SUBTYPES OF READING DISABILITY:
DIFFERENCES IN REAL WORD AND PSEUDOWORD RESPONSE PATTERNS

by

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A thesis submitted in conformity with the requirements for the degree of Master of Arts
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ABSTRACT

The present study examined subtypes of developmental dyslexia using a reading-level matched design. 17 phonological and 15 surface dyslexics were identified from a sample of 68 reading-disabled 3rd-grade children by comparing them to chronological-age controls on exception word and pseudoword reading. Words and pseudowords were separated into distinct categories according to the dimensions of regularity and consistency in order to examine surface dyslexics' and phonological dyslexics' reliance on small-unit and large-unit correspondence rules. As hypothesized, phonological dyslexics were relatively less adept at using small-unit correspondences than surface dyslexics and reading-level matched controls. However, surface dyslexics were not less adept at using large-unit correspondences than phonological dyslexics and reading-level matched controls.
ACKNOWLEDGEMENTS

There are several people to whom I would like to express my sincere gratitude for their assistance in the completion of my thesis. First, and foremost, I would like to thank my supervisor Dr. Keith Stanovich, for his guidance and encouragement throughout the stages of this thesis. I would also like to thank my second readers, Dr. Linda Siegel and Dr. Ester Geva for their helpful comments during the revision process.

I would like to thank my parents, Rosa and Frank Volante, for supporting me throughout my academic career. Their patience and encouragement are especially appreciated. I would also like to thank my older siblings, Tony, Patrick, and Sabina for their advice and guidance over the years. Finally, I would like to thank my fiance, Filomena, who is a source of constant inspiration.
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Introduction

Defining subtypes of reading disability has been a difficult task for the field of reading. The idea that reading disabled individuals differ in the way that they have become poor readers and in the cognitive correlates of their disability is an appealing concept for researchers attempting to design remediation programs. If it can be reliably shown that there are different types of reading disabilities, each with their own cluster of cognitive deficits, then researchers and educators may be able to design remedial programs that are best suited to the specific subtype of reading disability. Research has shown that reading disabled individuals possess cognitive deficits which are distinct from other types of learning disabled individuals (McKinney, 1984; Satz & Morris, 1981; Siegel & Heaven, 1986).

Unfortunately, very little progress has been made in differentiating subgroups of reading disabled individuals in terms of behavioral, genetic, or physiological characteristics. The field has made what has been termed "negative progress" (Stanovich, Siegel, Gottardo, Chiappe, & Sidhu, in press). This designation refers to the early history of the field in which the definition of reading disability or dyslexia was related to the idea of aptitude/achievement discrepancy (Siegel, 1993; Siegel, 1989; Siegel, 1988; Stanovich & Siegel, 1994; Stanovich & Stanovich, 1996).
"Early definitions of reading disability assumed knowledge of differential
cognitive profile (and causation) within the larger sample of poor
readers and defined the condition of reading disability in a way that
actually served to preclude empirical investigation of the unproven
theoretical assumptions that guided the formulation of these definitions"
(Stanovich & Stanovich, 1996, p.2). Thus, reading disability research
based on such definitions may have been misguided, and this conclusion
itself might be termed "negative progress".

From the very beginning of research on reading disability, it was
assumed that readers of high aptitude - as indicated by IQ test
performance - were cognitively and neurologically different from poor
readers of low aptitude. The label dyslexia, or reading disability, was
reserved for those children showing statistical discrepancies between
reading ability and intelligence test performance (Stanovich & Stanovich,
1996). However, research indicates that a reading disability
classification system based on the discrepancy notion does not
distinguish the processing profiles of discrepant versus non discrepant
readers (Siegel, 1992; Stanovich & Siegel, 1994; Stanovich, Siegel,
Gottardo, Chiappe, & Sidhu, in press). The phenotypic indicators of poor
reading, namely difficulties in phonological coding and weak
phonological sensitivity, do not seem to be correlated in any reliable way
with the degree of discrepancy between intelligence and reading ability
(Stanovich, Siegel, Gottardo, Chiappe, & Sidhu, in press). The evidence suggests that when there are differences between reading disabled individuals with and without an IQ discrepancy, these differences are less related to the fundamental processes involved in reading than for areas in which there are no differences (Siegel, 1992; Stanovich & Siegel, 1994). Thus, the practice of defining only those children with an IQ discrepancy as being reading disabled or dyslexic, simply is untenable.

Are there other ways by which poor readers can be categorized into specific groups? Although the classic literature has not been promising, there is a body of work which has attempted to interpret the cognitive profiles of reading disabled individuals within the framework of the dual-route theory (Castles & Coltheart, 1993; Manis, Seidenberg, Doi, McBride-Chang & Peterson, 1996). It should be pointed out that the previously noted authors do not subscribe to a strong version of the the dual route theory. Nevertheless, they all draw from the dual-route model when interpreting cognitive profiles in reading disabled individuals. According to the dual-route theory, there exist independent lexical and nonlexical routes for processing words (Beech & Awaida, 1992; Humphreys & Evett, 1985). The lexical processing route is thought to operate by a direct mapping of a word's visual characteristics onto a stored lexical representation. Thus, an individual learns to associate a words' orthographic representation with an acceptable pronunciation.
This is commonly referred to as a sight vocabulary and can only operate on familiar words.

Alternatively, the nonlexical processing route is thought to operate by translating the word's graphemic code into a phonological code on the basis of a small set of spelling-to-sound correspondences. This route is nonlexical because the operation of these rules does not depend on word-specific spelling-to-sound knowledge. Unfamiliar words and pseudowords are analyzed using this sublexical route. Although either of these routes can enable words to be recognized or named, on some views (see Share, 1995 and Share & Stanovich, 1995) the sublexical route should be thought of as the primary learning mechanism. Of course, the lexical route becomes of great importance for fluent adults with well instantiated orthographic lexicons. According to the dual-route theory, there may be subgroups that are relatively skilled at lexical processing compared with sublexical processing and subgroups that are relatively skilled at sublexical processing compared with lexical processing. The former is referred to as phonological dyslexia while the latter is referred to as surface dyslexia (Coltheart, Patterson, & Marshall, 1980; Patterson, Marshall & Coltheart, 1985).

In an attempt to uncover the previously mentioned subgroups, Castles and Coltheart (1993) compared the performance of dyslexic individuals to nondyslexic chronological age (CA) controls on exception
word and nonword or pseudoword reading. Given that pseudowords like *diss* have never been encountered before, they would have to be deciphered through a sublexical route. Similarly, exception words like *yacht* would have to be processed through a lexical route since they do not follow the grapheme-phoneme conversion rules that the sublexical route depends on. The results from the Castles and Coltheart (1993) study generally supported the existence of these subgroups. Some reading disabled individuals performed within the normal range on exception word reading but below the normal range on pseudoword reading, and other individuals displayed the opposite performance relationship. Castles and Coltheart (1993) defined the abnormal range as scores on exception word reading and nonword reading that fell outside the range in which 90% of the scores of the control subjects fell for these two types of words.

