	5.45 (1.28)	6.49 * (.49)
Frequency	3.87 (2.03)	6.10 ** (.97)
Letter length	5.46 (1.30)	4.60 (1.50)

* Significant ($p < 0.05$) ** Significant ($p < 0.01$)

T-tests on MJ's picture naming in Welsh found significant differences between the target word and the semantic error response for age of acquisition ($t(14) = 4.01$, $p < 0.01$), frequency ($t(14) = 4.72$, $p < 0.01$) and imageability ($t(14) = 3.35$, $p < 0.05$). These results show that the words produced as semantic errors by MJ were earlier acquired, more frequent and were also higher in imageability. There was no significant effect of letter length.

In MJ's Welsh reading, only 4 out of the 15 semantic errors produced by MJ had appropraite ratings from Fear (1997). Therefore, due to the small number of cases no analysis was carried out.

In order to determine whether the differences in AoA, frequency, imageability and letter length between target items and responses for each patient were real or due to all variables being inter-correlated, a series of ANCOVAs were carried out, taking each variable in turn and systematically partialing out the effects of the other variables. In every case the significant differences reported above were 'lost' or removed when ANCOVAs were run using each of the other variables in turn as the covariate. The same was found when all three variables were entered simultaneously as covariates. Thus the results shown in Tables 37 and 44 should be interpreted with caution.

In summary, the pattern that emerged from the analyses was that the same characteristics of semantic errors were found for both reading and naming that is, when PD, JWT and MJ produced semantic errors, they typically chose words that were earlier acquired, more frequent and shorter than the target words.

Each of the participant's results partly support those of Gerhand and Barry (2000) who found that in comparison to the target words, semantic errors produced by L.W were earlier acquired, shorter and were higher in frequency. The semantic errors of L.W were *not* any more concrete than the target words. None of the present series of patients produced semantic errors in reading that were more imageable than the target words but the semantic errors produced by PD in English picture naming and by JWT and MJ in Welsh picture naming were higher in imageability than the target items. It is not clear why the effect was not also found in reading. None the less, assuming that concreteness and imageability refer to highly related concepts, the present findings support those of Nickels and Howard (1994) who found an effect of concreteness in picture naming errors. Gerhand and Barry (2000) pointed out that the range of concreteness examined by Nickels and Howard (1994) was highly restricted; the same applies to the stimuli of the present study.

5.9 Summary and discussion of findings

It was hypothesised that if Welsh is more likely than English to be read using sub-lexical orthography-phonology conversion rules, then an effect of word length is more likely to be found in reading Welsh than English. However, an effect of word length was found for reading but only for one of the patients reading Welsh, both when cognates were included and when they were removed. There was also a word length effect in English picture naming. Consequently these findings do not support the idea that Welsh is read more 'phonically' than English. Arguably, a word length effect reflects an output rather than an input problem, but if so, it is not clear why the effect was not seen consistently for both tasks in both languages.

According to Whitney and Lavidor (2004) it is well known that letter string length has a greater impact on visual word recognition when letter strings are presented to the left visual field (LVF) than when they are presented to the right visual field (RVF). For example, in lexical decision experiments RVF reaction times are unaffected by the number of letters, while each additional letter increases LVF reaction times by 20-30ms (see Young and Ellis, 1985; Ellis et al. 1988; Lavidor and Ellis, 2002). Due to the routing of optic fibres at the optic chasm, stimuli in the LVF are initially projected to the right hemisphere, while stimuli in the RVF are projected to the left hemisphere. The asymmetry of the letter length effect has often been taken to reflect differing modes of lexical access stemming from the left hemisphere superiority for language, with efficient, parallel processing of letters in the left hemisphere and non-parallel processing in the right hemisphere (Whitney and Lavidor, 2004).

If deep dyslexics read with the right hemisphere due to left hemisphere damage, in line with Coltheart's (1980) right hemisphere reading hypothesis of deep dyslexia, then if Whitney and Lavidor are correct, one might have expected to see a length effect for both English and Welsh reading. The fact that this was not the case (or at least not consistently for all three patients) might therefore be seen as failure to support Coltheart's hypothesis.

The results from the regression analyses support other findings that age of acquisition is a factor that independently predicts reading and picture naming accuracy (e.g. Gerhand & Barry, 2000; Barry & Gerhand, 2003). Age of acquisition was found to significantly predict the distribution of responses across categories (correct, omission, semantic errors and all other errors) in reading (and picture naming) in Welsh for all three patients. Thus the prediction that lexical variables (such as frequency and age of acquisition which are considered to exert their effects post semantically) should *not* have an effect on reading transparent languages, since the dominant route these languages use is said to be the sub-lexical route, is not supported by the data of this study. The AoA effect may in fact be a sub-lexical variable reflecting ease of pronunciation since the bigram scores are higher and orthotactic regularity is greater for earlier acquired than later acquired words (a random sample of early and later acquired words confirmed this).

The fact that age of acquisition but not frequency influenced patients' responses is in accordance with the finding that Nickels and Howard (1994) reported for the production of semantic errors in aphasic naming.

The chapter also compared the number of cognate and non-cognate items responded to correctly for each task, patient and language. However, in no case did the difference reach statistical significance at the 5 % level. There was thus no evidence of a cognate facilitation effect in either language for picture naming or reading.

Finally, the characteristics of semantic errors were compared with those of the target items. The pattern that emerged from the analyses was that the same characteristics of semantic errors were found for both reading and naming. That is, when PD, JWT and MJ produced semantic errors, they typically chose words that were earlier acquired, more frequent and shorter than the target words. Each of the participant's results partly support those of Gerhand and Barry (2000) who found that in comparison to the target words, semantic errors produced by L.W were earlier acquired, shorter and were higher in frequency.

At this point in the investigation it was decided to examine another area of interest namely implicit phonological ability. The occurrence of semantic errors found in deep dyslexia suggests impairment of the sub-lexical route. However, Buchanan et al. (1994) claimed to find implicit phonological ability in deep dyslexia. Therefore the following experiments aim to examine the possibility of finding implicit phonological ability in the current deep dyslexic patients.

Chapter 6

6.0 Introduction

Several traditional cognitive models of deep dyslexia describe the acquired reading disorder in terms of multiple deficits reflecting impairment to the sub-lexical route as well as damage to the semantic system of the 'normal' reading system (see Barry & Richardson, 1988; Coltheart, 1982; Morton & Patterson, 1980; Friedman, 1993; Plaut & Shallice, 1993). Although these accounts differ on many levels, they share the view that deep dyslexic patients are unable to process phonology, that is, they all claim that the ability to piece together sub-lexical phonological information is eliminated. This assumption arose primarily from the observation that deep dyslexic patients are unable to read novel or non-words aloud and have difficulty with other phonological tests, for example, letter sound conversion and rhyme judgement. However, recent findings challenge this notion; for example, Katz and Lanzoni, (1992), Hildebrandt and Sokol (1993) and Buchanan et al. (1994, 1995, 1996, 1999, 2003) demonstrated that some deep dyslexics are sensitive to implicit phonological information for words and non-words, despite impaired explicit access. Colangelo et al. (2004) argued that this poses considerable problems for accounts couched in terms of damage to several components of the reading system as these 'implicit' results, among others (e.g. Buchanan et al., 1994), provide evidence that the primary locus of deep dyslexia is not sub-lexical.

Katz and Lanzoni (1992) questioned the nature of the deficits in deep dyslexia, by testing a patient with an 'output' type of deep dyslexia. Although JA's semantic system was relatively intact, he had difficulty reading words, made many semantic errors and was unable to read non-words. His performance in reading and in other 'explicit' tasks that used printed stimuli suggested that he was unable reliably to access the phonology of words from print. However, in contrast, Katz and Lanzoni (1992) found that the pattern of JA's reaction time on correct trials on a lexical decision task showed an effect based on the phonology of the stimulus items, similar to that seen in 'normal' subjects (see Meyer et al., 1974). The effect was apparent when content words were used as stimuli but not when function words were used. Katz and Lanzoni (1992) argued that automatic activation of the phonology of content words was greater than would be expected on the basis of the patient's oral reading performance. They concluded that deep dyslexics are influenced by phonology, even in tasks that do not specifically require that it be processed. This view suggests that phonological processing is more prevalent in deep dyslexia than was previously assumed.

Hildebrandt and Sokol (1993) argued that the lexical decision task is a valid implicit measure of sub-lexical phonological processing for a number of reasons. One is, that lexical decision does not require the explicit use of sub-lexical phonological information and there is no need to attend to spelling regularities in reading. Using a double word lexical decision task, Meyer et al. (1974) found that non-brain injured people were faster at deciding the lexical status of rhyming words with similar spelling (e.g. *bribe-tribe*) compared with control trials consisting of non-rhyming, similarly spelled words (e.g. *dead-bead*); they also found that participants were slower on non-rhyming words with similar spelling (e.g. *touch-couch*) than on non-rhyming words with dissimilar spellings (e.g. *rope-wall*). Meyer et al. (1974) explained their results by suggesting that the grapheme to phoneme conversion rules used in developing the phonemic representation for the first word are applied to the second when the two words are visually similar. This results in faster lexical access for the rhyming pairs but causes a delay in reaction time for the non-rhyming pairs.

Tasks often used to examine phonological processing involve the use of pseudohomophones; these are non-words that have the same phonology as real words (e.g. *rane*, *bloo*, *kwean*). Pseudohomophones are a sensitive tool for studying phonological language processing because their orthography does not represent a word but an application of grapheme-phoneme conversion results in a word-like representation, that is, they sound like real words (Atchley et al. 2003). According to Besner et al. (1985), in individuals with 'normal' access to phonological information the conflict between orthography and phonology makes processing these pseudohomophones difficult and thus increases response times compared with other non-words. An increased reaction time and a greater number of errors in relation to pseudohomophones relative to visually similar orthographic control non-words in a lexical decision task is referred to as the 'pseudohomophone effect'.

MacKay (1972) in one of the first pseudohomophone experiments asked participants to proof read sentences for spelling errors. Two types of spelling errors were used in the study, namely, pseudohomophones (e.g. ***werk*** for ***work***) and non-homophonic non-words which had been equated for orthographic similarity (e.g. *wark* for ***work***). MacKay (1972) found that the non-words were identified as misspelled words more frequently than were the pseudohomophones. Furthermore, participants performing the lexical decision task took more time to correctly reject pseudohomophones than to reject the orthographically controlled non-words. The pseudohomophone effect has been found in many subsequent experiments using non-brain injured patients (for example, Coltheart et al., 1977; Barron, 1978; McQuade, 1981 among others). The effect has also been investigated in acquired dyslexics and has provided mixed findings in relation to the hypothesis that the sub-lexical route is abolished or impaired in deep dyslexics.

Patterson and Marcel (1977) reported that their patients, D.E. and P.W. failed to show a pseudohomophone effect during lexical decision (even when the same set of stimuli demonstrated the effect in 'normal' controls). Since the effect is assumed to arise via the sub-lexical route, Patterson and Marcel (1977) concluded that the use of this pathway must be eradicated in deep dyslexia. Hildebrandt and Sokol (1993) also reported that their acquired dyslexic patient G.R did not display a 'normal' pseudohomophone effect. However, they did find a significant 'regularity effect' (words with typical spelling-sound correspondences are responded to more quickly and accurately in a lexical decision task than words with atypical spelling-sound correspondences). Hildebrandt and Sokol found that G.R. showed the 'normal' effect of spelling regularity with low-frequency words. Since this effect is typically attributed to the use of sub-lexical information in word recognition, they argued that GR's results provided evidence for intact implicit sub-lexical processing.

Martin (1982) found that in terms of reaction times there was no significant difference between pseudohomophones and orthographically controlled non-words in the lexical decision task used with her deep dyslexic patients B.L. and J.S. However, in terms of error rates Martin proposed that the pattern of the results conformed to that found in non-brain injured subjects, namely an increased number of errors to pseudohomophones compared to orthographically controlled non-words. Thus in terms of error rates it could be argued that B.L and J.S. did show the pseudohomophone effect. Nonetheless, Martin concluded that the non-significant difference between the two kinds of stimuli in her experiment indicated that the effect was orthographic rather than phonological since it was obtained in deep dyslexic readers.

According to Atchley et al. (2003), the application of pseudohomophones in lexical decision and priming paradigms used to study people with acquired or developmental language disorders has a distinct advantage over more explicit tests of phonological decoding such as non-word reading. They argue that with lexical decision measures it is possible to examine the early time course of phonological access and these techniques have been used effectively with a variety of patient populations that exhibit phonological processing deficits (see Katz & Lanzoni, 1992;1997, Hildebrandt & Sokol, 1993; Buchanan et al., 1994;1995;1996;2003). These tasks all claim to 'tap into' and expose implicit phonological awareness that may be absent in explicit demonstrations.

Buchanan, Kiss and Burgess (2000) and Buchanan et al. (2003) reported that two deep dyslexics read aloud pseudohomophones much better than orthographically controlled stimuli. The findings imply that the semantic content available through the word-like phonological information in the pseudohomophones can act, presumably through feedback to semantics and then feed forward to phonology, to constrain the response selection process. Buchanan et al. (2000) suggest that in previous studies hints of this dissociation have been dismissed on the basis of greater visual overlap between real words and pseudohomophones than between real words and orthographically controlled non-words. Buchanan et al. sought to solve this problem by contrasting a deep dyslexic patient's reading performance for pseudohomophones with that for "*very stringently*" matched orthographic control non-words. For example, the orthographic similarity to words was tested using the summed bigram frequency scores developed by Mayzner and Tresselt (1965) and the orthographic overlap was evaluated by the technique introduced by Bruck and Waters (1988). Buchanan et al. (2000) asked patient S.D. to read aloud 54 pseudohomophones and 54 orthographically controlled non-word equivalents. They found that her performance on this task favoured pseudohomophones, of which she read 36/54 correctly, over non-words, of which she read only 6/54 correctly. Buchanan et al. (2000) argued that the results were not due to a predisposition to provide real-word responses since S.D. produced several incorrect non-word responses during real word, pseudohomophone and non-word reading (e.g. she read 'coast' as 'oist'). Buchanan et al. (2000) argued that the stimulus set was so designed that the orthographic overlap always favoured the orthographic visual controls over the pseudohomophones. They concluded that they were '*...quite confident that the effects reported were of a phonological nature and not due to orthographic similarity to either a specific word or to words in general...*' (p. 66).

The implicit phonological ability found in patients who had previously failed to exhibit phonological awareness on a number of explicit tasks (e.g. letter sound conversion and non-word reading aloud) suggests that deep dyslexia may not involve a complete loss of phonological processing. However, the data (e.g. Katz & Lanzoni, 1992, 1997; Hildebrandt & Sokol, 1993) are limited to word level phonology only. Buchanan et al. (1994) elaborated on this and looked at the possibility that implicit knowledge extends to non-word phonology as well. They designed a priming experiment to study the extent to which implicit phonological ability influences lexical decision performance in a deep dyslexic patient. Buchanan et al. (1994) claimed to have examined their methodology carefully by using, for example, similarity ratings, bigram frequencies and a test of word-likeness, in order to make the claim that it was the phonology of the pseudohomophone that was responsible for the semantic priming and not the orthographic overlap between the non-word prime and the associated word from which it derived. The stimulus set used consisted of real target words, semantic primes and their orthographic control equivalents. However, unlike typical semantic priming experiments the primes used in the investigation were pseudohomophones (e.g. *wimin*, *taybul*, *wreed*). By using pseudohomophones as primes Buchanan et al. argued that they could examine the extent to which non-word phonology activates representations (e.g. *wreed*-write; *taybul*-chair; *dockter*-nurse) in the semantic system of a typical deep dyslexic patient. Traditional theories of deep dyslexia would predict no priming advantage for pseudohomophones since they assume that the ability to process phonological information from non-words is eliminated. Conversely, the concept of preserved implicit phonology predicts that a semantically related pseudohomophone would produce a facilitation effect in reaction times to target words relative to orthographically controlled non-words. Buchanan et al. (1994) found that J.C. produced a pseudohomophone effect and she was able to access semantic information from pseudohomophones. Furthermore, she could benefit from this information in terms of a priming advantage compared to orthographically controlled non-words. Buchanan et al. (1994) proposed that this knowledge must be confined to implicit processing since JC's performance on a naming task with identical stimuli indicated that she did not process the information well enough to name written non-words aloud. This finding was replicated in subsequent studies (Buchanan et al., 1996, 1999, 2003).

Given the findings discussed above, the aim of the following experiments was to examine whether evidence of implicit phonological ability would be found in patients PD, JWT, and MJ. In the language tests given to them they all made semantic errors while reading pseudohomophones (see chapter 3). For example: PD made two semantic errors, reading '*howse*' as '*house wife*' and '*nefew*' as '*wife*'; JWT read '*tode*' as '*frog*' and MJ read '*kat*' as '*dog*', '*sitee*' as '*sit*'.

Apart from the investigations by Buchanan and her colleagues, there has been little research done on implicit processing in deep dyslexia. The thought occurred that it would be feasible to use the Stroop effect to examine whether deep dyslexic patients could implicitly process phonology. The Stroop effect is argued to be a very good way of looking at automatic word recognition processes. Reading is such a well-learned activity, it is unavoidable, and requires little attention. The question of interest was: would evidence of automatic sub-lexical phonological processing show up as an increase in the time taken to respond to pseudohomophones printed in coloured ink as compared with orthographically controlled non-words?

Experiment 6.1

In 1935 J.R. Stroop published his seminal article on attention and interference. He was interested in how highly familiar words interfered with processing of various stimulus attributes and hit upon the idea of using a compound stimulus. Stroop (1935) compared the ability to name the colour of the ink of incongruent and congruent words. For example, he found that the task of naming the ink colour of incongruent stimuli (‘red’, ‘blue’, ‘yellow’) was significantly slower than when the word and ink colour were congruent (‘red’, ‘blue’, ‘[illegible]’). This became known as the ‘*Stroop effect*’ and was argued to be due to the automatic tendency to read the words. According to MacLeod (1991) the roots of Stroop’s research are evident fifty years earlier in the work of Cattell (1886) who reported that objects and colours took longer to name aloud than the corresponding words took to read aloud. For example, saying ‘*red*’ to a patch of colour was slower than saying ‘red’ to the word *red.* Cattell suggested that in the case of words and letters, the association between the idea and name has taken place so often that the process has become automatic, whereas in the case of colours and pictures it requires a voluntary effort to choose the name.

Stroop (1935) examined the effect of incongruent ink colour on reading words aloud. He used five words and five matching ink colours, namely, red, blue, green, brown and purple in his study. In the first control part of the task, participants were asked to read aloud the word (printed in black ink) as quickly as possible and their response time to complete the control condition was recorded. The second part required the subjects to name aloud the ink colour in which the word was written. In the experimental condition the ink colour was incongruent with the word and participants took significantly longer to complete the condition. Stroop (1935) described this increase in reaction time as a ‘*marked interference effect*’. Logan (1997) suggested that this interference effect can be taken as a measure of reading automaticity.

Logan argued that automaticity is a complex notion, generally considered to be a graded feature of task performance related to speed, voluntariness, attention, effort and conscious awareness. According to Protopapas et al. (2006) automatic processes are performed rapidly, without conscious intent or guidance, and with little effort, thus allowing the simultaneous performance of other tasks at little or no cost (see Atkinson and Shiffrin, 1968). Logan (1997) argued that the concept of automaticity remains central to our understanding of the Stroop task. As MacLeod (1991) stated, *"the basic idea is that processing of one dimension requires much more attention than does processing of the other dimension. Thus naming the ink colour draws more heavily on attentional resources than does reading the irrelevant word. Moreover, reading the word is seen as obligatory, whereas naming the ink colour is not. Presumably, this imbalance derives from our extensive history of reading words as opposed to naming ink colours"* (p. 188). Thus it could be argued that the Stroop effect would be a good indicator of implicit phonological ability in deep dyslexia.

According to Everatt et al. (1997), robust Stroop effects have been reported in poor readers, who are not reading 'automatically'. Moreover, they found more interference in children with dyslexia than in age matched controls. At present the Stroop test has not been conducted with acquired dyslexics. It was therefore decided to conduct a Stroop test with the present deep dyslexic patients. Similar to Stroop's (1935) methodology, experiment 6.1 used the principle of compound stimuli (using congruent and incongruent ink colours) with real words but pseudohomophones and orthographically controlled non-words were also included. Pseudohomophones were constructed along with orthographically controlled non-words in order to investigate whether deep dyslexics could derive sub-lexical phonology from print and thus show a 'pseudohomophone effect', i.e. an increase in reaction time to identify the ink colour in which incongruent pseudohomophones are written, compared to their orthographically controlled equivalents.

It was hypothesised that participants would take longer to respond to the colour of the ink of incongruent words (e.g. green) than to the ink colour of congruent words (e.g. green) (Stroop, 1935). It was further hypothesised that the ink colour of orthographically controlled non-words (e.g. blus) would elicit faster response times than pseudohomophones (e.g. bloo) as the former would not give rise to an 'interference effect'.

Experiment 6.1

Method

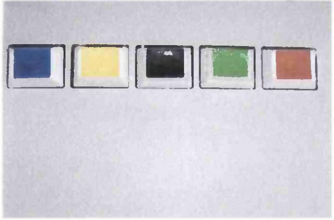
Participants

In addition to PD and JWT it was possible to recruit another patient, JPJ (aged 26). In brief: JPJ made semantic errors in reading, naming and drawing; he could not read non-words aloud and was considered to be deep dyslexic by virtue of the same criteria as applied to PD, JWT and MJ (see appendix 12 for all JPJ's preliminary language tests and scans). Thus there were three deep dyslexic patients available for this experiment. The participants in this study were all dysphasic; consequently they had difficulty naming words aloud. In Stroop's (1935) original experiment subjects were asked to read and name aloud words and colours but due to the nature of the participants '*output*' difficulties, it was decided that measuring spoken reaction time would not be appropriate. They were therefore required to respond in another way, namely by using a response box with coloured buttons.

Materials

A Cedrus response pad Model RB-730 was used (see figure 9); the order of coloured buttons was different for each participant.

Figure 9. Coloured button response box



Similar to Stroop's (1935) experiment, five colours were chosen; blue, black, yellow, green and brown (so that pseudohomophones could be constructed for each word). The orthographically controlled non-words were made by changing one letter of their real word equivalents. Davis's (2005) 'n watch' computer program was used to evaluate the Stroop stimuli. The n watch enables users to obtain a broad range of statistics concerning the properties of word and non-word stimuli including measures of bigram frequency and orthographic neighbourhood size (the number of words which can be created from the target item by changing one letter, see Coltheart et al., 1977). Previous studies have shown that, in general, facilitation effects in lexical decision occur for words with larger 'n scores' (e.g. Laxon et al., 1988; Laxon et al., 1994). The usual explanation of 'n effects' generally invokes the notion that a written word can activate not only its own lexical entry but also the entries for other words of similar appearance. In certain conditions at least, activating those other lexical entries can facilitate the processing of the target word (Coltheart et al., 1977).

The Stroop stimuli used in experiment 6.1 were input into the n watch program. Summed bigram frequency scores were calculated: the mean bigram score for the pseudohomophones was 9.34 and for the orthographically controlled non-words the mean bigram score was 10.23. The pseudohomophones had an orthographic neighbourhood total of 12 while the orthographically controlled non-words had a total of 17. These values imply that the orthographically controlled non-words were more similar to real words than were the pseudohomophones.

The experiment was conducted using a SuperLab programme and was split into two separate tests (which were carried out on different occasions). In the first test session (hereafter referred to as Stroop 1), real colour words were compared with pseudohomophones and in the second test session (Stroop 2) real colour words were compared with orthographically controlled non-words. There were 20 trials per session. Each participant was required to respond to the colour of the ink in which the item was written (i.e. either congruent or incongruent colour) by pressing the appropriate coloured button on the response pad, (for example, if the ink colour was red they had to press the red button on the response box). The order of the response button colours was determined randomly for each participant. Prior to the experiment each participant was tested for colour blindness using the Ishihara test.

The congruent and incongruent stimuli used are shown in tables 45 and 46 below:

Table 45. Congruent stimuli

Real word (control words)	Pseudohomophones (Stroop 1)	Orthographically controlled non-words (Stroop 2)
1. blue	**bloo**	**blus**
2. black	**belak**	**bleck**
3. yellow	**yelo**	**yetlow**
4. green	**grean**	**greem**
5. brown	**broun**	**broin**

Table 46. Incongruent stimuli

Real word	**Pseudohomophones (Stroop 1)**	**Orthographically controlled non-words (Stroop 2)**
1. blue written in brown	**bloo** written in brown	**blus** written in brown
2. black written in green	**belak** written in green	**bleck** written in green
3. yellow written in black	**yelo** written in black	**yetlow** written in black
4. green written in blue	**grean** written in blue	**greem** written in blue
5. brown written in yellow	**broun** written in yellow	**broin** written in yellow

Procedure

The target item appeared in the centre of the computer screen in an Arial Baltic style, font size 100. Participants sat at approximately 22 inches away from the computer screen. The item remained until an ink colour decision was made by the participant pressing the appropriate coloured button on the response box. Each item was presented in congruent and incongruent ink colours. Items were presented in random order for each participant. In Stroop 1 pseudohomophones appeared with real words and in Stroop 2 orthographically controlled non-words appeared with real words.

