The Relationship Between the Processes Involved in Reading and Spelling in Adults

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I declare that this thesis is my own work and that, to the best of my knowledge and belief, it does not contain material from published sources without proper acknowledgement, nor does it contain material which has been accepted for the award of any other higher degree or graduate diploma in any university.

Amanda Burley

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Abstract

Reading and spelling are learned abilities that require the recognition and processing of words. Several models of word recognition have been developed to show how skilled readers recognise words. The dual-route model is the most comprehensive model and involves two processing routes or mechanisms for recognizing printed words; the lexical route and the non-lexical route. Differences in the reliance on lexical and non-lexical processes used to read regular words, irregular words, and nonwords have been found in both normally functioning and impaired readers (Baron, 1979; Baron & Treiman, 1980; Freebody & Byrne, 1988; Byrne, Freebody, & Gates, 1992). Having identified such patterns in reading, researchers have begun to investigate whether spelling involves similar processes to reading and whether similar patterns of reliance exist. Spelling is considered the inverse of reading, with reading involving the conversion of an orthographic representation to a phonological representation, while spelling involves the transformation from phonology to orthography (Ellis, 1982). It has been found that readers who differ in reliance on lexical and non-lexical processes have a corresponding difference in their spelling styles (Baron, Treiman, Wilf, & Kellman, 1980). In order to determine whether spelling uses the same processes as reading future research could explore whether reading and spelling are similarly affected by word frequency and reading age.

Chapter 1

Introduction

Reading and spelling are both abilities that require learning. Thorough knowledge and understanding of how reading and spelling is achieved in normally functioning individuals is important for the understanding of how impairments in these abilities occur. Researchers have most often concentrated on exploring the mechanisms involved in reading and it is only recently that attention has turned to the mechanisms involved in spelling. As it is likely that common processes are involved in reading and spelling, researchers have been particularly interested in the possible interaction between mechanisms involved in reading and spelling. This literature review aims to explore what mechanisms are involved in reading and spelling and whether normally functioning readers differentially rely on these mechanisms when reading and spelling. In addition, it aims to obtain an understanding of the similarities and differences between the processes used in reading and spelling.

The next chapter will explore single and dual route theories of word recognition in order to gain an understanding of the processes thought to be involved in reading. The third chapter will review research focusing on types of developmental dyslexia and the differences in reading patterns that are associated with each disorder. This will be followed by a review of research into the reading styles of normally functioning readers and how these different styles are similar to the patterns found in groups of developmental dyslexics. Chapter Four will then focus on spelling and the arguments surrounding whether spelling uses the same mechanisms as reading. This will include a discussion of research suggesting that spelling styles analogous to reading styles can be found in normally functioning individuals and suggesting that reading and spelling use similar processing mechanisms. Chapter Five will conclude with a summary of the current status of research in the area and a discussion of directions for future research.

Chapter 2

Word Recognition

The ability to read is underpinned by an individuals' ability to recognize a visually presented word and the processes that are engaged when a word is read. That is, word recognition allows an individual to be able to read. How an individual is able to recognize words has been at the centre of much debate and several models of word recognition have been developed. The dual-route model first proposed by Coltheart (1978) has received a large amount of attention. The basic premise from which dual-route models have developed is that there are two processing routes or mechanisms for recognizing printed words. Each route is thought to have a distinct function. These routes are the direct lexical access or orthographic route and the indirect non-lexical access or phonological route. Evidence to support this model includes the finding that skilled readers are able to read aloud correctly two different types of letter strings, the pronounceable nonword and the irregular or exception word (Coltheart, 1985).

According to Coltheart (1985) the non-lexical procedure converts orthography to phonology by using a system of spelling to sound correspondences. The phonological unit is termed the phoneme while the orthographic unit is the written equivalent of the phoneme: the grapheme. Coltheart proposes that spelling-sound correspondences consist of rules for relating individual graphemes to individual phonemes, that is, grapheme-phoneme correspondences (GPCs). In order to achieve this, the non-lexical procedure is divided into a sequence of components; graphemic parsing, phoneme assignment and blending. These components act as three processing stages which enable a nonword to be correctly read aloud. In the first stage the letter string must be parsed into its constituent graphemes. Then from the set of GPCs, a decision is made as to what phoneme should be assigned to each of the graphemes identified. Finally, the separate phonemes are blended into a single, unified phonological form. The non-lexical procedure is utilized in this way to read nonwords aloud as it is assumed that there are no accurate representations of nonwords stored in the mental lexicon.

In contrast, Coltheart (1985) proposes that the lexical procedure for reading aloud accesses word specific information from the mental lexicon through the orthographic route. This procedure is used to recognize irregular words by using orthography or visual features to directly access them from the lexicon. It is proposed that the non-lexical procedure cannot be used to recognize irregular words because these words do not follow GPC rules. The orthographic route is argued to be used both for familiar irregular words as well as regular words. While familiar regular words could be accessed using either route, the orthographic route is thought to be preferred because access to it is faster and more efficient and requires less resources than the phonological route (Paap & Noel, 1991).

While the dual-route model postulates the existence of two routes for word recognition these routes are not thought to be entirely independent of one another. The two routes are believed to share the same initial processing stage, a letter identification stage. It is proposed that this initial processing then delivers its output to two different destinations, the orthographic input lexicon and the letter-sound rule system (Coltheart & Rastle, 1994). It is also believed that the two routes also share a final processing stage which is thought to be a level of phonemic representation used to generate a pronunciation (Coltheart & Rastle, 1994).

A computational version of the dual-route model has also been developed, the dual-route cascade (DRC) model (Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). The DRC model was proposed in order to offer an account of how word recognition is acquired rather than simply presenting a static picture of a mature system (Coltheart et al., 1993). The DRC model is a computational model in the sense that it exists as a complete computer program that takes letters as input and yields a phonemic representation as output. As with previous dual-route models the DRC model is proposed to have processing routes that proceed from print to speech. However, the DRC model developed by Coltheart et al. (2001) postulates that there are three rather than two processing routes; the lexical non-semantic route, the lexical semantic route and the non-lexical or GPC route. While three routes have been proposed, at this stage only the lexical non-semantic and non-lexical routes have been implemented and as such further discussion will focus on these two routes.

The DRC model is presented as a model in which information is processed and passed from stage to stage in a cascade manner rather than through thresholds as previous dual-route models have suggested. Within each route activation rises slowly in the various components of the model which enables word recognition to be achieved after numerous processing cycles. As soon as there is activation in any level of the model, this activation is communicated to adjacent levels (Coltheart & Rastle, 1994). Every level of the model contributes activation and inhibition to all of its adjacent levels in both directions. This means, for example, that activation in the phonological output lexicon can lead to excitation or inhibition of units in both the phoneme stage and orthographic input lexicon (Coltheart et al., 1993).

Within the DRC model the letter identification and word recognition components are based on the interactive activation (IA) model of visual word recognition first put forward by McClelland and Rumelhart (1981) and Rumelhart and McClelland (1982).

The model is able to operate with words between two and eight letters in length. At present the DRC model is only able to process monosyllabic words and within the orthographic lexicon there is a unit for each monosyllabic word contained in the CELEX linguistic database (Baayen, Piepenbrock, & van Rijn, 1993) that are two to eight letters in length. The CELEX linguistic database was produced by the Centre for Lexical Information and comprises representations of the orthographical, phonological, morphological, syntactic, and frequency properties of English homographs. Within the DRC model each of the units has a resting activation level that is a scaled value of its frequency of occurrence in the CELEX database (Coltheart et al., 1993). This means that when a word is presented to the model, the rate at which activation rises across processing cycles will either increase or decrease depending on the frequency of the word.

The phonological output lexicon was modelled on spreading activation models of the spoken word developed by Dell (1986) and Harley and MacAndrew (1992). This lexicon contains a unit for every one of the phonological distinct monosyllabic words in the CELEX database. There are one-to-one connections from the orthographic input lexicon to the phonological output lexicon which are bidirectional and excitatory in nature. This route assembles the letters into phonology serially one letter at a time. Phonological information from both routes converges at the common component of the model, the phoneme system. While information from both routes converges at this system the lexical route is considered to be faster than the non-lexical route. Despite being slower, the input from the non-lexical route can reach the phoneme system before activation from the lexical route has reached full value (Ans, Carbonnel, & Valdois, 1998). This can lead to conflict between the two routes when they produce different outputs. [For a detailed description of the DRC model readers are referred to Coltheart and Rastle (1994) and Coltheart et al. (2001)].

The DRC model is able to simulate the reading patterns of normal and impaired individuals (Coltheart et al., 1993; Coltheart et al., 2001; Coltheart & Rastle, 1994; Rastle & Coltheart, 2000; Decker, Simpson, Yates, & Locker, 2003; Ans et al., 1998). Through training the non-lexical route Coutheart et al. (1993) were able to show that the model is capable of learning the rules that govern the English language. This training then enabled the performance of skilled readers in pronouncing regular words and nonwords to be approximated by the non-lexical route of the model. Further, the model has also approximated the performance of skilled readers on lexical decision and reading aloud tasks (Coltheart et al., 2001; Coltheart & Rastle, 1994; Decker et al., 2003). For both tasks the model's latencies were found to be affected by word frequency, lexicality, and regularity in the same way as those of skilled readers. In addition the DRC model has been able to model the effects of surface and phonological dyslexia and provide an explanation of their occurrence. One view in regard to surface dyslexia is that it involves selective impairment of irregular word reading and results in the production of regularization errors. By modifying the lexical route of the DRC model, the effects of surface dyslexia have been reproduced. Thus Coltheart et al. argue surface dyslexia is caused through damage to the lexical route and preservation of the non-lexical route. It has been proposed that phonological dyslexia involves a selective nonword reading impairment and by modifying the non-lexical route of the DRC model this impairment has been reproduced. Coltheart et al. infer that phonological dyslexia results from damage to the non-lexical route and relative preservation of the lexical route.

In order for the DRC model to be seen as adequately accounting for the processes involved in reading the model now needs to be expanded to polysyllabic words. In a step towards this Rastle and Coltheart (2000) have begun to explore how the DRC model may be able to account for disyllabic words. It has been found that a set of non-lexical rules for the orthographic-phonological translation of disyllabic letter strings can predict how individuals assign stress to disyllabic nonwords (Rastle & Coltheart, 2000). Further it has also been found that the naming latencies for English disyllabic strings whose stress violates that predicted by the rules are longer than the latencies for words which obey these rules, especially when the words are low in frequency (Rastle & Coltheart, 2000). While these principles are yet to be integrated into the model, Rastle and Coltheart believe that the model can be expanded to accommodate the reading of disyllabic words.

Dual-route models have been challenged by models that do not assume separate routes are required for pronouncing irregular words and nonwords. The first challenge came from analogy models of the reading system (Glushko, 1979; Kay & Marcel, 1981; Marcel, 1980). Analogy models propose that the pronunciation of all words is assigned by analogy with and by specific reference to known lexical items. Nonwords are said to be pronounced by generalization from existing words (Glushko, 1979; Kay & Marcel, 1981; Marcel, 1980). The analogy theory assumes that only whole-word phonology is stored in long-term memory and that orthography-to-phonology conversion rules only exist implicitly in the integrated activation of words (Glushko, 1979). The analogy model, however, has not been shown to reproduce the performance of skilled readers reliably (Coltheart et al., 1993; Papp & Noel, 1991).

A second approach that has challenged the theory of the dual-route model is the parallel distributed processing (PDP) model of visual word recognition and pronunciation (Seidenberg & McClelland, 1989; 1990; Plaut & McClelland, 1993). The PDP model, first put forward by Seidenberg and McClelland (1989), consists of sets of semantic, orthographic, and phonological units and an inter level of hidden units. The implemented PDP model focuses on the interactions between the orthographic and phonological units and does not contain any semantic representations. Within the implemented model a visually presented letter string first makes contact with a set of hidden units, which in turn project to a layer of units that correspond to phonetic patterns (Seidenberg & McClelland, 1989). When the model is at a steady state, there is feedback from the hidden units to the orthographic level but not from the phonetic level to the hidden units. All of the units in each level are fully connected to one another.

When a letter string is presented to the model it is encoded into a pattern of activation over the orthographic units. In turn the hidden units are activated with the level of activation computed from the pattern of activation from the orthographic units. The activations from the hidden units are then used to compute activations for the phonological units and new activations for the orthographic units based on feedback from the hidden units (Seidenberg & McClelland, 1989; 1990). The model is able to recreate phonological input and generate phonological codes via learning that occurs when exposed to letter strings. In contrast to dual-route models, the PDP model operates without a lexicon or multiple routes and as such regular words, irregular words, and nonwords are processed using the one mechanism.

The PDP model has been able to simulate many aspects of skilled reader performance with regular words, irregular words, and nonwords (Seidenberg & McClelland, 1989). On reading aloud tasks the PDP models naming latencies were found to be affected by word frequency and regularity to the same extent as skilled readers (Seidenberg & McClelland, 1989). Similar to skilled readers, the PDP model is able to respond faster to higher frequency words than low frequency words and faster to regular words than irregular words (Seidenberg & McClelland, 1989). In accordance with results from skilled readers, a word frequency, regularity interaction was also found. For the PDP model, as with skilled readers, irregular words produced significantly longer naming latencies than regular words only when they were low frequency (Seidenberg & McClelland, 1989). In regard to lexical decision tasks, Seidenberg and McClelland (1989) have shown that the model simulates the results of skilled readers. Seidenberg and McClelland (1989; 1990) argue from these results that distributed representations can provide a basis for making lexical decisions in the absence of a whole-word level representation. Further, Seidenberg and McClelland (1989; 1990) believe these results confirm that word recognition can be achieved without recourse to two processing routes and without the need for any lexicon.

Questions have, however, arisen in regard to the PDP's ability to function without recourse to any lexicon or multiple routes in order to accurately simulate the performance of skilled readers (Besner, Twilley, McCann, & Seergobin, 1990). Simulations using the PDP model by Besner et al. (1990) found the model was only good at producing phonological patterns for words on which it was trained. It performed poorly with new words and nonwords that skilled readers were able to read without difficulty. The model was also unable to account for the regularity effect in lexical decision tasks and performance on phonological lexical decision tasks was at chance level (Besner et al., 1990). Although it is claimed that the PDP model has no lexicon Besner et al. argues that the model consists of distributed representations that provide a level of representation which interfaces the sensory surface with the semantic system and other lexical systems. Thus the model does have a lexicon but it is unclear how it can be used within the model in its present form (Besner et al. 1990). Besner et al. believe problems in simulating the performance of skilled readers may be resolved if multiple routes and an explicit lexical level of representation were incorporated into the model. However, Seidenberg and McClelland (1990) argue the model's performance differs from that of skilled readers in ways which are predictable from an understanding of the limitations of its implementation. According to Seidenberg and McClelland the principle limitations are the size of the training corpus and the phonological presentation.

A modified PDP model was put forward by Plaut and McClelland (1993) which uses improved orthographic and phonological representations and has a distributed pattern of activation over a set of units with position-specific representations. In addition a syllabic structure comprising the phonemic positions of onset, nucleus, and coda were implemented. This allowed the representation to encode more of the phonetic constraints of English (Seidenberg, Plaut, Petersen, McClelland, & McRea, 1994). Implementation of this model has shown that it is able to generate plausible nonword pronunciations and match skilled readers' responses accurately (Seidenberg et al., 1994). Seidenberg et al. concluded that the better performance of the revised model is consistent with the view that having a highly structured phonological representation in place facilitates the acquisition of reading skills.

Two further modifications to the PDP model have since occurred and have brought the model closer to simulating the abilities of both skilled readers and impaired readers including those with developmental phonological and surface dyslexia using a single-route model. The first of these modifications was made by Plaut, McClelland, Seidenberg, and Patterson (1996), who built additional structure into the orthographic and phonological representations. This was done by adding a semantic pathway to the phonological pathway. In contrast to the lexical and non-lexical procedures of dual route theories, which operate separately and in different ways the semantic and phonological pathways operate according to a common set of computational principles (Plaut et al., 1996). Operating in this way means that the nature of the processing in the two pathways is intimately related. A simulation using the modified model has accurately reproduced the effects of frequency and consistency in the naming latencies of normal readers (Plaut et al., 1996). In addition by incorporating a graded division of labour between the semantic and phonological processes the impaired naming accuracy of acquired and developmental dyslexic readers has also been simulated (Plaut et al., 1996). These simulations have lead Plaut et al. (1996) to argue that the proficiency of humans in quasi-regular domains stems not from the existence of separate rule-based and item specific mechanisms, but from the fact that our cognitive system adheres to certain general principles of computation in neural-like systems.

The second modification to the model was made by Harm and Seidenberg (1999), who added an attractor unit to improve phonological representations within the model. The phonological attractor architecture allows the model to fill missing features and segments in a realistic way. In simulations using the phonological attractor architecture it was found to facilitate learning of the orthography-to-phonology mapping task in a manner that was similar to that of skilled readers (Harm & Seidenberg, 1999). It was also found that compared with simple feed forward networks, representing phonological knowledge in an attractor network yielded improved learning and generalisation thus improving the models performance on reading nonwords to that of skilled readers. Further, through damage to different parts of the system, Harm and Seidenberg have also been able to simulate the reading performance of both phonological and surface dyslexics. Harm and Seidenberg argue that the use of the phonological architecture indicates that you do not need two-routes for the accurate representation of irregular words and nonwords. Instead it is argued that all that is needed is the capacity to combine orthographic and phonological units in a novel way as the phonological attractor architecture enables to be done.

While debate continues as to whether reading can be achieved through a single-route as proposed by PDP theorists or requires two-routes as proposed by Dual-route theorists there has been an attempt to combine both theories. Zorzi, Houghton, and Butterworth (1998) have proposed a connectionist dual-process model of reading, known as the two layer (TLA) model. The TLA model maintains the uniform computational style of the PDP model but does not adhere to the rigidity inherent in single-route models (Zorzi et al., 1998). The model consists of a two-layer feed forward network with input and output layers but no hidden units. The TLA model implements a non-lexical assembly procedure in which phonology of any letter string is computed according to the most common spelling-sound relationships (Zorzi et al., 1998). This allows both regular and nonwords to be recognised. A second route handles input on a whole-word basis enabling irregular words to be recognised. Separating productive knowledge about spelling-sound relationships from case-specific knowledge of the pronunciation of known words is believed to enable it to be more easily acquired and used (Zorzi et al., 1998). Research using the TLA model has shown that the interaction of assembled and retrieved phonologies can account for the combined effects of word frequency and regularity-consistency and for the reading performance of dyslexics (Zorzi et al., 1998). While two processing routes are necessary for the pronunciation of nonwords and irregular words, Zorzi et al. believe this does not necessarily have to involve a lexical route as put forward in dual-route models.

The literature reviewed here reveals there are several competing models that attempt to explain how word recognition is achieved in skilled readers. Dual-route theorists maintain that two processing routes are required in order for both irregular words and nonwords to be read accurately. Simulations using dual-route models, in particular the DRC model, have been able to accurately reproduce the performance of both skilled readers and phonological and surface dyslexics. PDP theorists maintain however, that only a single processing route is required in order for all word types to be read accurately. Simulations using modified PDP models have also been able to reproduce the performance of both skilled readers and phonological and surface dyslexics. While the debate continues as to whether one route or two is required researchers have begun to combine aspects of both models as in the TLA model. Further research using such models as the TLA may help to progress the area by refocussing the debate from whether one route or two is required to how best the theory from both sides can be combined and utilised in further researching how skilled reading is achieved.

Chapter 3

Lexical and Non-Lexical Reading Styles

Not all readers are able to read irregular and nonwords correctly and this is thought to be due to a reading disorder known as dyslexia (Castles & Coltheart, 1996; 1993; Seymour & Evans, 1993; Hanley, Hastie, & Kay, 1992; Goulandris & Snowling, 1991). Dyslexia can be produced by brain damage and this type is known as acquired dyslexia. Acquired dyslexia occurs when a previously competent reader suffers impairment, due to a brain injury, affecting their ability to read (Castles & Coltheart, 1993). Dyslexia can also be found in individuals who have not suffered any brain damage but in contrast have never attained competence in reading and this type is known as developmental dyslexia. When first discovered, developmental dyslexia was thought to be a unitary syndrome, with a single underlying cause. Attempts to isolate a factor that could explain all the symptoms of this disorder were unsuccessful (Castles & Coltheart, 1993). Recently, there has been increasing support for the view that developmental dyslexics do not form a homogenous group, but that they can be split into several subgroups (Coltheart, Masterson, Byng, Prior, & Ridoch, 1983; Seymour & McGregor, 1984; Snowling & Hulme, 1989; Goulandris & Snowling, 1991; Hanley et al., 1992; Seymour & Evans, 1993; Castles & Coltheart, 1993; 1996). While there is still strong debate about the nature of the divisions, it has been agreed that there are several types of developmental dyslexia (Castles & Coltheart, 1993). Two types of developmental dyslexia that have been researched are developmental surface dyslexia and developmental phonological dyslexia.

