

RUNNING HEAD: Reading Derived Words

The Effects of Phonological Transparency
on Reading Derived Words

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Abstract

The purpose of this study was to determine whether poor readers have more pronounced problems than average-reading peers reading derived words whose base forms undergo a phonological shift when a suffix is added (i.e., shift relations as in natural), as compared to derived words whose forms are phonologically and orthographically transparent (i.e., "stable" relations, as in cultural). Two computer-based word recognition tasks (Naming and Lexical Decision) were administered to children with reading disability (RD), peers with average reading ability, and adults. Across tasks, there was an effect for transparency (i.e., better performance on stable than shift words) for both child groups and the adults. For the children, a significant interaction was found between group and word type. Specifically, on the naming task, there was an advantage for the stable words, and this was most noteworthy for the children with RD. On the lexical decision task, trade-offs of speed and accuracy were evident for the child reader groups. Performances on the nonwords showed the poor readers to be comparable to the average readers in distinguishing legal and illegal nonwords; further analyses suggested that poor readers carried out deeper processing of derived words than their average reading peers. Additional study is needed to explore the relation of orthographic and phonological processing on poor readers' memory for and processing of derived words.

Introduction

Current literature abounds with documentation of a relationship between phonological awareness and reading development, with extensive evidence to suggest that reading disabilities arise from underlying phonological deficits (Lieberman, Shankweiler, & Liberman, 1989; Stanovich, 1986). While studies have shown that children with reading disabilities have significant problems with word reading accuracy and speed (Compton & Carlisle, 1994), such studies have generally focused on words of one morpheme. Of considerable interest is whether morphological structure plays a role in word reading speed and accuracy, and whether students with reading disabilities have greater problems reading morphologically complex words than morphologically simple words. Moreover, studying morphology as it relates to reading in the school-age years is important because of its educational relevance. Nagy, Anderson, Schommer, Scott, and Stallman (1989) found that after the fourth grade, over sixty percent of the words that children encounter through reading are morphologically complex. Employing an alphabetic strategy for reading morphologically complex words is bound to be only partially successful in providing access to meaning, as the addition of one or more suffixes often results in phonological changes in the base word (e.g., revise to revision) and the pronunciation of the suffix is not the sum of the parts (e.g., -sion).

There is evidence that the phonological properties of words affect morphological processing, and phonological aspects of morphological processing are related to reading achievement (Carlisle & Nomanbhoy, 1993; Fowler & Liberman, 1995; Shankweiler, et al., 1995; Singson, Mahoney, & Mann, 2000; Windsor, 2000). The demands of phonological processing are most evident on tasks that include morphologically complex words that undergo a shift in pronunciation when a derivational suffix is added to the base form. For example, the long vowel sound in nature is shortened when the suffix, -al is added to the base word to make natural. Recognizing that children with reading disabilities have difficulty with the phonological aspects of reading, we might suspect that they encounter particular difficulties reading derived words whose base forms may be obscured by such phonological shifts.

Shankweiler et al. (1995) found reading disabled children to be deficient in generating morphologically complex forms in an oral production task. These researchers found strong correlations between phonological skills and morphological skills. Their results suggested that underlying phonological deficits could be largely responsible for these children's difficulties in generating derived forms. Furthermore, children's facility with words that reflected shifts in pronunciation from base to derived form (e.g., five/fifth) more clearly separated poor readers from normal readers than words for which pronunciation remained stable (e.g., four/fourth). Similarly, Fowler and Liberman (1995) found that poor readers differed from good readers in the oral production of words that undergo phonological shifts and that students' sensitivity to morphologically complex words on an oral production task was related to their reading and spelling abilities. Additionally, Champion (1997) and Leong (1989) both contrasted good and poor readers. Leong showed that poor readers and spellers were slower at producing derived and base word forms than good readers/spellers, particularly when the words involved both phonological and orthographic changes from base to derived form. Champion found that while poor readers differed from good readers in awareness of the semantic and syntactic aspects of derived forms, the differences were more pronounced on reading than on oral tasks. These studies provide evidence for the importance of phonology as it relates to morphological processing, and they show connections between impairment in one or both of these processes and below average skills in reading.