Results of experiment 6.1

A pilot study was conducted with 3 control participants (see chapter 3) (individually matched to PD, JWT and JPJ for gender, age and education) to examine whether the conventional Stroop effect and a pseudohomophone effect would emerge. Only correct data was analysed and all outliers that were plus or minus 3 standard deviations from the mean were removed. Table 47 shows the control participants' results for Stroop 1.

Table 47. Mean, standard deviation and median response times (in milliseconds) of control participants to respond to ink colour in Stroop 1 (real words versus pseudohomophones).

Stroop 1	**E.D (male, age 53)**			**E.P (male, age 70)**			**M.D (male, aged 26)**		
	Mean RT	SD	Med RT	Mean RT	SD	Med RT	Mean RT	SD	Med RT
Real words (congruent)	1053.40	39.46	1072.00	1281.60	97.92	1242.00	708.60	47.72	693.00
Pseudo-homophones (congruent)	1042.40	61.97	1023.00	1349.80	155.04	1298.00	725.80	22.33	735.00
Real words (incongruent)	1869.00	233.35	1778.00	2420.20	201.29	2348.00	1036.60	173.52	1042.00
Pseudo-homophones (incongruent)	1395.00	84.10	1394.00	2123.00	256.71	2018.00	953.20	91.06	928.00

Table 48 shows the control participants results for Stroop 2.

Table 48. Mean, standard deviation and median response times (in milliseconds) of control participants to respond to ink colour in Stroop 2 (real words versus orthographically controlled non-words).

Stroop 2	**E.D (age 53)**			**E.P (age 70)**			**M.D (aged 26)**		
	Mean RT	SD	Med RT	Mean RT	SD	Med RT	Mean RT	SD	Med RT
Real words (congruent)	1054.00	106.52	991.00	1232.20	98.04	1282.00	563.60	170.20	598.00
Ortho-graphically controlled non-word (congruent)	1109.40	174.42	1001.00	1414.40	164.93	1400.00	611.20	58.73	634.00
Real words (incongruent)	1730.60	287.61	1841.00	2047.40	399.61	1886.00	831.00	158.73	795.00
Ortho-graphically controlled non-word (incongruent)	1160.60	107.27	1222.00	1486.80	203.69	1408.00	648.20	35.54	634.00

Due to the high variance and skew of the data the reaction time data was log transformed (using log 10). A 2x2 ANOVA was conducted on the each of the control participant's transformed data. The factors were item type (real words and non-words) and congruency (incongruent and congruent ink colours). In Stroop 1, E.D showed a significant main effect of item type (word vs. pseudohomophone) ($F (1, 4) = 9.66$; $p < 0.05$), a significant effect of congruency ($F (1, 4) = 194.60$; $p < 0.01$) and a significant word by congruency interaction ($F (1, 4) = 30.88$; $p < 0.05$). Despite the low number of trials, decomposing the interaction showed that there was a significant difference between real congruent and real incongruent items ($t (4) = 10.51$; $p <0.01$) and between pseudohomophone congruent and pseudohomophone incongruent items ($t (4) = 19.70$; $p < 0.01$). That is, there was an effect of congruency versus incongruency for words and pseudohomophones. There was no significant difference between real word congruent versus pseudohomophone congruent ($t (4) = .402$; $p >0.05$) items but a statistically significant difference was found between real word incongruent and pseudohomophone incongruent items ($t (4) = 4.04$; $p < 0.05$). The data suggest a slightly greater Stroop effect (i.e. of congruency) for real words than for pseudohomophones in E.D.

E.P showed a significant effect of congruency ($F (1, 4) = 101.55$; $p < 0.01$); M.D also showed a significant effect of congruency ($F (1, 4) = 77.85$; $p < 0.01$). For both participants congruent stimuli were responded to more quickly than incongruent stimuli. No other effects were statistically significant. Lack of interaction effects show that congruency effects were similar for words and pseudohomophones for both participants.

In Stroop 2, E.D again showed a significant main effect of item type (word vs. orthographically controlled non-word) ($F (1, 4) = 12.05$; $p < 0.05$), a significant effect of congruency ($F(1, 4) = 18.11$; $p < 0.05$) and a significant word by congruency interaction ($F(1, 4) = 34.90$; $p < 0.05$). Despite the low number of trials, subsequent decomposition of the interaction for E.D (using the transformed data) showed that there was a significant difference between real congruent and real incongruent items ($t(4) = 5.41$; $p< 0.05$). There was no significant difference between congruent and incongruent orthographically controlled items nor between congruent real words and congruent orthographically controlled items. A statistically significant difference was found between real word incongruent and orthographically controlled incongruent items ($t(4) = 4.67$; $p <0.05$). Thus the interaction showed that the conventional Stroop effect was found with real words but not with orthographically controlled non-words.

E.P's results in Stroop 2 displayed a significant congruency effect ($F(1, 4) = 29.73$; $p < 0.05$) plus a significant word by congruency interaction ($F(1, 4) = 31.08$; $p < 0.05$). Decomposing the interaction, a significant difference was found between real congruent and real incongruent items ($t(4) = 6.78$; $p< 0.05$). There was no significant difference between congruent and incongruent orthographically controlled stimuli nor between incongruent real words and orthographically controlled incongruent items. The difference between congruent real words and congruent orthographically controlled non-words was marginally significant ($t(4) = 2.62$, $p = 0.05$). E.P's results showed that the conventional Stroop effect was found with real words but not with orthographically controlled non-words.

M.D showed a significant congruency effect ($F(1, 4) = 13.39$; $p < 0.05$) plus a significant word by congruency interaction ($F(1, 4) = 19.36$; $p < 0.05$). Subsequent decomposition of the interaction for M.D (using the transformed data) showed that there was a significant difference between real congruent and real incongruent items ($t(4) = 4.37$; $p < 0.05$). There were no significant differences between orthographically controlled congruent and orthographically controlled incongruent items nor between real word congruent versus orthographically controlled congruent items. The difference between incongruent real words and incongruent orthographically controlled items fell just short of significance (t (4) = 2.54; p > 0.06). Thus the Stroop effect was found with real words but not with orthographically controlled non-words.

In summary, all three control participants' results showed that the stimuli gave rise to a significant Stroop effect, using either real words or pseudohomophones as stimuli (in Stroop 1), but not when orthographically controlled non-words were used (in Stroop 2).

The same Stroop experiment was carried out with the three deep dyslexic patients. The response times of the participants to complete the Stroop task was recorded. Only the correct data was analysed and all outliers were removed if greater than 3 standard deviations from the mean for the relevant condition.

The results from both sessions (Stroop 1 and 2) are shown in Tables 49 and 50

Table 49. Mean, standard deviation and median response time (in milliseconds) for patients PD, JWT and JPJ to respond to ink colour in Stroop 1 (real words versus pseudohomophones).

Stroop 1	**P.D**			**J.W.T**			**J.P.J**		
	Mean RT	SD	Med RT	Mean RT	SD	Med RT	Mean RT	SD	Med RT
Real words (congruent)	1345.20	430.87	1150.00	1117.20	143.06	1141.00	1010.00	21.68	1014.00
Pseudo-homophones (congruent)	1774.60	672.57	1358.00	1273.60	109.72	1234.00	1072.00	75.45	1069.00
Real words (incongruent)	3050.00	786.89	2705.00	1789.40	316.41	1918.00	1340.20	107.39	1374.00
Pseudo-homophones (incongruent)	2247.00	648.56	2141.00	1875.40	331.07	1847.00	1279.80	145.75	1207.00

Table 50. Mean, standard deviation and median response time (in milliseconds) for patients to respond to ink colour in Stroop 2 (real words versus orthographically controlled non-words).

Stroop 2	**P.D**			**J.W.T**			**J.P.J**		
	Mean RT	SD	Med RT	Mean RT	SD	Med RT	Mean RT	SD	Med RT
Real words (congruent)	1005.60	72.72	968.00	1121.00	119.21	1121.00	876.40	67.86	860.00
Ortho-graphically controlled non-word (congruent)	1085.00	84.87	1060.00	1337.60	83.15	1346.00	1022.60	92.11	1073.00
Real words (incongruent)	1178.60	171.75	1281.00	1423.40	166.91	1429.00	1150.60	101.99	1096.00
Ortho-graphically controlled non-word (incongruent)	1075.60	61.37	1092.00	1370.20	56.03	1356.00	1069.80	146.75	1070.00

The reaction times were transformed to reduce the high variance and skew of the data. A 2x2 ANOVA was conducted on the transformed data for each patient separately. The factors were item type (real words and non-words) and congruency (incongruent and congruent stimuli).The 2x2 ANOVA found that all three deep dyslexic participants displayed significant effects of congruency in Stroop 1 (**PD**: F (1, 4) = 16.26; $p < 0.05$; **JWT**: F (1, 4) = 71.55; $p < 0.01$; **JPJ**: F (1, 4) = 22.18; $p < 0.05$). These results show that PD, JWT and JPJ all showed a similar statistically significant effect of congruency using both real words and pseudohomophones. JPJ also displayed a significant word by congruency interaction (F (1, 4) = 12.94; $p < 0.05$). Decomposing this interaction revealed that there was a significant difference between congruent and incongruent real items (t (4) = 7.10; $p <0.02$) and between congruent and incongruent pseudohomophones (t (4) = 2.93; $p <0.05$). However, no statistically significant difference was found between real congruent versus pseudohomophone congruent nor between real incongruent versus pseudohomophone incongruent items. The significant interaction for JPJ appears to be due to a greater Stroop effect for real words versus pseudohomophones.

In Stroop 2, PD failed to show any significant effects of congruency (F (1, 4) = 1.93 $p > 0.05$) nor any congruency by item type interaction. Thus for PD the conventional Stroop effect was not found even with real words. However, both JWT and JPJ showed significant effects of congruency with real words as stimuli (**JWT**: F (1, 4) = 11.01; $p < 0.05$; **JPJ**: F (1, 4) = 12.31; $p < 0.05$) and JPJ showed a significant word by congruency interaction (**JPJ**: F (1, 4) = 18.34; $p < 0.05$). The lack of interaction for JWT shows that the effect of congruency was similar for both words and non-words. Subsequent decomposition of the interaction for JPJ showed that there was a significant difference between congruent and incongruent real items (t (4) = 4.21; $p < 0.05$). However, there was no significant difference found between congruent and incongruent orthographically controlled items (t (4) = 1.15; $p > 0.05$), nor between real versus orthographically controlled congruent items (t (4) = 2.47; $p > 0.05$), nor between real versus orthographically controlled incongruent items (t (4) =1.21; $p > 0.05$). JPJ, therefore showed the Stroop effect with words but not with non-words.

Discussion of experiment 6.1

The results for the three deep dyslexics participants show the conventional Stroop effect (1935) in that ink colour name congruency affected reaction times in Stroop 1 for both words and pseudohomophones. This finding supports the hypothesis that participants would take longer to respond to the colour of the ink of incongruent words than to the ink colour of congruent words. The results imply that PD, JWT and JPJ were able to access the phonology of the pseudohomophones since otherwise there would have been no difference between congruency conditions.

In Stroop 2, the orthographically controlled non-words showed no significant effect of congruency, that is, as anticipated, the Stroop effect was not found. However, nor was a significant effect found for real words nor a significant interaction.

In Stroop 1 the three deep dyslexic patients had increased reaction times to pseudohomophones, thus the results showed an effect of automatic processing of pseudohomophones. As the pseudohomophone stimuli were well matched to the orthographically controlled non-word items (i.e. the pseudohomophones had a lower score for both bigram frequency and orthographic neighbourhood size than the orthographically controlled stimuli) the results imply implicit processing of pseudohomophone non-word phonology, supporting other studies, for example Buchanan et al. (1994), showing that deep dyslexics can access phonological information from non-words 'implicitly'.

All three patients showed the Stroop effect (i.e. an effect of congruency) using real words and pseudohomophones in Stroop 1 but, as anticipated, not with orthographically controlled non-words in Stroop 2. However, only JWT and JPJ showed the Stroop effect with real words for a second time in Stroop 2; PD on the other hand, failed to display the conventional effect. This may be due to the fact that once a few stimuli are presented (i.e. real word Stroop repeated in session 2) the effect is lost. This was one of the main reasons why pseudohomophones were not explicitly compared with orthographically controlled non-words as subjects may have become used to the stimuli by then. The effect may also only occur when stimuli are highly familiar (i.e. colour words) and response alternatives are constrained (there are not many different responses available).

Despite not finding the real word conventional Stroop effect in Stroop 2, the results in Stroop 1 are suggestive of implicit phonological ability in the three deep dyslexic patients. However, on reflection it may have been better to have included real words, pseudohomophones and orthographically controlled non-words as a single experimental session so that pseudohomophones and orthographically controlled non-words could have been directly compared.

Experiment 6.2

The Stroop experiment (experiment 6.1) can be criticised on the grounds that only a limited and highly constrained number of stimulus items were presented. These could very likely be learned by participants such that the pseudohomophone effect is lost. In order to look at processing of a larger set of words, a tachistoscopic experiment (experiment 6.2) was conducted which examined whether pseudohomophones are read better than orthographically controlled non-words. A short stimulus duration was used in an attempt to reduce the likelihood of participants using an explicit grapheme-phoneme decoding strategy. The hope was that very short exposure times would lead to more 'automatic' processing of the letter string. Any pseudohomophone advantage under such circumstances might be taken to imply that access to phonology is possible even in the absence of extended stimulus exposure durations.

Experiment 6.2

Method

Participants

PD, JWT, MJ and JPJ were available for this study. In addition to the 4 deep dyslexic patients it was possible to recruit another patient, GT (aged 71) for this experiment. In brief: GT did not make any semantic errors in the preliminary language test (but see experiment 6.2.1 where he read '*tode*' as '*frog*' and '*pony*' as '*Tonto*'), nor could he read any non-words. While it is not appropriate to refer to him as being deep dyslexic, the question of implicit phonological ability applies as much to phonological dyslexia as to deep dyslexia. From the point of view of the continuum theory (see thesis review) there is no fundamental distinction between phonological and deep dyslexia and it is therefore of interest to include his data. (For details of GT's preliminary language assessment scores and CT scan see appendix 13).

Materials

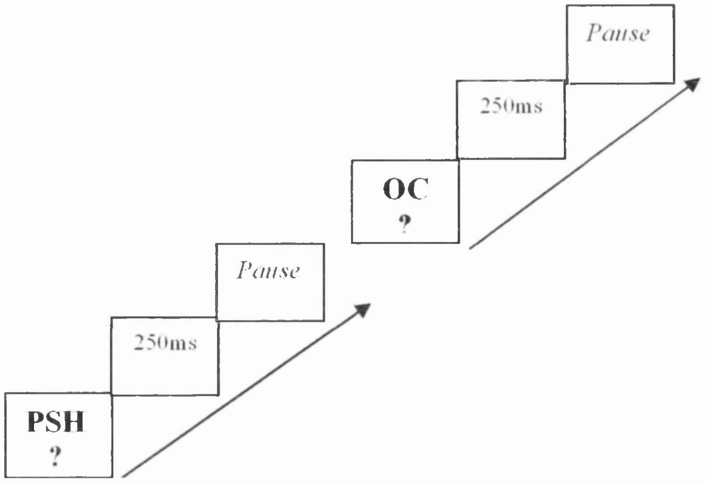
The stimulus set was part of the item list used by Buchanan et al. (1994). The first 30 pseudohomophones (e.g. 'taybul' to 'wimin') from the pseudohomophone list used by Buchanan et al. (1994) and the first 30 orthographically controlled non-words (e.g. 'tarble' to 'wamen') from the list of orthographically controlled words used by Buchanan et al. (1994) were used in experiment 6.2 (see appendix 14 for stimuli list).

Procedure

Thirty pseudohomophones and 30 orthographically controlled non-words were flashed one at a time, in random order, on a computer screen, each item being exposed for 250ms, (presented using the SuperLab computer programme). The black aerial baltic (font size 100) letter strings appeared in the centre of a white background screen.

After presentation of each non-word, participants were asked to report aloud the target item they had just seen. They were given as much time as necessary to respond. Once the participant was ready, the experimenter pressed the start button on the computer which then displayed the next target non-word. Once an answer was given there was a pause until the participant was ready to view the next target non-word. Responses were recorded by the experimenter. Participants were not informed that all stimuli were non-words.

Figure 10. Order of presentation in experiment 6.2



START

Results of experiment 6.2

Table 51 below displays the number of correct responses made to the pseudohomophone and orthographically controlled targets by each of the participants.

Table 51. Number of correct responses made to pseudohomophones and orthographically controlled non words by each patient

	PD	**JWT**	**MJ**	**GT**	**JPJ**
Orthographically controlled non-word (OC)	3 / 30	4 / 30	4 / 30	3 / 30	2 / 30
Pseudohomophone (PSH)	15 / 30	18 / 30	18 / 30	18 / 30	12 / 30

Table 51 shows that all participants read the pseudohomophone words better than orthographically controlled non-words suggesting that the phonology available from the pseudohomophones facilitated the reading of each participant. Statistical analysis of the data from each participant is given below.

PD

PD read pseudohomophones significantly better than orthographically controlled non-words ($\chi^2 = 9.60$, $p<0.005$) reading 50% of the pseudohomophones presented and only 10% from the orthographically controlled non-word list. He made two semantic errors after the pseudohomophone targets reading '*munth*' as '*week*' and '*muther*' as '*father*'. He also made one possible visual then semantic error after the presentation of the orthographically controlled non-word '*cight*' as he replied '*cigarette*' (via '*cigar*'?).

JWT

JWT read pseudohomophones significantly better than orthographically controlled non-words ($\chi^2 =12.13$, $p < 0.005$) reading 60% of the pseudohomophone stimuli and 13% of the orthographically controlled non-words. He made one semantic error after the presentation of a pseudohomophone, reading '*jale*' as '*doors*'.

MJ

MJ read pseudohomophones significantly better than orthographically controlled non-words ($\chi^2 =12.13$, $p<0.005$) reading 60% of the pseudohomophone list and 13% of the orthographically controlled non-word stimuli. She made two possible visual errors after the presentation of pseudohomophones, reading '*urly*' as '*curly*' and '*neet*' as '*meet*'.

GT

GT read pseudohomophones significantly better than orthographically controlled non-words ($\chi^2 = 14.30$, $p<0.005$) reading 60% of the pseudohomophones correctly, while only managing 10% on the orthographically controlled non-words. The first recorded semantic error given by GT was to a pseudohomophone; he read '*tode*' as '*frog*'. He made one possible visual then semantic error on the orthographically controlled list reading '*roaf*' as '*bread*' (via '*loaf*'?).

JPJ

JPJ read pseudohomophones significantly better than orthographically controlled non-words ($\chi^2 = 7.55$, $p<0.005$); he achieved 40% correct responses from the pseudohomophone list and only 7% from the orthographically controlled non-word stimuli. He made four semantic errors to pseudohomophones, reading '*kat*' as '*kitty*'; '*frute*' as '*banana*'; '*trane*' as '*truck*' and '*muther*' as '*mam*'. Furthermore, JPJ made probable visual then semantic errors to two of the pseudohomophones reading '*foan*' as '*bath*' (via '*foam*'?) and read '*urly*' as '*duckling*' (via '*ugly*'?). JPJ also made a possible visual then semantic error after the presentation of an orthographically controlled non-word reading '*knile*' as '*fork, no spoon*'.

Discussion of experiment 6.2

The results show that reading of pseudohomophones is significantly better than reading of orthographically controlled non-words even though the stimuli were presented for a very short duration of time. This suggests that the phonology of the pseudohomophones facilitates reading (see Buchanan, Kiss & Burgess, 2000). However, it is possible that the pseudohomophone advantage is artefactual. Perhaps the present pseudohomophone advantage is due to a better chance of correctly guessing pseudohomophones (given a few letters) than of guessing orthographically controlled non-words. For example, given the target items '*kniphe*' (pseudohomophone) and '*knile*' (orthographically controlled non-word) and assuming that the first two letters were processed, the subject might be more likely to give the pseudohomophone pronunciation in response rather than that of the orthographically controlled non-word.

Buchanan et al. (1994) claim that the summed bigram frequency of the stimuli used in their experiment (half of which were used in the present experiment) favoured orthographically controlled non-words over pseudohomophones. Control non-words were said to be more similar to real words than were pseudohomophones. In order to confirm this, in the present experiment, the stimulus items were entered in to Davis's (2005) 'n watch' computer program. The mean summed bigram frequency for the 30 pseudohomophone items was 1250.30, which was lower than the mean of 1609.96 for the 30 orthographically controlled non-words ($t(29) = 1.97$; $p = 0.05$). This confirms that the orthographically controlled non-words were more like real words than were the pseudohomophones. Conversely, measures of n (orthographic neighbourhood size) (see Coltheart et al., 1977) showed that the pseudohomophones had a higher neighbourhood size (mean = 5.76) than the orthographically controlled non-words (mean = 4.96). However, the n scores did not differ significantly ($t < 1$).

Experiment 6.2.1

Experiment 6.2.1 was conducted to examine whether under normal circumstances (i.e. with unlimited exposure duration) participants would read pseudohomophones better than orthographically controlled non-words. Buchanan, Kiss & Burgess (2000) reported that their deep dyslexic patient, S.D, read pseudohomophones significantly better than orthographically controlled non-words. However, a second patient, J.C. did not show a pseudohomophone advantage. It was therefore decided to examine whether other deep dyslexic patients (PD, JWT, MJ, GT and JPJ) would read pseudohomophones better than orthographically controlled non-words when presented without any limitation of time.

Experiment 6.2.1

Method

Participants

The same five participants took part in experiment 6.2 (PD, JWT, MJ, GT and JPJ)

Materials

The stimulus set was the entire list of 60 real words, 60 pseudohomophones and 60 orthographically controlled non-words used by Buchanan et al. (1994). This list was reported to produce a significant pseudohomophone effect for both normal and brain injured readers. The entire complement of 60 pseudohomophones and 60 orthographically controlled non-words from the Buchanan et al. stimulus list were included in present experiment 6.2.1 because when the n watch program (Davis, 2005) was conducted on these items *both* bigram frequency scores and measures of n were higher for orthographically controlled non-words than for pseudohomophones (when only 60 items, 30 pseudohomophones and 30 orthographically controlled non-words, were used as in experiment 6.2 the pseudohomophones had a higher n score). The mean bigram score (1427.46) of the 60 orthographically controlled non-words was significantly greater ($t(59) = 2.47$; $p < 0.05$) than that of the 60 pseudohomophones (1104.44). Although the mean n score for the orthographically controlled non-words (5.93) did not differ significantly ($t(59) = 1.91$; $p > 0.05$) from the pseudohomophones' n score of 4.33, it was still higher. It can thus be concluded that the pseudohomophones were not more similar to real words than were the orthographically controlled non-words.

Procedure

The five participants were asked to read aloud the 60 real words, 60 pseudohomophones and 60 orthographically controlled non-words. The real word, pseudohomophone and orthographically controlled non-words were randomly presented. Each letter-string was individually printed in 16 point font on 3 x 5 white index cards. Items were shown one at a time, to each subject until a response was made.

An example of the stimulus items used to test homophony is displayed in Table 52 below (for the full list see appendix 14).

Table 52. Examples of the stimuli used to test homophony in experiment 6.2.1

Real word e.g.	**Nurse**	**Doctor**
Orthographically Controlled non-word e.g.	**Narse**	**Dontor**
Pseudohomophone e.g.	**Nerse**	**Dokter**

Results of experiment 6.2.1

Table 53 below shows the number of correct responses made by each participant to the target letter strings.

Table 53. Number of correct responses made to three different types of letter string

	PD	JWT	MJ *	GT	JPJ *
Real word	34 / 60	43 / 60	39 / 42	47 / 60	26 / 42
Orthographically controlled non-word	3 / 60	8 / 60	5 / 42	8 / 60	2 / 42
Pseudohomophone	15 / 60	33 / 60	25 / 42	28 / 60	13 / 42

* *MJ died before completing entire list of 60 stimuli; JPJ became ill and did not finish the entire list.*

The data of Table 53 were analysed separately for each patient. Statistical analysis of the data from each participant is given below.

PD

PD read the real word list significantly better than pseudohomophones ($\chi^2 = 11.18$, $p<0.001$) and the orthographically controlled non-words ($\chi^2 = 35.17$, $p<0.001$). He also read the pseudohomophones significantly better than the orthographically controlled non-words ($\chi^2 = 7.91$, $p<0.001$).

PD made three semantic errors on the real word list, reading '*knob*' as '*door*'; '*truck*' as '*train*' and '*niece*' as '*nephew*'. Interestingly PD made two semantic errors on the pseudohomophone list reading '*howse*' as '*house wife*' and '*nefew*' as '*wife*'. PD made two probable visual errors on the pseudohomophone list; he read '*gluv*' as '*glue*' and '*bowt*' as '*bowl*'. He made two possible visual - then - semantic errors on the orthographically controlled non-word list e.g. '*denil*' read as '*teeth*' (via *dentist* ?) and '*cight*' read as '*fags*' (via *cigar* or *cigarette* ?).