This technique of comparing normal performance on one measure to abnormal performance on the other, was referred to as "hard subtypes" (Stanovich, Siegel, & Gottardo, 1997). It should be noted that Castles and Coltheart were able to identify additional cases of subgroups by examining the relative imbalances on the two tasks among children who showed depressed performance on both. These cases were defined as "soft" subtypes (Stanovich, Siegel, & Gottardo, 1997). Thus, depending on how one operationalizes surface and phonological dyslexia, there will
be differences in the number of cases reported.

Although the Castles and Coltheart (1993) results may seem convincing, the data is problematic given the lack of reading-level (RL) controls. "If the processing tradeoffs involving the lexical and sublexical procedures are specifically related to the overall level that the reader has attained, then extrapolating from the reading patterns of children at a higher reading level is an inappropriate way of defining abnormal patterns of processing at a lower level" (Stanovich, Siegel, Gottardo, Chiappe, & Sidhu, in press, p.4). Bryant and Impey (1986) noted that if the causes of a child's reading difficulties are to be traced back to his or her peculiar reading patterns, then these patterns must be different from those of other children whose progress in reading is quite normal. They argue that it could not be the case that a particular way of reading is the reason why certain children become dyslexic and that this same way of reading is to be found among children who read quite normally for their age. Any attempt to show that reading disabled children read in radically different ways from normal children, would have to compare their performance to normal children at the same reading level (Siegel, 1993).

Reanalysis of the Castles and Coltheart data by Stanovich, Siegel, and Gottardo (1997) indicated that when a reading-level matched design was employed, there was a significant reduction in the number of
surface dyslexics but not phonological dyslexics. On the basis of these findings, Stanovich, Siegel, and Gottardo (1997) argued that the majority of individuals manifesting a surface dyslexic profile are developmentally delayed (their performance is indistinguishable from RL controls), whereas the majority of individuals manifesting a phonological dyslexic profile are deviant from normal readers.

It appears that problems in phonological processing constitute the core deficit for reading disabled individuals. This view is supported by a body of research (e.g., Bruck, 1992; Bryant, MacLean, Bradley, & Crossland, 1990; Gillon & Dodd, 1995; Kochnower, Richardson, & DiBenedetto, 1983; Manis, Custodio, & Szeszulski, 1993; Morrison, 1993; Siegel & Ryan, 1988; Snowling, 1980; Wagner, Torgesen, & Rashotte, 1994). Rack, Snowling and Olson (1992) reviewed studies which compared dyslexics and reading-level-matched normal readers on measures of pseudoword reading. They found that approximately two thirds of the studies found specific pseudoword reading problems in the dyslexic group, and the remainder did not. In none of these studies did they find dyslexic readers to be superior to their younger reading-level-matched comparison groups. Despite these impressive findings, a number of studies had results inconsistent with the phonological deficit hypothesis.

Rather than dismissing those studies whose results were
inconsistent with the phonological deficit hypothesis. Rack et al. (1992) examined them to see what factors might account for the differing results. One important variable which seemed to distinguish the two groups of studies was age, in particular age of normal comparison readers. Rack et al. (1992) argued that 7-year-old normal readers might not yet have reached a stage in reading development which allows them to decode unfamiliar letter strings. The complexity of the pseudowords used to assess phonological reading strategies was another important variable that seemed to explain some of the differences between studies. Rack et al. (1992) found that pseudowords that were highly visually similar to real words could be read more easily than one would expect. They argued that these words do not require the same depth of phonological processing, and are therefore less sensitive measures of phonological skill. Similarly, Rosson (1983) has shown how lexical information can play a role in the pronunciation of words never encountered before. Specifically, she reported a marked bias in the pronunciation chosen for an ambiguous pseudoword as the result of priming a visually similar word.

Another important factor to consider when attempting to reconcile the inconsistent findings of the studies reviewed by Rack et al. (1992) revolves around the definition of dyslexia. As previously mentioned, a diagnosis of dyslexia has traditionally required normal intelligence, and
a significant discrepancy between measured ability and reading achievement. Thus, it is easy to envision how researchers may have been working with nonrepresentative samples of this disorder, particularly in cases where they classified subjects as dyslexic with high IQ's and average reading achievement scores. Rack et al. (1992) make no mention of this problem in attempting to explain those studies which did not find evidence for a phonological reading problem in reading disabled individuals.

The studies reviewed by Rack et al. (1992) used total pseudoword reading scores as their measure. Although Rack et al. (1992) make a distinction between one and two syllable words and pseudowords when reviewing the research literature, more refined methods exist for separating words and pseudowords in a systematic way. One way to separate words and pseudowords into distinct categories is according to the dimensions of regularity and consistency. Words are defined as consistent if all the orthographic neighbors show a consistent pronunciation of the rime unit (e.g., the three-letter ending ink) (Stanovich, Siegel, Gottardo, Chiappe, & Sidhu, in press). The regularity dimension concerns whether small-unit grapheme-phoneme correspondences conform to their most common pronunciation (Berndt, Reggia, & Mitchum, 1987). By varying these two dimensions it is possible to administer four distinct types of words to individuals. These
include regular consistent (RC), regular inconsistent (RI), irregular consistent (IC), and irregular inconsistent (II) words.

Similarly, it is possible to design distinct types of pseudowords based on regularity and consistency criteria. Pseudowords whose orthographic neighbors have the same pronunciation on the small-unit pronunciation are termed regular consistent; whereas pseudowords whose orthographic neighbors have a different pronunciation than the small-unit pronunciation are termed irregular consistent. Pseudowords whose real word orthographic neighbors have regular pronunciations are considered to be regular on this small-unit criterion. Pseudowords having several orthographic neighbors are considered ambiguous. Thus, it is possible to administer three distinct types of pseudowords to individuals. These include regular consistent (RC), ambiguous inconsistent (AI), and irregular consistent (IC) pseudowords.

Of the previously mentioned real word categories two are particularly useful for investigating the subgroups of phonological and surface dyslexia. IC words such as "fold" are correctly read by using an analogy based decoding strategy (i.e., analogous to "told"). If a reader attempts to decode an IC word by using small-unit correspondence rules the resulting pronunciation is a regularization error (i.e., "fold" read as /fald/ rather than /fold/). Thus, one would expect surface dyslexics to perform more poorly on this type of word than phonological dyslexics.
This is because surface dyslexics are relatively more impaired at using large-unit correspondences and use of a large-unit analogy is precisely what IC words require. In contrast, phonological dyslexics, who are relatively skilled at using large-unit correspondences should perform relatively better on this class of word. Conversely, RI words such as "bead" are correctly read by using small-unit correspondence rules. If a reader attempts to decode a RI word by using an analogy based strategy the resulting pronunciation is an incorrect one (i.e., "bead" read as /bed/ which is analogous to "head" or "read"). Thus, one would expect phonological dyslexics to perform relatively more poorly on this type of word than surface dyslexics.