A limitation of these studies is that they did not include a direct measure of reading aloud morphologically complex words. One study that did include such a measure was carried out by Elbro and Arnbak (1996). These researchers asked Danish teen-age dyslexics and younger normal readers to read a set of complex words that were semantically transparent and nontransparent; the set included compounds as well as inflected and derived words. The dyslexic students read morphologically transparent words faster and more accurately than non-transparent words. These researchers suggested that morpho-semantic transparency may be a compensatory

mechanism in word decoding and comprehension for dyslexic adolescents and may be more important for dyslexics than for reading-age matched controls.

Differences in reading phonologically transparent and non-transparent words have been found for normally achieving readers. Carlisle (2000) compared third and fifth graders' reading of derived words. Performance on words for which the pronunciation between corresponding base and derived forms was stable (e.g., enjoy-enjoyment) was compared to performance on words for which there were shifts in pronunciation (e.g., nature-natural), matched for word length and frequency (base and surface forms). Both third and fifth graders were significantly more accurate on reading transparent than shift words. We would expect this difference to be more pronounced for students with reading disabilities.

Questions remain about how to assess the effects of phonological transparency on students' reading of morphologically complex words. A word naming task can be used to investigate the extent to which morphological processing is used in reading morphologically complex words. This task requires pronunciation of the words aloud. Consequently, if reading derived words of transparent and shift relations, matched for word length and frequency, differs in speed or accuracy, the difference would reflect the relative ease with which the phonological representation of the base word facilitates recognition and pronunciation of the complex word form. Such facilitation would not take place if the complex word form was not decomposed morphologically. Thus, if transparent words are not read more quickly and accurately than shift words, a likely interpretation would be that the words were not processed with regard to their morphological structure. Further, evidence suggests that children with reading disabilities demonstrate difficulties in naming, which presumably include accessing the phonological representation in memory and preparing and delivering the speech act of naming the word (Denckla & Rudel, 1976). Naming problems may be an important contributor to difficulties reading aloud derived words, along with other aspects of phonological processing. For this reason, the gap between performance on transparent and shift words might be greater for students with RD than for their average-achieving peers

Because poor readers might have specific naming problems, it seemed desirable to include a second task that did not require an oral response—namely, a lexical decision task. Lexical decision tasks have shown that morphological structure affects word recognition (e.g., Cole, Beauvillain, & Segui, 1989; Stoltz & Feldman, 1995), but these results have come from studies of adults with average reading skills. With the exception of Gordon (1989), who used flashcards to record accuracy of lexical decisions with 5- through 9-year olds in order to explore a model of word formation, we are not aware of other studies that have utilized this task for studying morphology in children.

The lexical decision task requires students to make a judgment about whether a letter string is or is not a word. Presumably, the decision is made on the basis of whether the student does or does not find the string of letters stored as a word in memory. Models of word recognition indicate that finding a word in memory entails processing not only the orthographic representation but also the phonological and semantic representations (Besner, 1999). Thus, performance on the task might indicate whether phonological complexity influenced the speed and accuracy of processing shift as compared to stable words. However, studies of adults gave us reason to expect morphological composition to play a role in word recognition on this task as well. Performance on lexical decision tasks with priming have shown an effect for morphological structure that cannot be explained by orthographic, phonological, or semantic properties of the words (e.g., Stolz & Feldman, 1995). Furthermore, studies have shown that both high school students and adults make use of orthographic information in analyzing the morphological structure of words (Derwing, Smith & Wiebe, 1995; Templeton & Scarborough-Franks, 1985). If middle school students (with and without reading problems) also decompose words in the process of visual word recognition, we might expect to find an interference effect for derived words whose base forms undergo a sound shift but not for base forms whose phonological representation is fully incorporated in the derived counterpart.

An added value of the lexical decision task was its potential for exploring the extent to which orthographic processing of the letter string affects the reading of words and nonwords

differently for poor and average achieving readers. One issue is the level of orthographic awareness of students with reading disabilities. Results of previous studies have suggested that poor readers are sensitive to the "legality" of letter strings (i.e., combinations or patterns of letters found in English orthography) (Siegel, Share, & Geva, 1995). As a result, they would not be expected to differ from their peers in rejecting nonwords constructed of letter combinations that are not permissible in English. However, poor readers are less efficient in developing a full representation of words (including orthographic and phonological characteristics) than their peers and so might be slower and/or less accurate at recognizing legal letter strings as nonwords (Ehri, 1997). Readers make connections between graphemes and phonemes in the words that they encounter through print; with repeated exposures, these words are stored in memory and become sight words. Through experience with text, readers abstract orthographic rules about permissible letter patterns that are important for reading (Perfetti, 1992). The ease with which a reader forms connections between letter patterns and their corresponding phonological representations affects the process of learning to read over time (Berninger & Abbott, 1994). Thus, for example, Manis (1985) found that disabled readers were slower and less accurate than normal readers in processing unfamiliar real words (e.g., scaup), and it took more exposures to words before the disabled readers could recall them accurately.