JWT

JWT read real words significantly better than pseudohomophones ($\chi^2 = 2.91$, $p<0.05$) and orthographically controlled non-words ($\chi^2 = 39.42$, $p<0.001$). JWT read pseudohomophones significantly better than orthographically controlled non-words ($\chi^2 = 21.34$, $p<0.001$).

JWT made a semantic error on the real word list reading '*pear*' as '*apples*'. He made a semantic error on the pseudohomophone list, reading '*tode*' as '*frog*'. He also made a probable visual error on the pseudohomophone list reading '*unkle*' as '*ankle*'. On the orthographically controlled list JWT made a probable visual - then - semantic error reading '*roaf*' as '*bread*' (via '*loaf*'?).

MJ

MJ read the real words significantly better than the pseudohomophones ($\chi^2 = 11.09$, $p<0.05$) and the orthographically controlled non-words ($\chi^2 = 51.98$, $p<0.001$). She read pseudohomophones significantly better than orthographically controlled non-words ($\chi^2 = 18.72$, $p<0.001$).

MJ made one semantic error on the real word list, reading '*tracks*' as '*train*' and produced two possible visual or phonological errors reading '*drip*' as '*trip*' and '*raven*' as '*rave*'. MJ made two semantic errors on the pseudohomophone list, reading '*kat*' as '*dog*' and '*sitee*' as '*sit*'. In addition, she made four probable visual errors, reading '*urly*' as '*curly*', '*neet*' as '*meet*'; '*rane*' as '*rare*' and '*greane*' as '*great*'. On the orthographically controlled non-word list MJ made three possible visual errors, reading '*cit*' as '*city*'; '*roaf*' as '*loaf*' and '*spront*' as '*sprout*'.

GT

GT read real words significantly better than pseudohomophones ($\chi^2 = 11.52$, $p<0.005$) and orthographically controlled non-words ($\chi^2 = 48.47$, $p<0.001$). He read pseudohomophones significantly better than orthographic controls ($\chi^2 = 14.33$, $p<0.001$).

GT made one semantic error on the real word list, reading '*pony*' as '*Tonto*' (the Lone Ranger's Indian companion). He made one probable visual errors reading '*angel*' as '*angle*' a derivational/morphological error, reading '*aunt*' as '*auntie*', and a phonological (or visual) error, reading '*mug*' as '*plug*'. GT made five possible visual errors, reading '*urly*' as '*curly*'; '*jale*' as '*gale*'; '*trane*' as '*crane*'; '*unkle*' as '*ankle*' and '*wayk*' as '*walk*'. He also made phonological (or visual) errors, reading '*kar*' as '*scar*' and, arguably, '*wimin*' as '*swimming*'. On the orthographically controlled non-word list GT made four possible visual errors: '*roaf*' read as '*roof*'; '*tarble*' as '*treble*'; '*knile*' as '*knife*' and '*dooc*' as '*door*'.

JPJ

JPJ read real words significantly better than the pseudohomophones ($\chi^2 = 6.89$, $p<0.005$) and the orthographically controlled non-words ($\chi^2 = 28.34$, $p<0.001$). He read pseudohomophones significantly better than orthographic controlled non-words ($\chi^2 = 8.12$, $p<0.005$).

JPJ made six semantic errors on the real word list, reading '*nurse*' as '*hospital*'; '*fork*' as '*spoon*'; '*nine*' as '*eight*'; '*year*' as '*date*'; '*prison*' as '*jail*' and '*tidy*' as '*litter*'. JPJ also made semantic errors on the pseudohomophone list, reading '*nife*' as '*spoon*' and '*frute*' as '*grapes*'. He made two probable visual errors, reading '*urly* as '*ugly*' and '*ait*' as '*air*'.

Discussion of experiment 6.2.1

The results show that all five acquired dyslexic participants read pseudohomophones significantly better than their orthographically controlled non-word equivalents thereby suggesting implicit phonological ability. Interestingly, PD made two semantic errors on the pseudohomophone list reading '***howse***' as '***house wife***' and '*nefew*' as '*wife*' suggesting implicit phonological awareness and access to semantics. The findings imply that the semantic content available through the word-like phonological information in the pseudohomophones acts, presumably through feedback to semantics and then feed forward to phonology, to influence the participants' response.

The results of experiment 6.2.1 support Buchanan, Kiss and Burgess's (2000) finding with patient S.D. who could read pseudohomophones better than orthographically controlled non-words. However, the results contrast with those of patient J.C. of Buchanan et al. (1994) who did not read more pseudohomophones than orthographically controlled non-words. Furthermore, it is important to note that participants in the present experiment read words better than pseudohomophones. Presumably this is because the orthographic input lexicon is still intact in each patient (see Chapter 3 page 94; all patients performed well on the lexical decision tests).

It has been argued that the reason pseudohomophones are read with greater success than their orthographically controlled equivalents is that pseudohomophones are more visually similar to real words than are orthographically controlled non-words. Martin (1982) suggested that pseudohomophones tend to have many letters in common with the corresponding 'real' word, and therefore may be more visually similar to words than other non-words, that is, orthographically controlled non-words. In contrast, Coltheart et al. (1977) dismissed the visual similarity argument on the basis of results obtained in a lexical decision task in which they attempted to control the visual similarity of the pseudohomophones and control non-words. They created visual controls by changing one letter from the pseudohomophones to result in an orthographically controlled non-word that would not be pronounced as a real word but was still visually similar. However, Martin (1982) by using n measures found that the pseudohomophones used by Coltheart et al. were in fact more visually similar to real words than their orthographically controlled non-words. Martin (1982) concluded that the pseudohomophone effect is due to visual rather than phonological similarity to words.

If the pseudohomophone effect is purely visual then it could be argued that participants in Buchanan et al. (1994) and in the present study (experiment 6.2.1) should have read orthographically controlled non-words better than pseudohomophones as they were designed to look more visually similar to real words than were the pseudohomophones. Buchanan et al. (1994) argued that their stimulus set was designed such that the orthographic overlap always favoured the orthographic visual controls over the pseudohomophones. They concluded that they were '*...quite confident that the effects reported were of a phonological nature and not due to orthographic similarity to either a specific word or to words in general...*' (p. 66).

Buchanan et al. (1994) stated that the orthographically controlled non-words actually had numerically higher summed bigram frequencies than did the pseudohomophones and argued that there should not be any advantage to the pseudohomophones over the orthographic control items based on visual similarity. The n watch program (Davis, 2005) was used to verify the findings of Buchanan and colleagues; the program confirmed that when all 120 non-word items were used from Buchanan et al. (1994) (as in experiment 6.2.1), there was no pseudohomophone advantage. However, when only one half of the non-word stimuli of Buchanan et al. were used (as in experiment 6.2) the orthographic neighbourhood scores favoured pseudohomophones over orthographically controlled words although not significantly so. Thus, while the results of experiment 6.2 implicate orthographic factors, the present results support the view that pseudohomophones are read significantly better than orthographically controlled non-words based on the phonology.

As a further test of the 'word-likeness' of the non-words used in their experiment, Buchanan et al. (1994) asked patient J.C. to name each of the items from the experimental stimuli. The target non-words were presented to J.C. on a printed sheet of paper and she was asked to read aloud each of the letter-strings. Buchanan et al. (1994) found that J.C. produced possible visual errors that resulted in word responses to the non-words but this was true for both the orthographically controlled non-words and the pseudohomophones. Buchanan et al. suggested that this showed that the two kinds of non-word did not differ from each other in terms of orthographic familiarity. However, appendix c of Buchanan et al. (1994) not only shows that J.C did not read pseudohomophones significantly better than orthographically controlled non-words, but she also made more probable visual errors to the pseudohomophones than to the orthographically controlled non-words, suggesting that the former were more 'word-like' than the latter.

One of the differences between experiment 6.2 and 6.2.1 was that in 6.2.1 the stimuli were continuously present until participants responded. Given the status of a word, participants are perhaps more likely to give real word responses (which pseudohomophones are when spoken) than non-word responses (of which there might be a considerable number possible). Thus more correct responses might arise by chance in response to pseudohomophones than in response to visual orthographically controlled items. However, Buchanan, Kiss and Burgess (2000) argued that their results were not due to a predisposition to provide real-word responses as their patient, S.D, produced some incorrect non-word responses (e.g. she read 'coast' as 'oist') the actual number of non-word responses is not reported. The five patients in experiment 6.2.1 did not give any non-word responses (nor did patients J.C (Buchanan et al., 1994) or G.Z (Buchanan et al., 1996).

In conclusion, the results of experiments 6.2 and 6.2.1 support those of Buchanan, Kiss & Burgess (2000) in that participants read pseudohomophones significantly better than orthographically controlled non-words. Furthermore, patients PD, JWT, MJ, GT and JPJ all made semantic errors to pseudohomophones in experiment 6.2.1 (and except for MJ, even with very short exposure times). This suggests that they had processed the phonology of the non-word and accessed the semantic system; this implies at least some level of preserved phonological processing in deep dyslexia. The findings of experiments 6.2 and 6.2.1 support those of Katz and Lanzoni (1992) and Buchanan et al. (1994, 1996, 1999, 2003) in suggesting that deep dyslexics are able to process phonology implicitly if not explicitly.

Experiment 6.3

Experiments 6.2 and 6.2.1 demonstrated that at least some deep dyslexics can read aloud pseudohomophones significantly better than orthographically controlled non-words which suggests that they have some implicit phonological ability. Normal readers find pseudohomophones more difficult to reject in lexical decision than orthographically controlled non-words (e.g. see Coltheart et al., 1977). The 'pseudohomophone effect' refers to elevated reaction times and a greater number of errors made to pseudohomophones relative to orthographically controlled non-words. The presence of such an effect in deep dyslexics would support the view of implicit phonological processing. Pseudohomophones have a phonological representation that is associated with a real word and therefore can activate lexical and semantic representations. In contrast, orthographically controlled non-words do not have a real word phonological presentation and thus do not activate unique lexical and semantic representations. Buchanan et al. (1996) argue that the additional time required to reject pseudohomophones in lexical decision is an indication of conflict between the 'yes' responses from the lexical and semantic activation and the correct 'no' response that is based on the actual orthography of the letter string.

Experiments examining the pseudohomophone effect with acquired dyslexics have produced mixed results. For example, Patterson & Marcel (1977), Martin (1982) and Hildebrandt and Sokol (1993) all failed to find the effect during lexical decision with their patients. However, Buchanan et al. (1994, 1996) found a pseudohomophone effect with their two deep dyslexic patients thereby supporting the premise that the sub-lexical route is not eradicated in deep dyslexia. The aim of this experiment was to investigate whether deep dyslexic patients PD, JPJ and GT show a pseudohomophone effect.

It was decided to make a methodological improvement to experiments 6.2 and 6.2.1. Coltheart et al. (1977) attempted to control the visual similarity of the pseudohomophones and controlled non-words by creating visual controls by changing one letter from the pseudohomophones to result in an orthographically controlled non-word that would not be pronounced like a real word but was still visually similar to real words. Huntsman (2007) used two different types of pseudohomophone constructed by changing a letter from the real word to produce two different pseudohomophones. For example, one set of pseudohomophones included '*beed, nayl* and *wead*' while the other pseudohomophones included '*bede, nale* and *wede*'. He argued that because the spelling of many pseudohomophones is similar to that of their word counterparts, it is necessary to devise control words for pseudohomophones, not just real words, to ensure that reading of pseudohomophones is based on phonological similarity rather than orthographic similarity. Therefore, in order to improve the methodology of the following experiment pseudohomophone controls were introduced.

Experiment 6.3

Method

Participants

Three participants took part in this experiment, namely PD, JPJ and GT (MJ and JWT had died).

Materials

A lexical decision experiment was constructed using a SuperLab programme. Fifteen real words, 15 orthographically controlled non-words; 15 pseudohomophones and 15 pseudohomophone controls were used. The pseudohomophone control stimuli were created by changing one letter from each of the pseudohomophones in the same way that the orthographically controlled non-words in this experiment were constructed by changing one letter in each real word target. The items in the three non word lists (i.e. orthographically controlled non-words, pseudohomophones and pseudohomophone control non-words) all had the same number of letters as their real word equivalents (see Table 55 for stimuli). An additional 15 real word foils were added so that the Yes/No responses were not unduly biased towards ‘No’ answers. All five letter strings had the same number of letters and began with the same letter as the parent word (e.g. ‘*bread*’, ‘*brend*’, ‘*bredd*’, ‘*bradd*’ and ‘*board*’). Reaction time was recorded by a Cedrus Response pad Model RB-730. The N watch program (Davis, 2005) was used to calculate bigram frequency and n scores. The data are displayed in Table 54.

Table 54. Bigram frequency and n scores for lexical decision stimuli

	Mean Bigram frequency	**Mean n score**
Real words:	1199.27	4.86
Orthographically controlled non-words:	1132.13	3.47
Pseudohomophones:	822.48	3.33
Pseudohomophone controls:	737.63	2.53
Foils:	1016.17	4.67

Table 54 shows that the orthographically controlled non-words had a higher bigram frequency and n score than the pseudohomophones suggesting that they had a greater similarity to real words. However, one way ANOVAs conducted on the data found no statistically significant difference between the different stimlus items for either variable ($p>0.05$).

Procedure

The words and non-words were presented one at a time, in random order, in the centre of a computer screen and participants were instructed to make a decision as to whether the target item was a real word or not. A response pad was placed in front of the patient who was instructed to press the green 'YES' button if he thought the letter string was a real word or the red 'NO' button if he thought it was a non-word. The assignment of button to response was reversed for half of the participants. After making each response, participants were instructed to put the index finger of their dominant hand on the black spot (located on the response pad); this was to ensure each participant started from the same distance on each trial before making a response. After a response was made by the participant there was a short pause until the experimenter pressed the start button and the next letter-string appeared; this avoided patients missing the target items. The stimuli used in the lexical decision task are displayed in Table 55.

Table 55. Lexical decision stimuli

Real word	Orthographically controlled non-word	Pseudohomophone	Pseudohomophone Control	Foils
1. bread	brend	bredd	bradd	board
2. table	teble	taybl	toybl	tackle
3. queen	queon	kwean	krean	quake
4. nurse	narse	nerse	nepse	nudge
5. wife	wefe	wyfe	wyke	wipe
6. knife	knile	niphe	nophe	knock
7. train	traim	trane	trene	trail
8. nail	nait	nale	nule	neck
9. read	reab	wreed	wreet	road
10. leaf	leof	leef	leet	leap
11. key	kel	kee	kep	keg
12. bullet	bellet	boolet	booleg	ballet
13. circus	cirbus	syrcus	symcus	citric
14. photo	pheto	fotoe	fofoe	phone
15. cup	cip	kup	kug	cub

Results for experiment 6.3

The data for correct responses only were examined. The scores obtained by each participant are shown in the Table 56 below.

Table 56. Number of correct responses in lexical decision task by each participant

	PD	**JPJ**	**GT**
Real words	13 / 15	11 /15	13 / 15
Orthographically controlled non-words	14 / 15	13 / 15	12 / 15
Pseudohomophones	12 / 15	9 / 15	12 / 15
Pseudohomophone controls	14 / 15	13 / 15	13 / 15

Table 56 show that more errors were made by each of the participants to the pseudohomophones than to the two other non-word controls, but not significantly so for any comparison ($p > 0.05$).

The participants' reaction time data in lexical decision are shown in Table 57. Only correct data were analysed. Values that exceeded plus or minus three standard deviations from each patient's overall mean were discarded.

Table 57 below shows the mean and median reaction times after the exclusion of outliers.

Table 57. Participants' mean, standard deviation and median reaction time (RT) in milliseconds in a lexical decision task

	P.D			**J.P.J**			**G.T**		
	Mean RT	SD	Med RT	Mean RT	SD	Med RT	Mean RT	SD	Med RT
Real words	1139.00	211.42	1109.00	869.64	175.57	905.00	1128.38	166.30	1084.00
Ortho-graphically controlled non-words	1295.36	208.60	1252.00	953.15	130.41	964.00	1177.42	104.70	1178.00
Pseudo-homophones	1543.92	329.47	1554.00	1133.00	121.68	1184.00	1492.67	183.61	1554.00
Pseudo-homophone controls	1246.29	163.21	1240.00	1028.62	365.66	964.00	1188.69	110.76	1155.00

The data in Table 57 suggest that it took longer to respond to the pseudohomophones then to the other letter strings. However, due to the high variance, skew of the data and because Levene's test for homogeneity of variance was significant, the reaction time data was log transformed.

For each participant a one way ANOVA was carried out on the transformed reaction times. The ANOVA showed a statistically significant effect for both PD and GT (**PD**: F (3, 49) = 6.55, $p < 0.01$; **GT**: F (3, 46) = 14.26, $p < 0.01$) but JPJ's results failed to reach significance (**JPJ**: F (3, 42) = 2.72, $p > 0.05$). Tukey's HSD comparison found that for PD RTs to real words differed significantly from RTs to pseudohomophones ($p <0.01$) and RTs to pseudohomophones differed significantly from RTs to pseudohomophone controls ($p <0.01$). Tukey's HSD found that for GT real words differed significantly from pseudohomophones ($p <0.01$); pseudohomophones and orthographically controlled non-words differed significantly ($p <0.01$) as did pseudohomophones and pseudohomophone controls ($p<0.01$).

The results show that for PD and GT it took longer to reject the pseudohomophones than both the orthographically controlled non-words and the pseudohomophone controls in a lexical decision task.

Discussion of experiment 6.3

Two of the participants (PD and GT) displayed a significantly elevated mean response time to reject pseudohomophones relative to orthographically controlled non-words in a lexical decision task thereby showing a conventional pseudohomophone effect. Neither Hildebrandt and Sokol (1993) nor Patterson and Marcel (1977) obtained a pseudohomophone effect with their patients. However, Buchanan et al. (1994, 1996) did find an effect with three deep dyslexics. Buchanan et al. (1996) also found the pseudohomophone effect in terms of error rates for patients P.B and G.Z, but no mention is given of error rates for J.C of Buchanan et al. (1994). Martin (1982) argued that previous failures to find the pseudohomophone effect may have resulted from the methodology employed, arguing that more weight should be given to error rates. He reported that his patient (B.L) showed the pseudohomophone effect in terms of error rates (but not reaction time). In the present experiment all three participants made a greater number of errors with the pseudohomophone stimuli than with the other non-words although not to a statistically significant extent.

Buchanan et al. (1994, 1996) reported that their deep dyslexics produced significant pseudohomophone effects with 'stringent' orthographic controls. These authors argued that the conflict between the significant effects that they found and the null effects reported by Patterson and Marcel (1997) could be accounted for by differences in the analyses carried out. Patterson and Marcel presented their patients with two sets of stimuli, one containing real words and pseudohomophones, the other containing real words and orthographically controlled non-words. They conducted a reaction time analysis on 'overall' lexical decision reaction times to the lists rather than on individual items. Patterson and Marcel's analysis revealed that the block of trials with the pseudohomophones did not take longer to complete than the other block of trials with the orthographically controlled non-words. In contrast, Buchanan et al. (1994) analysed each patient's data from individual items (using a paired t-test) and found that the mean reaction times for the pseudohomophones were longer than the mean reaction time for the orthographically controlled non-words. However, the number of stimuli used in the experiment was only 29 out of 60 due to only analysing correct scores and trimming the data. Buchanan et al. (1994) argued that despite this loss of power the stimuli still produced significant effects. However, Buchanan et al. (1996) used a group t-test when analysing the data. They argued that this method avoided the potential criticism that the analysis relied too heavily on an assumption of matched orthography.

Pugh et al. (1995) suggested a second explanation for the inconsistency of the pseudohomophone effect in deep dyslexia. They argued that when orthographically controlled non-words are replaced by pseudohomophones, rejection times increase and acceptance times for real words decrease. While it takes longer to reject a pseudohomophone relative to an orthographically controlled non-word, the presence of pseudohomophones actually decreases reaction times to the real-words; this pattern would then result in null effects in the data. Buchanan et al. (1996) argue that this suggests a way to reconcile the conflicting reports with respect to the existence of a pseudohomophone effect in deep dyslexia. They suggested that the patients in the Patterson and Marcel (1977) study actually did produce a pseudohomophone effect but that due to the 'coarseness' of the analysis it was impossible to detect. Because Patterson and Marcel did not record response time to individual items, only the mean RT to eeach stimulus type. Buchanan et al. claimed that this explanation seems a reasonable way to reconcile the conflicting results with regard to the pseudohomophone effect in deep dyslexia.

In any event, experiment 6.3 found statistically significant results (for two of the deep dyslexic participants), suggesting that non-word phonology can access the lexical system and have an impact on performance in lexical decision. The results indicate that phonological sensitivity plays a greater role in lexical processing for at least some deep dyslexics (and phonological dyslexic) than most theories would predict. While it may be the case that *explicit* processing of phonological information is eradicated, it seems that *implicit* phonological processing can remain intact in deep dyslexia and influence performance, in some circumstances at least.

The final set of experiments was carried out to investigate whether deep dyslexics would show sub-lexical phonological processing (a pseudohomophone effect) in a semantic priming task.

Experiment 6.4

Introduction to priming experiments

Over three decades have elapsed since Meyer and Schvaneveldt (1971) reported their influential findings on semantic priming. In their experiment participants were asked either to press one key if *both* of the two simultaneously presented visual letter strings were English words or to press another key if not. They found that participants were faster and more accurate in responding to items containing two semantically/associatively related words (e.g. *bread* and *butter*) than to items with unrelated words (e.g. *doctor* and *butter*). This 'semantic priming effect' has been observed in a variety of tasks ranging from sentence verification (Loftus, 1973) to lexical decision (Meyer and Schvaneveldt, 1971) and naming (De Groot, 1985).

Neely (1991) argued that when two word meanings are related in memory, activation of one meaning in response to a visually presented '*prime*' word facilitates subsequent access to a related '*target*' word meaning. This facilitation of priming manifests as improved speed or accuracy in response to related targets, compared with an unrelated or 'neutral' baseline condition. Neely (1991) referred to the 'single-word semantic priming paradigm' in his extensive review of semantic priming. He defined the paradigm in terms of a trial that consisted of two events: firstly, a semantic context is provided by the presentation of a single word called the '*prime*', to which no response is required (although some experiments do require a response to be made to the prime - e.g. Buchanan et al. 1994, 1996). Secondly, the prime is followed by the presentation of a single letter string called the '*target*'. Neely (1991) observed that in most experiments using this paradigm, participants have been required either to make a lexical decision or to say the target aloud (known as the pronunciation task).

Crutch and Warrington (2007) suggested that whilst deep dyslexia has been the focus of intensive research over the past three or four decades, the role of semantic priming in deep dyslexia has been considered only rarely. Beringer and Stein (1930) (cited by Marshall and Newcombe, 1980) found a patient with the characteristics of deep dyslexia whose reading accuracy was improved with the provision of semantic cues either for individual words which she was having difficulty reading (e.g. *sixteen*; 'it's a number') or for a list of words from the same category (but only if she were told the category explicitly). According to Crutch and Warrington (2007) subsequent studies of patients with central dyslexia have tended to show facilitation of word reading with the provision of semantic primes (for example, Warrington and Shallice, 1979).

However, Colangelo, Buchanan and Westbury (2004) assessed word reading, lexical decision and the semantic judgment of a deep dyslexic patient J.O. (with lists of semantically related and unrelated words) and found that response accuracy was lower for the semantically related items (known as a 'semantic blocking effect'). Colangelo et al. (2004) attributed this finding not to a semantic deficit but to failure of inhibition at the level of phonological output (discussed in the literature review, see page 69). Crutch and Warrington (2007) argue that the semantic blocking effect observed in J.O stands in contrast to the typical facilitative effect of semantic context observed in the response accuracy of non brain injured participants (e.g. see Damian et al., 2001). The semantic facilitatory effects are also seen in a variety of neurological patients (e.g. Young et al., 1989; Mimura et al., 1996). However, Glosser at al. (1991) failed to find semantic priming effects for certain types of semantic relationships in patients with Alzheimer's disease.

Crutch and Warrington (2007) pointed out that the influence of semantic priming has been explored using several different types of prime-target relations. These include associatively related words from the same semantic category (e.g. *table* – *chair*), associatively unrelated words from the same semantic category (e.g. *bed* – *chair*) and category names (e.g. *furniture* – *chair*). Crutch and Warrington (2007) examined whether semantic (context) priming would facilitate word reading in a patient with deep dyslexia (R.O.M). They explored semantic (context) priming according to two principles: semantic similarity and semantic association, and asked whether they have equivalent effects upon the reading of abstract and concrete target words. Crutch and Warrington (2007) found that R.O.M read concrete words organised by semantic similarity significantly more accurately than unrelated concrete items, but showed no such advantage for semantically associated concrete words. By contrast, they found that semantically associated abstract words were read better than unrelated items, but there was no evidence of semantic context priming for semantically similar abstract words.