Similarly, two of the previously mentioned pseudoword categories are also particularly useful for investigating the subgroups of phonological and surface dyslexia. Both IC and AI pseudowords can be correctly read by using small-unit correspondence or large-unit analogy based decoding strategies. Take the AI pseudoword "stull" for instance. If one uses small-unit correspondence rules to decode this pseudoword the resulting pronunciation would be /stəll/ with a short "u" (i.e., analogous to /dull/). Conversely, if one uses a large-unit analogy based strategy to decode this pseudoword the resulting pronunciation would be /stüll/ with a short "oo" (i.e., analogous to /dool/). Thus, one would expect surface dyslexics responses to reflect their dependence on small-
unit strategies and phonological dyslexics responses to reflect their dependence on large-unit strategies when attempting to decode IC and AI pseudowords.

By varying words and pseudowords according to the dimensions of regularity and consistency, one can investigate the dual-route theory more completely. It may be possible to show that phonological dyslexics are less skilled at reading one type of word relative to surface dyslexics. These results could have important implications for remediation of these disorders. It may be useful to include categories of phonological dyslexia and surface dyslexia in batteries of diagnostic tests. One way to accomplish this would be to test subjects with stimuli such as the previously mentioned word categories which may differentiate between the two syndromes. Moreover, intervention for a phonological dyslexic could be directed at improving their phonological recoding skills in the specific types of words and pseudowords they are deficient at reading. A detailed analysis of reading errors on specific types of words and pseudowords is needed.

The strategy of analyzing reading errors in order to make inferences about information processing is not a novel idea. There have been a number of studies which have attempted to interpret the error patterns in both good and poor readers (Bryson & Werker, 1989; Fowler, Liberman & Shankweiler, 1977; Harding, 1984; Weber, 1970; Werker,
Bryson, & Wassenberg, 1989). Some general trends noted in these studies were that consonants in the final position of a syllable were twice as likely to be misread than those in the initial position. In contrast, errors on vowels show no effect of position. One must exercise caution when interpreting the previous conclusions. Unlike consonants, the position of vowels within words cannot be systematically varied. Vowels tend to be located in the middle and end of words rather than at the beginning. This makes it difficult to interpret a position effect.

In her analysis of first grade reading errors, Weber (1970) found that better readers approximated the correct responses more closely than weaker readers. Similarly, Harding (1984) found that children with specific reading disabilities make errors which show poor graphophonetic similarity to the original text. These results suggest that good readers possess better word analysis skills than poor readers. Although the previously noted studies provide important insights into the cognitive processes involved in reading they do little to illuminate differences that exist between specific types of reading deficiencies. As noted previously, an approach is needed which segments words and pseudowords into various categories. Perhaps studies which investigate the effects of regularity and consistency may offer more useful information into the nature of specific reading disabilities.

A number of studies have investigated the effects of regularity and
consistency on children's reading (Coltheart & Leahy, 1992; Coltheart, Laxon, Keating & Pool, 1986; Laxon, Masterson, & Coltheart, 1991). The results showed that good readers perform well on pseudoword reading and tend to regularize irregular words, e.g., pint -> /pInt/ (pronounced to rhyme with tint). For good readers, 70 per cent of the errors on irregular words were regularizations. On the other hand, poor readers did not perform well on pseudoword reading and made a minimal number of regularization errors. For poor readers, only 3 per cent of the errors on irregular words were regularizations. Given that regularization errors indicate an attempt to apply grapheme-phoneme rules, it was argued that poor readers have poor grapheme-phoneme conversion skills and are unaffected by regularity in spelling-to-sound correspondence (Coltheart et al., 1986). This assertion is further supported by research which reports a deficit in the application of small-unit correspondence rules for younger reading disabled individuals (Gottardo, Chiappe, Siegel, & Stanovich, unpublished manuscript; Szeszulski & Manis, 1987). There is however research which runs contrary to the previous assertion. Manis, Szeszulski, Howell, and Horn (1986) reported that their dyslexic children lagged behind reading-age matched control subjects in the application of large-unit analogy but not small-unit correspondence rules. In order to be included in their dyslexic group, Manis et al. (1986) required that a child possess an IQ of
at least 85, and score two or more years below grade level on the Woodcock Word Identification Test.

The present study seeks to resolve the inconsistencies in the research literature by examining subgroups of developmental dyslexia using a reading level matched design. In addition, the present study seeks to examine whether phonological and surface dyslexics are impaired at reading specific types of words and nonwords, and whether they make different types of errors. Their responses will also be analyzed according to regularity and consistency dimensions within these word types. Thus, while the present study is similar in nature to the Castles and Coltheart (1993) study, it entails a more refined level of analysis. Phonological and surface dyslexics were chosen according to the criteria set out by Stanovich, Siegel, and Gottardo (1997). A phonological dyslexic is a child who was an outlier when pseudowords were plotted against exception words but was within the normal range when exception words were plotted against pseudowords. Surface dyslexics were defined conversely.

Within the pseudoword reading task, it is hypothesized that the phonological dyslexics should do better on ambiguous pseudowords relative to regular pseudowords because they use the phonology of larger onset-rime units. They may be able to correctly get these pseudowords by analogy to real words. The surface dyslexics should
show the opposite relationship for the same reason outlined previously. Thus, phonological dyslexics can be expected to generate more large unit than small unit responses relative to surface dyslexics, while surface dyslexics should display the opposite pattern, namely, they will generate more small unit responses than large unit responses relative to phonological dyslexics.

Subject responses will be rated in terms of the types of errors committed. Analyses were conducted on the number of regularizations to irregular words, vowel errors, consonant errors, small-unit responses and large-unit analogy responses to pseudowords, as well as an "other" error category. The "other" error category consisted of errors which were unclassifiable with the previous error categories.

Given that problems in phonological processing constitute the core deficit for reading disabled individuals, it is hypothesized that the phonological dyslexics error patterns will reflect this deficiency. Thus, phonological dyslexics should make fewer regularization errors relative to surface dyslexics. This is because regularizations are considered an attempt to apply grapheme-phoneme rules, an ability which is deficient in poor readers. Similarly, phonological dyslexics should give fewer small-unit responses to irregular-consistent pseudowords (e.g., jook) and more large-unit responses to these stimuli than surface dyslexics. The surface dyslexics should display the opposite error pattern profile.
Moreover, the surface dyslexic error pattern profile should more closely approximate that of RL matched control subjects, which would support the argument that this subgroup is best interpreted as displaying a developmental delay (see Manis et al., 1996, and Stanovich, Siegel, & Gottardo, 1997). The existence of these relative differences would also provide convergent evidence indicating that phonological dyslexics are relatively impaired in the processing of small-unit grapheme-phoneme correspondences and relatively proficient at coding large-unit correspondences.
Method

Participants

The reading-disabled sample consisted of 68 third-grade children (29 boys and 39 girls, mean age = 107.5 months) attending suburban schools in a metropolitan area. These children all scored below the 25th percentile on the reading subtest of the Wide Range Achievement Test-Revised (WRAT-R) (Jastak & Wilkinson, 1984). The mean percentile rank of the less-skilled group on this subtest was 10.6. Their mean raw score on this subtest was 49.8 with a standard deviation of 5.3. The range of the reading-disabled group on the WRAT-R was 37 to 59. The chronological-age controls were 44 children (16 boys and 28 girls, mean age = 107.8 months) recruited from the same schools who scored above the 30th percentile on the reading subtest of the WRAT-R. The mean percentile rank of the chronological-age controls on this subtest was 58.5. Their mean raw score on this subtest was 68.2 with a standard deviation of 5.3. The range of the chronological-age controls on the WRAT-R was 61 to 84.