Dual-route theorists argue that developmental surface dyslexia occurs when an individual has difficulty using the lexical route to read and as such relies on the non-lexical route to read all word types. Case studies of individual developmental surface dyslexics and comparisons with normal readers indicate that such reliance results in a relatively poor ability to read irregular words in comparison to regular words and nonwords (Coltheart et al., 1983; Goulandris & Snowling, 1991; Hanley et al., 1992; Seymour & Evans, 1993). In addition it has been found that developmental surface dyslexics make frequent regularisation errors when reading irregular words (Coltheart et al., 1983; Goulandris & Snowling, 1991; Hanley et al., 1992; Seymour & Evans, 1993; Castles & Coltheart, 1993). This has been taken as indicating that reliance on the non-lexical route does not enable word-specific information to be used. This, inturn, creates regularisation errors from the general information about orthographic-phonological correspondences utilised for reading. A regularisation error occurs when words are spelt as they are pronounced, for example *done* spelled *"dun"*.

In relation to developmental phonological dyslexia dual-route theorists argue that this type of dyslexia occurs when an individual has difficulty using the non-lexical route to read and as such relies on the lexical route. Case studies of developmental phonological dyslexics and comparisons to normal readers have shown that that this group has difficulty reading nonwords aloud (Seymour & McGregor, 1984; Snowling & Hulme, 1989; Castles & Coltheart, 1993). In comparison to developmental surface dyslexics, developmental phonological dyslexics make significantly more errors that contain word components when reading nonwords aloud than either for regular or irregular words (Seymour & McGregor, 1984; Snowling & Hulme, 1989; Castles & Coltheart, 1993). It has been suggested that these dyslexics use real word analogies in order to attempt to pronounce nonwords.

Manis, Seidenberg, Doi, McBride-Chang, and Petersen (1996) argue, however, that the dyslexia subtypes can be more thoroughly explained within the Seidenberg and McClelland (1989) PDP model. Using methods developed by Castles and Coltheart (1993), Manis et al. identified two groups who fitted the profiles of phonological and surface dyslexia. Similarly to Castles and Colheart, Manis et al. found that surface dyslexics were relatively poorer at reading exception words compared to nonwords whereas phonological dyslexics showed the opposite pattern. However Manis et al. also found that while most dyslexics were impaired on reading both exception words and nonwords compared to same-age normal readers, surface dyslexics' performance was very similar to that of younger normal readers however the performance of phonological dyslexics' was not. Manis et al. argue, therefore, that phonological and surface dyslexia may arise from multiple underlying deficits rather than purely differences in levels of irregular word and nonword reading as put forwards in the dual-route account. Manis et al. believe that phonological dyslexia primarily results from impairment in phonological representation that affects the course of reading by impeding the acquisition of the ability to map from orthography to phonology. In contrast it is believed that developmental surface dyslexia derives from an underlying impairment that yields a general delay in all aspects of word reading skill. Manis et al. have identified two possible bases of such impairment: a computational resource limitation and a visual-perceptual deficit. Manis et al. believe, therefore, that performance on irregular words and nonwords is not sufficient to identify the basis of dyslexic behaviour. Manis et al. argue that information about children's performance on other tasks, their remediation experiences and the computational mechanisms that give rise to impairments must be taken into account as well.

Normally developing readers have also been found to vary in their ability to accurately read irregular words and nonwords aloud (Baron, 1979; Baron & Treiman, 1980a; Freebody & Byrne, 1988; Byrne, Freebody, & Gates, 1992). Some normally developing readers appear to have similar reading patterns as developmental surface and phonological dyslexics. Baron (1979) used lists of regular words, irregular words, and nonwords with fourth grade readers in order to determine if there were individual differences on the reliance of spelling-sound correspondence rules and word-specific information in normally developing readers. Using a correlational analysis Baron expected that the correlations between regular words (R), irregular words (I) and nonwords (N) would be able to predict reading reliance. This is because irregular words and nonwords rely on the two different processes to read while regular words can be read using either process. As such Baron argued that the correlations between the three word types could indicate whether there was any bias in the children's reading style. Baron hypothesised that if regular words are being read using a rules strategy then the correlation between performance on nonwords and regular words (r_{NR}) should be high. Also, if regular words are being read using a whole-word strategy then the correlation between performance on regular and irregular words (r_{RI}) should be high. Further, if individual differences exist and both of these strategies are involved in the reading of regular words, then both pairs of correlations should be significantly higher than the correlation between nonwords and irregular words (r_{NI}) as these items cannot be read using the same strategy. The results showed exactly what Baron had predicted, that is, both r_{RI} and r_{NR} were higher than r_{NI}. Baron concluded that normally developing readers vary in their reading reliance on a continuum from a letter-sound based or 'Phoenician' style to a whole-word based 'Chinese style'. In addition to the results regarding reliance, when Baron investigated the errors made by the children in reading, he found that 'Phoenicians' made more sound-preserving errors whereas the 'Chinese' children's errors tended to preserve the meaning of the words.

The results of Baron's (1979) study have since been replicated by Baron and Treiman (1980a) using second, third, and fourth grade readers and similar results were obtained by Baron and Strawson (1976) using an adult sample. Studies by Freebody and Byrne (1988) and Byrne, Freebody, and Gates (1992) also replicated the results of Baron using cluster analysis. Freebody and Byrne used cluster analysis to identify subgroups on the basis of word reading strategies for second and third grade normally developing readers. At both grade levels comparable subgroups were found with there being a large group performing well above average on both irregular word and nonword reading measures and a smaller group performing substantially below average on both measures. In addition, a pair of crossover groups were found with one group performing at average levels on irregular word reading and well below average levels on nonword reading identified as displaying a 'Chinese' style of reading. The second group were found to be performing at average levels on nonword reading and well below average levels on irregular word reading and were thus identified as displaying a 'Phoenician' style of reading. In a follow-up longitudinal study using the same participants, Byrne, Freebody, and Gates found that these subgroups and individual reading styles were consistent over time. It was concluded from both of these studies that, as was found by Baron, there are identifiable subgroups displaying reliance on one word-reading strategy at the expense of the other (Freebody & Byrne, 1988; Byrne, Freebody, & Gates, 1992).

Having identified patterns of reliance in reading, attention has turned to spelling. The domain of spelling has for some time been neglected with research predominantly conducted into reading. As researchers have begun to investigate the domain of spelling, one focus has been on determining whether word recognition in spelling uses similar processes to reading. In addition, research has begun to look at whether similar patterns of reliance are identifiable within the spelling domain and if they are whether they are congruent with the patterns of reliance found in reading.

Chapter 4

The Processes Involved in Spelling: Are They the Same as Those Involved in Reading?

Research into the spelling domain has begun to investigate whether the processes involved in spelling are similar to those involved in reading. Two arguments have been put forward by researchers in this area. The first is that spelling uses different processing mechanisms to reading (Frith & Frith, 1980; Waters, Bruck, & Seidenberg, 1985; Rohl & Tunmer, 1988; Goswami & Bryant, 1990). In particular, it is argued that phonological or sound-based strategies are used to spell words. This is evident from the invented spellings of beginning spellers (Goswami & Bryant, 1990). Through an analysis of invented spelling Goswami and Bryant (1990) have shown that there is a considerable relationship between the letters and sounds used in the invented spellings with the invented spellings being phonoligically plausible. This is interpreted as indicating that even beginner spellers recognise that when spelling there is a relationship between the letters and sounds of words. However Goswami and Bryant also recognise that children's invented spelling is often wrong because the children appear to use the phonological code too literally when spelling.

Research comparing children's reading and spelling further supports this view. Waters, Bruck, and Seidenberg (1985) gave a group of eight year old children regular, exception, and ambiguous words to spell and read. The exception words were found to be harder to spell and read than regular words, thus indicating that a phonological code was employed when children read and spelt the words. However, a different pattern was found when looking at the ambiguous words. Reading these words was found to be no harder than the regular words. In contrast when spelling the children made more errors for the ambiguous words than for regular words (Waters et al., 1985). An analysis of the content of the errors found that the children spelled ambiguous words in ways that were phonoligically plausible. In addition when Bradley and Bryant (1979) and Bryant and Bradley (1980) gave six and seven year old children lists of words to read and spell they found many of the children often spelled words, which they were unable to read, correctly. However if they were then taught to use a phonological reading strategy they were able to read these words indicating that children often read words on the basis of visual chunks and spell words on the basis of phonological segments (Bradley & Bryant, 1979; Bryant & Bradley, 1980).

Analogous with readers, spellers can be divided into good and poor spellers. The difference between good and poor spellers is thought to be that good spellers can spell words when sound is insufficient or a misleading cue (Frith & Frith, 1980). Good spellers are able to spell words accurately under these conditions because they have acquired and use spelling programs to spell words (Frith & Frith, 1980). Poor spellers, however, fail to spell the same words correctly because they have failed to acquire the spelling programs by rote (Frith & Frith, 1980). Therefore, reading and spelling are said to utilise different processes because reading is an input process that is flexible and based on visual code whereas skilled spelling is a rigid output process based on pre-programmed letter sequences (Frith & Frith, 1980).

The second argument maintains that spelling involves similar processes to reading. Spelling is seen, in effect, as the inverse of reading aloud (Goodman & Caramazza, 1986; Barry & Seymour, 1988; Caramazza, 1988; Tainturer & Rapp, 2000). While reading is said to involve the conversion of an orthographic representation to a phonological representation, spelling is thought to involve the transformation from phonology to orthography (Ellis, 1982). Analogous to reading, proponents of this view believe that spelling involves two major routes for translating between phonology and orthography; a lexical and a non-lexical route (Caramazza, 1988; Tainturer & Rapp, 2000). The lexical route is believed to be used to retrieve the spellings of familiar words while the non-lexical route is thought to be used to assemble spellings for unfamiliar words using knowledge of the systematic correspondences between phonemes and graphemes (Rapp, Epstein, & Tainturer, 2002; Folk, Rapp, & Goldrick, 2002). Within the lexical route a word's spelling is believed to be retrieved from the orthographic output lexicon. In contrast, within the non-lexical route plausible spelling is said to be assembled from a phonological code (Ellis, 1982; Goodman & Caramazza, 1986; Folk et al., 2002).

Evidence in support of this second argument comes from research into impairments of spelling, in particular, developmental surface and phonological dysgraphia. Congruent with reading and developmental surface and phonological dyslexia, similar patterns of impairment have been found in developmental dysgraphia. Case studies have been reported of individuals with phonological dysgraphia, who can spell words correctly but have impaired nonword spelling ability (Shallice, 1981; Roeltgen, Sevush, & Heilman, 1983). Similarly to phonological dyslexia, it is theorised that such individuals have difficulty using the non-lexical route and rely on the lexical route in order to spell all word types. There have also been case studies of developmental surface dysgraphia in which individuals have a poor ability to spell irregular words in comparison to regular words and nonwords (Beauvois & Derouesne, 1981; Hatfield & Patterson, 1983). Analogous with theories of developmental surface dyslexia, it is theorised that such individuals have difficulty using the lexical route and rely on the non-lexical route in order to spell all word types. In addition, case studies of individuals with both developmental surface and phonological dyslexia have shown that these individuals have poor spelling abilities which are congruent with their poor reading abilities (Goulandris & Snowling, 1991; Hanley et al., 1992). Researchers have concluded that these findings provide evidence that the same processing routes are used to read and spell and that reading and spelling share one lexicon (Goulandris & Snowling, 1991; Hanley, et al., 1992).

Further evidence has come from research looking to determine if individual spelling styles analogous to the 'Chinese-Phoenician' continuum found in reading by Baron (1979) also exists in spelling. Treiman (1984), using a similar design to Baron correlated the spelling performance of third and fourth grade children on regular words, irregular words, and nonwords. Consistent with the results of Baron for reading, the pattern of pairwise correlations indicated that rules were being used to spell regular words as well as nonwords (Treiman, 1984). Treiman also found that for irregular words, all errors were sound-preserving errors (S) analogous with regular words. These errors were found to correlate highly with the ability to spell regular words and nonwords but not irregular words. In addition the correlations for r_{SR} and r_{SN} were significantly greater than r_{SI}, however, they did not differ from one another (Treiman, 1984). Treiman interpreted this as indicating that the tendency to make sound-preserving errors correlates more highly with the ability use the rules of the non-lexical route than with the ability to use word-specific associations of the lexical procedure. Treiman concluded that these correlations provide evidence for the existence of 'Chinese' and 'Phoenician' spellers.

In a continuation of the study by Treiman (1984), Castles, Holmes, and Wong (1997) assessed the reading and spelling of third grade children. In addition to the correlational design employed in the previous study, groups of children who differed on reliance of the two routes in their spelling where identified and the nature of their spelling was then assessed. Groups were also assigned on the basis of their reading reliance in order to allow their spelling patterns to be analysed. The spelling analysis was also broadened from that used by Treiman to include measures of the functioning of the lexical procedure. The results of the pairwise correlations indicated that both lexical and non-lexical processes were involved in spelling. In relation to patterns of reliance in reading and spelling, Castles et al. (1997) found that reliance was consistent across the two domains. The non-lexically reliant readers were more accurate at spelling nonwords than the lexically reliant readers and they made a higher proportion of regularisation errors on irregular words. Consistent with this the lexically reliant readers made more errors containing partial lexical information when spelling irregular words.

Similar results have also been found with adults. Baron, Treiman, Wilf, and Kellman (1980b) selected adults as either 'Phoenician' or 'Chinese' on the basis of tests of reading and spelling. When these two groups were administered a spelling test containing regular and irregular words, the 'Phoenicians' produced a higher proportion of sound-preserving errors than the 'Chinese' group. This was taken as showing that readers who differ in reliance on lexical and non-lexical processes have a corresponding difference in their spelling styles (Baron et al., 1980b)

As discussed the domain of spelling has been neglected for some time and it is only recently that researchers have begun to examine the processing mechanisms involved in spelling. Researchers are divided as to whether spelling involves the same mechanisms as reading. Currently there is evidence to suggest that they may share processes but equally there is evidence to suggest that they may involve separate processes. It is only with further research that this issue will be clarified.

Chapter 5

Current State of Research and Future Directions

An understanding of the mechanisms involved in reading and spelling and how the system works as a whole is important for a thorough understanding of both normal and impaired functioning in both domains. Currently there are several models that purport to show how word recognition is achieved by skilled readers including dual-route models, PDP models and the TLA model. While dual-route and PDP theorists continue to debate over whether reading can be achieved using a single route or if two routes are needed, the TLA model has begun to combine theory from both sides in order to further explore how skilled reading is achieved.

In normally functioning readers it has been shown that there are differences in the reliance on lexical and non-lexical processes to read regular words, irregular words, and nonwords similar to those found in impaired readers. Having identified such patterns in reading, attention has turned to the domain of spelling. Currently there are two main arguments pertaining to the relationship between reading and spelling. The first is that spelling uses different processes to reading because while reading is an input process spelling is an output process. The second argument is that spelling is the inverse of reading and that both processes share the one lexicon. Research into this area has provided some support for both arguments.

In order to determine whether spelling uses the same processes as reading, future research could explore whether reading and spelling are similarly affected by word frequency and reading age. Future research could also look at the types of errors made in reading and spelling in order to determine if spelling errors are produced through a reliance on processing mechanisms similar to reading or as a result of poorly acquired spelling programs. Further it would also be valuable for future research to use more adult participants as the majority of studies have used children. This would enable it to be seen if patterns of reliance in adults are similar to those found in children.

References

Ans, B., Carbonnel, S., & Valdois, S. (1998). A connectionist multiple-trace memory model for polysyllabic word reading. *Psychological Review, 105*, 678-723.

Baayen, R. H., Piepenbrock, R., & van Rijn, H. (1993). *The CELEX lexical database.* Linguistic Data Consortium, University of Pennsylvania.

Baron, J., & Strawson, C. (1976). Use of orthographic and word-specific knowledge in reading words aloud. *Journal of Experimental Psychology: Human Perception and Performance, 2*, 386-393.

Baron, J. (1979). Orthographic and word-specific mechanisms in children's reading of words. *Child Development, 50*, 60-72.

Baron, J., & Treiman, R. (1980a). Use of orthography in reading and learning to read. In R. Venezky, & J. Kavanagh (Eds.), *Orthography, reading, and dyslexia* (pp171-189). Baltimore: University Park Press.

Baron, J., & Treiman, R., Wilf, J. F., & Kellman, P. (1980b). Spelling and reading by rules. In U. Frith (Ed.), *Cognitive processes in spelling.* London: Academic Press.

Barry, C., & Seymour, P. H. K. (1988). Lexical priming and sound-to-spelling contingency effects in nonword spelling. *The Quarterly Journal of Experimental Psychology, 40A*, 5-40.

Beauvois, M. F., & Derousne, J. (1981). Lexical or orthographic agraphia. *Brain, 104*, 21-49.

Besner, D., Twilley, L., McCann, R. S., Seergobin, K. (1990). On the association between connectionism and data: Are a few words necessary? *Psychological Review, 97*, 432-446.

Bradley, L., & Bryant, P. E., (1979). Independence of reading and spelling in backward and normal readers. *Developmental Medicine & Child Neurology, 21*, 504-514.

Bryant, P. E., & Bradley, L. (1980). Why children sometimes write words which they do not read. In U. Frith (Ed.), *Cognitive processes in spelling.* New York/London: Academic Press.

Byrne, B., Freebody, P., & Gates, A. (1992). Longitudinal data on the relations of word-reading strategies to comprehension, reading time, and phonemic awareness. *Reading Research Quarterly, 27,* 141-151.

Caramazza, A. (1988). Some aspects of language processing revealed through the analysis of acquired dysgraphia: The lexical system. *Annual Review of Neuroscience, 11*, 395-421.

Castles, A., & Coltheart, M. (1993). Varieties of developmental dyslexia. *Cognition, 47*, 149-180.

Castles, A., & Coltheart, M. (1996). Cognitive correlates of surface dyslexia: A single case study. *Cognitive Neuropsychology, 13*, 25-50.

Castles, A., Holmes, V. M., & Wong, M. (1997). Variations in spelling style among lexical and sublexical readers. *Journal of Experimental Child Psychology, 64*, 98-118.

Coltheart, M. (1979). Lexical access in simple reading tasks. In G. Underwood (Ed.), *Strategies of information processing* (pp.151-216). London: Academic Press.

Coltheart, M., Masterson, J., Bing, S., Proir, M., & Riddoch, J. (1983). Surface dyslexia. *Quarterly Journal of Experimental Psychology, 35A*, 469-495.

Coltheart, M. (1985). Cognitive neuropsychology and the study of reading. In M. Posner and O. Marin (Eds.) *Attention and performance XI* (pp3-37). London: Lawrence Erlbaum.

Coltheart, M., Curtis, B., Atkins, P., & Haller, M. (1993). Models of reading aloud: Dual-route and parallel-distributed-processing approaches.*Psychological Review, 4*, 589-608.

Coltheart, M., & Rastle, K (1994). Serial processing in reading aloud: Evidence for dual-route models of reading. *Journal of Experimental Psychology: Human Perception and Performance, 20*, 1197-1211.

Coltheart, M., & Rastle, K. (2000). Lexical and nonlexical print-to-sound translation of disyllabic words and nonwords. *Journal of Memory and Language, 42*, 342-364.

Coltheart, M., Rastle. K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascade model of visual word recognition and reading aloud. *Psychological Review, 108*, 204-256.

Decker, G., Simpson, G. B., Yates, M., & Locker, L. (2003). Flexible use of lexical and sublexical information in word recognition. *Journal of Research in Reading, 26*, 280-286.

Dell, G. S. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review, 104*, 801-838.

Ellis, A. W. (1982). Spelling and writing (and reading and speaking). In A. W. Ellis (Ed.), *Normality and pathology in cognitive functions.* New York: Academic Press.

Freebody, P., & Byrne, B. (1988). Word-reading strategies in elementary school children: Relations to comprehension, reading time, and phonemic awareness. *Reading Research Quarterly, 23*, 441-453.

Frith, U., & Frith, C. (1980). Relationships between reading and spelling. In R. Venezky, & J. Kavanagh (Eds.), *Orthography, reading, and dyslexia* (pp287-297). Baltimore: University Park Press.

Folk, J. R., Rapp, B., & Goldrick, M. (2002). The interaction of lexical and sublexical information in spelling: What's the point? *Cognitive Neuropsychology, 12*, 653-671.

Goodman, R. A., & Caramazza, A. (1986). Aspects of the spelling process: Evidence from a case of acquired dysgraphia. *Language and Cognitive Processes, 1*, 263-296.

Goswami, U., & Bryant, P. (1990). *Phonological skills and learning to read.* East Sussex: Lawrence Erlbaum.

Goulandris, N. K., & Snowling, M. (1991). Visual memory deficits: A plausible cause of developmental dyslexia? Evidence from a single case study. *Cognitive Neuropsychology, 8*, 127-154.

Glushko, R. J. (1979). The organization and activation of orthographic knowledge in reading aloud. *Journal of Experimental Psychology: Human Perception and Performance, 5*, 674-691.