Huntsman (2007) argued that in order to assess the role orthographic and phonological processing plays when performing the lexical decision task, pseudohomophones and non-words used as primes for their real word counterparts is the best methodological approach. Because the spelling of many pseudohomophones is similar to that of their word counterparts, it is necessary to ensure that pseudohomophones act as primes based on phonological similarity rather than on orthographic similarity. Huntsman (2007) devised two types of pseudohomophones to be included in his non-word priming stimuli. The idea that both phonological and orthographic influences in word recognition would produce more of a priming effect when pseudohomophones are spelled similarly to word targets was tested by using pseudohomophone controls (which were constructed by changing two letters from each of the real word items) that varied in the degree of their similarity in spelling to their homophone targets. For example, the pseudohomophone '*soop*' is very similar in spelling to 'soup'. The pseudohomophone control prime '*supe*' is less similar in spelling to '*soup*' but should be read better than the orthographically controlled non-word '*saup*'. Huntsman (2007) argued that if an orthographic representation is used directly in word recognition, then the likelihood that priming will be affected by orthographically-similar primes should be a function of the number of orthographic characteristics that they share with the target; thus, the pseudohomophone '*soop*' is likely to be a better prime than '*supe*'. Alternatively, if a pseudohomophone is transformed into a phonological representation that is independent of the orthographic structure of the prime, then there should be no difference in the repetition priming effect for pseudohomophone primes (Huntsman, 2007).

Besner et al. (1985) examined priming effects for pseudohomophones and non-word primes that had been equated for orthographic similarity. They found using non-brain injured participants that pseudohomophone primes exerted a priming effect on lexical decision response latencies over and above any priming due to orthographic similarity of the non-word primes. Lukatela and Turvey (1991) also found that pseudohomophones and words facilitated naming latencies for associated target words, relative to spelling control non-word primes. The standard model of deep dyslexia assumes that the ability to process phonological information from non-words is eradicated. This assumption notwithstanding, Buchanan et al. (1994) set out to examine the extent to which phonological knowledge of non-words plays a role in lexical decision for words. The stimuli used by Buchanan et al. (1994) in their priming experiment consisted of real target words, semantic primes and their orthographic controls. However, unlike typical semantic priming experiments, in their study they used pseudohomophones as the primes, for example, '*dockter - nurse*' and '*taybul - chair*', which were associatively related to the target. Buchanan et al. (1994) hypothesised that semantically related pseudohomophones would produce a priming effect in comparison to orthographic controlled non-words.

In the preceding experiments of this thesis the deep dyslexic patients showed better reading of, and were slower to reject, pseudohomophones relative to orthographically controlled non-words. Buchanan et al. (1994, 1996) claimed to have found a semantic priming effect using pseudohomophones as primes. It was therefore decided to exactly replicate the experiment conducted by Buchanan et al. (1994, 1996) to investigate with the present three deep dyslexics whether, relative to orthographically controlled non-words, semantically related pseudohomophone primes produce a priming effect to subsequent real target words.

Experiment 6.4

Method

Participants

The same three participants took part in this experiment as in experiments 6.3 (PD, JPJ and GT).

Materials

The lexical decision programme was designed on SuperLab and reaction time was recorded by a Cedrus Response pad Model RB-730 linked to a laptop computer. The stimulus items were those used by Buchanan et al. (1994) (see appendix 14). They consisted of two sets of letter strings; each set contained 60 real word targets and 60 non-word primes (i.e. a pseudohomophone or an orthographically controlled non-word). The black Aerial Baltic (font size 100) letter strings appeared in the centre of a white background screen. The participants sat approximately 22 inches away from the screen.

The pseudohomophone and orthographically controlled non-word primes were each derived from the same real word item (e.g. table - '*taybul*' and '*tarble*'). A calculation of orthographic overlap between the two types of non-words and real words was made by Buchanan et al. (1944) who claimed that in most cases the orthographically controlled non-words were more like the real words from which they were derived than were the pseudohomophones. In order to test this, the N watch program (Davis, 2005) was used in the present study to calculate bigram frequency and n scores using all 60 of the pseudohomophone primes and all 60 of the orthographically controlled primes. The orthographically controlled non-words were found to have a higher mean bigram frequency and n score than the pseudohomophone primes, thus indicating that they were more similar to real words than were the pseudohomophones.

Twenty non-word fillers were also included in the stimulus set so that patients could not predict the pattern of 'yes' and 'no' responses. All prime and target pairs used by Buchanan et al. (1994) were always related.

Procedure

The procedure followed exactly that reported by Buchanan et al. (1994). Participants were tested on two separate occasions. On the first occasion half of the real word targets appeared with their related pseudohomophones and the other half appeared with the orthographically controlled non-words. On the second occasion the pairing was reversed such that those words that appeared in the related pseudohomophone condition in the first occasion appeared with the orthographic controls. Thus the experiment was a counterbalanced within-subject design. The pairs of items were randomly chosen and were presented one at a time in the centre of a computer screen, following presentation of a fixation cross for 250ms (also in the centre of the screen). The participants were asked to decide as quickly as possible whether the item was a real word or not. The response pad was placed in front of each patient and they were instructed to press the green 'YES' button if they thought the letter string was a real word or the red 'NO' button if they thought it was a non-word. The prime (pseudohomophone or orthographically controlled non-word) was presented until a response was made. Once a response was made, the item disappeared and was replaced by the real word semantically related target, which also remained on the screen until a response was made. The non-word filler pairs were randomly interspersed with the other stimulus pairs. Therefore, participants had to make two consecutive lexical decisions per trial. This was to ensure that the participants had read the first letter string.

Results of experiment 6.4

As for Buchanan et al. (1994; 1996), the results for a trial were discarded if the response to either the prime or to the target was incorrect; only responses to targets that were preceded by correctly rejected non-word primes were analysed. According to Buchanan et al. (1994; 1996) this procedure eliminates the possibility that priming was due to visual confusion such that patients perceived the pseudohomophone as the word from which it was derived. For example, an incorrect acceptance of ‘*taybul*’ as a word would suggest that a reaction time advantage for the target item ‘*chair*’ was due not to the phonology of ‘*taybul*’ but to activation from the visual word-form of ‘*table*’ (see Buchanan et al., 1996). All outliers were removed if greater than 3 standard deviations from the mean for the relevant condition.

The target reaction time data are displayed in Table 58 below.

Table 58. Mean, standard deviation and median reaction times in milliseconds of positive (real word target) lexical decisions as a function of pseudohomophone and orthographically controlled non-word primes

Target RT: (For correct trials only)	**P.D**			**J.P.J**			**G.T**		
	Mean RT	SD	Med RT	Mean RT	SD	Med RT	Mean RT	SD	Med RT
Pseudo-homophones primes	916.04 (n = 46)	250.88	823.00 (n = 46)	893.17 (n = 53)	290.67	834.00 (n = 53)	1013.00 (n = 56)	344.52	937.00 (n = 56)
Ortho-graphically controlled non-words primes	966.26 (n = 43)	291.79	898.00 (n = 43)	958.38 (n = 56)	723.34	766.00 (n = 56)	1015.00 (n = 60)	154.01	956.00 (n = 60)

At first glance, the data for both PD and JPJ (mean target reaction time) suggest that the pseudohomophone primes were priming the target words more quickly than the orthographically controlled non-words. However, before further analysis was carried out, the data was log transformed (using log 10) due to the unequal variance and skew of the data.

Transformed RTs to pseudohomophone and orthographically controlled non-words were compared for each patient using a t-test. The analyses found no significant difference between pseudohomophones and orthographically controlled non-words for any of the three patients (**PD**: t (87) < 1. **JPJ**: t (107) < 1. **GT**: t (114) < 1).

Buchanan et al. (1994) claimed that the analysis should be carried out on individual items (i.e. a trial by trial comparison rather than on 'overall' groups because the letter string pairs are compared) rather than on the overall reaction time to complete the entire block. A paired t-test was therefore carried out on the transformed data; this resulted in the loss of several pairs/items for each patient (e.g. for PD only 24 pairs remained) as patients may have correctly rejected the pseudohomophone '*taybul*' prime but not the orthographically controlled non-word '*tarble*'. However, no significant difference between RTs to pseudohomophones and orthographically controlled non-words was found for any patient (**PD**: t (23) < 1. **JPJ**: t (29) < 1. **GT**: t (29) < 1).

Discussion of experiment 6.4

The results of this experiment do not show any difference in response times between pseudohomophones and orthographically controlled non-word primes in a lexical decision task. They provide no evidence to support the view that the phonology of non-words can be used by deep dyslexic patients to produce a priming advantage. Despite this experiment being an exact replication of Buchanan et al. (1994, 1996), the results contradict their findings that deep dyslexics are able to benefit from the phonology of pseudohomophone primes.

The dual response technique (participants make two consecutive lexical decisions, one to the prime and one to the target) is not usually used in semantic priming experiments. It was therefore decided to modify the experimental method in an attempt to see whether semantic priming by pseudohomophones could be produced using the conventional paradigm of a single response.

Experiment 6.4.1

Neely (1991) argued that the 'single-word semantic priming paradigm' (in which participants are only required to respond to the target) has potential advantages over the double response procedures, used originally by Meyer and Schvaneveldt (1971) and in Buchanan et al. (1994) as well as in experiment 6.4, in which participants have to make lexical decisions to *both* the prime and the target item. Neely (1991) argued that responding to the target word only is a much simpler action, in that the subject must respond on the basis of the lexicality of a single letter string rather than two letter strings. Furthermore, Neely (1991) suggested that with procedures in which participants respond to the prime and some time elapses before the target is presented (e.g. Meyer et al., 1974) one cannot examine semantic priming at prime-target stimulus onset asynchronies that are shorter than the participants' reaction times to the prime. He argued that when no response is required to the prime, semantic priming at these shorter prime-target stimulus onset asynchronies can be examined. It was therefore decided to repeat experiment 6.4 but using a brief exposure of the prime to which the participants were not required to make any overt response and to use a short prime-target interval.

Experiment 6.4.1

Method

Participants

The same three participants were used in this experiment as in experiment 6.4 (PD, JPJ and GT)

Materials and procedure

The same stimulus set was used as in experiment 6.2 (see Buchanan et al. 1994; 1996) which consisted of 30 real word targets with 30 pseudohomophone primes and 30 orthographically controlled non word primes. Twenty non-word fillers pairs were also included so that the target response was not always 'yes' in lexical decision. However, this time the primes were presented on the computer screen for 250 ms and were then replaced immediately by the non-word target stimulus. The target item remained on the screen until a single lexical decision response was made. As before, the prime and target word pairs were always related.

Example of stimulus sequence using pseudohomophones as primes:

Fixation point + ⇨ *PRIME 250ms* ⇨ *TARGET* ⇨ *lexical decision*
to target only
('*mayl*') ⇨ ('**letter**') ⇨ YES
('*dore*') ⇨ ('**knob**') ⇨ YES

Example of stimulus sequence using non-word filler pairs (a NO lexical decision):

Fixation point + ⇨ *PRIME 250ms* ⇨ *TARGET* ⇨ *lexical decision*
to target only
('beer') ⇨ ('**mook**') ⇨ NO
('book') ⇨ ('**dolp**') ⇨ NO

Results of experiment 6.4.1

Participants only made a lexical decision to the target item and only correct responses were analysed. All outliers were removed plus reaction times over 3 standard deviations from the mean. The results after trimming are shown in the Table 59 below.

Table 59. Mean, standard deviation and median reaction times for correct responses to real word targets using pseudohomophones and orthographically controlled non words primes for 250ms

Target RT: (For correct trials only)	**P.D**			**J.P.J**			**G.T**		
	Mean RT	SD	Med RT	Mean RT	SD	Med RT	Mean RT	SD	Med RT
Pseudo-homophones primes	882.52 (n = 27)	200.09	906.00 (n = 27)	909.05 (n = 20)	143.31	906.00 (n = 20)	1210.33 (n = 27)	296.92	1132.00 (n = 27)
Ortho-graphically controlled non-words primes	971.07 (n = 27)	178.39	958.00 (n = 27)	914.52 (n = 21)	171.30	895.00 (n = 21)	1156.54 (n = 26)	176.89	1140.00 (n = 26)

The data from Table 59 show no evidence of priming but the results are in the predicted direction (i.e. pseudohomophone primes are priming real word targets slightly more quickly than their orthographically controlled non-word equivalents). The data was log transformed (using log 10) to reduce skew; a t-test was then conducted on the transformed data. However, no significant difference in response times to pseudohomophones and to orthographically controlled non-words was found for any patient (**PD**: t (52) = 1.842; p >0.05; **JPJ**: t (39) < 1; **GT**: t (51) < 1).

In the previous experiment (6.4.1) the exposure time of 250 ms was used. However, it may be that the 250ms exposure of the non-word prime was too fast for the patients to be able to process the word fully. It was therefore decided to increase the amount of time the prime word appeared on the computer screen to 900ms to determine whether this made a difference to the results.

Experiment 6.4.2

The same participants took part along with the same stimuli and procedure, but the primes remained on the screen for longer (900ms). The participants only had to respond to the target item and only the correct data was analysed. The results, after trimming in the same way as for experiment 6.4.1, are displayed in the Table 60 below.

Table 60. Mean, standard deviations and median reaction times for correct responses to real word targets using pseudohomophones and orthographically controlled non words primes for 900ms

Target RT: (For correct trials only)	**P.D**			**J.P.J**			**G.T**		
	Mean RT	SD	Med RT	Mean RT	SD	Med RT	Mean RT	SD	Med RT
Pseudo-homophones primes	787.54 (n = 24)	140.16	788.00 (n = 24)	942.15 (n = 27)	125.46	943.00 (n = 27)	909.00 (n = 26)	87.86	918.00 (n = 26)
Ortho-graphically controlled non-words primes	837.96 (n = 25)	226.13	769.00 (n = 25)	985.14 (n = 29)	171.93	949.00 (n = 29)	903.33 (n = 24)	101.23	880.00 (n = 24)

The data for each patient was transformed (using log10) to reduce skew; a t-test found no significant difference between the two types of prime stimulus for any of the patients (**PD**: t (47) = < 1; **JPJ**: t (54) = < 1; **GT**: t (48) = < 1. There is therefore no evidence of a priming advantage for the pseudohomophones. Thus, the priming effect claimed to be found by

Buchanan et al. (1994, 1996) was not found with the current deep dyslexic patients, or else it was also found for the orthographic controls.

Discussion of experiments 6.4.1 and 6.4.2

It is clear from experiments 6.4.1 and 6.4.2 that in comparison with orthographically controlled non-words no statistically significant effect of semantic priming occurred for any of the three patients when pseudohomophones were used as primes. This stands in contrast to the findings of Buchanan et al. (1994; 1996) that pseudohomophones prime real target words better than orthographically controlled non-words.

The null effects might suggest a problem with either the stimuli or the methodology used. One potential problem with the stimuli used by Buchanan et al. (1994, 1996) is that letter number is not consistent across the stimuli (e.g. the real word '*table*' has 5 letters whereas the pseudohomophone '*taybul*' and orthographically controlled non-word '*tarble*' have 6 letters). A second possible reason for the null findings is that perhaps the primes used in experiments 6.4, 6.4.1 and 6.4.2 were not close enough semantic matches to the target (e.g. *fryl* (*frill*) – *ruffle*, *sien* (*sign*) - *poster*) to produce priming. No mention is made by Buchanan et al. (1994) of asking controls/deep dyslexics what words they may associate with the primes used, for example, by using a word association task to obtain prime-target agreement percentages, that is, asking '*what is the first response that comes to mind when you hear the word... 'dore'*? Furthermore, the stimulus set constructed by Buchanan et al. (1994) consisted of a mixture of semantically related but not 'associative' words (e.g. '*frute*' (*fruit*) and '*pear*'), 'associative' words ('*haire*' (*hair*) and '*brush*') and many primes that were only '*related*' in the sense that they mean the same thing ('*jale*' (*jail*) and '*prison*'; '*meel*' (*meal*) and '*food*'; '*payl*' (*pail*) and '*bucket*'). It could be argued that this does not fit a definition of semantically related items, as rather than being 'similar' in meaning the latter are actually identical. Another criticism of the Buchanan et al. data set is that there are a number of more abstract words such as '*payne*' (*pain*) and '*obay*' (*obey*) used as primes; these words are much more difficult for deep dyslexics to process than concrete words. Katz et al. (1992) found implicit phonological processing using concrete words, but not abstract words, while Crutch and Warrington (2007) found no evidence of an effect of semantic context for semantically similar abstract words.

A more important criticism is that Buchanan et al. (1994; 1996) (along with experiment 6.4 which was an exact replication and experiments 6.4.1 and 6.4.2 which were partial replications of Buchanan et al.) did not employ real words as primes. It is therefore difficult to interpret the absence of a priming effect with pseudohomophones without knowing whether participants would have shown a priming effect using real word primes with real word targets. Consequently, little can be concluded from the negative patient data from experiments 6.4.1 and 6.4.2. Finally, without data from non-brain injured control participants it is difficult to interpret negative findings in patients. Therefore, it was decided to devise another implicit priming experiment using new stimuli incorporating real word primes and including control participant data.

Experiment 6.5

Whilst it may be the case that accessing phonological representation of non-words is severely compromised in deep dyslexia, Buchanan et al. (1994; 1996; 1999; 2003) claim that implicit phonological ability exists in the acquired reading disorder. However, the results of the Buchanan et al. study could not be replicated in the present investigation with three deep dyslexic patients (as seen in experiments 6.4, 6.4.1 and 6.4.2). Therefore, the methodology was changed in the next experiment in order to investigate whether the patients would demonstrate phonological processing of non-words.

The new methodology focused on improving the priming stimuli. Neely (1991) suggested that semantically associated words (e.g. *doctor-nurse*) tend to prime better than any other word pairs. Thus the stimuli used in the new experiment were all semantically associated pairs. Furthermore, all letter strings were concrete words as deep dyslexics find abstract words much harder to read (see Katz et al., 1992). Nelson et al. (1998) suggested that the strength of semantic association between word pairs can be quantified through empirical measures such as discrete free word association. Morton (1964) argued that word association is linked to word recognition; it reflects feedback to the word recognition system from a semantic system where associative knowledge is represented. Therefore, association ratings for the new priming stimuli were sought. In addition, the new priming stimuli incorporated real word related and unrelated primes and pseudohomophone control non-words; non-brain injured control participants were included in the study.

Lukatela and Turvey (1994) found that pseudohomophones prime real words faster than their orthographically controlled equivalents (e.g. '*taybl*' primes '*chair*' more quickly than '*toybl*' primes '*chair*') with neurologically normal participants. Buchanan et al. (1994; 1996) claim to have found a priming effect with deep dyslexic patients but this result was not replicated in experiment 6.4 using the same stimuli as Buchanan et al. Thus, the aim of this experiment was to investigate whether using another set of stimuli would reveal semantic priming in deep dyslexia. It was hypothesised that real (related) words would prime more quickly than real (unrelated) words (e.g. *'knife'* would prime *'fork'* more quickly than *'knife'* appearing before the word *'king'*) as found by Meyer and Schvaneveldt (1971) and Neely (1991).

Experiment 6.5

Method

Participants

The same three participants (PD, JPJ and GT) were used as in experiments 6.3 and 6.4.

Materials

The experiment was conducted using SuperLab programme and reaction times were recorded by a Cedrus response pad Model RB-730. The 15 real word priming pairs were taken from the word association database devised by Nelson et al. (1998) (http://w3.usf.edu/FreeAssociation) The prime-target agreement for each item was over 90% (i.e. over 90% of people when asked "***what is the first word you think of when you hear the word … bread?***" replied *'butter'*, see Nelson et al. 1998). Furthermore, the selected primes were given to 30 control subjects to write down which words they associated with them. They were asked to write down the words they first think of when they hear/see...?; at least 26 out of the 30 (87%) control subjects replied with the target items used in the present study.

The prime and target stimuli are shown in Table 61.

Table 61. Priming stimuli used in experiment 6.5

Real word Primes	**Ortho-control non-word Primes**	**Pseudohomophone Primes**	**Pseudohomophone control non-word Primes**	**Real word TARGET (Related)**	**Non word TARGET (Related)**	**Real word TARGET (Unrelated)**
1. bread	1. brend	1. bredd	1. bradd	1. butter	1. botter	1. saucer
2. table	2. teble	2. taybl	2. toybl	2. chair	2. chaim	2. clown
3. queen	3. queon	3. kwean	3. krean	3. king	3. kint	3. gun
4. nurse	4. narse	4. nerse	4. nepse	4. doctor	4. doptor	4. picture
5. wife	5. wefe	5. wyfe	5. wyke	5. husband	5. husbang	5. lock
6. knife	6. knile	6. niphe	6. nophe	6. fork	6. forf	6. tree
7. train	7. traim	7. trane	7. trene	7. track	7. tramk	7. book
8. nail	8. nait	8. nale	8. nule	8. hammer	8. hamwer	8. husband
9. read	9. reab	9. rede	9. rete	9. book	9. boik	9. track
10. leaf	10. leof	10. leef	10. leet	10. tree	10. treg	10. hammer
11. key	11. kel	11. kee	11. kep	11. lock	11. leck	11. fork
12. bullet	12. bellet	12. boolet	12. booleg	12. gun	12. gub	12. chair
13. circus	13. cirbus	13. syrcus	13. symcus	13. clown	13. clowp	13. king
14. photo	14. pheto	14. fotoe	14. fofoe	14. picture	14. pocture	14. butter
15. cup	15. cip	15. kup	15. kug	15. saucer	15. sauter	15. doctor

The orthographically controlled non-words were devised by changing one letter from the real word equivalents, for example, '*bullet*' to '*bellet*'. They were designed to look more visually similar to real words than were the pseudohomophones in order to control for orthographic similarity. The pseudohomophone control non-words were made by changing one letter from each of the pseudohomophone stimuli (e.g. '*niphe*' to '*nophe*').

All non-word primes had the same letter length as the real word equivalents. Bigram frequency and n scores were calculated using Davis's (2005) N- watch program. The results are shown in Table 62.

Table 62. Bigram frequency and n scores for prime and target stimuli in experiment

Stimuli	**Mean Bigram frequency**	**Mean n score**
Real words (related) primes:	1199.27	4.86
Orthographically controlled non-word primes:	1132.13	3.47
Pseudohomophone primes:	822.48	3.33
Pseudohomophone control primes:	737.63	2.53

The bigram frequency and n scores suggest that the orthographically controlled non-words were more similar to the real word primes than were the pseudohomophones, but not statistically different ($p > 0.05$).

On half the trials real word targets were preceded by the four types of prime. On the other half of the trials the four types of stimulus were paired with non-words.

Table 63 shows the different conditions.

Table 63. The conditions of experiment 6.5

Condition	**Prime**	**Target**
1	Real word (n = 15)	*Real word (related)*
2	Orthographically controlled non-word (n = 15)	*Real word (related)*
3	Pseudohomophone (n = 15)	*Real word (related)*
4	Pseudohomophone control (n = 15)	*Real word (related)*
5 (control)	Real word (n = 15)	*Non-word*
6 (control)	Orthographically controlled non-word (n = 15)	*Non-word*
7 (control)	Pseudohomophone (n = 15)	*Non-word*
8 (control)	Pseudohomophone control (n = 15)	*Non-word*
9	Real word (n = 15)	*Real word (unrelated)*

Procedure

In total there were 135 priming trials; there were 60 trials with real related word targets; 60 trials with non-word targets plus 15 trials with real unrelated word targets. The 60 real related and 60 non-word targets appeared with 15 real word primes, 15 orthographic control primes, 15 pseudohomophone primes and 15 pseudohomophone control primes. The remaining 15 real word primes appeared with the 15 real unrelated target words. The black Aerial Baltic (font size 100) letter strings were presented one at a time in random order, in the centre of a computer screen. The participants were seated approximately 22 inches away from the screen. The participants were asked to decide as quickly as possible whether the item was a real word or not. Responses were recorded using a response pad which was placed in front of each patient; they were instructed to press the green 'YES' button if they thought the letter string was a real word or the red 'NO' button if they thought it was a non-word, assignment of the coloured buttons to the responses yes/no being altered between participants.

Unlike experiments 6.4.1 and 6.4.2 in which participants did not respond explicitly to the prime, in this experiment the primes remained present on the screen until a lexical decision response was made; this was to ensure that the participants had seen the stimulus. Once a response had been made the item disappeared and was replaced by either the real related word target, a non-word target or by a real unrelated word target; these also remained on the screen until a response was made. After a response was given to the target there was a pause until the participant was ready for the next prime-target trial; the experimenter then pressed the start button to initiate the next trial.

There were 5 experimental conditions (condition 1-4 and 9); conditions 5 to 8 were control trials in order that the target responses were not always ‘yes’. Condition 9 was also included in order to examine whether real (related) words prime more quickly than real (unrelated) words as Meyer and Schvaneveldt (1971) and Neely (1991) found. The conditions were presented in random order (chosen by the SuperLab program) and were different for each participant.