These children represented a subsample derived from testing approximately 200 third grade children in three schools within the same school district. The district serves a large multicultural population. Average achievement levels in the schools tested were substantially below the norms of most standardized tests. Thus, our relatively liberal
criterion for reading disability combined with the requirement that the comparison children achieve above the 30th percentile resulted in an over representation of reading-disabled children and an under representation of comparison children. We have examined a variety of more stringent criteria for reading disability and more liberal criteria for control status, but these different (and equally arbitrary) cut-off points did not materially affect any of the data patterns. At the time of the study, educational personnel felt that many of the lower SES students were not well served by the lack of emphasis on alphabetic coding in the curriculum (see Adams & Bruck, 1993; Hatcher, Hulme, & Ellis, 1994; Iverson & Tunmer, 1993; Share & Stanovich, 1995; Vellutino, 1991). We eliminated all children who were not native English speakers (36.9% of the sample) and with reported histories of speech, language or hearing difficulties (9.2% of the sample).

The RL controls consisted of 23 first- and second-grade children (13 boys and 10 girls, mean age = 88.9 months) whose mean raw score on the WRAT-R was matched to that of the reading disabled third graders. The mean percentile rank of the reading-level controls on this subtest was 49.5. Their mean raw score on this subtest was 51.1 with a standard deviation of 7.2. The range of the RL controls on the WRAT-R was 39 to 60. The children were tested in May and June of the school year.
Tasks

Experimental Words and Pseudowords. The children were asked to read 48 words and 30 pseudowords (see Appendix A for a list of the stimuli along with the frequency counts of the experimental words), the majority drawn from the work of Coltheart and Leahy (1992). The 48 words were drawn from five different categories that have been discussed in the word recognition literature (see Coltheart & Leahy, 1992; Glushko, 1979; Gottardo et al., unpublished manuscript; Jared & Seidenberg, 1990; Laxon, Masterson, & Moran, 1994; Laxon, Smith, & Masterson, 1995; Patterson & Morton, 1985; Seidenberg, Waters, Barnes, & Tanenhaus, 1984; Taraban & McClelland, 1987). The first category is that of regular consistent words (e.g., glide, stiff, press, blame, brace, tribe, smoke, crane, and puff) - those containing vowels pronounced with their most frequent small-unit correspondence (see Berndt, Reggia & Mitchum, 1987) and with word bodies (iff, ess, ame) all having consistent pronunciations. The second category of regular inconsistent words (e.g., bead, cove, paid, phone, dome, slave, dive, speak, and hull) are those containing vowels pronounced with their most frequent vowel pronunciation based on a context-free frequency count (e.g., Berndt et al., 1987) but that have neighbors whose shared word bodies are pronounced differently (for example, said, have, and give as neighbors of paid, slave, and dive). The third category of irregular consistent words
(e.g., fold, walk, child, mild, halt, half, hind, bind, and malt) have vowel pronunciations which are not the most common based on a context-free count of grapheme-phoneme correspondences (Berndt et al., 1987) but that have many neighbors that share their word bodies and pronunciations (bind: find, mind, kind, hind, etc.). Finally, the irregular inconsistent words (e.g., bear, wood, pint, sweat, broad, steak, worse, shove, and shoe) have vowel pronunciations which are of low frequency based on small-unit context-free counts (Berndt et al., 1987) and also have neighbors that conflict with their pronunciation (pint: hint, mint, lint, etc.). Twelve so-called "strange" words (see Balota & Ferraro, 1993: Seidenberg et al., 1984; Waters & Seidenberg, 1985) made up the fifth category of words. Strange words are not only pronounced irregularly, but they have unusual orthographic patterns and few orthographic neighbors (e.g., debt, yacht, ghost, island, ocean, doubt, rhyme, aisle, sword, muscle, amoeba and receipt).

The children attempted to pronounce 30 pseudowords divided into three categories. One set of pseudowords had bodies that derived from RC words (e.g., ving, fump, drace, biss, pask, hane, drack, lail, fide, hile and stell)(Gottardo et al., unpublished manuscript). Another set of pseudowords were derived from bodies of IC words (e.g., vind, tralf, pold, grall, bould, nalk, jook, fralt and rild)(Gottardo et al., unpublished manuscript). Finally, ambiguous inconsistent pseudowords (e.g., stull,
vood, sost, nush, bove, trome, zove, fown, slear and yone) had rimes that
derived from words that are pronounced several different ways, for
example yone (phone, gone, done) and stull (dull, pull) (Gottardo et al.,
unpublished manuscript). Vowel responses on the experimental
pseudoword reading task were scored according to strict and a lenient
coding criteria. For the strict criterion, all vowels and consonants had to
be pronounced in accordance with vowel and consonants in some real
words with the identical rime unit. For example, the pseudoword "bove"
would have to be pronounced to rhyme with one of the real words cove,
love, and move. All other pronunciations received a score of zero on the
strict criterion. For the lenient scoring criteria, the vowel pronunciation
had to conform to the pronunciation of that vowel in some real word
with the general vowel-consonant configuration but not necessarily one
with the identical rime. For example, the vowel in "bove" could be
pronounced as the vowel in "gone" under the lenient criterion but not
under the strict criterion. In essence, the strict criterion disallowed
pronunciations according to small-unit context-free correspondence
when the small-unit pronunciation did not occur with that specific word
body. Thus, responses based on the lenient criteria are more influenced
by the use of small-unit grapheme-phoneme correspondences (Gottardo
et al., unpublished manuscript).
Designation of Surface or Phonological Dyslexia. The dyslexia subtypes were defined by their performance on a set of experimental exception words and pseudowords largely drawn from the work of Coltheart and Leahy (1992) and from other studies in which word recognition mechanisms have been studied (e.g., Laxon, Smith, & Masterson, 1995; Patterson & Morton, 1985; Seidenberg, Waters, Barnes, & Tannenhaus, 1984, Waters & Seidenberg, 1985). Soft dyslexia subtypes were defined by plotting pseudoword performance against exception word performance (and vice versa) and examining the 90% confidence intervals around the regression line determined from the chronological age (CA) control group. A phonological dyslexic is a child who is an outlier when pseudowords are plotted against exception words but is within the normal range when exception words are plotted against pseudowords (Stanovich, Siegel, & Gottardo, 1997). A surface dyslexic is a child who is an outlier when exception words are plotted against pseudowords but is within the normal range when pseudowords are plotted against exception words (Stanovich, Siegel, & Gottardo, 1997). Figure 1 displays the data from the 68 third-grade reading-disabled children and plots experimental exception word performance against experimental pseudoword performance. The regression line and confidence intervals from the 44 CA controls are also displayed. All four groups are indicated on the plot. Specifically, the points labeled with Ys
are the surface dyslexics (low in the Exception Word x Pseudoword plot and in the normal range on the converse plot), the triangles are the phonological dyslexics (low in the Pseudoword x Exception Word plot and in the normal range on the converse plot), the Xs are participants who are low on both measures, and the crosses represent individuals who are low on neither. The mean raw score of the surface dyslexics on the WRAT-R was 53.1 with a standard deviation of 4.5. Their range of scores on this subtest was 44 to 59. The mean raw score of the phonological dyslexics on the WRAT-R was 49.9 with a standard deviation of 4.4. Their range of scores was 37 to 56.