The present study explored the difficulties that students with reading disabilities have reading derived words that undergo phonological shifts. Two experimental word recognition tasks (Word Naming and Lexical Decision) were presented to compare the speed and accuracy with which poor and average readers respond to shift words, as compared to stable words, when all of the words are orthographically transparent. Longer response latencies and less accurate responses to shift (e.g., natural) in comparison to stable words (e.g., cultural) would suggest that the phonological representation of base word is accessed and causes some amount of interference in the processing of the derived form. Differences in responses to the Naming and Lexical Decision tasks might indicate whether the requirement of an overt pronunciation particularly affected poor readers (i.e., greater difference between shift and stable words on the Naming than

the Lexical Decision task). In addition, we included a group of adult readers to determine whether the effect for shift words would be found for adult readers as well. We expected poor readers to be less accurate and slower on both word types and both tasks than average achieving readers because of less efficient processing of the orthographic representation and greater difficulty accessing orthographic and phonological representations from memory. However, we expected differences in performance on stable and shift words to be more pronounced for poor than average readers because of the likelihood that poor readers have difficulties learning complex phonological relations.

In addition to the comparison of derived forms that were orthographically transparent but different in phonological transparency, the study included analysis of the speed and accuracy of students' recognition of orthographically legal and illegal nonwords that resembled derived forms. This analysis provided a way to assess the role of orthographic sensitivity in word recognition. Specifically, as foils for the shift words and stable words in the lexical decision task described above, nonwords that ended in common suffixes (e.g., -ic, -ize) were presented. One-half of these nonwords consisted of legal orthographic sequences (e.g., hodropic, deromity), and one-half consisted of illegal letter sequences (e.g., reflsiber, oprbody).

The research questions were (1) Do poor readers differ from average achieving readers on speed and accuracy of naming derived forms with and without phonological shifts? (2) Is the same pattern of performance on the two types of derived words found on a lexical decision task? (3) Do adults also perform more accurately and rapidly on stable than shift words? (4) Do poor readers differ from average achieving readers on speed and accuracy of responses to legal and illegal nonword letter strings? (5) To what extent does speed of responding to legal and illegal nonword letter strings contribute to speed of recognizing derived words (shift and stable) for the two child reader groups?

Method

Subjects

Three groups of subjects were included in the study: two groups of children and a group of normal adult readers. All child subjects were attending one of two schools for children with learning problems and were in grades 4-9. Their ages ranged from 10.75 years to 15.75 years. There were two groups of children, defined in terms of Wide Range Achievement Test III (WRAT) Reading scores (Wilkinson, 1993). The Poor Readers (PR: $N = 18$) had WRAT Reading scores below 90. The Average Readers (AVR: $N = 33$) had WRAT scores of 90 or above. Children in both groups had receptive vocabulary at least in the Low Average range on the Peabody Picture Vocabulary Test III (PPVT ≥ 79) (Dunn & Dunn, 1997).

Descriptive statistics for the two groups of children are presented in Table 1. The two groups did not differ in mean age. However, there were significant differences in verbal ability (PPVT), $t(49) = 3.58$, $p < .001$, in word reading (WRAT), $t(49) = 8.25$, $p < .001$, and in word attack on the Woodcock Reading Mastery Test, Revised (WRMT), $t(46) = 4.40$, $p < .001$ (Woodcock, 1987).

Table 1 about here

The adult readers (AR) were 19 undergraduate or first-year graduate students with normal reading skills. Ages ranged from 18-27 years ($M = 20.61$, $SD = 2.89$). AR scores on the WRAT Reading subtest averaged 115.21 ($SD = 4.91$).

Tasks

Three tasks were administered to all subjects: two experimental word recognition tasks and a measure of simple choice reaction time, all presented on a microcomputer.