Results of experiment 6.5

Only the correct data from the responses to primes and to real word targets were analysed. The data were trimmed as before (i.e. all outliers removed); the results are displayed in Table 64 below:

Table 64. Mean, standard deviation and median reaction times in milliseconds to real word targets using different types of primes.

	P.D			**J.P.J**			**G.T**		
	Real Target RT			Real Target RT			Real Target RT		
Conditions ⇩	Mean RT	SD	Med RT	Mean RT	SD	Med RT	Mean RT	SD	Med RT
1. Real word related primes	1223.27 (n = 11)	283.90	1132.00 (n = 11)	956.00 (n = 11)	275.83	871.00 (n = 11)	1157.60 (n = 15)	124.68	1146.00 (n = 15)
2. Ortho-graphically controlled non-word primes	1210.71 (n = 14)	334.57	1068.50 (n = 14)	1085.69 (n = 13)	265.76	1081.00 (n = 13)	1172.53 (n = 15)	109.90	1154.00 (n = 15)
3. Pseudo-homophone primes	1180.43 (n = 14)	299.35	1037.00 (n = 14)	1002.43 (n = 14)	251.36	973.00 (n = 14)	1139.60 (n = 15)	98.50	1110.00 (n = 15)
4. Pseudo-homophone Control primes	1247.50 (n = 14)	340.36	1139.50 (n = 14)	1168.62 (n = 13)	376.76	1114.00 (n = 13)	1202.13 (n = 15)	155.26	1176.00 (n = 15)
5. Real word unrelated primes	1206.50 (n = 10)	520.99	944.00 (n = 10)	999.00 (n = 13)	271.19	1010.00 (n = 13)	1199.07 (n = 14)	204.68	1114.00 (n = 14)

The reaction time data was log transformed (using log 10) to reduce skew and to homogenise the variance. A one way ANOVA was conducted on each of the patient's transformed data and revealed that none of the results was statistically significant: **PD**: F (4, 58) < 1; **JPJ**: F (4, 59) < 1 and **GT**: F (4, 69) < 1. The results therefore show no effect of priming for any of the participants.

The same procedure was carried out with 3 of the control participants (referred to at the beginning of this Chapter) who were matched to PD, JPJ and GT, in order to examine whether a priming effect occurred in neurologically unimpaired participants. The results are displayed in Table 65.

Table 65. Control participant mean, standard deviations and median reaction time in milliseconds to real word targets using different types of primes.

	E.D (aged 53) Real Target RT			**M.D (aged 26)** Real Target RT			**E.P (aged 70)** Real Target RT		
Conditions ⇩	Mean RT	SD	Med RT	Mean RT	SD	Med RT	Mean RT	SD	Med RT
1. Real word related primes	639.71 (n = 14)	97.15	630.00 (n = 14)	583.87 (n = 15)	68.89	557.00 (n = 15)	717.85 (n = 13)	122.87	676.00 (n = 13)
2. Ortho-graphically controlled non-word primes	906.87 (n = 15)	129.90	841.00 (n = 15)	926.80 (n = 15)	67.03	922.00 (n = 15)	1095.54 (n = 13)	301.19	989.00
3. Pseudo-homophone primes	742.67 (n = 15)	157.29	721.00 (n = 15)	688.07 (n = 15)	91.82	700.00 (n = 15)	836.18 (n = 11)	72.58	840.00
4. Pseudo-homophone Control primes	931.13 (n = 15)	123.33	890.00 (n = 15)	903.62 (n = 13)	73.57	911.00 (n = 13)	1360.85 (n = 13)	370.47	1219.00 (n = 13)
5. Real word unrelated primes	889.87 (n = 15)	102.64	889.00 (n = 15)	750.86 (n = 14)	116.21	708.00 (n = 14)	990.53 (n = 15)	129.37	955.00 (n = 15)

The mean values from Table 65 suggest that, for control participants, real related words primed more quickly than real unrelated words and that pseudohomophones primed real targets words more quickly than orthographically controlled non-words. In order to examine whether these differences were significant an ANOVA was conducted after the data was transformed (using log10).

One way ANOVAs on the transformed data found that the results were statistically significant for all three control participants, **E.D**: F (4, 69) = 17.63, $p < 0.01$; **M.D**: F (4, 67) = 41.78, $p < 0.01$; **E.P**: F (4, 60) = 19.41, $p < 001$. Tukey's HSD test showed that for all 3 participants primes differed significantly ($p < 0.01$) from one another (except that for both E.D and E.P, real word primes and pseudohomophone primes did not differ significantly). In particular the transformed RTs to real word related targets primed by pseudohomophones were significantly faster than those primed by orthographically controlled primes for all 3 participants ($p < 0.02$).

Discussion of experiment 6.5

The control participants' results demonstrate that target stimuli preceded by related real words were responded to more quickly than when they were preceded by unrelated words, supporting similar findings obtained by Meyer et al. (1971) and Neely (1991). For each control participant pseudohomophones primed significantly more quickly than both orthographically controlled non-words and pseudohomophone control non-words. This is an important finding as the results show that the methodology and materials were adequate to reveal in 'normals' the priming effect being sought. However, no priming effect was found for any of the three acquired dyslexics. The latter results do not support those of Buchanan et al. (1994, 1996) suggesting that deep dyslexics have implicit knowledge of non-word phonology. In contrast to the lack of a pseudohomophone priming effect, the three acquired dyslexics did show a significant pseudohomophone effect in lexical decision in experiment 6.3 suggesting that non-word phonology *is* available at some level of processing in at least some deep dyslexics.

It may be that the deep dyslexics' semantic systems are more damaged than was previously thought. The Pyramid and Palm Trees test (used to assess language ability in Chapter 3) is a relatively easy task, it is therefore not difficult to obtain a high score from which it may appear that 'semantics' are virtually intact. However, further tests of semantic processing (e.g. PALPA 47 and 48; see Chapter 3 page 107 for results) revealed that 'semantics' were impaired in two of the three patients, as their scores were below the range of the PALPA control score.

One of the deep dyslexics involved in this investigation was given other semantic comprehension tests in order to examine whether he understood the words/non-word priming pairs. PD was asked to read the real word primes and then to indicate which of the two alternative targets he believed was semantically associated with the prime. For example, he was presented with 'bread' (prime) and then 'book' or 'butter' (targets); he scored 15/15 on this task. In addition, PD was asked to define each of the real word primes. He was given the prime list and was then asked individual questions for each of the prime words (e.g. 'bread' – "*is it a type of food or is it a plant*?") to which he responded verbally, or if he could not, then he pointed to a choice of either food or a plant; PD again scored 15/15. Each of the real word primes was also given to PD to draw (see appendix 15). Most of the pictures drawn by PD were recognisably correct; however, when drawing people such as 'queen' or 'nurse' he did not make them distinguishable from one another (e.g. perhaps drawing a crown for the queen or a medical cross for the nurse). PD also made one semantic error to 'leaf' as he seemed to draw a flower or plant in a pot but without including any leaves. On the whole though, PD's drawings of the prime items were very good. Furthermore, PD was asked to do a free word association task; the experimenter gave a prime word then PD was required to say the first word that came to mind. If the semantic system is intact in deep dyslexia, then patients should perform normally in a standard word association task when they are presented with a spoken cue and asked to respond with the first word that comes to mind. Most of PD's responses (10/15) were semantically associated with the prime (see appendix 16 for free association responses).

While assessing PD's semantic comprehension the pseudohomophone prime list (as used in experiment 6.5) was given to him with two alternative real word targets from which to choose a word associated in meaning; he correctly chose 13/15 of the real word targets that were associated to the pseudohomophone prime. This implied that he was able to derive the phonology of the pseudohomophone primes, which then activated his semantic system to enable him to choose which of the two targets was semantically associated to the prime.

Therefore, from the test of definition, drawing and free association it appears that PD had no trouble understanding the prime and target words used in the experiment. The other two participants were not tested on this as they became too ill. However, if PD's results can be extrapolated to the other two patients then it would appear that the lack of a priming effect in their data is unlikely to be due to a comprehension deficit.

Therefore, what is it that actually produces priming in the first place? Many theories propose that it is in the nature of the semantic links (see Plaut & Booth, 2000 for review of semantic priming theories). Collins and Loftus's (1975) spreading activation theory suggests that information about words and their meanings are stored in separate networks. One network is purely lexical; that is, it contains only phonemic and orthographic information about words. The other network is purely semantic and contains all concepts, including those linked to the word forms in the lexical network. Nodes in the lexical network are connected to each other on the basis of phonological and orthographic similarity, whereas nodes in the semantic network are connected to each other on the basis of semantic similarity. According to this theory, links between the lexical and the semantic network are as easily activated as are those within a network. Semantic facilitation or priming is usually attributed to the pre-activation of target representations within a semantic network (e.g. see Collins & Loftus, 1975; McNamara, 1994).

Lucas (2000) suggested that the spreading activation theory, in which lexical and conceptual knowledge is interactive, can be contrasted with a modular theory (e.g. Fodor, 1983 or Forster, 1979). On the modular viewpoint, priming within the lexical network of phonological and orthographic information is based on associative links which connect words that are often contiguous (e.g. *needle* and *thread*) but that may share few if any semantic features. This intra-lexical priming is automatic and unaffected by feedback from the conceptual (semantic) network. According to Lucas (2000) connections within the conceptual network (e.g. categories that share certain features) may prime each other, but this priming cannot provide feedback to the lexical network to facilitate the activation of related word forms. Facilitation arising from within the conceptual network can only influence later stages of processing such as the stage at which the most likely lexical candidate is selected from among a number of activated representations or the stage at which a lexical representation is integrated with others have preceded it. The absence of a priming effect in the present deep dyslexics may be due to a reduced number, or strength of, the links between nodes in semantic space. Thus, it might be that the nature of the semantic links is abnormal in brain injured patients. Perhaps the 'odd links' between items cause all words to be activated instead of the 'related' items needed. Alternatively, it maybe that in the case of deep dyslexia the semantic representations of the target words are not activated during lexical decision tasks. That is, deep dyslexics rely on the orthographic and phonological representation of an item to make a lexical decision; and no semantic information is activated during priming.

It maybe that methodological factors such as length of SOAs (the delay between onset of prime and onset of the target) can account for the null priming results. Neely (1991) suggests that the optimal SOA for priming is 500ms. Thus on reflection perhaps the 900ms in experiment 6.4.2 was too long and the 250ms prime in experiment 6.4.1 was too short (e.g. see Shore (1991) and Dickens (1995) in normal controls). Perhaps the timing in the experiments caused activation to fall off more quickly, or more steeply, in the deep dyslexics than in neurologically normal controls. Many individual differences could affect the magnitude of priming. Plaut and Booth (2000) suggest that priming effects are influenced by a variety of experimental factors, including target frequency, category dominance, relatedness proportion, stimulus quality, SOAs and the task performed by the participants.

According to Vitkovitch and Humphreys (1991) the semantic facilitation effect can be eliminated if the time between the associated prime and the target stimulus is longer than about 5 seconds. This rapid loss of associative priming is usually attributed to decay of activation in the target representation mediating the response. In contrast, under certain circumstances, Vitkovitch and Humphreys (1991) argued that processing can be impaired by the presence of associatively related items; a type of semantic interference. For example, picture naming can be disrupted by the simultaneous presentation of a word corresponding to a related stimulus producing a Stroop-type interference (see Caramazza & Costa, 2000). Naming can also be disrupted by previous identification of related objects (Humphreys, et al. 1988). Similarly, studies of name retrieval (e.g. Brown, 1979), simple arithmetic facts (e.g. Campbell & Clark, 1989) and of visual matching (e.g. Boucart & Humphreys, 1992) have all shown that responses can be slowed when stimuli are semantically related. This suggests that even though semantically related items have been shown to facilitate performance in some circumstances (e.g. semantic priming effects) they can also impair performance in others.

According to Lucas (2000) there has been controversy over whether or not *any* priming effects is automatic (see Boronat, 1998). Automaticity is usually defined by a set of criteria that include fast processing of a stimulus without awareness, attention, or intention (Posner & Snyder, 1975). However, a number of studies have shown that semantic priming can only occur if subjects attended to the primes (e.g. see Stolz & Besner, 1999). These findings have led some to conclude that semantic priming cannot be automatic. If this is true, then perhaps the reason why the current deep dyslexics did not show a priming effect was that they did not attend to the prime. On the other hand the analysis of data (e.g. in experiment 6.5) was only conducted on trials on which the priming stimulus was correctly identified in lexical decision task.

6.6 General discussion of implicit experiments

To summarise the findings of experiments 6.1- 6.5, the deep dyslexic patients were able to read pseudohomophones significantly better than orthographic control items; all of the participants even made semantic errors to some pseudohomophones implying that the semantic system had been accessed. It was also found that a significant pseudohomophone effect occurred in terms of Stroop type interference and lexical decision times. However, no semantic priming effect was found either with real related words or with pseudohomophones. The claim made by Buchanan et al. (1994, 1996) that semantic priming effects can be found in deep dyslexics when pseudohomophones are used as primes was not supported.

Colangelo et al. (2004) suggested that cumulatively the findings of Buchanan al. (1994, 1996) indicate that deep dyslexics are sensitive to implicit phonological information for words and non-words, despite impaired explicit access. Their findings (along with experiments 6.1, 6.2, 6.3 and 6.5 from this thesis) provide evidence that the primary locus of the deficit in deep dyslexia is not sub-lexical. They argued that this premise poses considerable problems for accounts of deep dyslexia couched in terms of multiple loci of damage, for which functionally distinct phonological and semantic-lexical pathways are postulated (e.g. Morton and Patterson, 1980; Coltheart, 1980). These models propose that deep dyslexia involves damage to the sub-lexical route such that it is rendered unavailable for reading. As a consequence, deep dyslexics are assumed to lack the capacity to assemble phonology (e.g. unable to read non-words). These models propose that reading is accomplished by a semantically mediated lexical route, which is capable of supporting reading through whole word access. A selective impairment is also assumed for the semantic-lexical route and it is the damage to this reading system that is hypothesised to lead to semantic errors in deep dyslexia. However, Colangelo et al. (2004) argued that "*...if implicit phonological ability does exist, then influential models* *of reading would require revisions to allow for the possibility that phonological analysis does occur in at least some of the deep dyslexic's word recognition process...* " (p.232).

Buchanan et al. (1994) proposed some revisions of previous models to accommodate their findings on implicit phonological ability. In terms of the dual route model (which postulates that the sub-lexical route is the primary way in which non-word phonology can be derived) neither a pseudohomophone effect nor a semantic priming effect with pseudohomophones would be possible if the sub-lexical route were totally compromised (as is said to be the case in dual route accounts of deep dyslexia). Buchanan et al. argued that pseudohomophones differ from other non-words in that the phonology of the word can activate lexical entries. If phonological processing of non-words is impossible, then the subsequent activation of lexical entries based on phonology would also be impossible. Thus in order to accommodate the results of Buchanan et al., and to explain why the current three deep dyslexics showed an advantage for pseudohomophones over orthographically controlled non-words in reading and in a lexical decision task, the dual route model would require the sub-lexical route to be functional at some level of processing at least.

Colangelo and Buchanan (2005) argued in favour of the failure of inhibition hypothesis (see Chapter 1 for review) that posits a theoretical distinction between implicit and explicit access to phonology in deep dyslexia. Specifically, the effects of failure of inhibition are assumed only in conditions that have an explicit selection requirement in the context of production (e.g. reading aloud). In contrast, the hypothesis proposes that implicit processing and explicit access to semantic information without production demands are intact in deep dyslexia. Colangelo and Buchanan (2005) argue that evidence for intact implicit access requires that performance of deep dyslexics parallels that observed in non-brain injured patients on tasks based on implicit processes. In other words, deep dyslexics should produce 'normal' effects in conditions with implicit task demands because failure of inhibition does not influence the availability of lexical information, only explicit retrieval and subsequent production. Colangelo and Buchanan (2005) considered lexical decision to be an implicit task because although individuals decide the lexical status of letter strings, priming of lexical access is indexed in terms of facilitation as measured by faster and more accurate response times for one condition relative to the other. This theory can thus explain why the current three deep dyslexics produced the pseudohomophone effect in lexical decision. Why then were patients better at reading pseudohomophones than orthographically controlled non-words?

The pseudohomophone advantage found in the experiments may, of course, be artefactual. One suggestion as to why a pseudohomophone advantage occurred in the deep dyslexic patients is that the pseudohomophone stimuli were more visually similar to real words than were the orthographically controlled non-words (as argued by Martin, 1982). Even though the orthographically controlled words were designed to be 'orthographically' similar to real words some may look 'visually odd' compared to their pseudohomophone equivalents. Perhaps the deep dyslexic participants, when making a lexical decision, glanced briefly at the letter-string and simply guessed whether the item looked like a real word or not. Thus the apparent pseudohomophone advantage occurred due to a better chance of correctly guessing pseudohomophones than orthographically controlled non-words. Furthermore, the correct pronunciation of a pseudohomophone is the same as reading a real word aloud; patients are therefore more likely to produce the phonological equivalent of the pseudohomophone (i.e. a real word) in response than to produce the phonology of orthographically controlled non-words. However, on the basis of the final experiment 6.5 (which was well controlled) even if it is accepted that an element of doubt exists with regard to the earlier experiments, the pseudohomophone advantage may actually be due to the phonology of the pseudohomophones which facilitates the patients' reading. However, if this was the case, why were the patients able to read pseudohomophones but unable to do letter-sound conversion?

The word superiority effect (Reicher, 1969) may explain why the deep dyslexics were able to read pseudohomophones better than individual letters. Reicher's (1969) experiment involved using a letter string which was presented very briefly, and then followed by a pattern mask. Subjects were asked to decide which of two letters was presented in a particular position (e.g. the third letter). Reicher found that performance was better when the letter string formed a word than when it did not. The word superiority effect indicates that information about the word presented can facilitate identification of the letters of that word. Bowers et al. (1996) found the word superiority effect in an acquired surface dyslexic who was a letter-by-letter reader. Furthermore, Carr et al. (1978) found that there is also a 'pseudo-word superiority effect'. That is, letters are better recognised when presented in pronounceable non-words (pseudohomophones) than in isolation. Thus it is easier in some circumstances to read letter strings as a whole than it is to read single letters. This may explain why the deep dyslexics are able to read pseudohomophones better than converting individual letters to sounds.

McClelland and Rumelhart (1981) and Rumelhart and McClelland's (1982) interactive activation model (IAM) of visual word recognition was argued to be an influential account of the word superiority effect (see chapter 1 for review). The pseudo-word superiority effect may also be explained by the IAM. When letters are embedded in pronounceable non-words, there will generally be some overlap of spelling patterns between pseudohomophones and the real word. This overlap is argued to produce additional activation of the letters presented in the pseudohomophone and therefore lead to a pseudo-word superiority effect. However, in spite of the general plausibility of McClelland and Rumelhart's (1981) theory, the interactive activation model is only designed to account for letter and word recognition in four-letter words written in capital letters. Therefore, it is not clear how successful it could be when applied to longer words.

Finally the question remains as to how the lack of semantic priming effect in the current deep dyslexics may be explained. Beeman and Chiarello (1998) suggested that close and weak semantic associates are processed differently in the left and right cerebral hemispheres; weakly (remotely) related word meanings appear to be preferentially processed by the right, as opposed to the left, hemisphere, while the left hemisphere appears to support priming of either strong or weak associates, depending on the time course. Frishkoff (2007) investigated the effect of associative strength on priming in the cerebral hemispheres with non-brain injured subjects. It was predicted that presentation of strong and weakly associated primes would elicit different patterns of hemispheric activity, indexed by high-density event-related brain potentials (ERPs). She found that priming occurred for both strong and weak associates over the left parietal sites, while priming over the right parietal sites is restricted to strongly related word pairs. According to Frishkoff's (2007) theory they should show priming with strongly associated words and not with weakly associated words. However, it was ensured that the primes used in experiment 6.5 were strongly associatively related to targets, and still no priming occurred with the three deep dyslexics; the results are not accommodated by either of the above hypotheses.

In conclusion, implicit phonological ability was found in terms of the Stroop effect with increased reaction times to pseudohomophones compared with orthographically controlled non-words. Patients were significantly better at reading pseudohomophones than orthographic controls and showed the 'pseudohomophone effect' in lexical decision. However, no evidence of semantic priming was found in the three deep dyslexics, even though the control subjects did show an effect with the new priming stimuli experiment. A concrete reason as to why these results emerged is not clear and a theory is still sought to explain the data. Further research is needed in order to examine the implicit ability of deep dyslexic patients to answer this question.

Chapter 7

7.1 Final summary and conclusion

The present thesis set out to examine the acquired reading disorder of deep dyslexia. The first part of the thesis reported a series of investigations carried out with bilingual readers of two orthographies, one deep, one shallow, namely English and Welsh respectively. The examination of three bilingual (English/Welsh) brain damaged patients showed that they all had acquired deep dyslexia in English and in Welsh. This was an important finding as the literature suggested that semantic errors of reading by aphasic patients were comparatively rare in languages with a shallow orthography. Miceli et al. (1994) argued in relation to reading aloud and writing that transparent orthographies are relatively 'protected' from the production of semantic errors. On a picture naming task in chapter 4, each of the three deep dyslexics made a similar proportion of semantic errors in the two languages as expected. However, contrary to the predictions of Miceli et al. (1994), in oral reading of the corresponding words no patient produced proportionally more semantic errors in English than in Welsh. Indeed, two of the patients made proportionally more semantic errors in Welsh.

Miceli et al. (1994) invoked the 'summation hypothesis' to explain apparent differences in frequency of semantic errors of reading in languages of different orthographic depth. It was concluded that the data of the patients involved in this thesis cast doubt upon the adequacy of this explanation as far as bilingual readers are concerned. It was further argued that the summation hypothesis as proposed by Miceli et al. (1994) is insufficiently specified to account for the semantic errors of monolingual readers of languages differing in orthographic depth. The findings of this thesis do not support the view that semantic errors are rare in a shallow orthography, although they do not constitute evidence against the summation (or triangle) hypotheses as such. To the contrary, the present findings show that, in bilingual patients at least, semantic errors may occur with considerable frequency in a shallow or transparent orthography.

The existence of the semantic errors of reading (in English and Welsh) were tentatively explained in terms of the failure of inhibition hypothesis (Buchanan et al., 1999). According to this hypothesis, slowed or reduced inhibitory connections account for a selection impairment in the phonological output lexicon in deep dyslexia. All candidate representations associated with the presented word are activated in the phonological lexicon and none are subsequently pruned through inhibition. Therefore, reduced inhibitory connections result in the incorrect selection of activated neighbours, hence the production of semantic errors.

With regard to bilingual aphasics it was of interest to ask whether the same psycholinguistic factors, that is, age of acquisition, frequency, imageability/concreteness and letter length, influenced picture naming and word reading in the same way for both the patients' languages. From the literature, it was argued that lexical variables, such as frequency and age of acquisition, should have relatively little, if any effect, on reading transparent languages, since the dominant route used for these languages is said to be the sub-lexical route. On the other hand, reading in such languages should be affected by word length. There was little reason to suppose that word length would have any greater effect on picture naming in one kind of language compared with the other, if any effect at all.

In Chapter 4 the data generated by presentation of the Snodgrass and Vanderwart (1980) set of pictures and the corresponding words to the deep dyslexics were examined with the above predictions in mind. This required that there be measures of the relevant variables in English as well as in Welsh. The first part of the investigation reported in Chapter 5 was an extension of Fear's (1997) Welsh ratings analysis. This enabled the reading and picture naming data to be analysed to determine which variables influenced the patients' performance in each language. The multinomial logistic regression analysis found that age of acquisition, imageability and letter length were all significant predictors of the patients' responses but not consistently across languages or patients. The data was in agreement with the viewpoint expressed by Morrison and Ellis (1995), among others, that a major component of what has been reported in the literature as a frequency effect in lexical processing is in fact due to a confound with age of acquisition, as frequency was not found to exert an independent effect on patients' responses.

Studies of bilingual aphasia considering the cognate status of words are extremely rare. Thus it was examined whether cognate status influenced the accuracy of the patients' naming and reading responses. However, when the cognate items were removed from the analysis, this had little effect on the results of the multinomial regressions. Some effects that were significant when cognates were included were no longer significant when the data for the cognates were removed from the data set. As the removal of the cognates reduced the number of items available for analysis it is not surprising some effects were nullified.

Roberts and Deslauriers (1999) reported that cognates increased the likelihood of correct picture naming by aphasic patients. Furthermore, Costa et al. (2000) found that the cognate status of picture names affected the performance of bilingual speakers more when they are naming in their non-dominant language. This was examined with the bilingual deep dyslexics. However, no cognate effect was present, for picture naming (or reading), that is to say no significant differences were found between cognates and non-cognates in the proportion of items responded to correctly by any patient in either English or Welsh. Analysis of the characteristics of the stimulus items used did not suggest that the absence of a cognate facilitation effect could be attributed to this source.