Hanley, J. R., Hastie, K., & Kay, J. (1992). Developmental surface dyslexia and dysgraphia: An orthographic processing impairment. *The Quarterly Journal of Experimental Psychology, 44A*, 285-319.

Harley, T.A.., & Grainger, J. (1992). Testing a semistochastic version of the interactive activation model in different word recognition experiments. *Journal of Experimental Psychology: Human Perception and Performance, 16*, 687-715.

Harm, M.W., & Seidenberg, M.S. (1999). Phonology, reading acquisition, and dyslexia: Insights from connectionist models. *Psychological Review, 106*, 491-528.

Hatfield, F. M., & Patterson, K. E. (1983). Phonological spelling. *Quarterly Journal of Experimental Psychology, 35A*, 451-468.

Kay, J., & Marcel, A. (1981). One process, not two, in reading aloud: Lexical analogies do the work of non-lexical rules. *Quarterly Journal of Experimental Psychology: Human Perception and Performance, 33A*, 397-413.

Manis, F.R., Seidenberg, M.S., Doi, L.M., McBride-Chang, C., & Petersen, A. (1996). On the bases of two subtypes of developmental dyslexia. *Cognition, 58*, 157-195.

Marcel, A. J. (1980). Surface dyslexia and beginning reading: A revised hypothesis of the pronunciation of print and its impairments. In M. Coltheart, K. Patterson, & J. C. Marshall (Eds.), *Deep dyslexia* (pp227-258). London: Routledge & Kegan Paul.

McClelland, J. L., & Rummelhart, D. E. (1981). An interactive activation model of context effects in letter perception: I. An account of basic findings. *Psychological Review, 88*, 375-407.

Papp, K. R. & Noel, R. W. (1991). Dual-route models of print to sound: Still a good horse race. *Psychological Research, 53*, 13-24.

Plaut, D. C. & McClelland, J. L. (1993). Generalisation with componential attractors: Word and nonword reading in an attractor network. In *Proceedings of the Fifteenth Annual Conference of the Cognitive Science Society,* (pp.824-829). Hillsdale, NJ: Erlbaum.

Plaut, D.C., McClelland, J.L., Seidenberg, M.S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review, 103*, 56-115.

Rapp, B., Epstein, C., & Tainturer, M. (2002). The integration of information across lexical and sublexical processes in spelling. *Cognitive Neuropsychology, 19*, 1-29.

Rastle, K., & Coltheart, M. (2000). Serial processing in reading aloud: A reply to Zorzi. *Journal of Experimental Psychology: Human Perception and Performance, 26*, 1232-1235.

Roeltgen, D. P., Sevush, S., & Heilman, K. M. (1983). Phonological agraphia: Writing by the lexical-semantic route. *Neurology, 33*, 755-765.

Rohl, M., & Tunmer, W. E. (1988). Phonemic segmentation skill and spelling acquisition. *Applied Psycholinguistics, 9*, 335-350.

Rummelhart, D. E., & McClelland, J. L. (1982). An interactive activation model of context effects in letter perception: II. The contextual enhancement effect and some tests and extensions of the model. *Psychological Review, 89*, 60-94.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review, 96*, 523-568.

Seidenberg, M. S., & McClelland, J. L. (1990). More words but still no lexicon: Reply to Besner et al. (1990). *Psychological Review, 97*, 447-452.

Seidenberg, M. S., Plaut, D. C., Petersen, A. S., McClelland, J. L., and McRae, K. (1994). Nonword pronunciation and models of word recognition. *Journal of Experimental Psychology: Human Perception and Performance,* 20, 1177-1196.

Seymour, P. H. K., & MacGregor, C. J. (1984). Developmental dyslexia: A cognitive experimental analysis of phonological, morphemic, and visual impairments. *Cognitive Neuropsychology, 1*, 43-82.

Seymour, P. H. K., & Evans, H. M. (1993). The visual (orthographic) processor and developmental dyslexia. In D. M. Willows, R. S. Kruk, & E. Corcos (Eds.). *Visual processes in reading and reading disabilities* (pp347-376). Hillsdale, NJ: Erlbaum.

Shallace, T. (1981). Phonological agraphia and the lexical route in writing. *Brain, 104*, 413-429.

Snowling, M., & Hulme, C. (1989). A longitudinal case study of developmental phonological dyslexia. *Cognitive Neuropsychology, 6*, 379-401.

Tainturier, M. J. & Rapp, B. (2000). The spelling process. In B. Rapp (Ed.), *What deficits reveal about the human mind: A handbook of cognitive neuropsychology.* Philadelphia, PA: Psychology Press.

Treiman, R. (1984). Individual differences among children in reading and spelling styles. *Journal of Experimental Child Psychology, 37*, 463-577.

Zorzi, M., Houghton, G., & Butterworth, B. (1998). Two routes or one in reading aloud? A connectionist dual-process model. *Journal of Experimental Psychology: Human Perception and Performance, 24*, 1131-1161.

Empirical Study

The Relationship Between the Processes Involved in Reading and Spelling in Adults

Abstract

This study examined whether spelling utilises the same processing mechanisms as reading and the effect of word frequency and reading age on the reading and spelling performance of adults. Sixty, third-year university students ranging in age from 18 to 50 years were presented with separate high and low frequency regular word, irregular word, and nonword reading and spelling lists on separate occasions. Pairwise correlations indicated that for reading lexical and non-lexical processes were used equally while for spelling a reliance on the lexical process was found. In contrast to previous studies with children, reliance on lexical and non-lexical processes was not found to be consistent across domains and as such there were no differences found in the number of regularization, partial lexicalisation, or lexicalization spelling errors made by the no reliance, non-lexically reliant, or lexically reliant reading groups. In relation to the effect of word frequency, Analysis of Variance indicated that participants produced fewer errors on high frequency words than low frequency words for both reading and spelling. For reading only, it was shown that participants with a reading age above 20 read significantly more irregular words and nonwords correctly than participants with a reading age below 20. Generally it was found that spelling utilises the same processing mechanism as reading thus supporting the dual-route model of spelling. The results further indicated that word frequency and reading age affect the reading and spelling performance of adults. As it is not known what effects word frequency and reading age have on the reading and spelling performance of children caution should be taken in interpreting results of children and in extrapolating the findings to adults.

Reading and spelling are learned abilities that require the recognition and processing of words. There is considerable knowledge about reading with several models of word recognition showing how skilled readers recognise words. Less is known about the processes involved in spelling. In particularly it is not yet known whether reading and spelling access the same processing mechanisms or not. Researchers have shown that similar patterns of reliance exist in reading and spelling and this has been interpreted as indicating that reading and spelling access the same processing mechanisms. However, in previous research the effects of word frequency and reading age have not been considered. Both word frequency and reading age have been found to affect reading and spelling ability (Kreiner & Gough, 1990; Waters, Bruck, & Seidenberg, 1985; McCusker, Hillinger, & Bias, 1981) and as such may influence patterns of reliance. The aim of this study, therefore, is to explore whether reading and spelling involve the same processing mechanisms by examining what effect word frequency and reading age have on reading and spelling abilities in adults.

The basis of reading is the ability to recognize words. Both single route and dual route models of word recognition have been developed (Seidenberg & McClelland, 1989, Plaut & McClelland, 1993; Coltheart, 1979; Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). The dual-route model is the most comprehensive model of word recognition and involves two processing routes or mechanisms for recognizing printed words; the lexical route and the non-lexical route. Two arguments have been put forward to explain the relationship between the processing mechanisms involved in reading and spelling. Researchers have argued that spelling involves different mechanisms to reading (Frith & Frith, 1980; Waters, Bruck, & Seidenberg, 1985; Rohl & Tunmer, 1988; Goswami & Bryant, 1990). Reading is viewed as a flexible input process that is based on visual code while spelling is considered a rigid output process that is based on pre-programmed letter sequences and involves phonological or sound-based strategies (Frith & Frith, 1980). It has also been argued that spelling involves the same processing mechanisms as reading and that they share one lexicon. Analogous to reading, spelling is said to involve two major routes for translating between phonology and orthography; a lexical and a non-lexical route (Caramazza, 1988; Tainturer & Rapp, 2000). The lexical route, used in reading to access word specific information from the mental lexicon, is used to retrieve the spellings of familiar words while the non-lexical route, used in reading to convert orthography to phonology, is used to assemble spellings for unfamiliar words using knowledge of the systematic correspondences between phonemes and graphemes (Rapp, Epstein, & Tainturer, 2002; Folk, Rapp, & Goldrick, 2002). Within the lexical route a word's spelling is retrieved from the orthographic output lexicon. In contrast, within the non-lexical route plausible spelling is assembled from a phonological code (Ellis, 1982; Goodman & Caramazza, 1986; Coltheart et al., 2001; Folk et al., 2002).

In reading, individual differences in the usage of the two routes to read regular words has been found. It has been shown that such differences are predictable from the types of errors made on irregular words and nonwords. Baron (1979), using a correlational analysis, found that fourth grade readers' reading reliance could be predicted from the correlations between regular words, irregular words, and nonwords. A high correlation between performance on nonwords and regular words indicated the use of a rules strategy to read regular words whereas a high correlation between performance on regular words and irregular words indicated the use of a whole word strategy to read regular words. These correlations where both found to be higher than the correlation between nonwords and irregular words which was taken to indicate that both strategies can be use to read regular words but that there are individual differences in the use of the strategies. Overall these results indicated that normally developing readers vary in their reading reliance on a continuum from a letter-sound based or 'Phoenician' style to a whole-word based 'Chinese style' (Baron, 1979). In addition to the results regarding reliance, when the errors made by the children were analysed it was found that 'Phoenicians' made more sound-preserving errors whereas the 'Chinese' children's errors tended to preserve the meaning of the words (Baron, 1979).

The question has now arisen as to whether similar patterns of reliance exist in spelling. Treiman (1984), using a similar design to Baron's, correlated the spelling performance of third and fourth grade children on regular words, irregular words, and nonwords. Consistent with the results of Baron for reading, the pattern of pairwise correlations indicated that rules were being used to spell regular words as well as nonwords (Treiman, 1984). Treiman also found that for irregular words, all errors were sound-preserving errors analogous with regular words. These errors were found to correlate highly with ability to spell regular words and nonwords but not irregular words. In addition the correlations between sound-preserving errors and regular words and sound-preserving errors and nonwords were significantly greater than the correlation between sound-preserving errors and irregular words, however, they did not differ from one another (Treiman, 1984). This indicates that the tendency to make sound-preserving errors correlates more highly with the ability to use the rules of the non-lexical route than with the ability to use word-specific associations of the lexical procedure (Treiman, 1984). Therefore, together with the correlations these results provide evidence for the existence of 'Chinese' and 'Phoenician' spellers.

However, the evidence is somewhat equivocal. As Castles, Holmes, and Wong (1997) point out, the correlations for spelling regular and irregular words and for spelling nonwords and irregular words did not differ significantly form each other in Treiman's (1984) study. These differences would have been expected if any of the children had been primarily relying on the lexical route for spelling. Castles et al. further criticised Treiman's study for being purely correlation and not identifying groups of spellers with opposing patterns of reliance. In light of these criticisms, Castles et al. performed a further study assessing the reading and spelling of regular words, irregular words, and nonwords of third grade children. The study was similar to those conducted by Baron (1979), and Treiman (1984) with three major changes to the design. Firstly, in addition to the correlation design employed in previous studies, groups of children who differed in reliance on the two routes in their reading were identified and the nature of their spelling was then assessed. Groups were also assigned on the basis of their reading reliance in order to allow their spelling patterns to be analysed. Finally the spelling analysis was broadened to include measures of the functioning of the lexical procedure. Therefore, in addition to looking at sound-preserving errors that are an indicator of processing using the non-lexical route, lexicalisation and partial lexicalisation errors were also examined. A lexicalisation error occurs when a word or nonword is misspelled by producing another word (e.g., spelling one as won). A partial lexicalisation occurs when a whole word spelling is not produced but the response does contain lexical information (e.g., yacht spelt yatch).

The results of the pairwise correlations indicated that both lexical and non-lexical processes are involved in spelling (Castles et al., 1997). In contrast to the results of Treiman's (1984) study, whole-word information was found to be used in addition to rules to spell regular words. Also in contrast to Treiman's results, the ability to spell irregular words was just as good a predictor of regular word spelling as was the ability to spell nonwords. Further, for reading only, rules were found to be used in reading aloud regular words (Castles et al., 1997). While providing stronger evidence that both lexical and non-lexical procedures are involved in spelling Castles et al. cite several possible reasons for the differences in their results to those of Treiman. Firstly, it may have occurred because the items on the words lists were constructed differently. Treiman's words were closely matched visually to each other whereas Castles et al. did not visually match the words. Secondly, the manner in which the word lists were presented may have led to the discrepancy. Whereas Treiman presented separate lists of regular words, irregular words, and nonwords, Castles et al. presented mixed lists for reading aloud. Presenting the word types in a mixed list may have caused greater use of the non-lexical route (Castles et al., 1997). Finally, the results may have differed because of differences in teaching methods. Castles et al.'s participants were exposed to the whole-word teaching method which may have placed greater emphasis on the use of whole-word knowledge whereas Treimen's participants where more likely to have been taught using a phonics based method placing greater emphasis on rules.

In relation to patterns of reliance in reading and spelling, Castles et al. (1997) found that reliance was consistent across the two domains. The non-lexically reliant readers were more accurate at spelling nonwords than the lexically reliant readers and they made a higher proportion of regularisation errors on irregular words. Consistent with this the lexically reliant readers made more errors containing partial lexical information when spelling irregular words. However, the lexically reliant group did not spell more irregular words correctly than the non-lexically reliant group suggesting patterns of reliance were not constant across domains. This may have been due to a floor effect resulting from the spelling test containing many low frequency words which were too difficult for the children to spell (Castles et al., 1997). Also, inconsistent with the patterns of reliance, there was no difference found in the proportion of lexicalisation errors in spelling produced by the two groups. This may have occurred because lexicalisation errors may be more likely to occur in reading (Castles et al., 1997). In spelling, a partial lexicalisation error may be more likely as the person correctly identifies the phonological form of the word and then incorrectly attempts to recall its orthographic form, resulting in a partial lexicalisation error (Castles et al., 1997). Castles et al. concluded that the results of the study are consistent with the dual-route account of spelling and support the proposal of a single-system for both reading and spelling.

The majority of studies in this area, including that of Castles et al. have used young children as their participants. Reading and spelling are skills that are acquired over time and require the integration of several skills including phoneme awareness, phonics, reading fluency, and comprehension skills for proficiency to be attained (Share 1995; 1999, Ehri 1980a; 1980b; 1992; 1997, Ehri & Wilce 1980). It has been shown that phonological and orthographic processing abilities increase with age (Martin, Claydon, Morton, Binns, & Pratt, 2003). Further older readers have been found to have superior orthographic and phonological processing strategies in comparison to younger readers (Martin et al., 2003). As such the reliance's found in children may reflect differences in the acquisition of phonological and orthographic skills rather than true differences in reading reliance. The aim of this study, therefore, is to investigate the processing mechanisms involved in reading and spelling through the use of separate regular word, irregular word, and nonword reading and spelling tests to extend the research conducted by Treiman (1984) and Castles et al. (1997) through an investigation into the use of rules and word specific associations in reading and spelling in adults.

Word frequency has been found to affect the number of errors produced on reading and spelling tests (Kreiner & Gough, 1990; McCusker, Hillinger, & Bias, 1981). Significantly more errors are made on low frequency words than on high frequency words for both reading and spelling (Kreiner & Gough, 1990; McCusker et al., 1981). More errors are produced on low frequency words because they may not have representations in the mental lexicon and are treated more like nonwords and processed through the non-lexical route (Kreiner & Gough, 1990). Therefore, while high frequency words use the word-specific associations of the lexical route these associations are generally unavailable for low frequency words and hence rules are used. Researchers have concluded that rules are only used when word-specific associations are unavailable as is thought to be the case for low frequency words (Kreiner & Gough, 1990; McCusker et al., 1981). Therefore the study also aims to examine the effects of word frequency on adult participants reading and spelling performance

In the study conducted by Treiman (1984) the reading age of participants was not assessed. Individuals of the same chronological age can differ markedly in their reading age. When individuals are compared without taking this into consideration it cannot be determined whether any differences found were the results of a manipulated variable or the result of differences due to experience with written language, stages in reading acquisition or difficulty in the task material (Backman, Mamen, & Ferguson, 1984). In addition, comparisons of reading age groups on spelling and reading tasks have previously shown that participants with a higher reading age produce significantly fewer errors than those with a lower reading age (Waters, Bruck, & Seidenberg, 1985).

Therefore, Trieman's findings may have resulted from differences in reading age rather than from differences in patterns of reliance. In addition reading age may also account for the differences found between Treiman's study and that of Castle's et al. (1997). While reading age was not assessed by Trieman, it was used as a control variable in Castle's et al. study with no significant differences in reading age found for the reading reliance groups selected. This study further aims to examine the effects reading age on adult participants reading and spelling performance by comparing groups of participants with different reading ages.

In addition the study will explore the spelling performance of lexically reliant, non-lexically reliant, and no reliance readers as well as the regularisation, lexicalisation, and partial lexicalisation errors made on tests of spelling and to compare the findings to those of Castle's et al (1997).

In relation to the use of rules and word specific associations in reading and spelling it is hypothesised that there will be a significant difference between the pairs of dependent correlations. It is hypothesized that if a rules strategy is being used then the correlation between nonwords (N) and regular (R) words (r_{NR}) will be significantly greater than the correlation between nonwords and irregular (I) words (r_{NI}). It is also hypothesized that if a whole word strategy is being used then r_{IR} will be significantly greater than r_{NR}. If both rules and word specific associations are being used to read and spell it is hypothesized that the difference between r_{NR} and r_{IR} will not be significant.

In relation to the effect of word frequency it is hypothesised that for both reading and spelling tests significantly more high frequency irregular words will be read and spelt correctly compared to low frequency irregular words. In relation to the spelling performance of reading reliance groups it is hypothesised that lexically reliant readers will spell significantly more irregular words correctly than non-lexically reliant readers. It is also hypothesized that non-lexically reliant readers will spell significantly more nonwords correctly than lexically reliant readers. In relation to the types of errors made by the reading reliance groups it is hypothesised that the non-lexically reliant group will make significantly more regularisation errors than the lexically reliant group. It is also hypothesised that the lexically reliant group will make significantly more lexicalisation errors than the non-lexically reliant group. It is further hypothesised that the lexically reliant group will make significantly more partial lexicalisation errors than the non-lexically reliant group.

Method

Participants

The participants were 51 female and 9 male third-year psychology students. The participants ranged in age from 18 to 50 (Mean Age= 22.5) and had a pre-morbid IQ estimate ranging from 87 to 115 (Mean IQ=103.9). The students participated as part of a class exercise. Participants were required to have normal to corrected-to-normal vision.

Materials

Three reading and spelling lists, one containing regular words, one containing irregular words, and one containing nonwords were used to examine lexical and non-lexical processes in reading and spelling.

The regular and irregular words were compiled from the Kucera-Francis (KF) written word frequency database (Kucera & Francis, 1967) and from Stanback (1992). For the regular word list, words with a KF frequency of over 350 were classified as high frequency words and words with a KF frequency less than 10 were classified as low frequency. For the irregular word list, words with a KF frequency over 120 were classified as high frequency words and words with a KF frequency of less than 30 were classified as low frequency words.

In order to minimize ceiling effects lists of 70 high and low frequency regular and irregular words where compiled and piloted with 10 post-graduate psychology students who did not participate further in the study. The participants were asked to read the words aloud and to spell the words. From the piloting 54 regular and irregular words each were chosen to be used in the study. Any word that was either read or spelt incorrectly by at least one participant was used in the study. The remainder of the words were chosen in relation to their frequency in order to ensure equal numbers of high and low frequency words (for details see Appendix A). The regular word list consisted of 27 high KF frequency words (Mean KF Frequency= 847.44) and 27 low KF frequency words (Mean KF Frequency= 1.70). The irregular word list also consisted of 27 high KF frequency words (Mean KF Frequency= 1217.40) and 27 low KF frequency words (Mean KF Frequency= 6.85). For each list the words were printed in 12 point Times New Roman font, capitalized, 1.5 spaced and in two columns, centered, on a single sheet of paper (Appendix B). For the nonword list, Form A of the Martin Pratt Nonword Reading test (Martin & Pratt, 2001) consisting of 54 nonwords was presented using the booklet provided.

The Word Identification Subtest of the Woodcock Reading Mastery Test (1987) was used to obtain a general reading age estimate for participants. The National Adult Reading Test (1982) was used to obtain a pre-morbid IQ estimate for each participant. A tape recorder was used to record each of the participants' responses to the three reading lists in order for detailed analysis to be conducted later.

Procedure

The participants were required to attend two sessions with a two- to three-week break between sessions. Before testing began the participants were informed of the purpose of the study and supplied with an information sheet and consent form (Appendix C). The participants were asked to read through the information sheet and consent form and to sign and return the consent form.