The Choice Reaction Time task was part of the Computerized Academic Assessment System (CAAS; Royer & Sinatra, 1994). Subjects were shown a series of stimuli consisting of three asterisks or plus signs, appearing in the center of the screen. For each trial, the subject had to respond by naming the stimulus (i.e., "star" or "plus"). Accuracy was recorded by the examiner (using a button box interface), but the major dependent variable was reaction time, which was recorded automatically by the computer using a voice-activated relay attached to a

headset microphone. Subjects' scores were percent correct and mean reaction time. To minimize the influence of aberrant trials, in calculating the reaction times, the computer automatically removed any individual item score that was more than 2 standard deviations from the subject's overall mean across trials.

For the two experimental word recognition tasks, subjects responded to letter strings appearing on the computer screen. The two tasks differed in processing and output demands. In the Naming task, subjects were asked to read each word aloud as quickly as possible into a headset microphone. In the Lexical Decision task, subjects were asked merely to indicate (by pressing one of two response buttons on an interface box) whether or not each letter sequence constituted a real word. For both tasks, accuracy was entered directly into the data base by the examiner, using a button box. Reaction time was recorded automatically by the computer. As for the Choice Reaction Time task, aberrant reaction times were removed by the computer during the calculation of the task averages for that student.

Three types of items were included in both word recognition tasks: shift, stable, and foils. The shift list consisted of 13 derived words containing a phonological shift in the base word with the addition of the suffix (e.g., natural, majority). The stable list consisted of 13 similar derived words without a phonological shift (e.g., cultural, maturity). The two word groups were matched for type of suffix (i.e., -al, -ity, -ence, -ce, or -tion), orthographic patterns, number of syllables (3.62 for shift and 3.46 for stable words), base word frequency (49.08 for shift and 50.28 for stable), and surface frequency (43.90 for shift and 44.92 for stable). The frequency figures are the Standard Frequency Index, representing frequency of word use in written texts through grade 9 (Carroll, Davies, & Richmond, 1971). See Appendix A for a complete list of the target words. The foils on the Naming task consisted of 19 derived words (e.g., suitable) that were comparable to the target words in length and frequency but that differed in morphological endings (e.g., -ly, -able, -ful). These words were interspersed randomly among the target words in order to reduce the likelihood that the subject would notice patterns in word endings. The foils on the Lexical Decision task consisted of the 19 foils from the Naming task plus 40 nonwords. The nonwords

ended in common suffixes (e.g., -ic, -ity) and were comparable in length to the target words (3-4 syllables; $M = 3.5$). One half of these words consisted of legal orthographic sequences (e.g., hodropic, deromity), and one-half consisted of illegal letter sequences (e.g., infsiole, zrenderize).

Procedures

The students took the standardized measures and completed the computer tasks in two sessions. In one session, all three standardized tests were administered and then the student completed the Naming task. In the second session, the student completed the Choice Reaction Time and Lexical Decision tasks. The experimental tasks were presented on a microcomputer. Each item consisted of a series of visual stimuli (displayed individually on the computer screen) to which the subject made a speeded response (via a button box or a voice-activated relay). The words on each task were presented in a random order for each subject. Subjects responded to all target and foil words. Only the shift and stable words were used in analyses of the Naming task, whereas analysis of performance on the Legal and Illegal nonwords was carried out for the Lexical Decision task in addition to analyses of the shift and stable words. Response latencies to both correctly and incorrectly named and recognized words were included so that the performance of groups could be compared on the basis of responses to the same number of words of each type.

Results

Group Differences in Choice Reaction Time

Possible differences in choice reaction time between the two child groups were examined using analysis of variance. Because of scheduling difficulties and computer malfunctions, these data were available for only a subset of each group (PR: $N = 15$; AVR: $N = 23$). As expected, the mean reaction times for these two groups did not differ significantly, $F(1, 36) = 1.74$, $p = .20$ (PR: $M = .689$, $SD = .176$; AVR: $M = .754$, $SD = .130$), indicating that children in these two groups are equally skilled at recognition and labeling of simple stimuli on response-choice tasks.

Effects of Phonological Transparency and Task Demands for the Child Reader Groups

The accuracy and speed data from the two experimental word recognition tasks were analyzed in two separate Group x Task x Transparency ANOVAs; the results are shown in Tables 2 and 3.

Tables 2 and 3 about here

There were significant differences as a function of group, task demand, and phonological transparency for both accuracy and speed of word recognition. Significant Group x Task Demand and Group x Transparency interactions indicated that the effect of task demands was greater for the PR group than for the AVR group, and that the effect of phonological transparency was also greater for the PR group. Tables 4 and 5 show descriptive statistics on speed and accuracy of responses on the Naming and Lexical Decision tasks.