An important question was to ask what factors influence the production of semantic errors in the three bilingual deep dyslexic patients. The multinomial regression parameter estimates showed that age of acquisition was significantly associated with semantic errors in Welsh reading for all three patients and in reading English for PD and JWT. This supports Gerhand and Barry's (2000) finding that age of acquisition was the most salient factor that predicted participant's responses.

For all the words to which single word semantic errors were produced by each of the three patients, a comparison was made between the target items and the semantic error responses given. Only those responses which had ratings were available could be used. There were too few items for the stimuli to be separated into responses to cognate and non-cognate words. In any case there was no reason to expect that the features of semantic errors would differ as between cognate and non-cognate target words. Analyses were carried out on the semantic errors generated by PD, JWT and MJ for both naming and reading in English and in Welsh. It was found that the semantic errors produced were words which were earlier acquired, more frequent and were shorter in length than the target words to which the errors were made. The same characteristics were found to influence both reading and naming in Welsh and in English. Each of the patient's results partly support those of Gerhand and Barry (2000) who found that in comparison to the target word the semantic errors produced by their deep dyslexic patient L.W were earlier acquired, shorter and were higher in frequency. The semantic errors produced by P.D in English picture naming and by JWT and MJ in Welsh picture naming were higher in imageability than the target items. This was only true for naming and it is not clear why the effect was not also found in reading.

In order to determine whether the differences in age of acquisition, frequency, length and imageability between the target items and semantic error responses for each patient were real or due to each variable being correlated with each of the others, a series of ANCOVAs was carried out, taking each variable in turn and systematically partialing out the effect of the other variables. This removed all previously significant effects for all patients so the original results must be treated with caution.

According to certain theories (e.g. dual route model), the occurrence of semantic errors found in deep dyslexia suggests impairment of the sub-lexical route. However, Katz and Lanzoni (1992) and Buchanan et al. (1994) claim that at least some deep dyslexic patients are sensitive to implicit phonological information. The second part of the thesis examined phonological decoding ability in deep dyslexia. The experiments reported in Chapter 6 found some evidence for implicit phonological ability in terms of the Stroop effect with increased reaction times to incongruent than to congruent stimuli when real words and pseudohomophones were presented, but no effect was found using orthographically controlled non-words. The results showed that the three deep dyslexics were able to access the phonology of the pseudohomophones since otherwise there would have been no difference between congruency conditions.

The three deep dyslexics were able to read pseudohomophones significantly better than orthographically controlled non-word equivalents. Furthermore, all of the patients made semantic errors to some pseudohomophones implying that the semantic system had been accessed which implies that the pseudohomophones made contact with their lexical equivalents. A significant pseudohomophone effect was also found in terms of lexical decision times. However, questions emerged as to whether the pseudohomophone advantages found in the experiments were artefactual. Many have argued (e.g. Martin, 1982) that the pseudohomophone effect is a visual rather than a phonological effect, proposing that pseudohomophones look more visually similar to real words than their orthographic controlled equivalents. The suggestion was made that in the present experiments, at least, the pseudohomophone advantage may simply have occurred due to a better chance of guessing pseudohomophones rather than orthographically controlled non-words. However, experiment 6.3 of Chapter 6 suggested that the pseudohomophone advantage may indeed be due to the phonology of the pseudohomophones.

The right hemisphere hypothesis proposed by Coltheart (1980) posits that the deficits in deep dyslexia reflect the contributions of the right hemisphere to reading after the dominant left hemisphere has been damaged. The hypothesis assumes that damage to the left hemisphere eliminates access to the left orthographic lexicon. Thus, in order for reading to proceed, orthographic access to a right-hemisphere lexicon is necessary. Coltheart et al. (1988) suggest that the right hemisphere "*is incapable of translating between orthography and phonology in either direction by using mappings between sub-word orthographic units and sub-word phonological units*" (p.428). However, recent findings have shown that this is not true for all deep dyslexic patients as some (including the current 3 deep dyslexics) are able to process the phonology of non-words in certain implicit tasks. According to Buchanan et al. (1994) the major strength of the right hemisphere hypothesis is that it can accommodate their finding of implicit phonological ability (and perhaps the findings of this thesis on implicit processing) since one need only claim that the right hemisphere is capable of implicit translation of orthography to phonology, but is incapable of explicitly accessing that information. Whitney and Lavidor (2004) found word length effects are more prevalent for the LVF (right hemisphere) than for the RVF (left hemisphere). However, the fact that a significant effect of word length in reading Welsh was not found for two of the present three patients (chapter 5), but was found in picture naming in English, was not considered to support Coltheart's right hemisphere hypothesis.

Lukatela and Turvey (1994) found in a lexical decision task with non-brain injured participants that pseudohomophones can serve as effective primes in a lexical decision task. Buchanan et al. (1994) investigated whether such effects could be observed in deep dyslexia, basing their experiments on the study by Lukatela and Turvey (1994). They claimed that, relative to orthographically controlled non-words, semantically related pseudohomophones produced a priming effect to subsequent real target words in their deep dyslexic patient (J.C). A replication of the priming experiment by Buchanan et al. (1994) was reported in Chapter 6. However, despite an exact replication of the study by Buchanan et al. (1994) the results contradicted their findings that deep dyslexics are able to benefit from the phonology of pseudohomophone primes. The experimental method subsequently modified in several ways but no significant priming effects were found for any of the present deep dyslexic patients.

It was therefore decided to carry out a more methodologically stringent implicit priming experiment, using new stimuli, incorporating real word primes and including control participant data. The control participants' results indicated that the methodology and materials used in the experiment were adequate to reveal in neurologically normal participants the priming effect being sought. However, no priming was found with any of the deep dyslexic patients. Thus the claim made by Buchanan et al. (1994, 1996) that a semantic priming using pseudohomophone primes can be observed in cases of deep dyslexia was not supported.

Several suggestions as to why the null priming effects occurred were proposed. It was suggested that the nature of the semantic links is abnormal in brain injured patients. It might be that the 'odd links' between items cause all words to be activated instead of the 'related' items needed. Alternatively, it maybe that in the case of deep dyslexia the semantic representation of the target words are not activated during lexical decision tasks.

Whatever the explanation of the failure to find the semantic priming effect, it is clear from the findings of Chapter 6 that current models of deep dyslexia need to be revised in order to accommodate the findings on implicit phonological ability. To explain why the three deep dyslexics showed an advantage for pseudohomophones over orthographically controlled non-words in reading and the finding of the pseudohomophone effect in lexical decision tasks, the dual route model would require the sub-lexical route to be functional at some level of processing.

In conclusion, it is hoped that the work presented in this thesis will serve to convince '*another soul who reads... through our book*' (Brunswick, 1995) that more than a quarter of a century after the 'first' patients of deep dyslexia the investigations on the acquired reading disorder of deep dyslexia is still a fruitful area worthy of further research. Finding deep dyslexia across languages may inspire clinicians (e.g. speech therapists) to examine acquired reading disorders further. Moreover, the possibility of implicit phonological ability may also assist future therapy interventions.

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Appendices

Appendix 1

PALPA 31 (Welsh version)

Tasg Darllen

alcohol
ysbyty
twndis
hyd
bwyell
cydweddiad
mam
gwyrth
ansawdd
gwenith
nos
peth
trugaredd
corryn
cynulleidfa
digofaint
bonws
tractor
ymddygiad
ffenestr
digwyddiad
priodas
cytundeb
cymeriad
gweithred
pilsen
aelod
llythr
syniad
coffi
mochyn
eiliad
arwydd
llaw
tan
eliffant
ymdrech
grefi
credo
modd

Appendix 1 continued

PALPA 31 (Welsh version)

Tasg Darllen 2

taten
meddwl
dychan
haf
disgyrchiad
syniad
tybaco
eironi
opiniwn
eglwys
amddiffyniad
pluen
argyfwng
mwnci
gwesty
llechwedd
pwrpas
brad
myfyriwr
ffolineb
penelin
egwyddor
teyrnas
damcaniaeth
drwm
awyren
teyrnged
darlun
cert
brwydr
radio
dewrder
ysgol
pentref
gwae
ffaith
wniwn
trefn
disgybl
sesiwn

Appendix 2

PALPA 32 (Welsh version)

Tasg Darllen

ymddangos	dioddef	anghywir	priod
gallu	ti	gyrfa	difrifol
na	golwg	cwrdd	diwethaf
lles	arwr	hapus	ysgrifennu
gwael	dilyn	neb	gofid
coch	dwys	doeth	pan
disgwyl	cyfan	cysyniad	llun
golwg	ar	meddwl	maint
hen	swm	llydan	siarad
ceg	fach	dinistrio	caled

Appendix 2 continued

PALPA 32 (Welsh version)

Tasg Darllen 2

gwrando	hongian	rhedeg	fi
disgrifio	rhywsut	clywed	datblygy
opiniwn	cloch	dylech	rhan
arall	tyfu	cario	cyntuno
tyner	llaith	rhinwedd	llydan
dim	islaw	cwsmer	anaml
anwybyddu	golygus	efallai	cyson
celf	er	oddi yma	i fyny
plws	uchaf	cyfartal	tasg
trychineb	rhywun	adeiladu	cynnes

Appendix 3

Control participants

For some of the tests included in the study control data was available (e.g. some PALPA norms are provided. However, when such information was not available, a control group of 5 non-brain injured participants was used. They were matched as closely as possible to the patients used in this study, for sex, age and education.

* E.D. (male, 53 years old, engineer) matched for P.D

* E.P. (male, 70 years old, retired head teacher) matched for J.W.T

* C.P. (female, 71 years old, retired Welsh primary school teacher) matched for M.J

* R.R. (male, 69 years old, worked in industry) matched for G.T.

* M.D. (male, 26 years old, worked in local government) matched for J.P.J

Scores for control participants

Reading aloud tests	E.D	E.P	CP
PALPA 31 (word reading aloud imageability & freq)	HI/HF = 20 / 20 HI/LF = 20 / 20 LI/HF = 20 / 20 LI/LF = 20 / 20	HI/HF = 20 / 20 HI/LF = 20 / 20 LI/HF = 20 / 20 LI/LF = 20 / 20	HI/HF = 20 / 20 HI/LF = 20 / 20 LI/HF = 20 / 20 LI/LF = 20 / 20
WELSH (translated version)	HI/HF = 20 / 20 HI/LF = 20 / 20 LI/HF = 20 / 20 LI/LF = 20 / 20	HI/HF = 20 / 20 HI/LF = 20 / 20 LI/HF = 20 / 20 LI/LF = 20 / 20	HI/HF = 20 / 20 HI/LF = 20 / 20 LI/HF = 20 / 20 LI/LF = 20 / 20
PALPA 32 (grammatical class reading)			
Nouns:	20 / 20	20 / 20	20 / 20
Adjectives:	20 / 20	20 / 20	20 / 20
Verbs:	20 / 20	20 / 20	20 / 20
Function:	20 / 20	20 / 20	20 / 20
WELSH (translated version)			
Nouns:	20 / 20	20 / 20	20 / 20
Adjectives:	19 / 20	20 / 20	19 / 20
Verbs:	20 / 20	20 / 20	20 / 20
Function:	20 / 20	20 / 20	20 / 20
PALPA 36 Welsh non-word reading			

Note: HI = high imageability. LI = low imageability. HF = high frequency. LF = low frequency.

Appendix 4

PALPA 36 non-word reading
(Welsh version)

ced

nas

fot

sidi

dwps

dwff

sneth

honys

glodd

drinas

chetio

siogol

peb

cun

lar

boac

barp

sofi

hawns

smoffi

grawp

sgafit

themsi

prawch

Appendix 5

PALPA 9 (Welsh repetition version)

digwyddiad	Twndis
damcaniaeth	Tractor
penelin	Argyfwng
llaw	Hyd
gwesty	Brwydr
taten	Arwydd
gwae	Safon
cymeriad	Corryn
eglwys	Pentref
gwenith	Gwithred
ymdrech	Grefi
ffolineb	Amddiffyniad
tan	Credo
teyrnged	Mwnci
disgyrchiad	Modd
ffaith	Teyrnas
dewrder	Llechwedd
eironi	Yfed
syniad	Aelod
bwyell	Dychan
darlun	Llythyr
ffenestr	Mochyn
brad	Tybaco
drwm	Egwyddor
meddwl	Sesiwn
trugaredd	Awyren
radio	Myfyriwr
cert	Nos
disgybl	Eiliad
gwyrth	Haf
wniwn	Priodas
ysbyty	Pluen
cynulleidfa	Peth
pwrpas	Bonws
ansawdd	Cytundeb
ysgol	Mam
ymddygiad	Opiniwn
trefn	Coffi
eliffant	Pilsen
digofaint	Cydweddiad

Appendix 6

The Welsh alphabet

a, b, c, ch, d, dd, e, f, ff, g, ng, h, i, j, l, ll, m, n, o, p, ph, r,
rh, s, t, th, u, w, y

Appendix 7

Welsh rhyme detection test

parc – marc
cloc – joc
pan – fan
fflat – pot
tric – crac
hi – ni
clo – clip
siop – mop
wal – wel
lamp – stamp
ffon – ton
glas – desg
be – car
ffens – piws
bath – sgarff
dot – cot
ffrind – pen
plwg – plant
bocs – inc
mat – bat

rygbi – babi
tri – coffi
lwc – pwnc
naw – braw
sym – bylb
dail – tail
jwg – mwg
pinc – sinc
rhent – peint
pwff – stwff
neis – sbeis
am – ham
drwm – dawn
gem – tim
post – tost
ci – ti
clwb – twb
iard – dad
clap – tap
bwmp – lwmp

Appendix 8

Examples of errors produced by each patient

PD's Semantic errors

PD

English NAMING

	Stimuli (target)	Response (Semantic Error)
1.	Sofa	Chair
2.	Arm	Hand
3.	Drum	Bin
4.	Lamp	Light
5.	Needle	Thimble
6.	Clock	Time
7.	Snowman	Balls
8.	Goat	Lama
9.	Motorbike	Bikes
10.	Peach	Pear
11.	Leopard	Cat
12.	Cigar	Fag
13.	Tiger	Cat
14.	Harp	Violin
15.	Cockerel	Duck
16.	Glove	Hands
17.	Screw	Bolt
18.	Pepper	Plum
19.	Lobster	Crab
20.	Arrow	Out
21.	Basket	Bag
22.	Rhinoceros	Bull
23.	Salt	Pepper
24.	Orange	Apple
25.	Envelope	Letter
26.	Crown	Queen
27.	Desk	Sit
28.	Skunk	Smell
29.	Mouse	Fox
30.	Pot	Bowl
31.	Fork	Spoon
32.	Heart	Love you
33.	Boot	Shoes
34.	Moon	Late
35.	Cup	Tea
36.	Waistcoat	Coat

37.	Sun	Shine
38.	Deer	Forest
39.	Sheep	Mutton
40.	Thumb	Finger
41.	Cherry	Plum
42.	Toothbrush	Teeth
43.	Lock	Bolt
44.	Church	School
45.	Wagon	Trolley
46.	Ashtray	Smoking

PD

Cross Linguistic Semantic Errors

English NAMING

	Stimuli (target)	Response Cross-linguistic (Semantic Error)
1.	Barrel	Cwrw (beer)
2.	Pig	Buwch (cow)
3.	Seal	Mor (sea)

PD

English READING

	Stimuli (target)	Response (Semantic Error)
1.	Ant	Nit
2.	Motorbike	Motor engine
3.	Pineapple	Apple
4.	Lobster	Cockles
5.	Foot	Boot
6.	Raccoon	Smells
7.	Cannon	Balls
8.	Bike	Brakes
9.	Cup	Beaker
10.	Cigarette	Fags
11	Fridge	Freezer
12	Toothbrush	Toothpaste
13	Zebra	Grass
14	Wagon	Wheel
15	Ashtray	Smoke

PD

Cross Linguistic Semantic Errors
English READING

	Stimuli (target)	Response (Semantic Error)
1	Salt	Pupur (pepper)

PD

Visual error TO Semantic error
English READING

	Stimuli (target)	Response Visual Error	Response Semantic Error
1	Hanger	Harbour	⇨ Anchor

PD

Welsh NAMING

	Stimuli (target)	Response (Semantic Error)
1.	Lori (lorry)	Car (car)
2.	Clust (ear)	Ceg (mouth)
3.	Soffa (sofa)	Bord (table)
4.	Braich (arm)	Llaw (hand)
5.	Cap (cap)	Tei (tie)
6.	Sgyrt (skirt)	Ffrog (dress)
7.	Nodwydd (needle)	Gwau (knit)
8.	Afal (apple)	Peren (pear)
9.	Morgrug (ant)	Crwban (tortoise)
10.	Acordion (accordion)	Miwsig (music)
11.	Broga (frog)	Crwban (tortoise)
12.	Crys (shirt)	Ffrog (dress)
13.	Ysgol (ladder)	Gardd (garden)
14.	Llewpart (leopard)	Llew (lion)
15.	Arth (bear)	Llew (lion)
16.	Bara (bread)	Tost (toast)
17.	Pel-droed (football)	Cymru (Wales)
18.	Cimwch (lobster)	Cragen (shell)
19.	Saeth (arrow)	Dde (right)
20.	Basged (basket)	Bag (bag)
21.	Crib (comb)	Gwallt (hair)
22.	Halen (salt)	Pupur (pepper)
23.	Amlen (envelope)	Llythyr (letter)
24.	Llygoden (mouse)	Llwynog (fox)
25.	Tomato (tomato)	Tatws (potatoes)

26.	Fforc (fork)	Cyllell (knife)
27.	Hanger (hanger)	Cot (coat)
28.	Ysgubor (barn)	Fferm (farm)
29.	Cwpan (cup)	Te (tea)
30.	Bord (table)	Ystol (stool)
31.	Dol (doll)	Merch (woman)
32.	Seren (star)	Lleuad (moon)
33.	Sigaret (cigarette)	Ffags (fags)
34.	Siwmper (jumper)	Cardigan (cardigan)
35.	Cas-dillad (suitcase)	Pasbort (passport)
36.	Bys (finger)	Llaw (hand)
37.	Carw (deer)	Asyn (donkey)
38.	Tostiwr (toaster)	Tost (toast)
39.	Bys-bawd (thumb)	Bysedd (fingers)
40.	Ceirios (cherry)	Pys (peas)
41.	Gwefus (lips)	Cusan (kiss)
42.	Cangarw (kangaroo)	Siraff (giraffe)
43.	Cwmwl (cloud)	Awyr (sky)
44.	Sebra (zebra)	Asyn (donkey)
45.	Fas (vase)	Jwg (jug)
46.	Plat-lludw	Ffags (fags)

PD

Cross Linguistic Semantic Errors

Welsh NAMING

	Stimuli (target)	Response Cross-linguistic (Semantic Error)
1.	Crwban (tortoise)	Frog
2.	Cloc (clock)	Time
3.	Telyn (harp)	Violin
4.	Brechdan (sandwich)	Toast
5.	Cyllell (knife)	Spoon
6.	Gorila (gorilla)	Bear
7.	Plwg (plug)	Hoover
8.	Cleren (fly)	Spider
9.	Coron (crown)	Queen
10.	Drewgi (skunk)	Weasel
11.	Pot (pot)	Spoon
12.	Lleuad (moon)	Stars
13.	Barcut (kite)	Sky
14.	Hofrennydd (helicopter)	Plane
15.	Pili-pala (butterfly)	Bird
16.	Brws-dannedd (toothbrush)	Toothpaste

Appendix 8 continued

PD

Welsh READING

	Stimuli (target)	Response (Semantic Error)
1.	Lori (lorry)	Car (car)
2.	Clust (ear)	Ceg (mouth)
3.	Braich (arm)	Breichled (bangle)
4.	Sgyrt (skirt)	Siwmper (jumper)
5.	Tren (train)	Trac (track)
6.	Modrwy (ring)	Bys (finger)
7.	Morgrug (ant)	Corryn (spider)
8.	Sled (sled)	Sgio (skiing)
9.	Llewpart (leopard)	Llew (lion)
10.	Sigar (cigar)	Ffags (fags)
11.	Arth (bear)	Cath (cat)
12.	Pin-afal (pineapple)	Afalau (apples)
13.	Pensil (pencil)	Pen (pen)
14.	Bara (bread)	Tost (toast)
15.	Tylluan (owl)	Adar (birds)
16.	Basged (basket)	Bag (bag)
17.	Halen (salt)	Pupur (pepper)
18.	Oren (orange)	Moron (carrot)
19.	Ffens (fence)	Ffenestr (window)
20.	Baril (barrel)	Cwrw (beer)
21.	Malwen (snail)	Ffrainc (France)
22.	Cwpan (cup)	Te (tea)
23.	Haul (sun)	Awyr (sky)
24.	Cloch (bell)	Cloc (clock)
25.	Cas-dillad (suitcase)	Pasbort (passport)
26.	Tostiwr (toaster)	Tost (toast)
27.	Haearn (iron)	Cadarn (strong/hard)
28.	Brws-dannedd (toothbrush)	Dannedd (teeth)
29.	Sebra (zebra)	Asyn (donkey)
30.	Fas (vase)	Jwg (jug)

PD

Cross Linguistic Semantic Errors

Welsh READING

	Stimuli (target)	Response Cross-linguistic (Semantic Error)
1.	Mefys (strawberry)	Peach
2.	Gwely (bed)	Sleep
3.	Cwningen (rabbit)	Carrots
4.	Bwt (boot)	Boot sale
5.	Dafad (sheep)	Flowers
6.	Gwefus (lips)	Whistle

Appendix 8

JWT's Semantic errors

JWT

English NAMING

	Stimuli (target)	Response (Semantic Error)
1.	Violin	Guitar
2.	Fish	Chips
3.	Apple	Pear
4.	Sled	Skates
5.	Shirt	Tie
6.	Leopard	Lion
7.	Hair	Wig
8.	Tiger	Lion
9.	Knife	Fork
10.	Pipe	Fags
11.	Lobster	Prawn
12.	Hammer	Handle
13.	Foot	Toe
14.	Raccoon	Fox
15.	Salt	Pepper
16.	Pen	Write
17.	Lettuce	Salad
18.	Flute	Record
19.	Onion	Potato
20.	Boot	Shoes
21.	Barn	Shed
22.	Umbrella	Rain
23.	Spider	Ant
24.	Thumb	Fingers
25.	Kangaroo	Ram
26.	Chair	Stool

JWT

Cross Linguistic Semantic Errors

English NAMING

	Stimuli (target)	Response Cross-linguistic (Semantic Error)
1	Broom	Brwsh (brush)
2	Tortoise	Crwban (turtle)
3	Ear	Ceg (mouth)
4	Tie	Crys-t (t-shirt)
5	Sun	Dwym (hot)
6	Sheep	Buwch (cow)

JWT

English READING

	Stimuli (target)	Response (Semantic Error)
1.	Ruler	Rubber
2.	Ring	Wedding
3.	Accordion	Music man
4.	Peach	Pear
5.	Pineapple	Banana
6.	Pumpkin	Christmas
7.	Pipe	Fags
8.	Lobster	Crab
9.	Envelope	Letter
10.	Celery	Cabbage
11.	Lemon	Melon
12.	Toothbrush	Tongue

JWT

Cross Linguistic Semantic Errors

English READING

	Stimuli (target)	Response (Semantic Error)
1	Dress	Sgyrt (skirt)
2	Penguin	Aderyn (bird)

Welsh NAMING

	Stimuli (target)	Response (Semantic Error)
1.	Blodyn (flower)	Gwair (grass)
2.	Cyw-iar (chicken)	Twrci (turkey)
3.	Nodwydd (needle)	Gwinio (sowing)
4.	Madarch (mushroom)	Moron (carrots)
5.	Pren-mesur (ruler)	Rwber (rubber)
6.	Esgid (shoe)	Troed (foot)
7.	Acordion (accordion)	Organ (organ)
8.	Crys (shirt)	Cot (coat)
9.	Peach (peach)	Afal (apple)
10.	Llewpart (leopard)	Llew (lion)
11.	Sigar (cigar)	Ffags (fags)
12.	Gwallt (hair)	Wig (wig)
13.	Gorila (gorilla)	Mwnci (monkey)
14.	Pensil (pencil)	Pen (pen)
15.	Car (car)	Modur (motor engine)
16.	Bara (bread)	Tost (toast)
17.	Bwyall (axe)	Bwrw (hit)
18.	Pib (pipe)	Ffag (fag)
19.	Rhinoseros (rhinoceros)	Hipo (hippo)
20.	Racwn (raccoon)	Drewi (stink)
21.	Letys (lettuce)	Tomato (tomato)
22.	Baril (barrel)	Cwrw (beer)
23.	Ffliwt (flute)	Picalo (piccolo)
24.	Pengwin (penguin)	Aderyn (bird)
25.	Hanger (hanger)	Cot (coat)
26.	Ysgybor (barn)	Fferm (farm)
27.	Cwpan (cup)	Te (tea)
28.	Hofrennydd (helicopter)	Awyren (plane)
29.	Pili-pala (butterfly)	Blodyn (flower)
30.	Corryn (spider)	Morgryg (ant)
31.	Bowl (bowl)	Pot (pot)
32.	Siaced (jacket)	Cot (coat)
33.	Tostiwr (toaster)	Tost (toast)
34.	Bys-bawd (thumb)	Bys (finger)
35.	Gwefus (lips)	Ceg (mouth)
36.	Plat-lludw (ashtray)	Ysmygu (smoking)