The first session took place in class time during which the regular word, irregular word, and nonword spelling lists were administered. The participants were provided with three response sheets, one for each word list. For the regular word and irregular word lists the participants were informed that they would be read each word one at a time. To clarify each word's meaning, the words were said by themselves and then presented in a sentence context and then said alone again. For example, if the word was cat, cat would be said aloud and then in a sentence *"The dog barked at the <u>cat</u>"*, the word cat would then be repeated alone (for details refer to Appendix D). After this time the participants were asked to spell the word by writing it down on the response sheet provided. This procedure was repeated for each of the words on the regular and irregular word lists. The participants were then informed that they were going to be asked to spell some nonwords. Each nonword was said aloud once and then repeated. For each nonword the participants were asked to spell them in the simplest way possible. At the end of this session individual times were booked for participants to complete the second part of the experiment two to three weeks later.

In the second session participants were administered the regular word, irregular word, and nonword reading tests, the Word Identification Subtest and the NART. The participants were informed that their responses would be taped for detailed analysis later and that after analysis the tapes would be destroyed. For the regular word and irregular word reading lists participants were informed that they were going to be shown a list of words and when asked they were to look at each word on the list and say them out loud one at a time. They were informed that all the words on the list were real words and to take as much time as they needed and to try their best. For the nonword reading test participants were informed that they were going to be shown some words that were not real words. They were told that they were funny made-up words but that you can still say them. Participants were asked to look at each word and then say it aloud and to take as much time as they needed. Participants were then presented with a number of practice items before testing began.

The Word Identification Subtest was then presented to the participants and they were asked to say each word that was presented on the page. After this the NART was presented and the participants were informed that they were going to given a list containing English words and they would be required to attempt to pronounce each word on the list. They were informed that all of the words were real English words but that some of them had irregular pronunciations and they may not have seen all of them previously. They were encouraged to attempt to pronounce each of the words even if they were not sure. Participants were informed that no one ever gets them all correct. The participant was then given the list of words and told to proceed when they were ready and to pronounce the words in their own time. There was no time limit for responding to each word. Approval from the Northern Tasmania Social Sciences Human Research Ethics (Tasmania) Network was gained before the study was conducted.

Scoring Procedure

Reading: On the reading tests, the words had to be pronounced accurately to be scored as correct. The pronunciation of nonwords were scored correct if they conformed with spelling-sound correspondence rules or if they were pronounced by analogy with real words. These criteria are the same as those used in previous studies and facilitated comparison with the results of these studies (Baron, 1979; Rohl & Tumner, 1988; Treiman, 1984; Waters et al., 1985; Castles et al., 1997).

Spelling: On the spelling tests, word items had to be spelled exactly, with no errors, to be scored as correct. Any item not attempted was scored as incorrect. Nonwords were scored as correct if the output could be pronounced to sound like the stimulus, either by analogy with a regular or irregular word or by the application of spelling-sound correspondence rules.

Spelling error types: In addition to these scores, the spelling errors for regular and irregular words were classified as either a regularization error or a lexicalization error. Similar to the scoring of nonwords, a misspelling was scored as a regularization error if it could be pronounced to sound like the target item. A misspelling was scored as a lexicalization error if a whole real word was produced instead of the target item. A misspelling of an irregular word was scored as a partial lexicalization error if the word produced contained evidence of partial lexical knowledge but was neither a complete regularization nor lexicalization. For example, if the word *foreign* was spelt as *'foriegn'* it was scored as a partial lexicalization error as the irregular component of the word has been misspelled however the spelling indicates partial lexical knowledge on the part of the speller.

Word Identification Subtest: On this subtest words had to be pronounced accurately to be scored correct. All correct responses were added together to produce a raw score. The raw score was then converted into an age-equivalent score. [For full details on the conversion of raw scores to age-equivalent scores readers are referred to Woodcock (1987)].

NART: From the NART an estimation of each participants pre-morbid IQ was produced by adding together the number of incorrectly pronounced words to give a raw error score that was then converted into an estimated IQ. [For full details on the production of an estimated pre-morbid IQ using the NART readers are referred to Nelson (1982)].

Design and Data Analysis

The study utilized a correlation design to assess the relationship between participants reading and spelling ability. Correlation coefficients were obtained for the relationships between reading and spelling scores for regular words, irregular words, and nonwords. McNemar's (1962) formula was used to determine the significant differences between the individual pairs of correlations.

The study utilized a 2x3x2 mixed design. The first independent and between groups variable was Reading Age Group with two levels, reading age above 20 and reading age below 20 as measured by the Woodcock Reading Mastery Word Recognition subtest. All further independent variables were repeated measures and included: Word Type with three levels, regular words, irregular words, and nonwords, and Task Type with two levels, reading and spelling. The dependent variables were the number of words correctly read and spelt on the regular word, irregular word, and nonword lists. Where required Post Hoc tests in the form of break down ANOVAs and analysis of simple main effects were used with a Bonferroni adjusted *p* value.

The study further utilized a 3x3 mixed design. The first independent and between groups variable was Reading Reliance Group with three levels, no reliance, lexically reliant, and non-lexically reliant. The second independent variable was a repeated measures factor and included: Word Type with three levels, regular words, irregular words, and nonwords. The dependent variable was the number of words correctly spelt on the regular word, irregular word, and nonword spelling lists.

Further the study utilized a 3x3x3 mixed design. The first independent and between groups variable was Reading Reliance Group with three levels, no reliance, lexically reliant, and non-lexically reliant. All further independent variables were repeated measures and included: Word Type with three levels, regular words, irregular words, and nonwords, and Spelling Error Type with three levels, regularizations, lexicalizations, and partial lexicalizations. Where required, Post Hoc tests in the form of break down ANOVAs and analysis of simple main effects were used with a Bonferroni adjusted *p* value.

Results

The data of the participants from all the tests were collected and collated (refer to Appendices E and F). The percentage of correct responses for the regular word, irregular word, and nonword reading and spelling tests are shown in comparison to those of Castles et al. (1997) in Table 1.

Table 1. Mean percentage correct (standard deviations in parenthesis) for each word type on reading and spelling tests.

	2004	Castles et al.	2004	Castles
Word Type	Reading		Spelling	
Regular	97.00 (2.26)	84.5 (18.6)	93.42 (5.47)	59.5 (21.0)
Irregular	90.58 (7.07)	50.00 (14.8)	82.77 (10.75)	24.5 (15.0)
Nonwords	83.45 (9.16)	65.2 (23.1)	68.30 (12.00)	63.5 (20.5)

The results of the current study indicate that overall participants correctly read a higher percentage of irregular words and nonwords than they spelt. In comparison to the results of Castles et al. (1997) it can be seen that for the irregular word and nonword reading tests and regular word and irregular word spelling tests, the participants from the current study obtained a higher percentage of correct responses. These differences may have occurred because Castles et al. used mainly low frequency words. The use of an equal number of high and low frequency words in the current study may have allowed participants to make fewer errors when responding. A second reason that could account for these differences is that the participants were at different stages of reading and spelling development. The participants from the Castles et al. study were children with an average age of eight years and five months whereas the participants in the current study were adults with an average age of 22 years and six months. As such the participants in the Castles et al. study were still acquiring reading and spelling skills while the participants in the current study had acquired these skills. While the percentage of correct responses for the regular reading test were similar for participants from both studies this may also be explained by the developmental level of the participants. The reading of regular words is acquired early in reading development and as such a difference would not be expected.

The mean percentage correct for each task with word types separated into high and low frequency groups are shown in Table 2. The results indicate that participants had a low percentage of correct responses for irregular low frequency words for the spelling task and nonwords for both reading and spelling tasks. Performance on all other reading and spelling tasks was near ceiling.

Table 2. Mean percentage correct (standard deviations in parentheses) for each word type and frequency on reading and spelling tests.

Word Type	Reading	Spelling
Regular High Frequency	99.75 (1.34)	99.69 (1.56)
Regular Low Frequency	94.19 (3.93)	87.09 (9.94)
Irregular High Frequency	99.25 (1.77)	98.76 (2.94)
Irregular Low Frequency	82.16 (13.21)	67.16 (19.05)
Nonwords	83.33 (9.24)	68.30 (12.00)

Correlation Analysis

In order to test the hypothesis that both rules and word specific associations are involved in reading and spelling a correlation analysis was performed. It was hypothesized that there would be a significant difference between the pairs of dependent correlations. It was hypothesized that r_{NR} would be significantly greater than r_{NI}. It was also hypothesized that r_{IR} would be significantly greater than r_{NR}. If both rules and word specific associations are being used to read and spell it was hypothesized that the difference between r_{NR} and r_{IR} would not be significant. The results, in comparison to those of both Castles et al. (1997) and Treiman (1984), are shown in Table 3. As can be seen the correlations for reading in the current study were all weaker than those found by Castles et al. and Treiman. The weaker correlations may have been due to a ceiling effect in the regular reading task as the majority of participants achieved 53 to 54 correct out of 54. In relation to the correlations for spelling, r_{NR} was weaker in comparison to the correlations found by Castles et al. and Treiman. The r_{NI} correlation was similar to that found by Castles et al. but weaker than that found by Treiman. However r_{IR} was stronger than that found by Castles et al. and Treiman.

Table 3. Correlations of the number of correct responses for the regular, irregular, and nonword reading and spelling tests in comparison to the results of Treiman (1984) and Castles et al. (1997).

	Reading Aloud			Spelling		
Correlation Coefficient	2004 Results	Castles (N=128)	Treiman (N=45)	2004 Results	Castles (N=128)	Treiman (N=45)
r_{NR}	.32	.84	.81	.59	.66	.89
r_{IR}	.25	.72	.75	.84	.72	.73
r_{NI}	.48	.71	.55	.56	.44	.67

McNemar's (1962) formula was used to test for significant differences between the pairs of dependent correlations. On the reading tasks, it was found that in contrast to the results of Castles et al. (1997) and Treiman (1984), r_{NR} was not significantly greater than r_{NI}, $t(57)=1.15, p>.05$. This indicates that there was no difference in the affect of rules on participants' accuracy in reading regular words compared with irregular words. Similar to Castles et al.'s findings, but in contrast to Treiman's findings, r_{IR} was found not to be significantly greater than r_{NI}, $t(57)=1.70, p>.05$. This gives no clear indication of word-specific information being used in reading regular words. Further, consistent with the results of Treiman but in contrast to those of Castles et al., r_{NR} was not significantly greater than r_{IR}, $t(57)=0.55$, $p>.05$. Therefore this indicates that neither rules nor word-specific information was more important for the reading of regular words. Overall these results suggest that for adults in this study neither rules nor word-specific associations were more important for reading regular words.

In relation to the spelling tasks it was found that in contrast to both the findings of Castles et al. and Treiman, r_{NR} was not significantly greater than r_{NI}, $t(57)=0.50$, $p>.05$. This indicates that, as was found for reading in this study, there was no difference in the effect of rules on participants' accuracy in spelling regular words compared with irregular words. Similar to the results of Castles et al. but in contrast to Treiman's results, r_{IR} was significantly greater than r_{NI}, $t(57)=4.34$, $p<.05$. This suggests that for spelling, word-specific associations were being used by the participants to spell regular words. Further, in contrast to Castles et al. and Treiman, r_{IR} was found to be significantly greater than r_{NR}, $t(57)=3.84$, $p<.05$. This indicates that for spelling, word-specific associations were a more important determinant of adult's ability to spell regular words than was the use of rules. Overall for spelling these results indicate that word-specific associations were being used to spell regular words.

Word Frequency

In order to test the hypotheses that significantly more high frequency irregular words would be read and spelt correctly compared to low frequency irregular words one-way ANOVAs were conducted with the number of correctly read and spelt high and low frequency irregular words being the dependent variable. For reading, there was a significant main effect of Frequency $F(1,59)=104.18$, $p<.001$ indicating that significantly more high frequency irregular words were read correctly than low frequency irregular words. For spelling, there was also a significant main effect of Frequency $F(1,59)=194.26$, $p<.001$ indicating that significantly more high frequency irregular words were spelt correctly than low frequency irregular words. In addition one-way ANOVAs were conducted with the number of correctly read and spelt high and low frequency regular words being the dependent variable. For reading, there was a significant main effect of Frequency $F(1,59)=135.00$, $p<.001$ indicating that significantly more high frequency regular words were read correctly than low frequency regular words. For spelling, there was also a significant main effect of Frequency $F(1,59)= 116.78$, $p<.05$ indicating that significantly more high frequency regular words were spelt correctly than low frequency words.

Groups Selected on Reading Age

The Word Identification subtest of the Woodcock Reading Mastery Test – Revised (1987) was used to determine each participant's reading age. The reading age groups were then selected by calculating the average reading age (Mean=22.18) and participants were then separated into two groups; reading age below 20 and reading age above 20. The characteristics of the two groups and total sample are shown in Table 4.

A 2 (Reading Age Group: reading age below 20; reading age above 20) x 2 (Task Type: Reading; Spelling) x 3 (Word Type: Regular; Irregular; Nonword) mixed analysis of variance (ANOVA) was performed in order to confirm that the reading and spelling ability of participants conformed to the reading age groups that they were placed into.

Table 4. Mean age, reading age, predicted IQ, regular word, irregular word, and nonword reading and spelling (standard deviations in parentheses) and number of males and females of the reading age groups and total sample.

	Reading Age Above 20	Reading Age Below 20	Total Sample
Age	22.03 (5.65)	22.30 (6.33)	22.17 (5.95)
Number of Males	6	3	9
Number of Females	24	27	51
Woodcock Reading Mastery Test Predicted Age Equivalent Score	29.11 (4.14)	16.63 (2.55)	22.87 (7.16)
National Adult Reading Test Pre-morbid IQ estimate	106.70 (5.05)	101.10 (5.46)	103.90 (5.93)
Regular Word Reading	52.47 (.86)	52.30 (1.51)	53.28 (1.22)
Irregular Word Reading	50.20 (2.68)	47.63 (4.36)	48.92 (3.81)
Nonword Reading	47.50 (1.81)	42.63 (5.85)	45.07 (4.95)
Regular Word Spelling	51.67 (1.62)	49.23 (3.47)	50.45 (2.95)
Irregular Word Spelling	46.47 (4.77)	42.93 (6.26)	44.70 (5.80)
Nonword Spelling	39.73 (3.77)	34.03 (7.37)	36.88 (6.48)

The dependent variables were the number of correct responses for the regular word, irregular word, and nonword reading and spelling tests. The main effects of Task Type $F(1,58)=164.29$, $p<.001$, and Word Type $F(2,116)=243.63$, $p<.001$ were significant. These main effects were modified by significant two-way interactions. There was a significant two-way interactions between Task Type and Word Type $F(2,116)=43.50$, $p<.001$. As shown in Figure 1 participants read more regular, irregular and nonwords correctly than they spelt. Post Hoc analysis of simple main effects revealed that participants read more regular words $t(59)=5.49$, $p<.001$, irregular word $t(59)=9.67$, $p<.001$, and nonwords $t(59)=10.80$, $p<.001$ correctly than they spelt. It was further shown that participants read significantly more regular words correctly than irregular words $t(59)=7.25$, $p<.001$, and nonwords $t(59)=12.07$, $p<.001$. It was also shown that participants read significantly more irregular words correctly than nonwords $t(59)=6.59$, $p<.001$. In addition it was revealed that participants spelt significantly more regular words correctly than irregular words $t(59)=12.08$, $p<.001$ and nonwords $t(59)=19.85$, $p<.001$. Finally it was shown that participants spelt significantly more irregular words correctly than nonwords $t(59)=10.52$, $p<.001$.

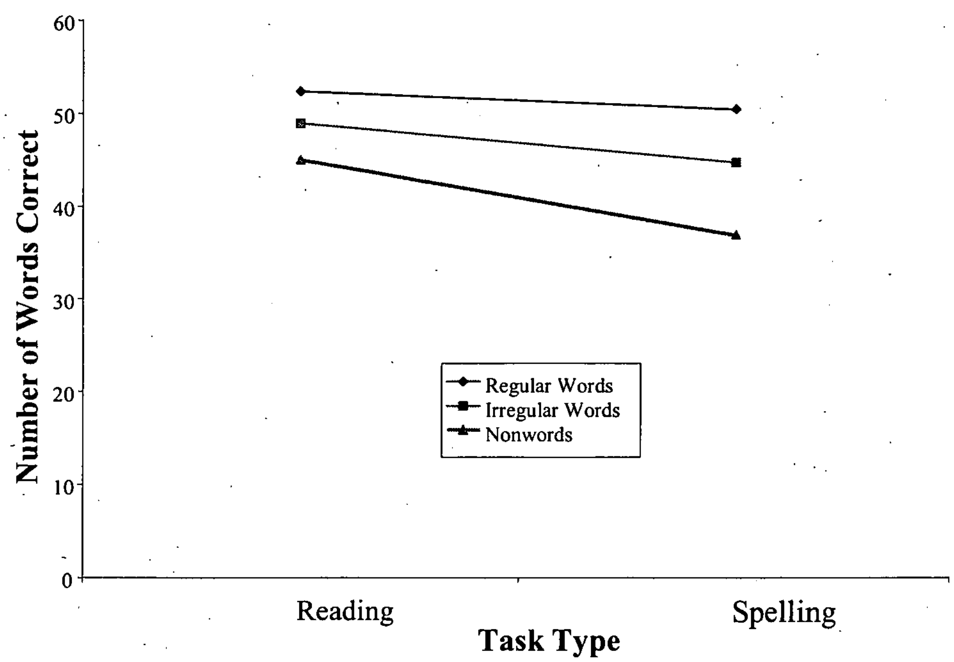

Figure 1. Mean number of regular words, irregular words, and nonwords read and spelt correctly by participants.

There was also a significant two-way interaction between Word Type and Reading Age Group $F(1,116)=8.50$, $p<.001$. As shown in Figure 2 participants with a Reading Age above 20 read and spelt more nonwords correctly than participants with a Reading Age below 20. Post Hoc analysis of simple main effects revealed that participants with a Reading Age above 20 read and spelt significantly more regular words $t(58)=2.97$, $p<.05$, irregular words $t(58)=2.69$, $p<.05$, and nonwords $t(58)=4.71$, $p<.05$, correctly than those with a Reading Age below 20. It was also shown that participants with a Reading Age above 20 read and spelt significantly more regular words correctly than irregular words $t(29)=6.81$, $p<.001$, and nonwords $t(29)=18.76$, $p<.001$. It was further shown that participants with a Reading Age above 20 also read and spelt significantly more irregular words correctly than nonwords $t(29)=7.53$, $p<.001$. It was also shown that participants with a Reading Age below 20 read and spelt significantly more regular words correctly than irregular words $t(29)=8.15$, $p<.001$ and nonwords $t(29)=14.75$, $p<.001$. Finally it was shown that participants with a Reading Age below 20 read and spelt significantly more irregular words than nonwords $t(29)=17,18$, $p<.001$

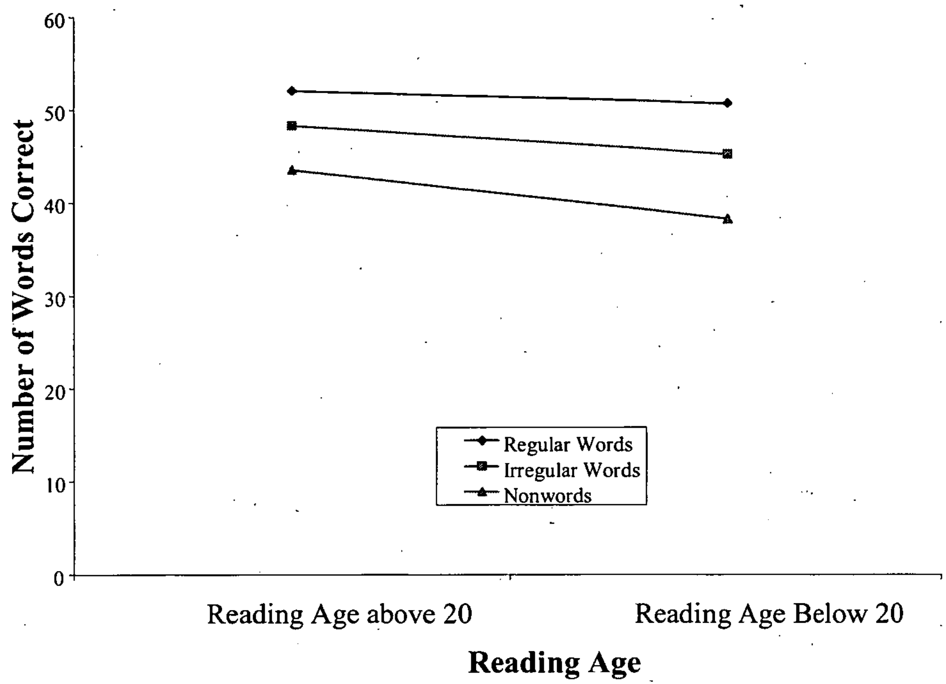

Figure 2. Mean number of regular words, irregular words, and nonwords read and spelt correctly by participants with reading ages above and below 20.

There was a trend towards a significant two-way interaction between Task Type and Reading Age Group $F(1,116)=3.56, p=.064$. As is shown in Figure 3 participants with a Reading Age above 20 appear to have been better at spelling the words types than participants with a Reading Age below 20.