One interesting difference between the present sample, taken from the original Stanovich, Siegel, and Gottardo (1997) study, and those involving the CA controls in the Castles and Coltheart (1993) and Manis et al. (1996) investigations concerns the fact that Manis et al. (1996) found only 9.8% of their sample were outside the regression criterion on both measures, and Castles and Coltheart (1993) found only 5.7% of their sample to be low on both (Stanovich, Siegel, & Gottardo, 1997). In contrast, 27.9% of the dyslexics (19 of 68 children) were low on both types of stimuli, in the present sample. Stanovich, Siegel, and Gottardo (1997) suggest that these findings may indicate that, with development, there is increasing dissociation between lexical and sublexical processes in dyslexics. They note that the proportion of surface dyslexics was
fairly similar across the three studies (30.2% in the Castles & Coltheart study, 29.4% in Manis et al., and 22.1% in the Stanovich, Siegel, & Gottardo study). In contrast, the proportion of phonological dyslexics in the Castles and Coltheart (1993) study (54.7%) was higher than that observed in the other two investigations (33.3% in Manis et al., and 25.0% in the Stanovich, Siegel, & Gottardo, 1997).

Response Pattern Analysis

Real Words

Participants' responses on real words were classified as correct or incorrect. Incorrect responses were further subdivided into five mutually exclusive error categories. These included regularization, analogy, vowel, consonant, and an "other" error category. Regularization errors involved the inappropriate application of small-unit grapheme-phoneme conversion rules (i.e., "fold" read as /fald/). Regularization errors could only occur in IC and II words. Analogy errors involved the generation of an analogy response to words that would presumably be read by applying small-unit correspondence rules (i.e., "bead" read as /bed/ which is analogous to "head"). Analogy errors could only occur in RI and II words. It is important to note that II words represented a special case in that the same response could be categorized as a regularization or analogy error (i.e., "bear" read as /bear/ with a long "e" sound). Vowel errors occurred when all consonants were decoded
correctly without reference to order and with no consonant insertions (i.e., "glide" read as /gold/). Consonant errors involved either an incorrect decoding, consonant omission, or single consonant addition (i.e., "bead" read as /bred/). Consonant errors could occur with or without vowel errors and were collapsed into a single consonant error category. The "other" error category consisted of errors which were unclassifiable via the previous categories. The "other" error type was a "catch all" category including various error types too infrequent for statistical analysis (i.e., "child" read as /children/, "phone" read as /ponny/, or "press" read as /present/). Mutually exclusive vowel, consonant, and "other" errors could occur in all the real word types.

**Pseudowords**

Participants' responses on the pseudowords were classified as correct or incorrect. A correct response could consist of a small-unit response or large-unit response depending on the pseudoword. Small-unit responses were those that followed small-unit grapheme-phoneme correspondence rules (i.e., "sost" read as /sast/ with a short "o" sound). Large-unit responses were those that were analogous to some real word (i.e., "sost" read as /sost/ which is analogous to "host", "most", or "post"). Small-unit responses could be made to all three pseudoword categories whereas large-unit responses could only be made to IC and AI words. Incorrect responses consisted of mutually exclusive vowel, consonant, or
"other" error types, and could occur in all pseudoword types. These error categories followed the same criteria as outlined in the real word section reported above. For example, if the AI pseudoword "zove" was read as /zeve/ with a long "e", it would be classified as a vowel error. Similarly, if the IC pseudoword "vind" was read as /wind/ with a short "i", it would be classified as a consonant error. Lastly, if the RC pseudoword "drace" was read as /draf/ with a short "a", it would be classified as an "other" error. As with real words, the "other" error type for pseudowords was a "catch all" category including various error types too infrequent for statistical analysis.
Results

A 2-factor repeated measures ANOVA was conducted to examine the tendency to respond with small-unit versus large-unit strategies across real word and pseudoword categories, for three groups of readers. It should be reiterated that small-unit and large-unit strategies resulted in both correct and incorrect responses depending on the type of word to which they were applied. The following analyses collapse both correct and incorrect responses into the comprehensive small-unit and large-unit response categories\(^2\). The small-unit category consisted of small-unit responses to AI pseudowords (i.e., "stull" read as /stull/ with a short "u" sound) and IC pseudowords ("vind" read as /vInd/ with a short "i" sound). In addition, correct responses to RI real words and regularization errors to IC real words were included in this category. Recall that IC real words are correctly read by using an analogy based decoding strategy. If a reader attempts to decode an IC real word by using small-unit correspondence rules the resulting pronunciation is a regularization error. The large-unit category consisted of large-unit responses to AI pseudowords (i.e., "stull" read as /stool/) and IC pseudowords (i.e., "vind" read as /vind/ with a long "i" sound). Correct responses to IC real words and analogy based errors to RI real words were also included in this category. Recall that RI words can only be

\(^2\) In Appendix B, group by stimulus type analyses (words versus pseudowords) were conducted on both small-unit and large-unit responses. Tables and analyses are reported.
correctly read by using small-unit correspondence rules. If a reader attempts to decode a RI word by using an analogy based strategy the resulting pronunciation is an incorrect one.

The results showed that the interaction between reader group (i.e., surface dyslexic, phonological dyslexic, and RL control) and response strategy (i.e., small-unit versus large-unit) did not reach conventional levels of statistical significance. $F(2, 53) = 2.84, p<.07$. However, as illustrated in Tables 1 and 2, the profile of the surface and RL controls was quite similar on small-unit and large-unit criterion, while the profile of phonological dyslexics tended to deviate from that of the two other groups. This outcome is consistent with the results in the Stanovich, Siegel, & Gottardo (1997) study, indicating that the surface dyslexic profile more closely approximates that of reading-level matched control subjects. More fine-grained comparisons between the less-skilled readers and RL controls were conducted to further examine their response patterns according to small-unit and large-unit criterion.

A single factor ANOVA was conducted to examine the tendency to respond with a small-unit strategy across real word and pseudoword categories, for the three groups of readers. The analysis indicated that the effect of reader group on the number of small-unit responses was significant, $F(2, 52) = 11.103, p<.001$. As illustrated in Table 1, and as indicated by the Scheffe post-hoc tests, phonological dyslexics gave
significantly fewer small-unit responses than surface dyslexics and RL controls, who did not differ from each other. This result provides converging evidence indicating that phonological dyslexics are impaired in the processing of small-unit grapheme-phoneme correspondences.