Tables 4 and 5 about here

For speed of word recognition, group differences as a function of phonological transparency were much more pronounced on the Naming task than on the Lexical Decision task. This differential effect was less pronounced for accuracy and was not statistically reliable. These findings remained the same when variation in receptive vocabulary or in choice reaction time was controlled.

Transparency and Task Effects for the Adult Readers

Although there were effects of phonological transparency in the adult readers, there was no evidence of a differential effect of phonological transparency as a function of task demands, as Tables 4 and 5 show. Because the adults made no errors naming the Stable words, statistical analysis would not be appropriate. For the reaction time data, ANOVA revealed a significant effect of Transparency, $F(1,18) = 7.23$, $p = .015$, but no effect of Task Demand, $F(1, 18) = 1.59$, $p = .22$, and no significant interaction, $F(1, 18) = .02$, $p = .90$.

The Role of Sensitivity to Orthographic Patterns

A question of some importance in interpreting the results of the Naming and LD tasks is the extent to which sensitivity to orthographic composition affected performance. An initial

analysis of reader group differences in sensitivity to orthographic legality was conducted on the data for the two child reader groups by contrasting reaction times for rejecting legal versus illegal nonword letter strings. In terms of response latencies, the results of a Group (RD, AVR) x Legality (legal, illegal) ANOVA indicated a significant effect of Legality, $F(1, 49) = 48.0$, $p < .001$, but no difference as a function of reading group, $F(1, 49) = .19$, $p = .67$, and no significant interaction, $F(1, 49) = .92$, $p = .34$. In terms of accuracy, there was again a significant effect for Legality, $F(1, 49) = 125.96$, $p < .001$, but no difference between reading groups, $F(1, 49) = 2.71$, $p = .11$ and no significant interaction, $F(1, 49) = 2.50$, $p = .12$. Responses to illegal and legal nonwords are summarized in Table 6.

Table 6 about here

We assumed that speed of responding to illegal words reflects ease of recognizing letter combinations that are not permissible in English, a relatively superficial level of orthographic awareness. In contrast, speed of responding to legal nonwords involves integration of the orthographic and phonological representations of a letter string, as well as semantic processing to determine lexical status. This represents a more complex and time-consuming process. Both levels of orthographic processing might play a role in the recognition of stable and shift real words, but the two levels may contribute to word recognition in different ways for students who are PR and AVR. To explore this possibility, we carried out four parallel hierarchical regression analyses. For each analysis, we entered the measure of rate of responding to illegal words first in the prediction, followed by the measure of rate of responding to legal nonwords. These analyses were run separately for the two reader groups. For each group, we ran one analysis predicting speed of response to Shift words and one analysis predicting speed of response to Stable words. In order to normalize the data distributions, these analyses were conducted using log-transformed reaction time measures. The results from these analyses are summarized in Tables 7 and 8.

Tables 7 and 8 about here

Overall, the role of the two orthographic processing measures in predicting speed of response to the real words was similar for the Shift and Stable words, but the pattern of

predictors was different for the two groups. For both groups, when speed of response to illegal nonwords was entered as the sole predictor variable, it played a powerful role in predicting speed of response to Shift words (Beta values of .89 and .88 for the PR and AVR groups, respectively). However, when speed of response to legal nonwords was added to the predictive equation in a second step, this measure became the main predictor for the PR group (Beta = .90), reducing the contribution of the illegal nonword measure to non-significance (Beta = .09). In contrast, for the AVR group, the legal nonword measure played no significant predictive role (Beta = .30); instead, speed of response to illegal nonwords remained the important predictor (Beta = .60). A similar pattern was evident for the Stable words (see Table 8).

In addition, it is interesting to note that the orthographic processing variables accounted for more of the variance in the speed of recognizing shift and stable words for the PR than the AVR group: for PR, 96% of the variance in Shift words and 97% of the variance in Stable words; for AVR, 79% of the variance in Shift words and 81% of the variance in Stable words.