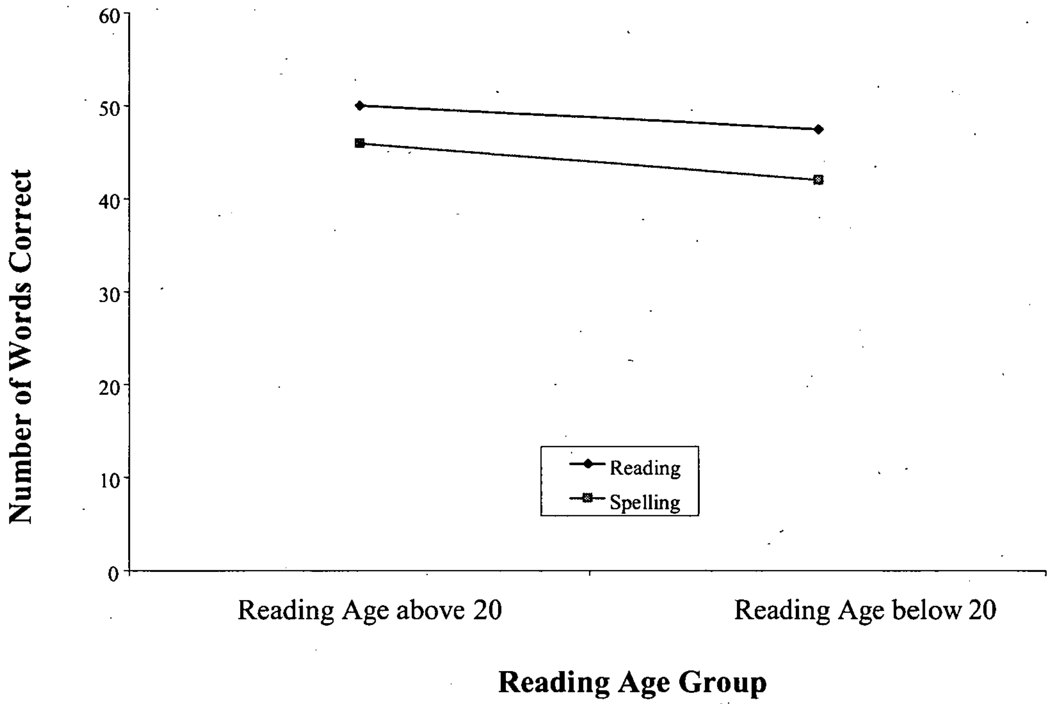

Figure 3. Mean number of regular words, irregular words, and nonwords, read and spelt correctly by participants with reading ages above and below 20.

The three-way interaction between Task Type, Word Type and Reading Age Group was not significant $F(2,116)=.63, p>.05$.

Groups Selected on Reading Reliance

In order to investigate the effect of reading reliance, groups were selected using the same procedure as that used by Castles et al. (1997). Reading reliance was calculated by converting participants' scores to *z* scores and then subtracting each participant's nonword *z* score from their irregular word *z* score. A high positive difference score reflected relatively better irregular word reading than nonword reading and was taken to indicate lexical reliance. A high negative difference score indicated relatively better nonword than irregular word reading and was taken to indicate non-lexical reliance. The characteristics of the three groups are shown in Table 5.

Table 5. Mean age, reading age, predicted IQ, regular word, irregular word, and nonword spelling and reading, *z* scores (standard deviations in parentheses) and number of males and females of the reading reliance groups.

	No Reliance	Non-Lexical Reliance	Lexical Reliance
Age	24.45 (9.37)	21.62 (3.64)	20.62 (1.52)
Males	3	1	5
Females	17	15	19
Woodcock Reading Mastery Test Predicted Age Equivalent Score	24.00 (5.62)	24.64 (7.93)	20.75 (7.51)
National Adult Reading Test Pre-morbid IQ Estimate	105.35 (4.42)	103.18 (6.63)	103.16 (6.53)
Regular Word Spelling	51.20 (1.88)	49.50 (3.82)	50.45 (2.96)
Irregular Word Spelling	45.80 (3.98)	41.93 (7.20)	45.62 (5.67)
Nonword Spelling	38.60 (5.04)	35.68 (7.90)	36.25 (6.48)
Regular Word Reading	52.50 (0.94)	52.63 (0.88)	52.13 (1.56)
Irregular Word Reading	50.35 (1.81)	45.94 (4.49)	49.71 (3.59)
Nonword Reading	47.15 (2.56)	47.44 (2.09)	41.75 (5.94)
Z Score	-0.04 (0.21)	-1.25 (0.91)	0.87 (0.55)

In order to examine the effect of word frequency on reading reliance, reading reliance was also calculated for high and low frequency words separately. As is shown in Table 6 for high frequency words a higher percentage of participants were reliant on neither route however for low frequency words a higher percentage of participants were reliant on the lexical route.

Table 6. Mean percentage of reliance on lexical, non-lexical or neither process for high and low frequency words.

	No Reliance	Non-Lexical Reliance	Lexical Reliance
High Frequency	36.66%	30%	33.33%
Low Frequency	31.66%	31.66%	36.66%

It was hypothesised that lexically reliant readers would spell significantly more irregular words correctly than non-lexically reliant readers and that non-lexically reliant readers would spell significantly more nonwords correctly than lexically reliant readers. In order to test these hypotheses a 3 (Reading Reliance Group: No Reliance, Lexical Reliance, Non-lexical Reliance) x 3 (Word Type: Regular, Irregular, Nonword) mixed ANOVA was performed. The dependent variables were the number of correctly spelt regular words, irregular words, and nonwords. The main effect of Word Type was significant $F(2,114)=2016.76$, $p<.001$ indicating that all participants, regardless of reading reliance, spelt significantly more regular words correctly than irregular words or nonwords. The two-way interaction between Word Type and Reading Reliance Group was not significant $F(4,114)=1.59$, $p>.05$.

Spelling Error Analysis

The percentages of each reading reliance group's spelling errors that were either a regularisation, lexicalisation, or partial lexicalisation error were computed. As some participants did not make any mistakes and others only made mistakes of one or two types but not all three, analyses of each error type was conducted separately with data from participants who did make an error of that particular type.

The percentages of spelling errors on regular and irregular words that were regularisation errors, compared with the results of Castles et al. (1997), are shown in Table 7. Similar percentages of errors were found in comparison to the regularisation errors made by the groups in Castles et al.'s study except for the percentage of regularisation errors made by the lexically reliant groups for irregular words. In this study there were a higher percentage of regularisation errors for irregular words made by the lexically reliant group compared to Castles et al.'s lexically reliant group.

Table 7. Mean percentage of spelling errors that were regularisations (with standard deviations in parenthesis) for each word type as a function of reading reliance group.

	2004	Castles et al. (1997)	2004	Castles et al. (1997)
Reading Reliance Group	Regular Words		Irregular Words	
No Reliance	41.66 (21.67)	41.1 (23.1)	45.18 (22.52)	33.4 (15.9)
Non-lexical Reliant	35.68 (12.55)	48.8 (21.4)	31.11 (15.39)	36.9 (16.9)
Lexical Reliance	40.27 (12.92)	37.5 (34.6)	40.02 (19.85)	21.0 (12.4)

It was hypothesised that the non-lexically reliant group would make significantly more regularisation errors than the lexically reliant group. One-way ANOVAs indicated that there were no significant differences between the three groups in the percentage of regularisation errors made for either regular words $F(2,29)=.36$, $p>.05$, or irregular words $F(2,29)=2.27$, $p>.05$

The percentages of spelling errors on regular words, irregular words, and nonwords that were lexicalisations, compared with the results of Castles et al. (1997), are shown in Table 8. A higher percentage of lexicalisation errors for both regular words and irregular words were found in this study compared with Castles et al.'s study.

It was hypothesised that the lexically reliant group would make significantly more lexicalisation errors than the non-lexically reliant group. One-way ANOVAs indicated that there were no significant differences between the three groups in the

Table 8. Mean percentage of spelling errors that were lexicalisations (with standard deviations in parenthesis) for each word type as a function of reading reliance group.

	2004	Castles et al. (1997)	2004	Castles et al. (1997)	2004	Castles et al. (1997)
Reading Reliance Group	Regular Words		Irregular Words		NonWords	
No Reliance	52.87 (32.69)	6.4 (6.3)	20.12 (6.29)	5.5 (4.6)	9.37 (3.8)	7.8 (8.8)
Non-lexical Reliance	40.43 (26.90)	7.0 (7.3)	17.19 (5.83)	5.6 (4.6)	9.60 (5.10)	4.6 (7.1)
Lexical Reliance	37.00 (23.74)	13.7 (13.1)	16.44 (8.87)	2.8 (5.4)	9.49 (3.97)	5.6 (7.3)

percentage of regularisation errors made for either regular words $F(2,54)=1.68, p>.05$, irregular words $F(2,40)=.92, p>.05$, or nonwords $F(2,50)=.01, p>.05$.

The percentage of spelling errors on irregular words that were partial lexicalisations, compared with the results of Castles et al. (1997), are shown in Table 9. In contrast to the results found by Castles et al. a higher percentage of partial lexicalisation errors were found for both the no reliance group and non-lexically reliance group.

It was hypothesised that the lexically reliant group would make significantly more partial lexicalisation errors than the non-lexically reliant group. A one-way

ANOVA indicated that there were no significant differences between the three groups in the percentage of partial lexicalisation errors made for irregular words $F(2,46)=.09$, $p>.05$.

Table 9. Mean percentage of spelling errors that were partial lexicalisations (with standard deviations in parenthesis) for irregular words as a function of reading reliance group.

	2004	Castles et al. (1997)
Reading Reliance Group	Irregular Words	
No Reliance	26.51 (12.38)	13.1 (12.6)
Non-lexical Reliance	27.64 (13.28)	12.7 (7.1)
Lexical Reliance	25.61 (11.49)	22.7 (14.6)

A further analysis was conducted using all participants in an analysis for each error type. The percentage of regularisation errors, lexicalisation errors and partial lexicalisation errors made by each reliance group was calculated for each word type in order to determine if reliance groups differed in their overall propensity to make each type of error.

The overall percentage of regularisation errors made by each reliance group for regular and irregular words is shown in Table 10. As can be seen the results indicate that for regular words the three reliance groups made a similar percentage of regularisation errors. The results also indicate that in relation to irregular words the no reliance group made a higher percentage of regularisation errors than either the lexically reliant or non-lexically reliant groups.

Table 10. Overall mean percentage of spelling errors that were regularisation errors (with standard deviations in parenthesis) for regular words and irregular words as a function of reading reliance group.

	Regular Words	Irregular Words
No Reliance	18.51 (25.44)	45.18 (22.52)
Non-lexical Reliance	20.07 (20.25)	31.11 (15.39)
Lexical Reliance	22.76 (22.53)	40.02 (19.85)

The overall percentage of lexicalisation errors made by each reliance group for regular words, irregular words, and nonwords is shown in Table 11. As can be seen the results indicate that in relation to regular words the no reliance group made a higher percentage of errors that were lexicalisation errors than either the non-lexically reliant or lexically reliant groups. In relation to irregular words the results indicate that the reading reliance groups made a similar percentage of lexicalisation errors. In relation to nonwords the results also indicate that the reading reliance groups made a similar percentage of lexicalisation errors.

Table 11. Overall mean percentage of spelling errors that were lexicalisation errors (with standard deviations in parenthesis) for regular words, irregular words, and nonwords as a function of reading reliance group.

	Regular Words	Irregular Words	Nonwords
No Reliance	52.87 (32.69)	12.07 (11.19)	7.50 (5.16)
Non-Lexical Reliance	40.43 (26.90)	13.96 (8.67)	9.00 (5.48)
Lexical Reliance	33.78 (25.02)	10.96 (10.68)	7.91 (5.11)

The overall percentage of partial lexicalisation errors made by each reliance group for irregular words is shown in Table 12. The results indicate that the three reading reliance groups made a similar percentage of partial lexicalisation errors for irregular words.

Table 12. Overall mean percentage of spelling errors that were partial lexicalisation errors (with standard deviations in parenthesis) for irregular words as a function of reading reliance group.

	Irregular Words
No Reliance	22.53 (14.95)
Non-lexical Reliance	22.46 (16.29)
Lexical Reliance	18.14 (15.27)

Discussion and Conclusions

The aims of this study were to investigate the processing mechanisms involved in reading and spelling through the use of separate regular word, irregular word, and nonword reading and spelling tests. The study aimed to extend the research conducted by Treiman (1984) and Castles et al. (1997) through an investigation into the use of rules and word-specific associations in reading and spelling in adults. It further aimed to examine the effects of word frequency and reading age on participants' reading and spelling performance. In addition the study explored the spelling performance of lexically reliant, non-lexically reliant, and no reliance readers as well as the regularisation, lexicalisation, and partial lexicalisation errors made on tests of spelling.

In relation to the use of rules and word-specific associations in reading and spelling it was hypothesized that there would be a significant difference between the pairs of dependent correlations. It was hypothesized that r_{NR} would be significantly greater than r_{NI}. It was also hypothesized that r_{IR} would be significantly greater than r_{NR}. If both rules and word specific associations are being used to read and spell it was hypothesized that the difference between r_{NR} and r_{IR} would not be significant. For reading, the correlation analysis performed indicated that neither rules (r_{NR} was not significantly greater than r_{NI}) nor word-specific associations (r_{IR} was not significantly greater than r_{NI}) were involved in reading nor was either a more important determinant (r_{NR} was not significantly greater than r_{IR}) of reading. These results differ from results found previously with children including those of Baron (1979) who found that both rules and word specific associations were involved in reading but neither process was found to be a more important determinant of reading ability. Similar to the current study, Treiman (1984) found that neither rules nor word-specific associations were a more important determinant of ability to read regular words. However, Treiman (1984) also found that both rules and word-specific associations were involved in the reading of regular words. In contrast to the results of the current study Castles et al. (1997), found evidence for the involvement of rules but not word-specific associations. In addition Castles et al. found that rules were a more important determinant of ability to read regular words than word-specific associations. When the results of the current study are compared to these previous studies they indicate that adults differ in their use of rules of the non-lexical route and word-specific associations of the lexical route in comparison to children. It appears that adults utilise both lexical and non-lexical processes equally whereas children appear to rely more on one or other process. Therefore, as has been found by Martin et al. (2003), the use of lexical and non-lexical processes may increase with age with older readers having superior processing skills compared to younger readers. Caution needs to be taken, however, in interpreting these weak correlations as there was a ceiling effect in relation to the reading of regular words which may have distorted the correlations. The ceiling effect may account for the differences found between the results found by Treiman and Castles et al. and those of the current study.

The results of the correlation analysis for spelling differed somewhat to those found for reading. For spelling the results indicated that rules were not involved in spelling regular words (r_{NR} was not significantly greater than r_{NI}), however, word-specific associations were found to be involved in spelling regular words (r_{IR} was significantly greater than r_{NI}) and were found to be a more important determinant of ability to spell regular words than rules (r_{IR} was found to be significantly greater than r_{NR}). These results also differ to those previously found by Castles et al. (1997) and Treiman (1984). Castles et al. found that neither rules nor word-specific associations were a more important determinant of ability to spell regular words and that both rules and word specific associations were involved in spelling regular words. However, Castles et al. did find that r_{IR} was greater than r_{NR} but not significantly indicating that as was found in the current study the lexical route was involved in the spelling of regular words. Conversely, Treiman (1984) found that only rules were involved in spelling and that rules were a more important determinant of ability to spell regular words than word-specific associations. In contrast to the current study Treiman found the non-lexical route to be involved in the spelling of regular words.

The differences in results between those found in the current study and those of Treiman (1984) indicate that it is possible that the way an individual is taught to spell either using a whole-word method or a phonics based method can influence patterns of reliance. As in Castles et al.'s (1997) study, it is possible that the participants of the current study were taught using a whole-word method rather than a phonics method. While data was not collect on how participants were taught to read and spell, given state educational policy at the time, it is probable that the majority of participants were taught using the whole-word method. As such, what the results of this study, and those conducted by Castles et al. and by Treiman highlight is that both lexical and non-lexical procedures can be used to spell regular words but which is used may be determined by how an individual is taught to spell. This would also account for why the spelling of nonwords was considerably poor in the current study. If participants were relying on the word-specific association of the lexical route and since nonwords do not have a representation in the lexicon, they may have guessed the spelling of the word as they did not have suitable knowledge of rules to be able to spell the nonword using the non-lexical route correctly. While there was not a significant difference in the use of rules and word-specific associations for reading, what was shown was that participants were significantly better at reading irregular words than nonwords. This indicates that as with spelling participants did not have adequate knowledge of rules to be able to correctly read nonwords which would occur if participants were taught to read using a whole-word reading method.

In relation to the effect of word frequency it was hypothesised that significantly more high frequency irregular words would be read and spelt correctly compared to low frequency irregular words. As was found by Kreiner and Gough (1990) and McCusker et al. (1981), participants produced fewer errors on high frequency irregular words than low frequency irregular words for both reading and spelling. In addition it was found that participants produced fewer errors on high frequency regular words than on low frequency regular words for both reading and spelling tests. These results indicate that as was found by Kreiner and Gough and McCusker et al. word frequency does have an effect on reading and spelling performance at least for adults. The effect of word frequency on the reading and spelling performance of children is not known however as previous studies have not taken word frequency into consideration.

Nevertheless, contrary to the assertions of Kreiner and Gough (1990) and McCusker et al. (1981) there was no evidence to suggest that high and low frequency irregular words rely on different routes for processing. Examination of reading reliance for high frequency irregular words indicated that a higher proportion of participants relied on neither process to read these words while for low frequency irregular words a higher proportion of participants relied on the lexical route. This indicates that rather than treating low frequency irregular words as nonwords and relying on the non-lexical route, participants relied on the lexical route to read low frequency irregular words. Therefore, as is proposed in dual-route models of reading, known irregular words are stored in the mental lexicon (Coltheart, 1979; Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) and for adults this does not appear to be affected by the word's frequency. As adult readers have more words stored in their mental lexicon and in particular more low frequency irregular words stored than children it is not known whether word frequency affects the way in which low frequency irregular words are processed by children.

In examining the effects of word frequency on participants' use of the lexical and non-lexical procedures consideration needs to be made, however, to the way in which the regular and irregular word lists were constructed and presented. In the study by Trieman (1984) the regular and irregular words were matched visually and presented in separate lists while in the study by Castles et al. (1997) the words were matched on frequency but presented in mixed lists. In the present study the frequency of the words was deliberately manipulated so that there was an equal distribution of high and low frequency words and they were presented in separate lists. The use of an equal number of high and low frequency words for both regular and irregular words may have affected the results of the currents study. Using an equal number of high and low frequency words contributed to a ceiling effect which restricted the range of responses that could be produced by participants. Using more low frequency words may have increased the range of responses and thus increased the likelihood of capturing the range of lexical and non-lexical abilities of the adults. It appears from the current research and previous studies conducted by Treiman and Castles et al. that the most appropriate way to examine lexical and non-lexical processed may be to carefully match regular and irregular words on frequency and present them in separate lists. Further research using this method is required in order to establish the utility of this procedure.

In relation to the effect of reading age on performance of reading, as was found by Waters et al. (1985), participants with a higher reading age produced significantly fewer errors on irregular words and nonwords than those with a lower reading age. For spelling, however, reading age was not found to affect performance on irregular words and nonwords indicating that, for adults, reading and spelling are differentially affected by reading age. This also indicates that for adults chronological age is an inappropriate grouping variable when assessing reading performance as differences found may be due to experience with written language, stages in reading acquisition or difficulty in the task material (Backman et al., 1984). As Treiman (1984) did not assess the reading age of participants so it is unclear how reading age may have affected the performance of the children however from the results of the current experiment it is clear that reading age does affect the reading performance of adults. Therefore, when assessing participants reading and spelling performance it appears appropriate to control for the effects of reading age by either making reading age a separate variable or as was done by Castles et al. controlling for the effects by using participants with similar reading ages.

In relation to the spelling performance of reading reliance groups it was hypothesised that lexically reliant readers would spell significantly more irregular words correctly than non-lexically reliant readers. It was also hypothesized that non-lexically reliant readers would spell significantly more nonwords correctly than lexically reliant readers. In contrast to these hypotheses there were no differences found in the number of irregular words and nonwords spelt correctly by lexically reliant, non-lexically reliant, and no reliance readers. In relation to the types of errors made by the reading reliance groups it was hypothesised that the non-lexical reliant group would make significantly more regularisation errors than the lexical reliant group. It was also hypothesised that the lexically reliant group would make significantly more lexicalisation errors than the non-lexically reliant group. It was further hypothesised that the lexically reliant group would make significantly more partial lexicalisation errors than the non-lexically reliant group. When the spelling errors of the reading reliance groups were examined, however, no differences in the number of regularisation errors, partial lexicalisation errors, or lexicalisation errors were found. While these results are in contrast to those found by both Treiman (1984) and Castles et al. (1997) they are congruent with the other findings of this study. In the current study participants utilised the lexical and non-lexical processing mechanisms differently to read and spell. In reading there was equal use of the processing mechanisms while in spelling there was reliance on the lexical route. Thus, it is not unexpected that there were no similarities in reading and spelling performance or types of errors made by the reading reliance groups. It appears that for such patterns to be found reliance needs to be consistent across domains.