A single factor ANOVA was conducted to examine the tendency of the three groups of readers to respond with a large-unit strategy across real word and pseudoword categories. The analysis indicated that the effect of reader group on the number of large-unit responses was not significant, $F(2, 52) = 1.281, p > .05$. Table 2 illustrates the performance pattern of the three groups of readers on large-unit criterion. The fact that the phonological dyslexics produced somewhat fewer large-unit responses is perhaps related to the fact that they made more consonant and "other" errors (as will be described below).

**Subsidiary Analyses On Vowel, Consonant, & Other Error Categories**

The following analysis collapses vowel errors across real word and pseudoword types. A single factor ANOVA was conducted to examine the number of vowel errors made by the three groups of readers. The analysis indicated that the effect of reader group on the number of vowel error responses did not reach conventional levels of statistical significance, $F(2, 52) = 2.481, p < .10$. As illustrated in Table 3, the RL controls made somewhat more vowel errors than the less-skilled surface

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3 In Appendix C, a group by stimulus type analysis (words versus pseudowords) was conducted on vowel error responses. The table and analysis are reported.
and phonological dyslexics. Surface dyslexics and phonological dyslexics made an equivalent number of errors which runs contrary to the previous hypothesis that surface dyslexics would behave more like RL controls.

The following analysis collapses consonant errors across real word and pseudoword types. A single factor ANOVA was conducted to examine the number of consonant errors made by the three groups of readers. The analysis indicated that the effect of reader group on the number of consonant error responses failed to reach conventional levels of statistical significance, $F(2, 52) = 2.975, p<.06$. As illustrated in Table 4, the means of the surface dyslexics and RL controls were very similar while the mean of phonological dyslexics deviated from the previously mentioned groups. The phonological dyslexics tended to produce more consonant errors.

The following analysis collapses "other" errors across real word and pseudoword word types. A single factor ANOVA was conducted to examine the number of "other" errors made by the three groups of readers. The analysis indicated that the effect of reader group on the number of "other" error responses was significant, $F(2, 52) = 11.538, p<.001$. As illustrated in Table 5, phonological dyslexics made

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4 In Appendix D, a group by stimulus type analysis (words versus pseudowords) was conducted on consonant error responses. The table and analysis are reported.

5 In the Appendix E, a group by stimulus type analysis (words versus pseudowords) was conducted on other error responses. The table and analysis are reported.
significantly more "other" errors than surface dyslexics and RL controls, who did not differ from each other. Moreover, Table 5 clearly indicates that the means of the surface and RL controls were very similar. "Other" errors are best viewed as "wild" responses - that is, those that displayed very little phonological correspondence. When a subject committed an error which was classified as "other", it usually began with the same first sound but bore little phonetic relationship to the stimulus word thereafter (i.e., "paid" read as /pilk/ with a short "i"). Thus, it may not be incorrect to view "other" errors as the most 'severe' type of error committed. The fact that phonological dyslexics make a large number of these errors relative to surface dyslexics suggests that this subgroup of readers is the more severely disabled of the two.
Discussion

The present study examined subtypes of developmental dyslexia using a reading-level match design. As previously mentioned, in order to demonstrate that reading disabled children read in radically different ways from normal children, their performance must be compared to that of normal children at the same reading level (Bryant & Impey, 1986). Studies employing a reading-level matched design have consistently reported a phonological processing deficit in reading disabled individuals (see Rack, Snowling, & Olson, 1992). In the majority of studies reviewed by Rack, Snowling, & Olson (1992), significant pseudoword reading problems were noted in reading disabled individuals. However, the previous studies were not able to delineate specific types of response patterns to words and pseudowords that characterized subgroups of reading disabled individuals. Thus, an analysis of response patterns to words and pseudowords separated in a systematic way may offer important insights into the nature of specific reading disabilities.

In the present study, words and pseudowords were separated into distinct categories according to the dimensions of regularity and consistency. This procedure allowed us to examine surface dyslexics' and phonological dyslexics' reliance on small-unit versus large-unit correspondence rules. One interesting difference between the present study and those that have been conducted to date, is that the present
study examined small-unit versus large-unit strategies irrespective of whether an answer was correct or not. That is, both correct and incorrect responses were classified as small-unit or large-unit strategies depending on the type of response generated.

The results indicated that phonological dyslexics were relatively less adept at using small-unit correspondences than surface dyslexics and reading-level matched controls. This result is consistent with previous research (see Manis et al., 1996; Stanovich, Siegel, & Gottardo, 1997) suggesting that phonological dyslexics' primary deficit lies in the processing of small-unit grapheme-phoneme correspondences. Both Stanovich, Siegel, & Gottardo (1997), as well as Manis et al. (1996), have found severe deficits among phonological dyslexics on measures of phonemic awareness but not on measures of orthographic skill. In both studies, phonological dyslexics performed significantly more poorly on nonword reading versus exception word reading. The reader may recall that nonword reading requires the ability to translate a word's graphemic code into a phonological code on the basis of a small set of spelling-to-sound correspondences, whereas exception word reading requires the ability to recall a learned association between a word's orthographic representation and its acceptable pronunciation. Results also displayed a marked similarity in the profile of surface dyslexics and reading-level matched controls on small-unit criterion. This outcome
supports the notion that surface dyslexics are best interpreted as
displaying a developmental delay (see Manis et al., 1996; Stanovich,
Siegel, & Gottardo, 1997). The developmental delay/deviance distinction
advanced by Stanovich, Siegel, and Gottardo (1997) is further supported
by the fact that in many of the analyses conducted the performance of
surface dyslexics was indistinguishable from RL controls.

It is important to note that in the subsidiary analyses conducted,
phonological dyslexics made significantly more "other" errors and non-
significantly more consonant errors than surface dyslexics and RL
controls. The "other" errors are best interpreted as those displaying
little phonological sensitivity. Thus, the present results suggest that
problems in phonological processing constitute the core deficit for
reading disabled individuals. As noted previously, this view is
supported by a body of research (e.g., Bruck, 1992; Bryant, MacLean,
Bradley, & Crossland, 1990; Gillon & Dodd, 1995; Kochnower, Richardson,
& DiBenedetto, 1983; Manis, Custodio, & Szczulski, 1993; Morrison,
1993; Siegel & Ryan, 1988; Snowling, 1980; Wagner, Torgesen, &
Rashotte, 1994).

One of the practical implications of the present study concerns the
early identification and remediation of reading disabilities. Given that
phonological dyslexics represent the most severe type of reading
disability, it may be useful to test children with stimuli that differentiate
between this disabled subgroup and normal readers. The present study suggests that children be presented with words that test their ability to apply small-unit correspondence rules. For example, a list of RI real words could be administered to a child suspected of having a reading disability. Recall that RI real words can only be correctly read through the application of small-unit grapheme-phoneme correspondence rules. Thus, poor performance on such words may indicate a selective deficit in the application of such rules. Remedial efforts could then be directed at improving children's application of small-unit correspondence rules. Previous research by Olson and Wise (1992) has investigated the benefits of using computers to provide corrective feedback to students experiencing reading difficulties. Their results indicated that the most severely disabled readers showed the largest phonological decoding gains from syllable feedback as opposed to using a whole-word feedback strategy. Thus, remedial efforts geared at improving small-unit correspondence rules tend to generate the greatest improvements in severely disabled readers.