Discussion

This study was undertaken to determine whether students with word reading disabilities had more pronounced problems than their average-reading peers in the reading of derived words whose base forms undergo a phonological shift (e.g., nature, natural), in comparison to words whose base forms are phonologically transparent (i.e. "stable" relations, as in culture and cultural). Comparison of performance on these word types should help us determine the extent to which students with reading disabilities have particular difficulties processing the complex phonological relations that characterize so many derived forms. The results of previous studies have shown that the phonological complexities of morphologically complex words are related to the word reading skill of students with reading disabilities, but this has been determined on the basis of correlations of oral morphological awareness tasks with performance on general word reading tests (e.g., Fowler & Liberman, 1995; Singon, Mahoney, & Mann, 2000). We had reasons to expect that both average-achieving and poor readers would perform less well on shift than stable derived words. Earlier work (Carlisle, 2000) had shown that average third and fifth

graders read transparent derived words more accurately than shift derived words, but we also had reason to expect that poor readers would be relatively weaker at naming shift and stable words than their peers. For example, Windsor (2000) found that for students with language-learning disabilities, phonological complexities of derived words posed particular problems for performance in reading.

Transparency Effects Across Tasks

Overall, our results showed that for all three reader groups, the effect for transparency was evident on both naming and lexical decision tasks. Our investigation was particularly focused on the children who were poor readers, and the results confirmed the expectation that poor readers have less difficulty reading stable than shift words. These results provide support for Elbro and Arnbak's (1996) argument that morpho-semantic processing may be a particular advantage for poor readers. The average-achieving readers showed a similar pattern of responses, but the difference in performance on the two word types was far less pronounced in their case. The effect of transparency was significant for the capable adult readers as well, when performance on shift and stable words was collapsed across tasks.

Performance on the Naming task showed a stronger effect for phonological transparency than on the Lexical Decision task. In fact, for the lexical decision task, interpretation of the results is somewhat problematic. The poor readers were less accurate on shift than stable words, but their response latencies to the two word types were very similar; on the other hand, average achieving readers were equally accurate identifying shift and stable words as words, but they were slower on the shift words. Overall, poor readers showed a greater advantage for stable words than their peers, but this effect was noteworthy only when they were asked to pronounce words aloud. These results did not change when group differences in speed of naming simple stimuli and vocabulary knowledge were controlled.

To interpret the results, it is important to remember that the shift and stable words were presented without any reference to their base forms. In addition, these word types did not differ in word length or frequency. For both shift and stable words, the spelling contains almost all of

the base form—for some words among the shift and stable word set, a final e (or, for one word, y) is dropped to add the suffix (e.g., intense, intensity and sincere, sincerity). The orthographic redundancy of base and derived forms is considerable, and it is comparable for the two word types. Thus, it is not the orthographic representation of the base word that provides an advantage for recognition of the stable words. More likely, it is the phonological match of the base in the derived form that makes stable words easier than shift words. The longer response latencies and less accurate responses to shift than stable words are attributable to difficulties accessing the phonological representation of the word via the phonology of the sub-word morphological units.

Differences in responses to shift and stable words by poor and average-achieving readers underscore difficulties learning the rule-governed phonological form of some base morphemes. However, students evidently engaged in morphological analysis; had they not done so, performance on the shift and stable words would not have differed significantly for either group. Note that, in Figures 1 A and B, both the poor and average-achieving readers had more difficulties with the shift than the stable words, especially in comparison to the adults. The difference between the children reader groups is a matter of degree, not of kind. Nonetheless, the poor readers' very slow reading of the shift words, in particular, is striking.

Figure 1 A and B about here

The important point may be that the weaker readers' poor performance on derived words whose base forms have a different phonological form suggests difficulties with a particular aspect of morphological learning--the mastery of systematic relations or allomorphs in the representation of base forms in their derived counterparts.

Differing Strategies for Naming Versus Lexical Decision Tasks

On the naming task, one explanation for the slower and less accurate responses to the shift words is that the students process the word for pronunciation by noticing first the base form (e.g., nature). The time course of subsequent processing of the word may be such that the reader is mentally preparing to pronounce the base form before he or she has fully processed the affix and the stress pattern of the whole word, which in the case of natural would involve the shortening of

the vowel. In effect, prolonged focus or reliance on the base form interferes with the process of accessing or constructing the phonological representation of the derived word.

The lexical decision task offered a comparison of performance on shift and stable words when a pronunciation was not required. On this task, the transparency effect was evident but subtle, as Figures 2 A and B show. As noted earlier, there appear to be accuracy-speed trade-offs.