The results of the current study support the previous finding by Treiman (1984) and Castles et al. (1997) that both lexical and non-lexical processes are involved spelling. The results are also consistent with the dual-route model of spelling proposed by Caramazza (1988) and Tainturer and Rapp (2000). The results do not, however, support the notion of their being a continuum for normally developed adult readers or spellers from 'Phoenician' to 'Chinese' as found in children by Baron (1979), Treiman, and Castles et al.. In contrast to research using children, in the current study there was no evidence of individual differences on reliance on lexical and non-lexical processing mechanism for reading suggesting that these are used equally in this population. For spelling, rather than there being a continuum, adult's reliance appeared to be affected by the way in which the participants were taught to spell using either a whole-word or phonics method. In addition this study demonstrates that reading age affects the reading performance of adults, while word frequency affects both the reading and spelling performance of adults. It is not yet known how reading age or word frequency affects the reading and spelling performance of children, therefore caution needs to be taken in interpreting the results of children and in extrapolating the finding to adults. In addition both the Word Identification test of the Woodcock reading mastery test –revised (1987) and NART overlap in theory with the tests of regular and irregular words used in this study which may have affected the results of the study because of the similar nature of the testing material.

While this study provides further support for the dual-route account of spelling some caution needs to be taken in interpreting the results as exposure to whole-word and phonics based teaching methods was not explored in the current study. However as it appears that teaching methods may affect the use of lexical and non-lexical processing mechanisms in reading and spelling future research may like to examine the effect of teaching methods on processing mechanisms and how such methods may best be combined in the teaching of reading and spelling in order to maximise these processes.

References

Backman, J.E., Mamen, M., & Ferguson, H. B. (1984). Reading level design: conceptual and methodological issues in reading research. *Psychological Bulletin, 96*, 560-568.

Baron, J. (1979). Orthographic and word-specific mechanisms in children's reading of words. *Child Development, 50*, 60-72.

Caramazza, A. (1988). Some aspects of language processing revealed through the analysis of acquired dysgraphia: The lexical system. *Annual Review of Neuroscience, 11*, 395-421.

Castles, A., Holmes, V. M., & Wong, M. (1997). Variations in spelling style among lexical and sublexical readers. *Journal of Experimental Child Psychology, 64*, 98-118.

Coltheart, M. (1979). Lexical access in simple reading tasks. In G. Underwood (Ed.), *Strategies of information processing* (pp.151-216). London: Academic Press.

Coltheart, M., Curtis, B., Atkins, P., & Haller, M. (1993). Models of reading aloud: Dual-route and parallel-distributed-processing approaches. *Psychological Review, 4*, 589-608.

Coltheart, M., Rastle. K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascade model of visual word recognition and reading aloud. *Psychological Review, 108*, 204-256.

Ellis, A. W. (1982). Spelling and writing (and reading and speaking). In A. W. Ellis (Ed.), *Normality and pathology in cognitive functions.* New York: Academic Press.

Ehri, L.C. (1980a). The development of orthographic images. In U. Frith (Ed.), *Cognitive processes in spelling* (pp. 311-338). London: Academic Press.

Ehri, L.C. (1980b). The role of orthographic images in learning printed words. In J.F. Kavanagh & R.L. Venezky (Eds.), *Orthography, reading, and dyslexia* (pp. 155-170). Baltimore: University Park Press.

Ehri, L.C. (1992). Reconceptualising the development of sight word reading and its relationship to recoding. In P.B. Gough, L.C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 107-144). Hillsdale NJ: Erlbaum.

Ehri. L.C. (1992). Sight word learning in normal readers and dyslexics. In B.A. Blachman (Ed.), *Foundations of reading acquisition and dyslexia: Implications for early intervention* (pp. 163-189). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Ehri, L.C., & Wilce, L.S. (1980). The influence of orthography on readers' conceptualization of the phonemic structures of words. *Applied Psycholinguistics, 1*, 371-385.

Frith, U., & Frith, C. (1980). Relationships between reading and spelling. In R. Venezky, & J. Kavanagh (Eds.), *Orthography, reading, and dyslexia* (pp287-297). Baltimore: University Park Press.

Folk, J. R., Rapp, B., & Goldrick, M. (2002). The interaction of lexical and sublexical information in spelling: What's the point? *Cognitive Neuropsychology, 12*, 653-671.

Goodman, R. A., & Caramazza, A. (1986). Aspects of the spelling process: Evidence from a case of acquired dysgraphia. *Language and Cognitive Processes, 1*, 263-296.

Goswami, U., & Bryant, P. (1990). *Phonological skills and learning to read.* East Sussex: Lawrence Erlbaum.

Kreiner, D.S., & Gough, P.B. (1990). Two ideas about spelling: Rules and word-specific memory. *Journal of Memory and Language, 29*, 103-118.

Kucera, H. and Francis, W.N. (1967). Computational Analysis of Present-Day American English. Providence: Brown University Press.

Martin, F., & Pratt, C. (2001). *Martin and Pratt Nonword Reading Test.* Melbourne: ACER Press.

Martin, F., Claydon, E., Morton, A., Binns, S., Pratt, C. (2003). The development of orthographical and phonological strategies for the decoding of words in children. *Journal of Research in Reading, 26*, 191-204.

McCusker, L.X., Hillinger, M.L., & Bias, R.G. (1981). Phonological recoding and reading. *Psychological Bulletin, 89*, 217-245.

Nelson, H.E. (1982). *National Adult Reading Test (NART): Test Manual. NFER.* UK: Windsor.

Plaut, D. C. & McClelland, J. L. (1993). Generalisation with componential attractors: Word and nonword reading in an attractor network. In *Proceedings of the Fifteenth Annual Conference of the Cognitive Science Society,* (pp.824-829). Hillsdale, NJ: Erlbaum.

Rapp, B., Epstein, C., & Tainturer, M. (2002). The integration of information across lexical and sublexical processes in spelling. *Cognitive Neuropsychology, 19*, 1-29.

Rohl, M., & Tunmer, W. E. (1988). Phonemic segmentation skill and spelling acquisition. *Applied Psycholinguistics, 9*, 335-350.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review, 96*, 523-568.

Share, D.L. (1995). Phonological recoding and self-teaching: *sin qua non* of reading acquisition. *Cognition, 55*, 151-218.

Share, D.L. (1999). Phonological recoding and orthographic learning: A direct test of the self-teaching hypothesis. *Journal of Experimental Child Psychology, 72*, 95-129.

Stanback, M. L. (1992). Syllable and rime patterns for teaching reading: Analysis of a frequency-based vocabulary of 17,602 words. *Annals of Dyslexia, 42*, 196-221.

Tainturier, M. J. & Rapp, B. (2000). The spelling process. In B. Rapp (Ed.), *What deficits reveal about the human mind: A handbook of cognitive neuropsychology.* Philadelphia, PA: Psychology Press.

Treiman, R. (1984). Individual differences among children in reading and spelling styles. *Journal of Experimental Child Psychology, 37*, 463-577.

Waters, G.S., Bruck, M., & Seidenberg, M. (1985). Do children use similar processes/to read and spell words? *Journal of Experimental Child Psychology, 39*, 511-530.

Woodcock, R.W. (1987). *Woodcock reading mastery tests – Revised.* Minnesota: American Guidance Service.

Appendix A: Regular and Irregular Word Piloting Data

Regular Words

Word	Word Frequency	Percentage Read Correct	Percentage Spelt Correct
Part	500	100%	100%
Right	613	100%	100%
Harp	1	100%	100%
Back	967	100%	100%
Even	1171	100%	100%
Archer	1	80%	90%
Lode	1	100%	40%
Small	542	100%	100%
Animosity	3	80%	100%
Still	782	100%	100%
Number	472	100%	100%
General	497	90%	100%
Many	1030	100%	100%
See	772	100%	90%
Pledge	3	100%	90%
Helmet	1	80%	100%
Frown	1	100%	100%
Sop	1	100%	70%
Year	660	100%	100%
Figment	2	90%	100%
Riddle	1	100%	100%
Fact	447	100%	100%
Time	1599	100%	100%
Sage	2	100%	90%
Life	715	100%	100%
Fable	2	100%	100%
Broil	2	100%	90%
Can	1772	100%	100%
Gig	2	100%	100%
Scavenger	1	100%	80%
Wig	1	100%	100%
Three	610	100%	100%
Creeper	1	80%	60%
Better	414	90%	100%
Allegory	3	70%	50%
Lament	1	80%	60%
Salute	3	90%	70%
Must	1013	100%	100%
Hostage	2	90%	90%
Blush	2	100%	100%
State	808	100%	100%
Other	1702	100%	100%
Sleet	1	100%	90%
Left	480	100%	100%
Thought	515	100%	100%
Like	1290	100%	100%
Home	547	100%	100%
Adversity	2	90%	90%
Well	897	100%	100%
Toil	1	100%	100%
Jade	1	100%	100%
Parcel	1	100%	80%
House	591	100%	100%

Make	794	100%	100%
Yelp	2	100%	100%
Man	1207	100%	100%
Last	676	100%	100%
Hop	2	100%	100%
Day	686	100%	100%
Smelt	2	100%	100%

Irregular Words

Word	Word Frequency	Percentage Read Correct	Percentage Spelt Correct
Tow	1	100%	90%
One	3292	100%	100%
Come	630	100%	100%
Head	424	100%	100%
Work	760	100%	100%
Answer	152	100%	90%
Sure	264	90%	100%
Pretty	107	90%	100%
Put	437	100%	100%
Been	2427	100%	90%
Eye	122	100%	100%
Done	320	100%	100%
Good	807	100%	100%
Give	391	100%	100%
Have	3941	100%	100%
Soul	47	100%	100%
Said	1961	100%	100%
Shoe	14	100%	100%
Blood	121	100%	100%
Want	329	100%	100%
Island	167	90%	90%
Both	730	100%	100%
Foreign	158	80%	70%
Word	274	100%	100%
Tongue	35	100%	100%
Ceiling	31	100%	80%
Were	3284	100%	80%
Great	665	100%	90%
Wolf	6	80%	90%
Schism	1	60%	70%
Chorus	18	90%	90%
Pint	13	70%	100%
Sword	7	90%	80%
Cough	7	100%	80%
Ton	13	90%	40%
Bouquet	4	80%	90%
Champagne	13	80%	90%
Tomb	11	90%	100%
Circuit	23	100%	100%
Most	1160	100%	100%
Meringue	1	90%	60%
Was	9816	100%	100%
Gauge	12	70%	80%
Choir	8	100%	90%
Depot	13	90%	100%
Beret	1	90%	80%
Debris	8	70%	90%
Drought	5	90%	100%
Sovereign	30	90%	90%
Trough	3	90%	80%
Indict	2	60%	70%
Distraught	1	90%	70%
Brooch	1	90%	70%

Quay	1	70%	60%
Yacht	4	100%	90%
Benign	1	90%	80%
Scythe	1	70%	60%
Plover	1	100%	60%
Nought	1	90%	60%

Appendix B: Regular Word List and Irregular Word List

Regular Word List

PART
RIGHT
BACK
EVEN
ARCHER
LODE
SMALL
ANIMOSITY
STILL
NUMBER
GENERAL
MANY
SEE
PLEDGE
HELMET
SOP
YEAR
FIGMENT
RIDDLE
TIME
SAGE
LIFE
FABLE
BROIL
CAN
GIG
SCAVENGER

THREE
CREEPER
ALLEGORY
LAMENT
SALUTE
MUST
HOSTAGE
BLUSH
STATE
OTHER
SLEET
THOUGHT
LIKE
HOME
ADVERSITY
WELL
TOIL
JADE
PARCEL
HOUSE
MAKE
YELP
MAN
LAST
HOP
DAY
SMELT

Irregular Word List

HAVE
ONE
BLOOD
ISLAND
SOVEREIGN
CHORUS
BROOCH
TROUGH
WORK
WERE
TOW
PINT
PRETTY
MOST
SAID
BEEN
WOLF
FRIEND
WAS
NOUGHT
DEPOT
GOOD
DROUGHT
BENIGN
PLOVER
WANT
MERINGUE

EYE
GAUGE
CHOIR
GREAT
WORD
GIVE
SCHISM
PUT
BERET
SHOE
YACHT
BOUQUET
CHAMPAGNE
SWORD
COME
SCYTHE
INDICT
HEAD
DONE
QUAY
FOREIGN
COUGH
ANSWER
BOTH
TON
DISTRAUGHT
SURE

Appendix C: Information Sheet and Consent Form

The Relationship Between the Processes Involved in Reading and Spelling in Adults.

Chief Investigator: Dr Frances Martin
Research Assistant: Amanda Burley

This study is being undertaken as part of the requirements for a Masters of Psychology (Clinical) degree. The purpose of the study is to investigate the relationship between the processes involved in reading and spelling in adults.

To be eligible to participate in this study you must be aged 18 years old or over. It is required that you have normal or corrected to normal vision.

As a participant you will be asked to attend two 25 min sessions. During the first session you will be asked to complete three tests; a regular word spelling test, irregular word spelling test, and a nonword spelling test. Two weeks later you will be asked to attend a second session in which you will be asked to complete five tests; a regular word reading test, irregular word reading test, the Martin Pratt Nonword Reading Test (2001), the Word Identification Subtest of the Woodcock Reading Mastery Test (1987) and the National Adult Reading Test (1982).

For participating Psychology 1 students 1 hour course credit will be given for participation in this study.

All information collected from participants in this study will remain fully confidential and data will be kept in a secure place. Anonymity will be given to each participant through the use of code numbers to identify data.

If more information is required relating to this study please contact Dr Frances Martin
E-mail: F.Martin@utas.edu.au

If you have any concerns of an ethical nature or complaints about the manner in which this project is being conducted contact the Chair of the Northern Tasmania Social Sciences Research Ethics Committee or the Executive Officer **Amanda McAully (6226 2763).**

If you have any personal concerns related to this study, you may also choose to discuss these concerns confidentially with a University Counsellor.

Ethical Approval for this study has been received from the University of Northern Tasmania Social Sciences Human Research Ethics Committee.

The group results of this study will be available to all participants on the Psychology website at the end of the study.

Statement of Informed Consent

The Relationship Between the Processes Involved in Reading and Spelling in Adults.

A statement by the participant:

1. I have read and understood the 'Information Sheet' for this study.
2. The nature and possible effects of the study have been explained to me.
3. I understand that the study involves the following procedures:
   I will be asked to attend two 25 minute sessions. In the first session I will be asked to complete three separate tests; a regular word spelling test, irregular word spelling test, and a nonword spelling test. Two weeks later I will then be asked to attend a second session in which I will be asked to complete five tests; a regular word reading test, irregular word reading test, the Martin Pratt Nonword Reading Test (2001), the Word Identification Subtest of the Woodcock Reading Mastery Test (1987) and the National Adult Reading Test (1982).
4. I understand that all research data will be treated as confidential.
5. Any questions that I have asked have been answered to my satisfaction.
6. I agree that research data gathered for the study may be published provided that I cannot be identified as a participant.
7. I agree to participate in this investigation and understand that I may withdraw at any time without prejudice to my academic standing.

Name of participant ....

Signature of participant .... Date ....

A statement by the Investigator:

I have explained this project and the implications of participation in it to this Volunteer and I believe that the consent is informed and that he/she understands the implications of participation.

Name of investigator ....

Signature of investigator .... Date ....

Appendix D: Regular word and irregular word list sentences

Regular Word List Sentences

PART – The mechanic looked for a new part. – PART

RIGHT – The car turned right. – RIGHT

HARP – The woman played the harp. – HARP

BACK – The man hurt his back. – BACK

EVEN – The scales were even. – EVEN

ARCHER – The archer grabbed a bow. – ARCHER

LODE – A vein of metallic ore is called a lode - LODE

SMALL - The kitten was small. – SMALL

ANIMOSITY – There was animosity between the teams. - ANIMOSITY

STILL – The dog sat still. - STILL

NUMBER – Eight is a number. – NUMBER

GENERAL – The customer entered the general store. – GENERAL

MANY – There were many birds. – MANY

SEE – The captain could see the horizon. – SEE

PLEDGE – The children took the pledge. – PLEDGE

HELMET – The child put his helmet on. HELMET

SOP – A bribe is a sop. – SOP

YEAR – It was the end of the financial year. – YEAR

FIGMENT – The ghost was a figment of the child's imagination. –FIGMENT

RIDDLE – The man told a riddle. – RIDDLE

TIME – The woman asked the man the time. – TIME

SAGE – The woman picked some sage from the garden. – SAGE

LIFE – The murderer was sentenced to life imprisonment. – LIFE

FABLE – The children listened to the fable. – FABLE

BROIL – The chef decided to broil the meat. – BROIL

CAN – The child picked up the can. – CAN

GIG – The band played a gig. GIG

SCAVENGER – The bird was a scavenger. – SCAVENGER

THREE – The child could count up to three. – THREE

CREEPER – The plant was a creeper. – CREEPER

ALLEGORY – The poem was full of allegory. – ALLEGORY

LAMENT – The woman was full of lament at the loss of her cat. – LAMENT

SALUTE – The soldiers gave a salute. – SALUTE

MUST – The father told his son that he must clean his room. – MUST

HOSTAGE – The gunman took all staff hostage. – HOSTAGE

BLUSH –The man made the woman blush. – BLUSH

STATE – Tasmania is a state. - STATE

OTHER – The man found his keys in the other hand. – OTHER

SLEET – There was sleet in the rain. SLEET

THOUGHT – The boy had a thought. THOUGHT

LIKE – The dog looked like it was friendly. LIKE

HOME – The family arrived home. – HOME

ADVERSIT –The runner over came adversity to win the race.-ADVERSITY

WELL – The man was not well. – WELL

TOIL – The man finished hours of toil in the hot sun. – TOIL

JADE – The house was painted jade. JADE

PARCEL – The postman delivered a parcel. – PARCEL

HOUSE – The family bought a house. – HOUSE

MAKE – The child asked her mother to make her a drink. – MAKE

YELP – The dog let out a yelp. – YELP

MAN – The boy sat next to the man. – MAN

LAST – The girl finished last. – LAST

HOP – Kangaroos hop. – HOP

DAY – The children played games during the day. – DAY

SMELT – The woman smelt the rose. – SMELT

Irregular Word List Sentences

HAVE – The child asked if it could have a drink. – HAVE

ONE – There was one apple. – ONE

BLOOD – The man donated blood. – BLOOD

ISLAND – Tasmania is an island. – ISLAND

CHORUS – The girl sang the chorus. – CHORUS

BROOCH – The woman wore a brooch. – BROOCH

TROUGH – The animals fed at the trough. – TROUGH

WORK – The man went to work. – WORK

WERE – There were two cats. – WERE

TOW – The man prepared to tow the car. – TOW

PINT – The man ordered a pint of beer. – PINT

PRETTY – The dress was pretty. – PRETTY

MOST – At the circus the girl liked the clowns the most. – MOST

SAID – It was hard to understand what the child said. – SAID

BEEN – The boy had never been to the movies. – BEEN

WOLF – The dog chased the wolf. – WOLF

FRIEND – The boy played games with his friend. – FRIEND

WAS – There was a rainstorm. – WAS

NOUGHT – The cricketer got out for nought. - NOUGHT

DEPOT – The bus pulled in to the depot. – DEPOT

GOOD – The student had completed a good assignment. – GOOD

DROUGHT – Australia often suffers the effects of drought. – DROUGHT

BENIGN – The tumor was benign. – BENIGN

PLOVER – The bird was a plover. – PLOVER

WANT – The child did not want an ice cream. – WANT

MERINGUE – The chef made a meringue. – MERINGUE

EYE – The doctor examined the patient's eye. – EYE

GAUGE – The man checked the rain gauge. – GAUGE

CHOIR – The choir sang at the gala. – CHOIR

GREAT – The family had a great day at the park. – GREAT

WORD – The teacher taught the class a new word. – WORD

GIVE – The child would not give the baby the biscuit. – GIVE

SCHISM – A schism began to arise in the group. – SCHISM

PUT – The man could not remember where he had put his keys. – PUT

BERET – The man wore a beret. – BERET

SHOE – The dog chewed the shoe. – SHOE

YACHT – The man watched the yacht race. – YACHT

BOUQUET – The women prepared a bouquet of flowers. – BOUQUET

CHAMPAGNE – The couple celebrated with champagne. – CHAMPAGNE

SWORD – The attacker wielded a sword. – SWORD

COME – The man told the dog to come and sit. – COME

SCYTHE – The man used the scythe to cut the grass. – SCYTHE

INDICT – The police prepared to indict the man for fraud. – INDICT

HEAD – The doctor examined the child's head. – HEAD

DONE – The student had done well on the exam. – DONE

QUAY – The man fished off the quay. – QUAY

FOREIGN – The bank notes were foreign. – FOREIGN

COUGH – The child had a cough. – COUGH

ANSWER – The student gave the correct answer. – ANSWER

BOTH – The man wanted to buy both shirts. - BOTH

TON – The piano weighed a ton. – TON

DISTRAUGHT – The woman was distraught. – DISTRAUGHT

SURE – The man was sure the door was locked. – SURE

Appendix E: SPSS Analysis Output

Mean percentage correct for reading and spelling.