Limitations Of The Study

The present study possessed limitations which may account for the failure to reach significance levels in various analyses. One main problem with the present study was the relatively small sample size. As mentioned previously, there were 15 surface dyslexics, 17 phonological
dyslexics, and 23 RL controls. This shortcoming in terms of power should not be ignored, especially given that in the vast majority of cases the pattern of results were in the hypothesized direction. Even more important than sample size, was the fact that the study was conducted with a restricted set of words. The discrete word and pseudoword categories had a range of 9 to 11 stimulus words. This reduced the reliability of each of the error categories. Increased power (in the form of a larger sample size) and increased reliability (in the form of a larger number of stimuli) may have resulted in more accurate estimates of the reader group differences, and in some cases, perhaps results that attained higher levels of significance.

Conclusion

The present study suggests that one key variable which distinguishes among reading disabled individuals is their ability to processes small-unit grapheme-phoneme correspondences. Phonological dyslexics tend to be particularly deficient in the application of these rules. The reader may recall that the performance profile of surface dyslexics and reading-level controls were indistinguishable on this criterion. This pattern of results, whereby surface dyslexics tended to approximate normal readers more closely than phonological dyslexics, seemed to generalize to the other types of analyses conducted. Future studies which take into account the limitations of the present study may
be able to provide higher levels of significance on the subsidiary analyses conducted. Lastly, the present study suggests that one potentially useful strategy in the early identification of reading disabilities could be to test children with stimuli that selectively tap their ability to apply small-unit correspondences.
References


Gottardo, A., Chiappe, P., Siegel, L. S., & Stanovich, K. E. (unpublished manuscript). Less-skilled readers have a specific problem coding small-unit spelling-sound correspondences.


Table 1

Comparisons Between Phonological Dyslexics \((n = 17)\), Surface Dyslexics \((n = 15)\), and Reading-Level Controls \((n = 23)\) on the Number of Small-Unit Correspondence (SUC) Responses (Standard Deviations are in Parentheses)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Number of SUC Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonological Dyslexics</td>
<td>8.8(^a) (4.0)</td>
</tr>
<tr>
<td>Surface Dyslexics</td>
<td>15.3(^b) (5.3)</td>
</tr>
<tr>
<td>Reading-Level Controls</td>
<td>14.4(^b) (4.0)</td>
</tr>
</tbody>
</table>

Note. Superscripts with different letters indicate significant differences at the .05 level in Scheffe post-hoc comparisons.
Table 2

Comparisons Between Phonological Dyslexics (n = 17), Surface Dyslexics (n = 15), and Reading-Level Controls (n = 23) on the Number of Large-Unit Analogy (LUA) Responses (Standard Deviations are in Parentheses)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Number of LUA Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonological Dyslexics</td>
<td>8.3a (4.0)</td>
</tr>
<tr>
<td>Surface Dyslexics</td>
<td>10.6a (5.3)</td>
</tr>
<tr>
<td>Reading-Level Controls</td>
<td>9.2a (3.2)</td>
</tr>
</tbody>
</table>

Note. Superscripts with different letters indicate significant differences at the .05 level in Scheffe post-hoc comparisons.
Table 3

Comparisons Between Phonological Dyslexics (n = 17), Surface Dyslexics (n = 15), and Reading-Level Controls (n = 23) on the Number of Vowel Error Responses (Standard Deviations are in Parentheses)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Number of Vowel Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonological Dyslexics</td>
<td>10.2a (4.2)</td>
</tr>
<tr>
<td>Surface Dyslexics</td>
<td>9.9a (5.0)</td>
</tr>
<tr>
<td>Reading-Level Controls</td>
<td>13.2a (5.8)</td>
</tr>
</tbody>
</table>

Note. Superscripts with different letters indicate significant differences at the .05 level in Scheffe post-hoc comparisons.
Table 4

Comparisons Between Phonological Dyslexics (n = 17), Surface Dyslexics (n = 15), and Reading-Level Controls (n = 23) on the Number of Consonant Error Responses (Standard Deviations are in Parentheses)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean Number of Consonant Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonological Dyslexics</td>
<td>7.4a (3.1)</td>
</tr>
<tr>
<td>Surface Dyslexics</td>
<td>5.5a (3.6)</td>
</tr>
<tr>
<td>Reading-Level Controls</td>
<td>5.2a (2.4)</td>
</tr>
</tbody>
</table>

Note. Superscripts with different letters indicate significant differences at the .05 level in Scheffe post-hoc comparisons.
Table 5

Comparisons Between Phonological Dyslexics (n = 17), Surface Dyslexics (n = 15), and Reading-Level Controls (n = 23) on the Number of Other Error Responses (Standard Deviations are in Parentheses)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Number of Other Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonological Dyslexics</td>
<td>18.5&lt;sup&gt;a&lt;/sup&gt; (12.3)</td>
</tr>
<tr>
<td>Surface Dyslexics</td>
<td>6.3&lt;sup&gt;b&lt;/sup&gt; (5.8)</td>
</tr>
<tr>
<td>Reading-Level Controls</td>
<td>7.4&lt;sup&gt;b&lt;/sup&gt; (5.5)</td>
</tr>
</tbody>
</table>

Note. Superscripts with different letters indicate significant differences at the .05 level in Scheffe post-hoc comparisons.
Figure 1. Performance on exception word reading plotted against pseudoword reading for the reading-disabled children in this study. The regression line and confidence intervals were derived from the data of the chronological controls. Y = surface dyslexics, ▲ = phonological dyslexics, X = low on both, + = low on neither. Larger points indicate two individuals with the same scores.
Appendix A

Experimental Words and Pseudoword Stimuli (Frequency of Experimental Words according to the American Heritage Word Frequency Book in Parentheses)

Experimental Words

<table>
<thead>
<tr>
<th>Regular Consistent Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>glide (7)</td>
</tr>
<tr>
<td>stiff (22)</td>
</tr>
<tr>
<td>press (31)</td>
</tr>
<tr>
<td>blame (10)</td>
</tr>
<tr>
<td>brace (3)</td>
</tr>
<tr>
<td>tribe (21)</td>
</tr>
<tr>
<td>smoke (70)</td>
</tr>
<tr>
<td>crane (9)</td>
</tr>
<tr>
<td>puff (17)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Regular Inconsistent Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>bead (5)</td>
</tr>
<tr>
<td>cove (4)</td>
</tr>
<tr>
<td>paid (63)</td>
</tr>
<tr>
<td>phone (10)</td>
</tr>
</tbody>
</table>
slave (31)
dive (17)
speak (95)
hull (3)

Irregular Consistent Words
fold (32)
walk (258)
child (149)
mild (5)
halt (1)
half (258)
hind (23)
bind (1)
malt (2)