Figure 2 A and B about here

The child readers took about twice as long as the adult readers to respond to the words. The average-achieving child readers were reasonably accurate (88 to 90% correct for shift and stable words), whereas the poor readers' accuracy on the two word types was lower (79 and 88% for shift and stable words). The poor readers were more accurate on the stable than the shift words, but their response latencies were similar on the two word types. The average-achieving readers, on the other hand, were quite accurate at identifying shift and stable words as words, but they were slower at responding to the shift than the stable words. For both groups, the effect of transparency is less pronounced than it was on the naming task. Interestingly, the response latencies of the adult readers, shown in Figure 2 A and B, were similar to those of adults on other types of lexical decision tasks (about 600 to 700 ms) (e.g., Stolz & Feldman, 1995).

The data from the lexical decision task raise questions about the difficulty of the words for the 4th through 9th grade readers, as well as the nature of the processing and the basis for decision-making they used. Additional concerns about interpretation of the results of the lexical decision task stem from the relationship between lexical decision responses and performances on the WRAT Reading and the WRMT Word Attack, shown in Table 9.

Table 9 about here

Standardized word reading measures were significantly related to accuracy of responses to words (shift and stable) on the Naming and Lexical Decision tasks, whereas standardized reading measures were significantly related to speed of responding to words on the Naming but not the Lexical Decision task. Further, performances on the standardized measures were generally not related to nonword lexical decision responses (speed or accuracy). We were particularly

surprised to find that accuracy of responses to legal nonwords was only weakly related to WRMT Word Attack performance ($r = .27, p < .05$). A strong relation was expected because both measures involve legal nonwords.

These results suggest that the presence of both legal and illegal nonwords on the lexical decision task directed attention to aspects of orthographic representation. As Balota (1990) pointed out, the lexical decision task is not an identification task but rather a discrimination task. Characteristics of both the target words and the nonword foils may influence the readers' basis for distinguishing words from nonwords (see Besner, 1999).

Differences in Depth of Processing in Word Recognition

Performance on the nonword items of the lexical decision task provided some information about the processing of the letter strings that students engaged in on their way to making a lexical decision. The two reader groups responded more rapidly and accurately on illegal than legal nonwords, as we had expected. However, the groups did not differ in speed or accuracy. These results support Siegel et al's (1995) conclusion that poor readers are able to distinguish legal from illegal letter strings as well as their peers. The relative speed of responses suggests that legal nonwords required more thorough processing; illegal words were responded to in less than 1 1/2 seconds, whereas legal nonwords were responded to in close to 2 seconds. Correct identification of illegal nonwords involves awareness of permissible orthographic letter combinations and positions in English. For example, amhparitic might be rejected quickly because of the "amhp-" at the beginning; more complete processing of the letter string might not be necessary. In contrast, orthographic processing of legal nonwords might involve going beyond a superficial orthographic analysis to the formation of a phonological representation (Balota, 1990; Perfetti, 1992). In order to reject deromity, for example, the reader needs to determine that no such is found in his/her mental dictionary. This decision involves phonological and semantic as well as orthographic processing. Because of the presence of illegal nonwords, the students may have adopted an approach of checking letter strings for sequences that are not permissible in

English (whether consciously or not). As noted earlier, the nature of the task may have predisposed the students to focus on the orthographic characteristics of the items.

Further examination of the processing of words and nonwords was carried out to determine whether depth of processing of the illegal and legal nonwords would account for speed of recognition of the target words (shift and stable). For the poor reader group, the results showed that speed of processing of the legal nonwords accounted for a very large portion of the variance in speed of responding to both the real shift and stable words. In contrast, for the average-achieving reader group, only speed of responses to illegal nonwords was related to performance on the shift and stable words. In addition, nonword performance (in total) accounted for a smaller portion of the variance in word recognition than was the case for the poor readers. Thus, for the poor readers, the close relation between speed of processing real words and legal nonwords suggests activation of both orthographic and phonological representations, whereas the average readers appear to have used a surface-level orthographic processing approach on this task. The poor readers may processed the real derived words as if they were not familiar words for which they have an easily accessed representation in memory.

There are several possible explanations for these results. One is that developing ready access to orthographic and phonological codes in memory is a challenge for poor readers (e.g., Manis, 1985). Another possibility is that poor readers have less experience reading complex words because they tend to read easier books and to read less overall than their peers (Stanovich, 1986). Derwing et al. (1995) raised the possibility that orthographic awareness of the structure of derived words may come from educational experiences. However, because both the poor and the average-achieving readers in this study attended the same schools and these were schools that taught systematic phonics, we cannot attribute the pattern of results for the reader groups to differences in word-reading instruction. In short, the nature of our study does not provide a basis for determining why the two child reader groups differed in the depth of processing of words and nonwords.