JWT

Cross Linguistic Semantic Errors

Welsh NAMING

	Stimuli (target)	Response Cross-linguistic (Semantic Error)
1.	Cadwyn (chain)	Rope
2.	Llyfr (book)	Pages
3.	Cimwch (lobster)	Prawns
4.	Halen (salt)	Pepper
5.	Bwt (boot)	Foot
6.	Seren (star)	Sky

JWT

Welsh READING

	Stimuli (target)	Response (Semantic Error)
1.	Hosan (sock)	Esgid (shoe)
2.	Cartref (house)	Garaj (garage)
3.	Deilen (leaf)	Coed (trees)
4.	Llewpart (leopard)	Llew (lion)
5.	Cyllell (knife)	Fforc (fork)
6.	Pin-afal (pineapple)	Afal (apple)
7.	Tylluan (owl)	Lleuad (moon)
8.	Basged (basket)	Bag (bag)
9.	Racwn (raccoon)	Croen (skin)
10.	Bws (bus)	Beic (bike)
11.	Cwpan (cup)	Te (tea)
12.	Trwsus (trousers)	Trainers (trainers)
13.	Lemwn (lemon)	Melwn (melon)
14.	Ymbarel (umbrella)	Glawio (raining)
15.	Haul (sun)	Dwym (hot)
16.	Cloch (bell)	Cloc (clock)
17.	Hofrennydd (helicopter)	Hedfan (fly)
18.	Siaced (jacket)	Sanau (socks)
19.	Tostiwr (toaster)	Tost (toast)
20.	Cwmwl (cloud)	Awyr (sky)
21.	Sebra (zebra)	Stripiau (stripes)

JWT

Cross Linguistic Semantic Errors

Welsh READING

	Stimuli (target)	Response Cross-linguistic (Semantic Error)
1.	Esgid (shoe)	Foot
2.	Hwyaden (duck)	Lion
3.	Sigar (cigar)	Cigarette
4.	Siswrn (scissors)	Cut
5.	Buwch (cow)	Field
6.	Trwmped (trumpet)	Trombone
7.	Malwen (snail)	Shell

Appendix 8

MJ's Semantic errors

MJ

English NAMING

	Stimuli (target)	Response (Semantic Error)
1.	Giraffe	Kangaroo
2.	Well	Wishes
3.	Violin	Cello
4.	Lorry	Car
5.	Drum	Band
6.	Nail	Needle
7.	Caterpillar	Moth
8.	Spoon	Tea
9.	Ant	Spider
10.	Peach	Apple
11.	Leopard	Tiger
12.	Cigar	Cigarette
13.	Hair	Hat
14.	Screwdriver	Spanner
15.	Pliers	Spanner
16.	Nut	Bolt
17.	Pineapple	Apple
18.	Gorilla	Monkey
19.	Ostrich	Turkey
20.	Lobster	Crab
21.	Comb	Hair
22.	Salt	Pepper
23.	Envelope	Letter
24.	Skunk	Squirrel
25.	Watch	Clock
26.	Flute	Cornet
27.	Anchor	Boat
28.	Hanger	Clothes
29.	Guitar	Violin
30.	Bus	Car
31.	Swan	Duck
32.	Peacock	Ostrich
33.	Hand	Arm
34.	Key	Lock
35.	Spider	Ant
36.	Deer	Nanny-goat
37.	Thumb	Finger
38.	Toothbrush	Cleaning
39.	Ashtray	Smoking

MJ

Cross Linguistic Semantic Errors

English NAMING

	Stimuli (target)	Response Cross-linguistic (Semantic Error)
1.	Ear	Ceg (mouth)
2.	Eagle	Gwdihw (owl)
3.	Ruler	Mesur (measure)
4.	Cooker	Cwcan (cooking)
5.	Nose	Ceg (mouth)
6.	Stool	Godro (milking)

MJ

English READING

	Stimuli (target)	Response (Semantic Error)
1.	Sock	Shoes
2.	Lamp	Light
3.	Peach	Pear
4.	Pineapple	Apple
5.	Axe	Trees
6.	Comb	Hair
7.	Fence	Gate
8.	Watch	Wrist
9.	Nose	Nostril
10.	Boot	Foot
11.	Cup	Tea
12.	Sun	Shine
13.	Star	Skies
14.	Cigarette	Smoke

MJ

Cross Linguistic Semantic Errors

English READING

	Stimuli (target)	Response (Semantic Error)
1.	Skirt	Ffrog (dress)
2.	Clock	Cloch (bell)
3.	Mitten	Llaw (hand)
4.	Leopard	Llew (lion)
5.	Pumpkin	Pasc (Easter)
6.	Bird	Gwdihw (owl)

Welsh NAMING

	Stimuli (target)	Response (Semantic Error)
1.	Brwsh (brush)	Mop (mop)
2.	Braich (arm)	Llaw (hand)
3.	Lamp (lamp)	Bord (table)
4.	Drws (door)	Ffenestr (window)
5.	Hoelen (nail)	Mwrthwl (hammer)
6.	Lindys (caterpillar)	Neidir (snake)
7.	Peach (peach)	Afal (apple)
8.	Ysgol (ladder)	Gris (step)
9.	Llewpart (leopard)	Teigr (tiger)
10.	Sigar (cigar)	Ysmygu (smoking)
11.	Gorila (gorilla)	Mwnci (monkey)
12.	Bwyall (axe)	Coed (trees)
13.	Pib (pipe)	Ysmygu (smoking)
14.	Cimwch (lobster)	Crab (crab)
15.	Saeth (arrow)	Arwydd (sign)
16.	Crib (comb)	Gwallt (hair)
17.	Racwn (raccoon)	Cath (cat)
18.	Halen (salt)	Pupur (pepper)
19.	Cleren (fly)	Colomen (dove)
20.	Drewgi (skunk)	Gwiwer (squirrel)
21.	Oriawr (watch)	Cloc (clock)
22.	Ffliwt (flute)	Cornet (cornet)
23.	Pengwin (penguin)	Colomen (dove)
24.	Gitar (guitar)	Ffidil (violin)
25.	Bws (bus)	Car (car)
26.	Cwpan (cup)	Mwg o de (mug of tea)
27.	Gwasgod (waistcoat)	Trwsers (trousers)
28.	Hofrennydd (helicopter)	Awyr (sky)
29.	Ystol (stool)	Godro (milking)
30.	Carw (deer)	Geifr (goat)
31.	Siaced (jacket)	Cot fach (small coat)
32.	Morlo (seal)	Drewgi (skunk)
33.	Haearn (iron)	Smwddo (ironing)
34.	Ceirios (cherry)	Plwm (plum)
35.	Cwmwl (cloud)	Awyr (sky)
36.	Cadair (chair)	Stol (stool)
37.	Fas (vase)	Jwg (jug)
38.	Plat-lludw (ashtray)	Ysmygu (smoking)

MJ

Cross Linguistic Semantic Errors
Welsh NAMING

	Stimuli (target)	Response Cross-linguistic (Semantic Error)
1.	Pren-mesur (ruler)	Rubber
2.	Pliers (pliers)	Wrench
3.	Cneuen (nut/bolt)	Screwdriver
4.	Pin-afal (pineapple)	Apple
5.	Alarch (swan)	Duck
6.	Paun (peacock)	Ostrich
7.	Barget (kite)	Fly
8.	Allwell (key)	Open
9.	Corryn (spider)	Ant

MJ

Welsh READING

	Stimuli (target)	Response (Semantic Error)
1.	Lori (lorry)	Car (car)
2.	Miten (mitten)	Llaw (hand)
3.	Gwniadur (thimble)	Bys (finger)
4.	Llewpart (leopard)	Llew (lion)
5.	Sigar (cigar)	Ysmygu (smoking)
6.	Sbaner (spanner)	Sgriw (screw)
7.	Tyrnsgriw (screwdriver)	Sgriw (screw)
8.	Pin-afal (pineapple)	Gamwn (gammon)
9.	Drewgi (skunk)	Drewi (smelly)
10.	Oriawr (watch)	Awr (hour)
11.	Lleuad (moon)	Nos (night)
12.	Sigaret (cigarette)	Sigar (cigar)
13.	Tostiwr (toaster)	Tost (toast)
14.	Clo (lock)	Allwell (key)
15.	Ffenestr (window)	Drws (door)
16.	Cadair (chair)	Stol (stool)

MJ

Cross Linguistic Semantic Errors
Welsh READING

	Stimuli (target)	Response Cross-linguistic (Semantic Error)
1.	Cas-dillad (suitcase)	Holiday
2.	Moron (carrots)	Rabbit

Appendix 8

JPJ's Semantic errors

JPJ

English NAMING

	Stimuli (target)	Response (Semantic Error)
1.	Well	Bucket
2.	Sofa	Chair
3.	Squirrel	Nuts no sparrow
4.	Skirt	Dress
5.	Door	In and out
6.	Ruler	Tape, pencil and pens
7.	Mitten	Gloves
8.	Shoe	Trainers
9.	Leaf	Acorn
10.	Goat	Baah!
11.	Swing	See-saw
12.	Asparagus	Corn
13.	Motorbike	Bikes
14.	Accordion	Organ
15.	Sled	Snow
16.	Shirt	Trousers
17.	Peach	Cherry
18.	Peanut	Nuts
19.	Leopard	Tiger no lion
20.	Bear	Polar bear
21.	Tiger	Lion
22.	Cockerel	Cockle-doodle-do
23.	Screwdriver	Spanner
24.	Knife	Spoon
25.	Pliers	Spanner
26.	Gorilla	Chimps
27.	Axe	Hammer
28.	Rugby ball	Scarlets!
29.	Glass	Water
30.	Lobster	Crab
31.	Arrow	Left
32.	Foot	Toe
33.	Rhinoceros	Dinosaur
34.	Raccoon	Skunk
35.	Envelope	Letter
36.	Fence	Gate
37.	Crown	King
38.	Desk	Draws

39.	Skunk	Badger
40.	Mouse	Cat
41.	Cannon	Gun
42.	Anchor	Boat
43.	Heart	Love
44.	Boot	Shoes
45.	Pig	Mooo! Cow
46.	Snail	France
47.	Table	Chair
48.	Trousers	Shoes no jeans
49.	Lemon	Orange
50.	Cigarette	Ash no smoking
51.	Spider	Ants
52.	Toaster	Toast
53.	Cherry	Grape
54.	Lock	Key no gate
55.	Cloud	Sky
56.	Ashtray	Smoking

JPJ

English READING

	Stimuli (target)	Response (Semantic Error)
1.	Pear	Peach
2.	Giraffe	Zoo
3.	Lorry	Train
4.	Mountain	Hills
5.	Lamp	Light
6.	Leg	Knee
7.	Snowman	Walking in the air!
8.	Goat	Baah!
9.	Motorbike	Bike
10.	Sled	Snowing
11.	Peanut	Nuts
12.	Hair	Hair-spray
13.	Cockerel	Cockle-doodle-do
14.	Knife	Knife and fork
15.	Gorilla	Monkeys
16.	Pencil	Pen
17.	Axe	Saw
18.	Pumpkin	Halloween
19.	Plug	Lead
20.	Lobster	Crab under the sea
21.	Windmill	Windy
22.	Crown	Crown-court

23.	Desk	Teacher
24.	Corn	Weetabix
25.	Trumpet	Trombone
26.	Rabbit	Lovely and fluffy
27.	Flute	Harp
28.	Anchor	Ship
29.	Boot	Shoes
30.	Moon	Blue-moon
31.	Dog	Oscar (his dog)
32.	Whistle	Whistle while you work
33.	Cigarette	Tobacco smoke
34.	Jumper	T-shirt
35.	Suitcase	Jacket
36.	Sheep	Cow no little lambs
37.	Iron	Bunsen burner
38.	Toothbrush	Teeth
39.	Lips	Lip-stick
40.	Kangaroo	Australia
41.	Lock	Key
42.	Wagon	Wagon-wheels
43.	Ashtray	Ash

JPJ

Probable visual reading errors

English READING

	Stimuli (target)	*Response (Visual Error)*
1.	Glasses	Glass
2.	Chain	Chair
3.	Ant	And
4.	Asparagus	Aspirin
5.	Leopard	Lepricorn
6.	Foot	Fool
7.	Fence	Fern
8.	Barrel	Barnardos
9.	Barn	Burn
10.	Swan	Swansea
11.	Snake	Shake

Appendix 9

AGE OF ACQUISITION

Initials: __________
Gender: male / female
Age (date of birth): _________ (/ /)

Instructions

The acquisition of words is a gradual process. First words are learnt early in childhood but our vocabulary continues to grow throughout the lifespan. In this study we are interested to know about the age at which people believe words are learnt. In the following pages you are going to find lists of words. Your task is **to estimate the age at which you believe you have learned each word either in their spoken or written form.**

Please feel free to use all the numbers in the scale (1-7):

Welsh Words	Learned at the age of 0-2	Learned at the age of 3 -4	Learned at the age of 5-6	Learned at the age of 7-8	Learned at the age of 9-10	Learned at the age of 11-12	Learned at the age of 13- after
acordion	1	2	3	4	5	6	7
crocodil	1	2	3	4	5	6	7
angor	1	2	3	4	5	6	7
morgrug	1	2	3	4	5	6	7
braich	1	2	3	4	5	6	7
plat-lludw	1	2	3	4	5	6	7
merllys	1	2	3	4	5	6	7
pel	1	2	3	4	5	6	7
baril	1	2	3	4	5	6	7
gwegus	1	2	3	4	5	6	7
beic	1	2	3	4	5	6	7
aderyn	1	2	3	4	5	6	7
bwt	1	2	3	4	5	6	7
pili-pala	1	2	3	4	5	6	7
botwm	1	2	3	4	5	6	7
cannwyll	1	2	3	4	5	6	7
magnel	1	2	3	4	5	6	7
car	1	2	3	4	5	6	7
lindys	1	2	3	4	5	6	7
seleri	1	2	3	4	5	6	7
cadair	1	2	3	4	5	6	7
cyw-iar	1	2	3	4	5	6	7
sigar	1	2	3	4	5	6	7
sigaret	1	2	3	4	5	6	7
cwmwl	1	2	3	4	5	6	7
clown	1	2	3	4	5	6	7
crib	1	2	3	4	5	6	7
cwcer	1	2	3	4	5	6	7
coron	1	2	3	4	5	6	7
carw	1	2	3	4	5	6	7

dol	1	2	3	4	5	6	7
asyn	1	2	3	4	5	6	7
drwm	1	2	3	4	5	6	7
eryr	1	2	3	4	5	6	7
amlen	1	2	3	4	5	6	7
ffens	1	2	3	4	5	6	7
bys	1	2	3	4	5	6	7
fflag	1	2	3	4	5	6	7
ffliwt	1	2	3	4	5	6	7
cleren	1	2	3	4	5	6	7
troed	1	2	3	4	5	6	7
pel-droed	1	2	3	4	5	6	7
rhewgell	1	2	3	4	5	6	7
siraff	1	2	3	4	5	6	7
sbectol	1	2	3	4	5	6	7
gorila	1	2	3	4	5	6	7
grawnwin	1	2	3	4	5	6	7
gitar	1	2	3	4	5	6	7
dryll	1	2	3	4	5	6	7
mwrthwl	1	2	3	4	5	6	7
llaw	1	2	3	4	5	6	7
delyn	1	2	3	4	5	6	7
calon	1	2	3	4	5	6	7
hofrennydd	1	2	3	4	5	6	7
siaced	1	2	3	4	5	6	7
cangarw	1	2	3	4	5	6	7
barget	1	2	3	4	5	6	7
coes	1	2	3	4	5	6	7
lemwn	1	2	3	4	5	6	7
llewpart	1	2	3	4	5	6	7
gwefus	1	2	3	4	5	6	7
cimwch	1	2	3	4	5	6	7
clo	1	2	3	4	5	6	7
miten	1	2	3	4	5	6	7
beic-modur	1	2	3	4	5	6	7
madarch	1	2	3	4	5	6	7
wnionyn	1	2	3	4	5	6	7
estrys	1	2	3	4	5	6	7
tylluan	1	2	3	4	5	6	7
paun	1	2	3	4	5	6	7
cneuen	1	2	3	4	5	6	7
peren	1	2	3	4	5	6	7
pengwin	1	2	3	4	5	6	7
pupur	1	2	3	4	5	6	7
pin-afal	1	2	3	4	5	6	7
pib	1	2	3	4	5	6	7
pwmpen	1	2	3	4	5	6	7

racwn	1	2	3	4	5	6	7
rhinoseros	1	2	3	4	5	6	7
pren-mesur	1	2	3	4	5	6	7
llong-hwylio	1	2	3	4	5	6	7
halen	1	2	3	4	5	6	7
brechdan	1	2	3	4	5	6	7
llif	1	2	3	4	5	6	7
sgriw	1	2	3	4	5	6	7
tyrnsgriw	1	2	3	4	5	6	7
morlo	1	2	3	4	5	6	7
dafad	1	2	3	4	5	6	7
sgyrt	1	2	3	4	5	6	7
drewgi	1	2	3	4	5	6	7
sled	1	2	3	4	5	6	7
malwen	1	2	3	4	5	6	7
dyn-eira	1	2	3	4	5	6	7
hosan	1	2	3	4	5	6	7
sbaner	1	2	3	4	5	6	7
seren	1	2	3	4	5	6	7
mefys	1	2	3	4	5	6	7
cas-dillad	1	2	3	4	5	6	7
siglen	1	2	3	4	5	6	7
bord	1	2	3	4	5	6	7
teliffon	1	2	3	4	5	6	7
gwniadur	1	2	3	4	5	6	7
tostiwr	1	2	3	4	5	6	7
brws-dannedd	1	2	3	4	5	6	7
crwban	1	2	3	4	5	6	7
trwmped	1	2	3	4	5	6	7
ymbarel	1	2	3	4	5	6	7
fas	1	2	3	4	5	6	7
ffidil	1	2	3	4	5	6	7
gwagen	1	2	3	4	5	6	7
gwasgod	1	2	3	4	5	6	7
wats	1	2	3	4	5	6	7
melwn	1	2	3	4	5	6	7
ffynnon	1	2	3	4	5	6	7
chwiban	1	2	3	4	5	6	7
melyn-wynt	1	2	3	4	5	6	7
sebra	1	2	3	4	5	6	7

Appendix 9

FREQUENCY

Initials: __________
Gender: male / female
Age (date of birth): _________ (/   /   )

Instructions

Words differ in how commonly or frequently they have been encountered. Some words are encountered very frequently, whereas other words are encountered infrequently. The purpose of this study is to rate a list of words with respect to frequency. Because words can be encountered in many different ways we ask you to base your ratings according to **how often you think you read, hear, write or say each word.**

Please feel free to use all the numbers of the scale:

1 = never, 2 = once a year, 3 = once a month, 4 = once a week, 5 = every two days, 6 = once a day, 7 =several times a day.

Welsh Words	Never	Once a year	Once a month	Once a week	Every two days	Once a day	Several times a day
acordion	1	2	3	4	5	6	7
crocodil	1	2	3	4	5	6	7
angor	1	2	3	4	5	6	7
morgrug	1	2	3	4	5	6	7
braich	1	2	3	4	5	6	7
plat-lludw	1	2	3	4	5	6	7
merllys	1	2	3	4	5	6	7
pel	1	2	3	4	5	6	7
baril	1	2	3	4	5	6	7
gwegus	1	2	3	4	5	6	7
beic	1	2	3	4	5	6	7
aderyn	1	2	3	4	5	6	7
bwt	1	2	3	4	5	6	7
pili-pala	1	2	3	4	5	6	7
botwm	1	2	3	4	5	6	7
cannwyll	1	2	3	4	5	6	7
magnel	1	2	3	4	5	6	7
car	1	2	3	4	5	6	7
lindys	1	2	3	4	5	6	7
seleri	1	2	3	4	5	6	7
cadair	1	2	3	4	5	6	7
cyw-iar	1	2	3	4	5	6	7
sigar	1	2	3	4	5	6	7
sigaret	1	2	3	4	5	6	7
cwmwl	1	2	3	4	5	6	7
clown	1	2	3	4	5	6	7
crib	1	2	3	4	5	6	7
cwcer	1	2	3	4	5	6	7
coron	1	2	3	4	5	6	7
carw	1	2	3	4	5	6	7

dol	1	2	3	4	5	6	7
asyn	1	2	3	4	5	6	7
drwm	1	2	3	4	5	6	7
eryr	1	2	3	4	5	6	7
amlen	1	2	3	4	5	6	7
ffens	1	2	3	4	5	6	7
bys	1	2	3	4	5	6	7
fflag	1	2	3	4	5	6	7
ffliwt	1	2	3	4	5	6	7
cleren	1	2	3	4	5	6	7
troed	1	2	3	4	5	6	7
pel-droed	1	2	3	4	5	6	7
rhewgell	1	2	3	4	5	6	7
siraff	1	2	3	4	5	6	7
sbectol	1	2	3	4	5	6	7
gorila	1	2	3	4	5	6	7
grawnwin	1	2	3	4	5	6	7
gitar	1	2	3	4	5	6	7
dryll	1	2	3	4	5	6	7
mwrthwl	1	2	3	4	5	6	7
llaw	1	2	3	4	5	6	7
delyn	1	2	3	4	5	6	7
calon	1	2	3	4	5	6	7
hofrennydd	1	2	3	4	5	6	7
siaced	1	2	3	4	5	6	7
cangarw	1	2	3	4	5	6	7
barget	1	2	3	4	5	6	7
coes	1	2	3	4	5	6	7
lemwn	1	2	3	4	5	6	7
llewpart	1	2	3	4	5	6	7
gwefus	1	2	3	4	5	6	7
cimwch	1	2	3	4	5	6	7
clo	1	2	3	4	5	6	7
miten	1	2	3	4	5	6	7
beic-modur	1	2	3	4	5	6	7
madarch	1	2	3	4	5	6	7
wnionyn	1	2	3	4	5	6	7
estrys	1	2	3	4	5	6	7
tylluan	1	2	3	4	5	6	7
paun	1	2	3	4	5	6	7
cneuen	1	2	3	4	5	6	7
peren	1	2	3	4	5	6	7
pengwin	1	2	3	4	5	6	7
pupur	1	2	3	4	5	6	7
pin-afal	1	2	3	4	5	6	7
pib	1	2	3	4	5	6	7
pwmpen	1	2	3	4	5	6	7

racwn	1	2	3	4	5	6	7
rhinoseros	1	2	3	4	5	6	7
pren-mesur	1	2	3	4	5	6	7
llong-hwylio	1	2	3	4	5	6	7
halen	1	2	3	4	5	6	7
brechdan	1	2	3	4	5	6	7
llif	1	2	3	4	5	6	7
sgriw	1	2	3	4	5	6	7
tyrnsgriw	1	2	3	4	5	6	7
morlo	1	2	3	4	5	6	7
dafad	1	2	3	4	5	6	7
sgyrt	1	2	3	4	5	6	7
drewgi	1	2	3	4	5	6	7
sled	1	2	3	4	5	6	7
malwen	1	2	3	4	5	6	7
dyn-eira	1	2	3	4	5	6	7
hosan	1	2	3	4	5	6	7
sbaner	1	2	3	4	5	6	7
seren	1	2	3	4	5	6	7
mefys	1	2	3	4	5	6	7
cas-dillad	1	2	3	4	5	6	7
siglen	1	2	3	4	5	6	7
bord	1	2	3	4	5	6	7
teliffon	1	2	3	4	5	6	7
gwniadur	1	2	3	4	5	6	7
tostiwr	1	2	3	4	5	6	7
brws-dannedd	1	2	3	4	5	6	7
crwban	1	2	3	4	5	6	7
trwmped	1	2	3	4	5	6	7
ymbarel	1	2	3	4	5	6	7
fas	1	2	3	4	5	6	7
ffidil	1	2	3	4	5	6	7
gwagen	1	2	3	4	5	6	7
gwasgod	1	2	3	4	5	6	7
wats	1	2	3	4	5	6	7
melwn	1	2	3	4	5	6	7
ffynnon	1	2	3	4	5	6	7
chwiban	1	2	3	4	5	6	7
melyn-wynt	1	2	3	4	5	6	7
sebra	1	2	3	4	5	6	7

Appendix 9

IMAGEABILITY

Initials: __________
Gender: male / female
Age (date of birth): _________ (/ /)

Instructions

Words differ in their capacity to evoke mental images. Thus, while some words are easy to imagine (e.g., *apple*) others are not (e.g., *fact*). The purpose of this test is to estimate **how easy or difficult it is to imagine a list of words**. The scale ranges from 1 to 7. Rate a word with 7 if you think the word is very easy to imagine, with 1 if you think the word is very difficult to imagine and give an intermediate value for those words which are neither very easy or very difficult to imagine.