Irregular Inconsistent Words
bear (116)
wood (206)
pint (16)
sweat (10)
<table>
<thead>
<tr>
<th>Word</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>broad</td>
<td>39</td>
</tr>
<tr>
<td>steak</td>
<td>5</td>
</tr>
<tr>
<td>worse</td>
<td>26</td>
</tr>
<tr>
<td>shove</td>
<td>2</td>
</tr>
<tr>
<td>shoe</td>
<td>58</td>
</tr>
</tbody>
</table>

**Strange Words**

<table>
<thead>
<tr>
<th>Word</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>debt</td>
<td>1</td>
</tr>
<tr>
<td>yacht</td>
<td>0</td>
</tr>
<tr>
<td>ghost</td>
<td>13</td>
</tr>
<tr>
<td>island</td>
<td>35</td>
</tr>
<tr>
<td>ocean</td>
<td>182</td>
</tr>
<tr>
<td>doubt</td>
<td>12</td>
</tr>
<tr>
<td>rhyme</td>
<td>102</td>
</tr>
<tr>
<td>aisle</td>
<td>0</td>
</tr>
<tr>
<td>sword</td>
<td>4</td>
</tr>
<tr>
<td>muscle</td>
<td>15</td>
</tr>
<tr>
<td>amoeba</td>
<td>0</td>
</tr>
<tr>
<td>receipt</td>
<td>0</td>
</tr>
</tbody>
</table>
Pseudowords

Ambiguous Inconsistent Pseudowords
stull
vood
sost
nush
bove
trome
zove
fown
slear
yone

Irregular Consistent Pseudowords
vind
tralf
pold
grall
bould
nalk
jook
fralt
rild

Regular Consistent Pseudowords

ving
fump
dace
biss
pask
hane
drack
lail
fide
hile
stell
Appendix B

Comparisons Between Phonological Dyslexics (n = 17), Surface Dyslexics (n = 15), and Reading-Level Controls (n = 23) on the Number of Small-Unit Correspondence (SUC) Responses Made on Real Words (RW) versus Pseudowords (PW) (Standard Deviations are in Parentheses)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Number of SUC Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RW</td>
</tr>
<tr>
<td>Phonological Dyslexics</td>
<td>4.9 (2.4)</td>
</tr>
<tr>
<td>Surface Dyslexics</td>
<td>7.7 (3.2)</td>
</tr>
<tr>
<td>Reading-Level Controls</td>
<td>6.2 (2.2)</td>
</tr>
</tbody>
</table>

A 2 (stimulus type: words versus pseudowords) by 3 (subject group: phonological dyslexics, surface dyslexics, and reading-level controls) ANOVA indicated that there was a main effect of subject group $F(2, 52) = 11.103$, $p < .001$, but no main effect of stimulus type. However, there was a significant group by stimulus type interaction, $F(2, 52) = 7.517$, $p < .01$. This interaction came about because the RL group performed better on the pseudoword stimulus type than the real word stimulus type whereas this was not true for the other two groups who instead performed at least as well on real words as pseudowords.
Comparisons Between Phonological Dyslexics (n = 17), Surface Dyslexics (n = 15), and Reading-Level Controls (n = 23) on the Number of Large-Unit Analogy (LUA) Responses Made on Real Words (RW) versus Pseudowords (PW) (Standard Deviations are in Parentheses)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Number of LUA Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RW</td>
</tr>
<tr>
<td>Phonological Dyslexics</td>
<td>4.9 (2.1)</td>
</tr>
<tr>
<td>Surface Dyslexics</td>
<td>5.1 (3.2)</td>
</tr>
<tr>
<td>Reading-Level Controls</td>
<td>5.1 (2.3)</td>
</tr>
</tbody>
</table>

A 2 (stimulus type: words versus pseudowords) by 3 (subject group: phonological dyslexics, surface dyslexics, and reading-level controls) ANOVA indicated that there was no main effect of subject group and no main effect of stimulus type. However, there was a significant group by stimulus type interaction, $F(2, 52) = 3.347, p < .05$. This interaction came about because the phonological group performed more poorly on the pseudoword stimulus type than the real word stimulus type whereas this was not true for the other two groups who instead performed almost as well on pseudowords as real words.
Appendix C

Comparisons Between Phonological Dyslexics (n = 17), Surface Dyslexics (n = 15), and Reading-Level Controls (n = 23) on the Number of Vowel Error Responses Made on Real Words (RW) versus Pseudowords (PW) (Standard Deviations are in Parentheses)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Number of Vowel Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RW</td>
</tr>
<tr>
<td>Phonological Dyslexics</td>
<td>4.5</td>
</tr>
<tr>
<td>Surface Dyslexics</td>
<td>4.8</td>
</tr>
<tr>
<td>Reading-Level Controls</td>
<td>6.9</td>
</tr>
</tbody>
</table>

A 2 (stimulus type: words versus pseudowords) by 3 (subject group: phonological dyslexics, surface dyslexics, and reading-level controls) ANOVA indicated that all vowel error trends were the same for both word types. There was no main effect of subject group, no main effect of stimulus type, and no significant group by stimulus type interaction, $F = (2, 52) = 1.645, p > .05$. 
Appendix D

Comparisons Between Phonological Dyslexics (n = 17), Surface Dyslexics (n = 15), and Reading-Level Controls (n = 23) on the Number of Consonant Error (CE) Responses Made on Real Words (RW) versus Pseudowords (PW) (Standard Deviations are in Parentheses)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Number of Consonant Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RW</td>
</tr>
<tr>
<td>Phonological Dyslexics</td>
<td>3.8 (2.1)</td>
</tr>
<tr>
<td>Surface Dyslexics</td>
<td>3.3 (2.7)</td>
</tr>
<tr>
<td>Reading-Level Controls</td>
<td>2.5 (1.8)</td>
</tr>
</tbody>
</table>

A 2 (stimulus type: words versus pseudowords) by 3 (subject group: phonological dyslexics, surface dyslexics, and reading-level controls) ANOVA indicated that all consonant error trends were the same for both word types. There was no main effect of subject group, no main effect of stimulus type, and no significant group by stimulus type interaction, $F = (2, 52) = 1.082, p>.05$. 
Appendix E

Comparisons Between Phonological Dyslexics ($n = 17$), Surface Dyslexics ($n = 15$), and Reading-Level Controls ($n = 23$) on the Number of Other Error (OE) Responses Made on Real Words (RW) versus Pseudowords (PW) (Standard Deviations are in Parentheses)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Number of Other Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RW</td>
</tr>
<tr>
<td>Phonological Dyslexics</td>
<td>7.8 (6.3)</td>
</tr>
<tr>
<td>Surface Dyslexics</td>
<td>3.2 (3.7)</td>
</tr>
<tr>
<td>Reading-Level Controls</td>
<td>3.5 (3.9)</td>
</tr>
</tbody>
</table>

A 2 (stimulus type: words versus pseudowords) by 3 (subject group: phonological dyslexics, surface dyslexics, and reading-level controls) ANOVA indicated that there was a main effect of subject group $F(2, 52) = 11.538, p < .001$, but no main effect of stimulus type. There was no significant group by stimulus type interaction, $F(2, 52) = 2.872, p > .05$. 