	N	Minimum	Maximum	Mean	Std. Deviation
Percentage of Regular Read	60	85.19	100.00	97.00	2.26
Percentage of Irregular Read	60	68.52	98.15	90.58	7.07
Percentage of Nonword Read	60	44.44	96.30	83.45	9.16
Percentage of Regular Spelt	60	68.52	100.00	93.42	5.47
Percentage of Irregular Spelt	60	46.30	98.15	82.77	10.75
Percentage of Nonword Spelt	60	31.48	87.04	68.30	12.00
Valid N (listwise)	60				

Mean percentage correct for high and low frequency regular and irregular words

	N	Minimum	Maximum	Mean	Std. Deviation
Read Regular High	60	92.59	100.00	99.75	1.34
Read Regular Low	60	77.78	100.00	94.19	3.93
Read Irregular High	60	92.59	100.00	99.25	1.77
Read Irregular Low	60	37.04	96.30	82.16	13.21
Spell Regular High	60	88.89	100.00	99.69	1.56
Spell Regular Low	60	48.15	100.00	87.09	9.94
Spell Irregular High	60	81.48	100.00	98.76	2.94
Spell Irregular Low	60	7.41	96.30	67.16	19.05
Valid N (listwise)	60				

Correlations between regular words, irregular words, and nonwords for reading and spelling.

Pearson Correlation

	Reading Regular	Reading Irregular	Reading Nonwords	Spelling Regular	Spelling Irregular	Spelling Nonword
Reading Regular	1	.25	.32(**)	.38(**)	.22	.04
Reading Irregular	.25	1	.48(**)	.72(**)	.83(**)	.52(**)
Reading Nonwords	.32(**)	.48(**)	1	.46(**)	.39(**)	.38(**)
Spelling Regular	.38(**)	.72(**)	.46(**)	1	.84(**)	.48(**)
Spelling Irregular	.22	.83(**)	.39(**)	.84(**)	1	.48(**)
Spelling Nonword	.04	.52(**)	.38(**)	.48(**)	.48(**)	1

** Correlation is significant at the 0.01 level (2-tailed).

One-way Analysis of Variance (ANOVA)
Word Frequency for Irregular Words Reading

Within-Subjects Factors
Measure: MEASURE_1

frequency	Dependent Variable
High	Reading Irregular High
Low	Reading Irregular Low

Descriptive Statistics

	Mean	Std. Deviation	N
Read Irregular High	26.80	.480	60
Read Irregular Low	22.18	3.56	60

Multivariate Tests(b)

Pillai's Trace

Effect	Value	F	Hypothesis df	Error df	Sig.
frequency	.63	104.18(a)	1.00	59.00	.000

a Exact statistic
b Design: Intercept Within Subjects Design: frequenc

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
frequency	1.00	.000	0	.	1.00	1.00	1.00

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept Within Subjects Design: frequenc

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
frequency	Sphericity Assumed	639.40	1	639.40	104.18	.000
	Greenhouse-Geisser	639.40	1.00	639.40	104.18	.000
	Huynh-Feldt	639.40	1.00	639.40	104.18	.000
	Lower-bound	639.40	1.00	639.40	104.18	.000
Error(frequency)	Sphericity Assumed	362.09	59	6.13		
	Greenhouse-Geisser	362.09	59.00	6.13		
	Huynh-Feldt	362.09	59.00	6.13		
	Lower-bound	362.09	59.00	6.13		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	frequency	Type III Sum of Squares	df	Mean Square	F	Sig.
frequency	Linear	639.40	1	639.40	104.18	.000
Error(frequency)	Linear	362.09	59	6.13		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	71981.008	1	71981.00	10551.47	.000
Error	402.492	59	6.82		

One-way ANOVA
Word Frequency for Irregular Words Spelling

Within-Subjects Factors

Measure: MEASURE_1

frequency	Dependent Variable
High	Spelling Irregular High
Low	Spelling Irregular Low

Descriptive Statistics

	Mean	Std. Deviation	N
Spell Irregular High	26.67	.795	60
Spell Irregular Low	18.13	5.144	60

Multivariate Tests(b)

Pillai's Trace

Effect	Value	F	Hypothesis df	Error df	Sig.
frequency	.76	194.26(a)	1.00	59.00	.000

a Exact statistic
b Design: Intercept Within Subjects Design: frequenc

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
frequency	1.00	.00	0	.	1.00	1.00	1.00

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept Within Subjects Design: frequenc

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
frequency	Sphericity Assumed	2184.53	1	2184.53	194.26	.000
	Greenhouse-Geisser	2184.53	1.00	2184.53	194.26	.000
	Huynh-Feldt	2184.53	1.00	2184.53	194.26	.000
	Lower-bound	2184.53	1.00	2184.53	194.26	.000
Error(frequency)	Sphericity Assumed	663.46	59	11.24		
	Greenhouse-Geisser	663.46	59.00	11.24		
	Huynh-Feldt	663.46	59.00	11.24		
	Lower-bound	663.46	59.00	11.24		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	frequency	Type III Sum of Squares	df	Mean Square	F	Sig.
frequency	Linear	2184.53	1	2184.53	194.26	.000
Error(frequency)	Linear	663.46	59	11.24		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	60211.20	1	60211.20	3800.23	.000
Error	934.80	59	15.84		

One-way ANOVA
Word Frequency for Regular Words Reading

Within-Subjects Factors

Measure: MEASURE_1

frequency	Dependent Variable
High	Reading Regular High
Low	Reading Regular Low

Multivariate Tests(b)

Effect		Value	F	Hypothesis df	Error df	Sig.
frequency	Pillai's Trace	.696	135.00(a)	1.00	59.00	.000
	Wilks' Lambda	.304	135.00(a)	1.00	59.00	.000
	Hotelling's Trace	2.288	135.00(a)	1.00	59.00	.000
	Roy's Largest Root	2.288	135.00(a)	1.00	59.00	.000

a Exact statistic
b Design: Intercept Within Subjects Design: frequenc

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
frequency	1.00	.000	0	.	1.00	1.00	1.00

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept Within Subjects Design: frequenc

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
frequency	Sphericity Assumed	67.50	1	67.50	135.00	.000
	Greenhouse-Geisser	67.50	1.00	67.50	135.00	.000
	Huynh-Feldt	67.50	1.00	67.50	135.00	.000
	Lower-bound	67.50	1.00	67.50	135.00	.000
Error(frequency)	Sphericity Assumed	29.50	59	.50		
	Greenhouse-Geisser	29.50	59.00	.50		
	Huynh-Feldt	29.50	59.00	.50		
	Lower-bound	29.50	59.00	.50		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	frequency	Type III Sum of Squares	df	Mean Square	F	Sig.
frequency	Linear	67.50	1	67.50	135.00	.000
Error(frequency)	Linear	29.50	59	.50		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	82268.03	1	82268.03	107942.49	.000
Error	44.96	59	.76		

One-way ANOVA
Word Frequency for Regular Words Spelling

Measure: MEASURE_1

frequency	Dependent Variable
High	Spelling Regular High
Low	Spelling Regular Low

Multivariate Tests(b)

Effect		Value	F	Hypothesis df	Error df	Sig.
frequency	Pillai's Trace	.664	116.78(a)	1.00	59.00	.000
	Wilks' Lambda	.336	116.78(a)	1.00	59.00	.000
	Hotelling's Trace	1.979	116.78(a)	1.00	59.00	.000
	Roy's Largest Root	1.979	116.78(a)	1.00	59.00	.000

a Exact statistic
b Design: Intercept Within Subjects Design: frequenc

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
frequency	1.00	.000	0	.	1.00	1.00	1.00

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept Within Subjects Design: frequenc

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
frequency	Sphericity Assumed	346.80	1	346.80	116.78	.000
	Greenhouse-Geisser	346.80	1.00	346.80	116.78	.000
	Huynh-Feldt	346.80	1.00	346.80	116.78	.000
	Lower-bound	346.80	1.00	346.80	116.78	.000
Error(frequency)	Sphericity Assumed	175.20	59	2.96		
	Greenhouse-Geisser	175.20	59.00	2.96		
	Huynh-Feldt	175.20	59.00	2.96		
	Lower-bound	175.20	59.00	2.96		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	frequency	Type III Sum of Squares	df	Mean Square	F	Sig.
frequency	Linear	346.80	1	346.80	116.78	.000
Error(frequency)	Linear	175.20	59	2.96		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	76305.63	1	76305.63	17291.12	.000
Error	260.36	59	4.41		

Means and standard deviations of age, reading age, predicted IQ, regular word, irregular word, and nonword reading and spelling and number of males and females for the reading age groups.

	N	Minimum	Maximum	Mean	Std. Deviation
AgeA20	30	18	50	22.03	5.65
AgeB20	30	18	46	22.30	6.33
ReadAgeA20	30	24.00	38.08	29.11	4.14
ReadAgeB20	30	11.04	20.15	16.63	2.55
NARTA20	30	95	115	106.70	5.05
NARTB20	30	87	112	101.10	5.46
rREGA20	30	51	54	52.47	.86
rREGB20	30	46	54	52.30	1.51
rIRREGA20	30	40	53	50.20	2.68
rIRREGB20	30	37	53	47.63	4.36
rNONA20	30	44	51	47.50	1.81
rNONB20	30	24	52	42.63	5.85
sREGA20	30	48	54	51.67	1.62
sREGB20	30	37	54	49.23	3.47
sIRREGA20	30	32	52	46.47	4.77
sIRREGB20	30	25	53	42.93	6.26
sNONA20	30	12	24	19.00	3.37
sNONB20	30	6	22	15.83	4.20
Valid N (listwise)	0				

Means and standard deviations of age, reading age, predicted IQ, regular word, irregular word, and nonword reading and spelling and number of males and females for the total sample.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Age	60	18	50	22.17	5.95
Word Identification Test age equiv	60	11.04	38.08	22.87	7.16
National Adult Reading Test IQ Equiv	60	87	115	103.90	5.93
Reading Regular Correct	60	46	54	52.38	1.22
Reading Irregular Correct	60	37	53	48.92	3.81
Reading Nonwords Correct	60	24	52	45.07	4.94
Spelling Regular Correct	60	37	54	50.45	2.95
Spelling Irregular Correct	60	25	53	44.70	5.80
Spelling Nonword Correct	60	6	24	17.42	4.10
Valid N (listwise)	60				

Three-way ANOVA
2 (Reading Age) x 2 (Task Type) x 3 (Word Type)

Within-Subjects Factors
Measure: MEASURE_1

tasktype	wordtype	Dependent Variable
Reading	Regular	Reading Regular
	Irregular	Reading Irregular
	Nonword	Reading Nonwords
Spelling	Regular	Spelling Regular
	Irregular	Spelling Irregular
	Nonword	Spelling Nonwords

Between-Subjects Factors

		Value Label	N
groups by word identification AE	1	Above 20	30
	2	Below 20	30

Descriptive Statistics

	groups by word identification AE	Mean	Std. Deviation	N
Reading Regular	Above 20	52.47	.86	30
	Below 20	52.30	1.51	30
	Total	52.38	1.22	60
Reading Irregular	Above 20	50.20	2.68	30
	Below 20	47.63	4.36	30
	Total	48.92	3.81	60
Reading Nonwords	Above 20	47.50	1.81	30
	Below 20	42.63	5.85	30
	Total	45.07	4.94	60
Spelling Regular	Above 20	51.67	1.62	30
	Below 20	49.23	3.47	30
	Total	50.45	2.95	60
Spelling Irregular	Above 20	46.47	4.77	30
	Below 20	42.93	6.26	30
	Total	44.70	5.80	60
Spelling Nonword	Above 20	19.00	3.37	30
	Below 20	15.83	4.20	30
	Total	17.42	4.10	60

Multivariate Tests(b)

Pillai's Trace

Effect	Value	F	Hypothesis df	Error df	Sig.
tasktype	.95	1149.59(a)	1.00	58.00	.000
tasktype * wigroup	.01	.59(a)	1.00	58.00	.445
wordtype	.98	1440.42(a)	2.00	57.00	.000
wordtype * wigroup	.20	7.38(a)	2.00	57.00	.001
tasktype * wordtype	.96	725.73(a)	2.00	57.00	.000
tasktype * wordtype * wigroup	.17	6.02(a)	2.00	57.00	.004

a Exact statistic

b Design: Intercept+wigroup Within Subjects Design: tasktype+wordtype+tasktype*wordtype

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
tasktype	1.00	.00	0	.	1.00	1.00	1.00
wordtype	.86	8.23	2	.01	.88	.92	.50
tasktype * wordtype	.47	42.64	2	.00	.65	.67	.50

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b Design: Intercept+wigroup Within Subjects Design: tasktype+wordtype+tasktype*wordtype

Tests of Within-Subjects Effects

Measure: MEASURE_1
Sphericity Assumed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
tasktype	11424.40	1	11424.40	1149.59	.000
tasktype * wigroup	5.87	1	5.87	.59	.445
Error(tasktype)	576.38	58	9.93		
wordtype	26823.53	2	13411.76	1137.23	.000
wordtype * wigroup	113.77	2	56.88	4.82	.010
Error(wordtype)	1368.02	116	11.79		
tasktype * wordtype	12156.81	2	6078.40	1053.67	.000
tasktype * wordtype * wigroup	61.33	2	30.669	5.31	.006
Error(tasktype*wordtype)	669.17	116	5.769		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	tasktype	wordtype	Type III Sum of Squares	df	Mean Square	F	Sig.
tasktype	Linear		11424.40	1	11424.40	1149.59	.000
tasktype * wigroup	Linear		5.87	1	5.87	.59	.445
Error(tasktype)	Linear		576.38	58	9.93		
wordtype		Linear	24421.83	1	24421.83	2931.37	.000
		Quadratic	2401.70	1	2401.70	157.43	.000
wordtype * wigroup		Linear	110.70	1	110.70	13.28	.001
		Quadratic	3.06	1	3.06	.20	.655
Error(wordtype)		Linear	483.20	58	8.33		
		Quadratic	884.81	58	15.25		
tasktype * wordtype	Linear	Linear	9920.20	1	9920.20	1429.34	.000
		Quadratic	2236.61	1	2236.61	486.51	.000
tasktype * wordtype * wigroup	Linear	Linear	59.00	1	59.00	8.50	.005
		Quadratic	2.33	1	2.33	.50	.479
Error(tasktype* wordtype)	Linear	Linear	402.54	58	6.94		
		Quadratic	266.63	58	4.59		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	670464.71	1	670464.71	16243.88	.000
wigroup	700.01	1	700.01	16.96	.000
Error	2393.94	58	41.27		

Breakdown ANOVA for Reading

Within-Subjects Factors

Measure: MEASURE_1

wordtype	Dependent Variable
Regular	Reading Regular
Irregular	Reading Irregular
Nonword	Reading Nonword

Between-Subjects Factors

		Value Label	N
groups by word identification AE	1	Above 20	30
	2	Below 20	30

Descriptive Statistics

	groups by word identification AE	Mean	Std. Deviation	N
Reading Regular	Above20	52.47	.86	30
	Below 20	52.30	1.51	30
	Total	52.38	1.22	60
Reading Irregular	Above 20	50.20	2.68	30
	Below 20	47.63	4.36	30
	Total	48.92	3.81	60
Reading Nonwords	Above 20	47.50	1.81	30
	Below 20	42.63	5.85	30
	Total	45.07	4.94	60

Multivariate Tests(b)

Pillai's Trace

Effect	Value	F	Hypothesis df	Error df	Sig.
wordtype	.78	102.27(a)	2.00	57.00	.000
wordtype * wigroup	.27	10.81(a)	2.00	57.00	.000

a Exact statistic
b Design: Intercept+wigroup Within Subjects Design: wordtype

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
wordtype	.913	5.178	2	.07	.92	.96	.50

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept+wigroup Within Subjects Design: wordtype

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
wordtype	Sphericity Assumed	1607.47	2	803.73	96.36	.000
	Greenhouse-Geisser	1607.47	1.84	873.53	96.36	.000
	Huynh-Feldt	1607.47	1.93	832.70	96.36	.000
	Lower-bound	1607.47	1.00	1607.47	96.36	.000
wordtype * wigroup	Sphericity Assumed	165.70	2	82.85	9.93	.000
	Greenhouse-Geisser	165.70	1.84	90.04	9.93	.000
	Huynh-Feldt	165.70	1.93	85.83	9.93	.000
	Lower-bound	165.70	1.00	165.70	9.93	.003
Error(wordtype)	Sphericity Assumed	967.48	11	8.34		
	Greenhouse-Geisser	967.48	106.73	9.06		
	Huynh-Feldt	967.48	111.96	8.64		
	Lower-bound	967.48	58.00	16.68		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	wordtype	Type III Sum of Squares	df	Mean Square	F	Sig.
wordtype	Linear	1606.00	1	1606.00	193.32	.000
	Quadratic	1.46	1	1.46	.17	.677
wordtype * wigroup	Linear	165.67	1	165.67	19.94	.000
	Quadratic	.02	1	.02	.00	.957
Error(wordtype)	Linear	481.81	58	8.30		
	Quadratic	485.6	58	8.37		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	428464.02	1	428464.02	25606.00	.000
wigroup	288.80	1	288.80	17.25	.000
Error	970.51	58	16.73		

Simple Main Effects for Reading

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Read Regular Above 20	52.46	30	.86037	.15708
	Read Irregular Above 20	50.20	30	2.68328	.48990
Pair 2	Read Regular Above 20	52.4667	30	.86037	.15708
	Read Nonword Above 20	47.5000	30	1.81469	.33132
Pair 3	Read Irregular Above 20	50.2000	30	2.68328	.48990
	Read Nonword Above 20	47.5000	30	1.81469	.33132
Pair 4	Read Regular Below 20	52.3000	30	1.51202	.27606
	Read Irregular Below 20	47.6333	30	4.36667	.79724
Pair 5	Read Regular Below 20	52.3000	30	1.51202	.27606
	Read Nonword Below 20	42.6333	30	5.85152	1.06834
Pair 6	Read Irregular Below 20	47.6333	30	4.36667	.79724
	Read Nonword Below 20	42.6333	30	5.85152	1.06834

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Read Regular Above 20 & Read Irregular Above 20	30	-.117	.540
Pair 2	Read Regular Above 20 & Read Nonword Above 20	30	-.199	.292
Pair 3	Read Irregular Above 20 & Read Nonword Above 20	30	.283	.129
Pair 4	Read Regular Below 20 & Read Irregular Below 20	30	.372	.043
Pair 5	Read Regular Below 20 & Read Nonword Below 20	30	.449	.013
Pair 6	Read Irregular Below 20 & Read Nonword Below 20	30	.374	.042

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Read Reg Above 20 - Read Irreg Above 20	2.26	2.91	.53	1.17	3.35	4.26	29	.000
Pair 2	Read Reg Above 20 - Read Non Above 20	4.96	2.15	.39	4.16	5.77	12.61	29	.000
Pair 3	Read Irreg Above 20 - Read Non Above 20	2.70	2.78	.50	1.66	3.73	5.31	29	.000
Pair 4	Read Reg Below 20 - Read Irreg Below 20	4.66	4.05	.74	3.15	6.18	6.30	29	.000
Pair 5	Read Reg Below 20 - Read Non Below 20	9.66	5.34	.97	7.67	11.66	9.90	29	.000
Pair 6	Read Irreg Below 20 - Read Non Below 20	5.00	5.84	1.06	2.81	7.18	4.68	29	.000

Group Statistics

	groups by word identification AE	N	Mean	Std. Deviation	Std. Error Mean
Read Regular	Above 20	30	52.47	.86	.15
	Below 20	30	52.30	1.51	.27
Read Irregular	Above 20	30	50.20	2.68	.49
	Below 20	30	47.63	4.36	.79
Read Nonwords	Above 20	30	47.50	1.81	.33
	Below 20	30	42.63	5.85	1.06

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Read Regular	Equal variances assumed	1.39	.242	.52	58	.602	.167	.318	-.469	.802
	Equal variances not assumed			.52	45.99	.602	.167	.318	-.473	.806
Read Irregular	Equal variances assumed	7.32	.009	2.74	58	.008	2.567	.936	.694	4.440
	Equal variances not assumed			2.74	48.16	.009	2.567	.936	.685	4.448
Read Nonwords	Equal variances assumed	10.78	.002	4.35	58	.000	4.867	1.119	2.628	7.106
	Equal variances not assumed			4.35	34.52	.000	4.867	1.119	2.595	7.139

Breakdown ANOVA for Spelling

Within-Subjects Factors

Measure: MEASURE_1

wordtype	Dependent Variable
Regular	Spell Regular
Irregular	Spell Irregular
Nonword	Spell Nonword