Please feel free to use all the numbers in the scale (1-7):

Welsh Words	Very hard to evoke a mental image	Hard to evoke a mental image	Slightly hard to evoke a mental image	Neither very easy or difficult to imagine	Slightly easy to evoke a mental image	Easy to evoke a mental image	Very easy to evoke a mental image
acordion	1	2	3	4	5	6	7
crocodil	1	2	3	4	5	6	7
angor	1	2	3	4	5	6	7
morgrug	1	2	3	4	5	6	7
braich	1	2	3	4	5	6	7
plat-lludw	1	2	3	4	5	6	7
merllys	1	2	3	4	5	6	7
pel	1	2	3	4	5	6	7
baril	1	2	3	4	5	6	7
gwegus	1	2	3	4	5	6	7
beic	1	2	3	4	5	6	7
aderyn	1	2	3	4	5	6	7
bwt	1	2	3	4	5	6	7
pili-pala	1	2	3	4	5	6	7
botwm	1	2	3	4	5	6	7
cannwyll	1	2	3	4	5	6	7
magnel	1	2	3	4	5	6	7
car	1	2	3	4	5	6	7
lindys	1	2	3	4	5	6	7
seleri	1	2	3	4	5	6	7
cadair	1	2	3	4	5	6	7
cyw-iar	1	2	3	4	5	6	7
sigar	1	2	3	4	5	6	7
sigaret	1	2	3	4	5	6	7
cwmwl	1	2	3	4	5	6	7
clown	1	2	3	4	5	6	7
crib	1	2	3	4	5	6	7
cwcer	1	2	3	4	5	6	7
coron	1	2	3	4	5	6	7

carw	1	2	3	4	5	6	7
dol	1	2	3	4	5	6	7
asyn	1	2	3	4	5	6	7
drwm	1	2	3	4	5	6	7
eryr	1	2	3	4	5	6	7
amlen	1	2	3	4	5	6	7
ffens	1	2	3	4	5	6	7
bys	1	2	3	4	5	6	7
fflag	1	2	3	4	5	6	7
ffliwt	1	2	3	4	5	6	7
cleren	1	2	3	4	5	6	7
troed	1	2	3	4	5	6	7
pel-droed	1	2	3	4	5	6	7
rhewgell	1	2	3	4	5	6	7
siraff	1	2	3	4	5	6	7
sbectol	1	2	3	4	5	6	7
gorila	1	2	3	4	5	6	7
grawnwin	1	2	3	4	5	6	7
gitar	1	2	3	4	5	6	7
dryll	1	2	3	4	5	6	7
mwrthwl	1	2	3	4	5	6	7
llaw	1	2	3	4	5	6	7
delyn	1	2	3	4	5	6	7
calon	1	2	3	4	5	6	7
hofrennydd	1	2	3	4	5	6	7
siaced	1	2	3	4	5	6	7
cangarw	1	2	3	4	5	6	7
barget	1	2	3	4	5	6	7
coes	1	2	3	4	5	6	7
lemwn	1	2	3	4	5	6	7
llewpart	1	2	3	4	5	6	7
gwefus	1	2	3	4	5	6	7
cimwch	1	2	3	4	5	6	7
clo	1	2	3	4	5	6	7
miten	1	2	3	4	5	6	7
beic-modur	1	2	3	4	5	6	7
madarch	1	2	3	4	5	6	7
wnionyn	1	2	3	4	5	6	7
estrys	1	2	3	4	5	6	7
tylluan	1	2	3	4	5	6	7
paun	1	2	3	4	5	6	7
cneuen	1	2	3	4	5	6	7
peren	1	2	3	4	5	6	7
pengwin	1	2	3	4	5	6	7
pupur	1	2	3	4	5	6	7
pin-afal	1	2	3	4	5	6	7
pib	1	2	3	4	5	6	7

pwmpen	1	2	3	4	5	6	7
racwn	1	2	3	4	5	6	7
rhinoseros	1	2	3	4	5	6	7
pren-mesur	1	2	3	4	5	6	7
llong-hwylio	1	2	3	4	5	6	7
halen	1	2	3	4	5	6	7
brechdan	1	2	3	4	5	6	7
llif	1	2	3	4	5	6	7
sgriw	1	2	3	4	5	6	7
tyrnsgriw	1	2	3	4	5	6	7
morlo	1	2	3	4	5	6	7
dafad	1	2	3	4	5	6	7
sgyrt	1	2	3	4	5	6	7
drewgi	1	2	3	4	5	6	7
sled	1	2	3	4	5	6	7
malwen	1	2	3	4	5	6	7
dyn-eira	1	2	3	4	5	6	7
hosan	1	2	3	4	5	6	7
sbaner	1	2	3	4	5	6	7
seren	1	2	3	4	5	6	7
mefys	1	2	3	4	5	6	7
cas-dillad	1	2	3	4	5	6	7
siglen	1	2	3	4	5	6	7
bord	1	2	3	4	5	6	7
teliffon	1	2	3	4	5	6	7
gwniadur	1	2	3	4	5	6	7
tostiwr	1	2	3	4	5	6	7
brws-dannedd	1	2	3	4	5	6	7
crwban	1	2	3	4	5	6	7
trwmped	1	2	3	4	5	6	7
ymbarel	1	2	3	4	5	6	7
fas	1	2	3	4	5	6	7
ffidil	1	2	3	4	5	6	7
gwagen	1	2	3	4	5	6	7
gwasgod	1	2	3	4	5	6	7
wats	1	2	3	4	5	6	7
melwn	1	2	3	4	5	6	7
ffynnon	1	2	3	4	5	6	7
chwiban	1	2	3	4	5	6	7
melyn-wynt	1	2	3	4	5	6	7
sebra	1	2	3	4	5	6	7

Appendix 10

AGE OF ACQUISITION

Initials: _________
Gender: male / female
Age (date of birth): _________ (/ /)

Instructions

The acquisition of words is a gradual process. First words are learnt early in childhood but our vocabulary continues to grow throughout the lifespan. In this study we are interested to know about the age at which people believe words are learnt. In the following pages you are going to find lists of words. Your task is **to estimate the age at which you believe you have learned each word either in their spoken or written form.**

Please feel free to use all the numbers in the scale (1-7):

Welsh Words	Learned at the age of 0-2	Learned at the age of 3-4	Learned at the age of 5-6	Learned at the age of 7-8	Learned at the age of 9-10	Learned at the age of 11-12	Learned at the age of 13- after
balwn	1	2	3	4	5	6	7
arth	1	2	3	4	5	6	7
llyfr	1	2	3	4	5	6	7
brws	1	2	3	4	5	6	7
moron	1	2	3	4	5	6	7
eglwys	1	2	3	4	5	6	7
yd	1	2	3	4	5	6	7
ci	1	2	3	4	5	6	7
ffrog	1	2	3	4	5	6	7
llygad	1	2	3	4	5	6	7
fforc	1	2	3	4	5	6	7
gafr	1	2	3	4	5	6	7
ty	1	2	3	4	5	6	7
cyllell	1	2	3	4	5	6	7
llew	1	2	3	4	5	6	7
mynydd	1	2	3	4	5	6	7
trwyn	1	2	3	4	5	6	7
mochyn	1	2	3	4	5	6	7
modrwy	1	2	3	4	5	6	7
neidr	1	2	3	4	5	6	7
stol	1	2	3	4	5	6	7
ceiliog	1	2	3	4	5	6	7
olwyn	1	2	3	4	5	6	7
bwyall	1	2	3	4	5	6	7
plwg	1	2	3	4	5	6	7
ysgubor	1	2	3	4	5	6	7
ceirios	1	2	3	4	5	6	7
teigr	1	2	3	4	5	6	7
cadwyn	1	2	3	4	5	6	7
hwyaden	1	2	3	4	5	6	7

Appendix 10

FREQUENCY

Initials: __________
Gender: male / female
Age (date of birth): _________ (/   /   )

Instructions

Words differ in how commonly or frequently they have been encountered. Some words are encountered very frequently, whereas other words are encountered infrequently. The purpose of this study is to rate a list of words with respect to frequency. Because words can be encountered in many different ways we ask you to base your ratings according to **how often you think you read, hear, write or say each word.**

Please feel free to use all the numbers of the scale:

1 = never, 2 = once a year, 3 = once a month, 4 = once a week, 5 = every two days, 6 = once a day, 7 =several times a day.

Welsh Words	Never	Once a year	Once a month	Once a week	Every two days	Once a day	Several times a day
balwn	1	2	3	4	5	6	7
arth	1	2	3	4	5	6	7
llyfr	1	2	3	4	5	6	7
brws	1	2	3	4	5	6	7
moron	1	2	3	4	5	6	7
eglwys	1	2	3	4	5	6	7
yd	1	2	3	4	5	6	7
ci	1	2	3	4	5	6	7
ffrog	1	2	3	4	5	6	7
llygad	1	2	3	4	5	6	7
fforc	1	2	3	4	5	6	7
gafr	1	2	3	4	5	6	7
ty	1	2	3	4	5	6	7
cyllell	1	2	3	4	5	6	7
llew	1	2	3	4	5	6	7
mynydd	1	2	3	4	5	6	7
trwyn	1	2	3	4	5	6	7
mochyn	1	2	3	4	5	6	7
modrwy	1	2	3	4	5	6	7
neidr	1	2	3	4	5	6	7
stol	1	2	3	4	5	6	7
ceiliog	1	2	3	4	5	6	7
olwyn	1	2	3	4	5	6	7
bwyall	1	2	3	4	5	6	7
plwg	1	2	3	4	5	6	7
ysgubor	1	2	3	4	5	6	7
ceirios	1	2	3	4	5	6	7
teigr	1	2	3	4	5	6	7
cadwyn	1	2	3	4	5	6	7
hwyaden	1	2	3	4	5	6	7

Appendix 10

IMAGEABILITY

Initials: _________

Gender: male / female

Age (date of birth): _________ (/   /   )

Instructions

Words differ in their capacity to evoke mental images. Thus, while some words are easy to imagine (e.g., *apple*) others are not (e.g., *fact*). The purpose of this test is to estimate **how easy or difficult it is to imagine a list of words**. The scale ranges from 1 to 7. Rate a word with 7 if you think the word is very easy to imagine, with 1 if you think the word is very difficult to imagine and give an intermediate value for those words which are neither very easy nor very difficult to imagine.

Please feel free to use all the numbers in the scale (1-7):

Welsh Words	Very hard to evoke a mental image	Hard to evoke a mental image	Slightly hard to evoke a mental image	Neither very easy or difficult to imagine	Slightly easy to evoke a mental image	Easy to evoke a mental image	Very easy to evoke a mental image
balwn	1	2	3	4	5	6	7
arth	1	2	3	4	5	6	7
llyfr	1	2	3	4	5	6	7
brws	1	2	3	4	5	6	7
moron	1	2	3	4	5	6	7
eglwys	1	2	3	4	5	6	7
yd	1	2	3	4	5	6	7
ci	1	2	3	4	5	6	7
ffrog	1	2	3	4	5	6	7
llygad	1	2	3	4	5	6	7
fforc	1	2	3	4	5	6	7
gafr	1	2	3	4	5	6	7
ty	1	2	3	4	5	6	7
cyllell	1	2	3	4	5	6	7
llew	1	2	3	4	5	6	7
mynydd	1	2	3	4	5	6	7
trwyn	1	2	3	4	5	6	7
mochyn	1	2	3	4	5	6	7
modrwy	1	2	3	4	5	6	7
neidr	1	2	3	4	5	6	7
stol	1	2	3	4	5	6	7
ceiliog	1	2	3	4	5	6	7
olwyn	1	2	3	4	5	6	7
bwyall	1	2	3	4	5	6	7
plwg	1	2	3	4	5	6	7
ysgubor	1	2	3	4	5	6	7
ceirios	1	2	3	4	5	6	7
teigr	1	2	3	4	5	6	7

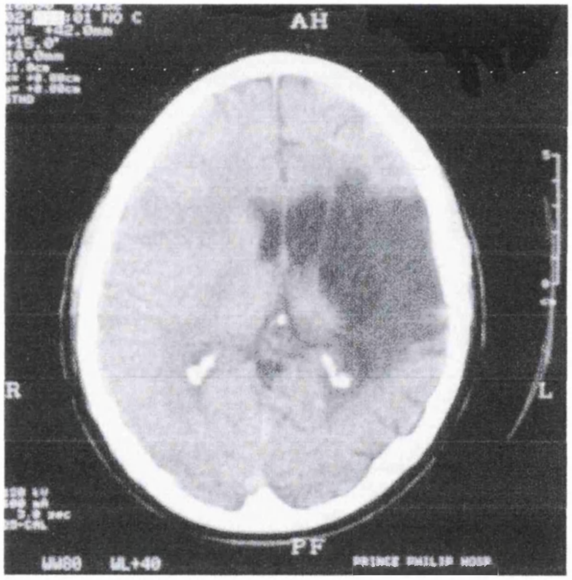
cadwyn	1	2	3	4	5	6	7
hwyaden	1	2	3	4	5	6	7

Case history

Patient **JPJ** was a monolingual, 26 year old, right handed male at the time of testing. He suffered a left sided CVA following a left carotid artery dissection in December 1999 that resulted in right sided hemiparesis along with speech and reading disorders. JPJ was a music and drama student at Middlesex University before his CVA. His speech therapist's report suggested that *"there is evidence of word finding difficulties and comprehension of written language problems, with specific difficulties in verb retrieval, function word reading and grapheme-phoneme conversion"*.

His CT scan shortly after admission to hospital showed a large area of infarction in the left tempro-parietal region. No other features of note.

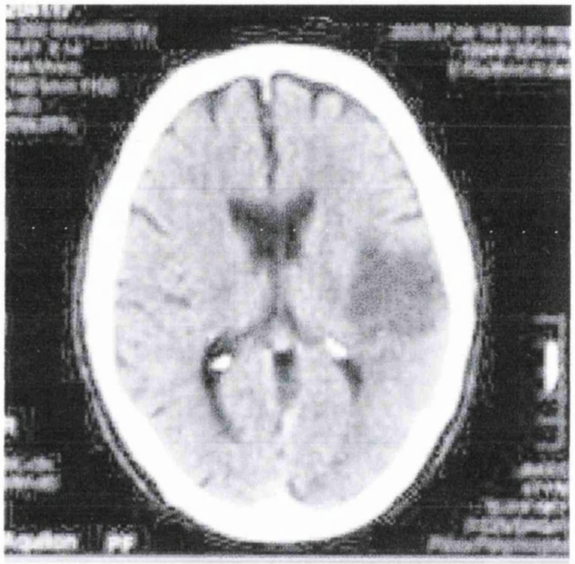
JPJ (male, at age 21 years). FIG. 5



<u>Appendix 12</u>

Patient **GT** was a bilingual, 69 year old, right-handed male at the time of testing. GT was taught through the medium of English and Welsh at Grammar school where he obtained GCSEs; after leaving he became a qualified fitter. He suffered a left CVA in July 2003; causing right sided hemiparesis and dysphasia. According to the radiologist's report on his CT scan *"there is an acute infarct involving the left parietal lobe. No haemorrhage or surface collection seen and no midline shift identified."*

G.T. (male, at age 67 years). FIG. 4



Appendix 13

WAB APAHSIA SCORES FOR GT and JPJ

WAB test	**G.T. scores**	**J.P.J scores**
Spontaneous speech		
(a) Information content	8 (max = 10)	8 (max = 10)
(b) Fluency	2 (max = 10)	4 (max = 10)
Comprehension		
(a) Auditory verbal comprehension	57 (max = 60)	48 (max = 60)
(b) Auditory word recognition	56 (max = 60)	46 (max = 60)
(c) Sequential commands	36 (max = 80)	10 (max = 80)
Word Repetition	30 (max =100)	32 (max =100)
Object naming	37 (max = 60)	30 (max = 60)
(a) Word fluency	7 (max = 20)	10 (max = 20)
(b) Sentence completion	4 (max = 10)	8 (max = 10)
(c) Responsive speech	10 (max = 10)	10 (max = 10)
Reading		
(a) Reading comprehension	26 (max = 40)	20 (max = 40)
(b) Reading commands	10 (max = 20)	6 (max = 20)
(c) Written word-object matching	6 (max = 6)	6 (max = 6)
(d) Written word-picture matching	6 (max = 6)	6 (max = 6)
(e) Picture stimuli-word matching	6 (max = 6)	6 (max = 6)
(f) Spoken word-visual word match	4 (max = 4)	3 (max = 4)
(g) Spoken word-visual letter name	4 (max = 6)	6 (max = 6)
(h) Oral spelling *(by examiner: patient word spelled)*	0 (max = 6)	1 (max = 6)
Spelling	1 (max = 6)	0 (max = 6)
Writing		
(a) On request (e.g. name & address	3 (max = 6)	5 (max = 6)
(b) Written output from pics stimuli	0 (max = 34)	1 (max = 34)
(c) Writing to dictation	0 (max = 10)	1 (max = 10)
(d) Writing words from visual stimu	0 (max = 10)	0 (max = 10)
(e) Writing the alphabet	11 (max=12.5)	7 (max =12.5)
(f) Writing numbers 0-20	9.5 (max = 10)	10 (max = 10)
(g) Dictated letter names	2 (max = 2.5)	2 (max = 2.5)
(h) Dictated numbers	4 (max = 5)	1 (max = 5)
(i) Copying a sentence from a card	9.5 (max = 10)	9 (max = 10)
Apraxia		
Carrying out oral commands	60 (max = 60)	60 (max = 60)
Constructional and calculation		
(a) Construction - drawing	15 (max = 30)	17 (max= 30)
(b) Calculation	24 (max = 24)	18 (max = 24)
NART Score	4 / 50	1 / 50

Note: WAB = Western Aphasia Battery. NART = National Adult Reading Test.

Summary scores of semantic processing tests administered to GT and JPJ

Tests of **Semantic processing**	**G.T**	**J.P.J**
Pyramid & Palm trees (a) picture-picture version (b) word-word version	(max score = 52) 49 50	(max score = 52) 49 49
PALPA 47 Spoken word-picture matching)	36 / 40	29 / 40
PALPA 48 Written word-picture matching)	37 / 40	31 / 40

Tests of **Reading aloud**	**G.T**	**J.P.J**
PALPA 35 Regularity of reading ENGLISH *Regular words: -* *Exception(Irregular)words:*	 20 (max = 30) 21 (max = 30)	 21 (max = 30) 18 (max = 30)
Reading ENGLISH *Concrete words: -* *Abstract words: -*	(max score = 12) 11 7	(max score = 12) 9 2
PALPA 24 Visual lexical decision: *Regular words: -* *Irregular words: -* *Non-words: -*	 15/15 14/15 30/30	 13/15 13/15 30/30
PALPA 25 Visual lexical decision: imageability & freq *Real words identified: -* *Non-word identified: -* *miss hits (false positives): -*	 HI/HF = 14/15 HI/LF = 14/15 LI/HF = 13/15 LI/LF = 10/15 51 (max = 60) 55 (max = 60) 5	 HI/HF = 15/15 HI/LF = 13/15 LI/HF = 12/15 LI/LF = 13/15 53 (max = 60) 38 (max = 60) 22
PALPA 31 Word reading aloud Imageability & freq *High imageability: -* *Low imageability: -* *High frequency: -* *Low frequency: -*	 HI/HF = 17/20 HI/LF = 16/20 LI/HF = 11/20 LI/LF = 8/20 33 (max = 40) 19 (max = 40) 28 (max = 40) 24 (max = 40)	 HI/HF = 12/20 HI/LF = 12/20 LI/HF = 2/20 LI/LF = 2/20 24 (max = 40) 4 (max = 40) 14 (max = 40) 14 (max = 40)
PALPA 32 Grammatical class reading *Nouns-*	 14 (max = 20)	 7 (max = 20)

Adjectives- *Verbs-* *Function-*	14 (max = 20) 10 (max = 20) 5 (max = 20)	6 (max = 20) 4 (max = 20) 1 (max = 20)
PALPA 36 Non word reading in ENGLISH (legal)	3 (max = 24)	1 (max = 24)
Letter-sound conversion Written letter-spoken sound Letter SOUND *English -*	5 / 26	2 / 26
Letter NAME English Spoken sound-written letter	5 / 26	3 / 26

Appendix 14

Buchanan et al. (1994) experiment stimuli

Pseudohomophone	Orthographic control	Target word
1. taybul	tarble	chair
2. dockter	dontor	nurse
3. howse	hoase	home
4. whyte	whote	black
5. kat	cit	dog
6. nife	knile	fork
7. bight	bete	teeth
8. bredd	bresd	butter
9. dore	dooc	knob
10. urly	earty	late
11. ait	cight	nine
12. frute	frait	pear
13. graid	grude	school
14. munth	manth	year
15. jale	jaib	prison
16. mayl	moil	letter
17. meel	merl	food
18. neet	neab	tidy
19. nunn	nome	zero
20. otes	oals	rye
21. obay	oley	serve
22. payn	parn	hurt
23. foan	foald	number
24. rane	rame	cloud
25. wreed	reab	write
26. roed	roaf	street
27. tode	tord	frog
28. trane	troin	tracks
29. muther	mather	child
30. wimin	wanen	men
31. eyce	ine	skate
32. greane	greel	red
33. sprynt	spront	race
34. skye	sby	blue
35. sitee	rity	town
36. gunn	gan	bullet
37. dropp	drap	drip
38. swete	sneet	heart
39. baise	bame	ball
40. krow	crom	raven
41. kar	cir	truck
42. kup	cip	mug

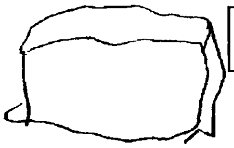
43. gluv	glive	hand
44. payl	parl	bucket
45. pensil	poncid	paper
46. nefew	nephem	niece
47. rowse	roxe	flower
48. paige	pake	book
49. sheap	sheel	lamb
50. haire	haic	brush
51. bowt	boaf	ship
52. kolt	cols	pony
53. kee	kay	lock
54. devyl	denil	angel
55. unkle	unsle	aunt
56. rong	wronc	right
57. wayk	wahe	sleep
58. sien	sige	poster
59. topp	tod	bottom
60. fryl	froll	ruffle

Appendix 15

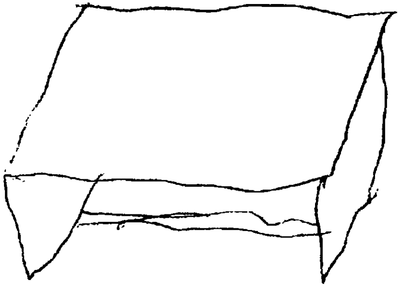
Semantic comprehension task administered to PD

Bread:	butter	book	brush
Table:	clown	chair	cheese
Queen:	knife	king	kettle
Nurse:	doctor	duck	drain
Wife:	hand	husband	hat
Knife:	fork	fridge	fox
Train:	turtle	tramp	track
Nail:	hole	hammer	harp
Read:	book	bridge	bike
Leaf:	tree	trick	train
Key:	lamp	lock	light
Bullet:	gun	girl	goat
Circus:	car	clown	computer
Photo:	peach	plant	picture
Cup:	sausage	saucer	scissors

Appendix 15 **Examples of PD's semantic comprehension: drawing ability.**



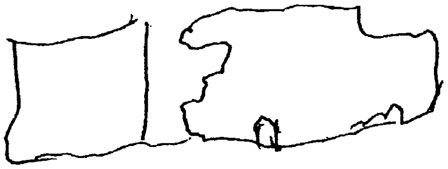
Bread



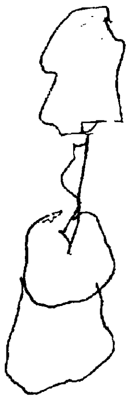
Table

Knife

Train

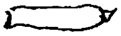


Nail

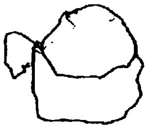


Leaf

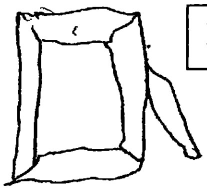
Key



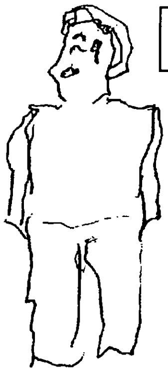
Bullet



Cup

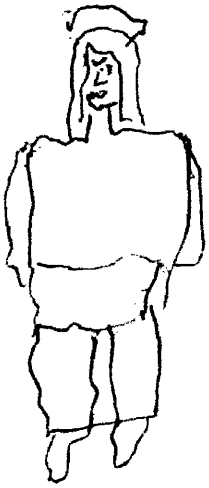


Photo



Queen

Nurse



Clown

Read

Appendix 16 **PD's free association responses**

Item	**PD Response**
Knife	*Fork*
Cup	*Leaf*
Photo	*Tea*
Circus	*Fair*
Bullet	*Fishing*
Key	*Finish*
Leaf	*Life*
Read	*Book*
Nail	*Screws*
Train	*Book*
Knife	*Pepper*
Wife	*Man*
Nurse	*Doctor*
Queen	*Lady*
Table	*Chairs*
Bread	*Coffee*