Between-Subjects Factors

		Value Label	N
groups by word identification AE	1	Above 20	30
	2	Below 20	30

Descriptive Statistics

	groups by word identification AE	Mean	Std. Deviation	N
Spell Regular	Above 20	51.67	1.62	30
	Below 20	49.23	3.47	30
	Total	50.45	2.95	60
Spell Irregular	Above 20	46.47	4.77	30
	Below 20	42.93	6.26	30
	Total	44.70	5.80	60
Spell Nonword	Above 20	19.00	3.37	30
	Below 20	15.83	4.20	30
	Total	17.42	4.10	60

Multivariate Tests(b)

Pillai's Trace

Effect	Value	F	Hypothesis df	Error df	Sig.
wordtype	.98	2396.59(a)	2.00	57.00	.000
wordtype * wigroup	.03	.96(a)	2.00	57.00	.389

a Exact statistic
b Design: Intercept+wigroup Within Subjects Design: wordtype

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
wordtype	.73	17.39	2	.000	.79	.82	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept+wigroup Within Subjects Design: wordtype

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
wordtype	Sphericity Assumed	37372.87	2	18686.43	2026.36	.000
	Greenhouse-Geisser	37372.87	1.58	23601.98	2026.36	.000
	Huynh-Feldt	37372.87	1.64	22669.58	2026.36	.000
	Lower-bound	37372.87	1.00	37372.87	2026.36	.000
wordtype * wigroup	Sphericity Assumed	9.41	2	4.70	.51	.602
	Greenhouse-Geisser	9.41	1.58	5.94	.51	.559
	Huynh-Feldt	9.41	1.64	5.70	.51	.567
	Lower-bound	9.41	1.00	9.41	.51	.478
Error(wordtype)	Sphericity Assumed	1069.71	11	9.22		
	Greenhouse-Geisser	1069.71	91.84	11.64		
	Huynh-Feldt	1069.71	95.61	11.18		
	Lower-bound	1069.71	58.00	18.44		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	wordtype	Type III Sum of Squares	df	Mean Square	F	Sig.
wordtype	Linear	32736.03	1	32736.03	4700.50	.000
	Quadratic	4636.84	1	4636.84	403.94	.000
wordtype * wigroup	Linear	4.03	1	4.03	.57	.450
	Quadratic	5.37	1	5.37	.46	.496
Error(wordtype)	Linear	403.93	58	6.96		
	Quadratic	665.77	58	11.47		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	253425.08	1	253425.08	7349.98	.000
wigroup	417.08	1	417.08	12.09	.001
Error	1999.82	58	34.48		

2 (Word Type) x 2 (Reading Age Group) for Spelling

Within-Subjects Factors

Measure: MEASURE_1

wordtype	Dependent Variable
Regular	Spelling Regular
Irregular	Spelling Irregular

Between-Subjects Factors

		Value Label	N
groups by word identification AE	1	Above20	30
	2	Below 20	30

Multivariate Tests(b)

Effect		Value	F	Hypothesis df	Error df	Sig.
wordtype	Pillai's Trace	.71	146.92(a)	1.00	58.00	.000
	Wilks' Lambda	.28	146.92(a)	1.00	58.00	.000
	Hotelling's Trace	2.53	146.92(a)	1.00	58.00	.000
	Roy's Largest Root	2.53	146.92(a)	1.00	58.00	.000
wordtype * wigroup	Pillai's Trace	.02	1.34(a)	1.00	58.00	.251
	Wilks' Lambda	.97	1.34(a)	1.00	58.00	.251
	Hotelling's Trace	.02	1.34(a)	1.00	58.00	.251
	Roy's Largest Root	.02	1.34(a)	1.00	58.00	.251

a Exact statistic
b Design: Intercept+wigroup Within Subjects Design: wordtype

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a) Greenhouse-Geisser	Huynh-Feldt	Lower-bound
wordtype	1.00	.000	0	.	1.00	1.00	1.00

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept+wigroup Within Subjects Design: wordtype

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
wordtype	Sphericity Assumed	991.87	1	991.87	146.92	.000
	Greenhouse-Geisser	991.87	1.00	991.87	146.92	.000
	Huynh-Feldt	991.87	1.00	991.87	146.92	.000
	Lower-bound	991.87	1.00	991.87	146.92	.000
wordtype * wigroup	Sphericity Assumed	9.07	1	9.07	1.34	.251
	Greenhouse-Geisser	9.07	1.00	9.07	1.34	.251
	Huynh-Feldt	9.07	1.00	9.07	1.34	.251
	Lower-bound	9.07	1.00	9.07	1.34	.251
Error(wordtype)	Sphericity Assumed	391.55	58	6.75		
	Greenhouse-Geisser	391.55	58.00	6.75		
	Huynh-Feldt	391.55	58.00	6.75		
	Lower-bound	391.55	58.00	6.75		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	wordtype	Type III Sum of Squares	df	Mean Square	F	Sig.
wordtype	Linear	991.87	1	991.87	146.92	.000
wordtype * wigroup	Linear	9.07	1	9.07	1.34	.251
Error(wordtype)	Linear	391.55	58	6.75		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	271605.67	1	271605.67	8580.99	.000
wigroup	267.00	1	267.00	8.43	.005
Error	1835.81	58	31.65		

Tests of simple main effects

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Spell Regular Grp1	51.67	30	1.62	.29
	Spell Irregular Grp1	46.47	30	4.77	.87
Pair 2	Spell Regular Grp2	49.23	30	3.47	.63
	Spell Irregular Grp2	42.93	30	6.269	1.144

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Spell Regular Grp1 & Spell Irregular Grp1	30	.82	.000
Pair 2	Spell Regular Grp2 & Spell Irregular Grp2	30	.85	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	SpRegGrp1 - SpIrregGrp1	5.20	3.56	.65	3.86	6.53	7.98	29	.000
Pair 2	SpRegGrp2 - SpIrregGrp2	6.300	3.779	.69	4.88	7.71	9.12	29	.000

Group Statistics

	groups by word identification AE	N	Mean	Std. Deviation	Std. Error Mean
Spell Regular	Above 20	30	51.67	1.62	.29
	Below 20	30	49.23	3.47	.63
Spell Irregular	Above 20	30	46.47	4.77	.87
	Below 20	30	42.93	6.26	1.14

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Spell Regular	Equal variances assumed	2.92	.09	3.47	58	.001	2.43	.70	1.03	3.83
	Equal variances not assumed			3.47	41.14	.001	2.43	.70	1.02	3.84
Spelling Irregular	Equal variances assumed	.57	.45	2.45	58	.017	3.53	1.43	.65	6.41
	Equal variances not assumed			2.45	54.17	.017	3.53	1.43	.64	6.41

Reading Reliance Descriptives

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Age No Reliance	20	19.00	50.00	24.45	9.37
Age Non Reliance	16	18.00	33.00	21.62	3.64
Age Lexical Reliance	24	18.00	24.00	20.62	1.52
NART No Reliance	20	98.00	112.00	105.35	4.42
NART NonLexical	16	95.00	115.00	103.18	6.63
NART Lexical	24	87.00	113.00	103.16	6.53
Reading Age No Reliance	20	16.05	33.57	24.00	5.62
Reading Age Non Lexical	16	14.08	38.08	24.64	7.93
Reading Age Lexical	24	11.04	33.57	20.75	7.51
Spell Regular No Reliance	20	48.00	54.00	51.20	1.88
Spell Regular Non Lexical	16	37.00	53.00	49.50	3.82
Spell Regular Lexical	24	40.00	54.00	50.45	2.96
Spell Irregular No Reliance	20	37.00	53.00	45.80	3.98
Spell Irregular Non Lexical	16	25.00	50.00	41.93	7.20
Spell Irregular Lexical	24	27.00	52.00	45.62	5.67
Spell Nonword No Reliance	20	12.00	24.00	18.15	3.64
Spell Nonword Non Lexical	16	6.00	24.00	16.68	4.98
Spell Nonword Lexical	24	9.00	24.00	17.29	3.88
Valid N (listwise)	0				

	N	Minimum	Maximum	Mean	Std. Deviation
No Reliance Regular	20	50	54	52.50	.94
NonLex Reliance Regular	16	51	54	52.63	.88
Lexical Reliance Regular	24	46	54	52.13	1.56
No Reliance Irregular	20	45	53	50.35	1.81
NonLex Reliance Irregular	16	37	52	45.94	4.49
Lex Reliance Irregular	24	38	53	49.71	3.59
No Reliance Nonword	20	40	52	47.15	2.56
NonLex Reliance Nonword	16	44	51	47.44	2.09
Lex Reliance Nonword	24	24	48	41.75	5.94
No Reliance Z score	20	-.33	.30	-.045	.21
NonLex Reliance Z score	16	-3.11	-.37	-1.25	.91
Lex Reliance Z score	24	.36	2.45	.87	.55
Valid N (listwise)	0				

Two-way ANOVA
3 (Word Type) x 3 (Reading Reliance)

Within-Subjects Factors

Measure: MEASURE_1

wordtype	Dependent Variable
Regular	Spell Regular
Irregular	Spell Irregular
Nonword	Spell Nonword

Between-Subjects Factors

		Value Label	N
RdGroup	0	No Reliance	20
	1	Nonlexical Reliance	16
	2	Lexical Reliance	24

Descriptive Statistics

	RdGroup	Mean	Std. Deviation	N
Spelling Regular	No Reliance	51.20	1.88	20
	Nonlexical Reliance	49.50	3.83	16
	Lexical Reliance	50.46	2.96	24
	Total	50.45	2.95	60
Spelling Irregular	No Reliance	45.80	3.98	20
	Nonlexical Reliance	41.94	7.20	16
	Lexical Reliance	45.63	5.67	24
	Total	44.70	5.80	60
Spelling Nonword	No Reliance	18.15	3.64	20
	Nonlexical Reliance	16.69	4.99	16
	Lexical Reliance	17.29	3.88	24
	Total	17.42	4.10	60

Multivariate Tests(c)

Pillai's Trace

Effect	Value	F	Hypothesis df	Error df	Sig.
wordtype	.98	2257.02(a)	2.00	56.00	.000
wordtype * RdGroup	.09	1.42	4.00	114.00	.230

a Exact statistic
c Design: Intercept+RdGroup Within Subjects Design: wordtype

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

					Epsilon(a)		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
wordtype	.75	15.72	2	.000	.80	.85	.50

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept+RdGroup Within Subjects Design: wordtype

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
wordtype	Sphericity Assumed	36156.37	2	18078.18	2016.76	.000
	Greenhouse-Geisser	36156.37	1.60	22503.46	2016.76	.000
	Huynh-Feldt	36156.37	1.70	21215.83	2016.76	.000
	Lower-bound	36156.37	1.00	36156.37	2016.76	.000
wordtype * RdGroup	Sphericity Assumed	57.23	4	14.30	1.59	.180
	Greenhouse-Geisser	57.23	3.21	17.81	1.59	.193
	Huynh-Feldt	57.23	3.40	16.79	1.59	.190
	Lower-bound	57.23	2.00	28.61	1.59	.212
Error(wordtype)	Sphericity Assumed	1021.89	11	8.96		
	Greenhouse-Geisser	1021.89	91.58	11.15		
	Huynh-Feldt	1021.89	97.14	10.52		
	Lower-bound	1021.89	57.00	17.92		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	wordtype	Type III Sum of Squares	df	Mean Square	F	Sig.
wordtype	Linear	31805.76	1	31805.76	4450.42	.000
	Quadratic	4350.61	1	4350.61	403.53	.000
wordtype * RdGroup	Linear	.60	2	.30	.04	.959
	Quadratic	56.62	2	28.31	2.62	.081
Error(wordtype)	Linear	407.36	57	7.14		
	Quadratic	614.53	57	10.78		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	245044.80	1	245044.80	6174.93	.000
RdGroup	154.93	2	77.46	1.95	.151
Error	2261.97	57	39.68		

Regular regularisation errors

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
NoReliance	8	16.67	66.67	41.66	21.67
NonLexicalReliance	9	20.00	50.00	35.68	12.55
LexicalReliance	13	20.00	50.00	40.27	12.92
Valid N (listwise)	0				

Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
no reliance (z between -.3 and +.3)	8	41.66	21.67	7.66	23.54	59.78	16.67	66.67
sublexically reliant (z<-.3)	9	35.68	12.55	4.18	26.04	45.33	20.00	50.00
lexically reliant (z>.3)	13	40.27	12.92	3.58	32.46	48.08	20.00	50.00
Total	30	39.26	15.23	2.78	33.58	44.95	16.67	66.67

Irregular regularisation errors

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
NoReliance	20	10.00	100.00	45.18	22.52
NonlexicalReliance	16	7.14	75.00	31.11	15.39
LexicalReliance	24	9.09	100.00	40.02	19.85
Valid N (listwise)	0				

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1776.65	2	888.32	2.27	.112
Within Groups	22262.32	57	390.56		
Total	24038.97	59			

Regular lexicalisation errors

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
NoReliance	18	16.67	100.00	52.87	32.69
NonLexicalReliance	16	14.29	100.00	40.43	26.90
LexicalReliance	21	7.14	100.00	37.00	23.74
Valid N (listwise)	0				

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2610.69	2	1305.34	1.68	.196
Within Groups	40310.61	52	775.20		
Total	42921.30	54			

Irregular lexicalisation errors

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
NoReliance	12	6.25	30.00	20.12	6.29
NonlexicalReliance	13	7.14	25.00	17.19	5.83
LexicalReliance	16	7.69	40.00	16.44	8.87
Valid N (listwise)	0				

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	98.89	2	49.44	.92	.404
Within Groups	2026.20	38	53.32		
Total	2125.10	40			

Nonword Lexicalisation errors

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
NoReliance	16	3.13	16.67	9.37	3.87
NonLexicalReliance	15	2.50	20.59	9.60	5.10
LexicalReliance	20	2.63	20.00	9.49	3.97
Valid N (listwise)	0				

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.409	2	.20	.011	.989
Within Groups	890.56	48	18.55		
Total	890.97	50			

Irregular Partial lexicalisation errors

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
NoReliance	17	10.00	50.00	26.51	12.38
NonlexicalReliance	13	13.33	60.00	27.64	13.28
LexicalReliance	17	11.11	46.15	25.61	11.49
Valid N (listwise)	0				

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	30.220	2	15.110	.099	.906
Within Groups	6686.833	44	151.973		
Total	6717.053	46			

Appendix F: Raw Data

Code	Age	Sex	Read Regular	Read Irregular	Read Nonword	Spell Regular	Spell Irregular	Spell Nonword	Reading Age	IQ
A1	22	F	53	44	44	47	32	35	13;08	95
A2	23	F	52	49	50	52	49	33	28	106
A3	20	M	53	53	51	52	49	30	13;08	111
A5	24	M	52	53	45	50	51	32	33.51	113
A6	21	M	52	53	48	52	49	38	33.57	108
A7	22	F	52	51	49	48	37	32	24	101
A8	20	F	52	48	42	51	38	36	14;04	101
A9	27	F	51	51	50	53	50	33	33.57	115
A10	20	F	51	52	47	52	48	33	33.57	108
B1	20	F	52	50	43	50	43	35	14;8	100
B2	19	F	53	51	47	49	42	32	18;9	100
B3	20	F	51	51	46	53	47	33	33.51	105
B4	21	F	52	51	49	53	48	36	33.51	103
B5	20	F	52	52	40	50	50	35	16;05	106
B6	19	F	52	51	48	52	48	38	24	108
B7	20	F	53	51	47	51	45	40	24	105
B8	50	F	51	51	47	54	51	38	28	112
B9	41	F	53	53	52	54	53	32	20	112
B10	33	F	53	40	48	46	34	43	15;05	100
B41	20	M	52	47	44	52	45	40	16;05	100
B81	24	F	54	51	45	54	52	38	28	108
C1	21	F	53	52	42	50	50	36	18;9	110
C3	20	F	54	46	44	51	42	37	16;05	97
C5	19	F	54	49	47	50	41	34	28	97
C6	21	F	53	52	51	52	50	32	33.54	112
C7	20	F	53	50	49	51	50	36	24	113
C8	20	F	53	49	46	49	44	40	18;9	98
C9	21	M	54	50	48	49	38	41	28	111
C10	20	M	52	49	37	50	43	43	17;09	100
D1	20	M	53	51	46	53	47	35	28	110
D2	20	F	53	46	47	50	39	36	28	98
D3	26	F	53	50	45	53	45	36	24	105
D4	20	F	52	50	47	53	50	33	28	107
D5	19	F	53	50	40	52	48	35	17;01	105
D6	21	F	54	50	48	51	44	33	20;15	111
D7	20	F	51	49	42	51	49	45	20	102
D8	21	F	52	50	49	53	49	30	33.57	112
D9	22	F	51	37	45	37	26	48	14;8	100
D10	21	F	53	51	49	51	45	32	24	105
E1	46	F	50	50	46	50	47	35	18;09	100
E2	21	F	52	49	42	50	47	33	16;05	101
E3	22	M	46	38	29	40	27	38	11;10	87
E4	21	F	53	48	41	50	43	42	20	97
E5	20	F	52	50	45	48	45	35	17;01	105
E6	20	F	53	50	43	50	49	35	15;11	98
E7	20	F	52	53	48	50	47	35	20;15	107
E8	20	F	53	40	46	51	39	38	20;15	101
E9	24	F	51	42	24	44	41	43	11;4	89

E10	20	M	52	47	48	50	44	41	24	101
F5	20	F	52	52	46	53	51	32	28	110
F6	20	F	52	52	48	53	50	33	33.51	107
F7	20	F	53	46	46	48	40	42	15;11	96
F8	20	F	53	52	44	52	44	41	15;11	103
F9	19	F	53	52	45	53	48	35	24	110
F10	22	F	53	51	47	51	46	42	28	103
G1	20	F	53	45	40	51	44	39	20	103
G2	20	F	53	47	48	49	42	40	15;05	106
G10	21	F	54	45	32	50	43	41	15;0	97
F1	18	F	53	51	45	51	45	36	16;05	101
F2	18	F	52	45	47	51	45	34	28	102

Code	Read Regular High	Read Regular Low	Read Irregular High	Read Irregular Low	Spell Regular High	Spell Regular Low	Spell Irregular High	Spell Irregular Low
A1	27	26	27	17	27	20	25	7
A2	27	25	27	22	27	25	27	22
A3	27	26	27	26	27	25	27	22
A5	27	26	27	26	27	23	27	24
A6	27	25	27	26	27	25	27	22
A7	27	25	27	24	27	21	26	11
A8	27	24	27	21	27	24	26	12
A9	27	24	27	24	27	26	27	23
A10	27	24	27	25	27	25	27	21
B1	27	25	26	24	27	23	27	16
B2	27	26	27	24	27	22	27	15
B3	27	24	27	24	27	26	27	20
B4	27	25	27	24	27	26	27	21
B5	27	25	27	25	27	23	27	23
B6	27	25	27	24	27	25	27	21
B7	27	26	27	24	27	24	27	18
B8	27	24	27	24	27	27	27	24
B9	27	26	27	26	27	27	27	26
B10	27	26	25	15	27	19	27	7
B41	27	25	27	20	27	25	27	18
B81	27	27	26	25	27	27	27	25
C1	27	26	27	25	27	23	27	23
C3	27	27	27	19	27	24	26	16
C5	27	27	27	22	27	23	27	14
C6	27	26	27	25	27	25	27	23
C7	27	26	27	23	27	24	27	23
C8	27	26	27	22	27	22	27	17
C9	27	27	27	23	27	22	27	11
C10	27	25	27	22	27	23	27	17
D1	27	26	27	24	27	26	27	20
D2	27	26	27	19	27	23	26	13
D3	27	26	27	23	27	26	26	19
D4	27	25	27	23	27	26	27	23
D5	27	26	27	23	27	25	27	21
D6	27	27	26	24	27	24	27	17
D7	25	26	26	23	27	24	27	22
D8	27	25	27	23	27	26	26	23
D9	27	24	27	10	27	13	22	4
D10	27	26	27	24	27	24	26	19
E1	27	23	27	23	27	23	26	21
E2	27	25	27	22	27	23	26	21
E3	25	21	27	11	26	14	25	2
E4	27	26	26	22	27	23	26	17
E5	27	25	27	23	26	22	27	18
E6	27	26	26	24	27	23	27	22
E7	27	25	27	26	27	23	27	20
E8	27	26	27	13	27	24	27	12

E9	27	24	25	17	27	17	27	14
E10	27	25	27	20	27	23	27	17
F5	27	25	27	25	27	26	27	24
F6	27	25	27	25	27	26	27	23
F7	27	26	27	19	27	21	27	13
F8	27	26	27	25	27	25	27	17
F9	27	26	27	25	27	26	27	21
F10	27	26	27	24	27	24	27	19
G1	27	26	27	18	27	24	27	17
G2	27	26	26	21	27	22	27	15
G10	27	27	26	19	27	23	27	16
F1	27	26	27	24	27	24	27	18
F2	27	25	27	18	27	24	27	18