Although the results from the lexical decision task suggest possible differences in word recognition approaches, it is not clear that performance on this task provides a trustworthy measure of phonological processing of shift and stable words. We recommend further studies that employ different methodologies, such as lexical decision tasks with a very short exposure of the words or priming tasks. These might shed light on the role of phonological interference in the processing of complex words (see Balota, 1990; Fowler, Napps & Feldman, 1985).

One limitation of the present study is that we did not include a group of younger children matched to the poor readers in reading ability. This is because younger children (2nd or 3rd graders) would not have had experience with many of the words used for purposes of studying phonological shifts of derived words. Very high frequency derived words tend not to be characterized by the systematic phonological shifts found in less common words like majority. Furthermore, high frequency derived words (e.g., happiness) may be processed as single lexical items, without regard for morphological structure (Gordon, 1989). Nonetheless, the results of an earlier study (Carlisle & Stone, in press) suggest that the poor readers would be likely to resemble a reading-age matched group, at least in their reading of the transparent words.

Educational Implications

While it may be premature to consider educational implications of our results in any depth, at this point the findings seem to suggest that poor readers experience difficulties learning the complex phonological representation of base forms of derived counterparts. In addition, to pronounce derived words aloud, poor readers may need to carry out more deliberate analysis of the word form than average readers. Accessing the full representation of a letter string (i.e., both orthographic and phonological codes) is a slow process for many poor readers. Such problems can be addressed by instructional programs that include word study beyond basic phonics.

Instructional programs should provide guidance in understanding complex phonological relations and a variety of strategies for working out the pronunciation of complex words, one of which involves looking for ways to use known morphemes to help arrive at the pronunciation of an unfamiliar word. For example, a program developed by Lovett, Lacerenza, and Borden (2000)

includes "peeling off" as a strategy for morphological decomposition. In addition, guided experiences recognizing base morphemes that have undergone phonological and orthographic changes (e.g., decide, decision; strong, strength) may sensitize students to morphological relations. Morphological family members can be used to remember unexpected spellings and pronunciations of words (e.g., muscle, muscular).

As others have shown, poor readers need ample experience in order to develop trustworthy mental representations of words (e.g., Manis, 1985), and this principle is bound to hold for reading complex as well as simple words. Programs should include sufficient practice to assure that the particular words students are learning are recognized rapidly and accurately. In addition, decoding strategies should become a well-engrained habit, so that they are used spontaneously to assist in the analysis of unfamiliar words. It is probably not possible to over-emphasize the need to make sure that students are experiencing success when it comes to using strategies to work out the pronunciation of unfamiliar words (see Lovett, et al., 2000).

Word study that focuses on morphemes not only facilitates the development of decoding strategies but also helps students acquire a strategy for figuring out word meanings. Instructional programs in morphological analysis skills therefore can provide valuable links between word reading and comprehension. Rationale and guidelines for morphological instruction can be found in Henry (1988), Moats (2000), and Carreker (1999).

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Table 1

Differences Between the Two Child Reader Groups on Descriptive Measures

Measure	Poor Readers	Average Readers	t-test (df = 49)
Age	13.62 (1.28)	13.31 (1.47)	.74
PPVT	95.83 (10.65)	108.27 (12.47)	3.58*
WRAT Reading	83.39 (5.75)	98.76 (6.66)	8.25*
WRMT Word Attack	88.50 (6.22)	98.20 (8.00)	4.40*

* $p < .01$

Table 2

Effects of Child Reader Group, Task Demands, and Phonological Transparency
on the Accuracy of Word Recognition

Source	Degrees of Freedom	Mean Square	F Value
Group (G)	1	.797	18.9***
Error	49	.042	
Task Demand (TD)	1	1.050	62.3***
G x TD	1	.259	15.4***
Error	49	.017	
Transparency (T)	1	1.087	94.9***
G x T	1	.079	6.9*
Error	49	.011	
TD x T	1	.472	38.1***
G x TD x T	1	.000	.01
Error	49	.012	

* $p < .05$; ** $p < .01$; *** $p < .001$

Table 3

Effects of Child Reader Group, Task Demands, and Phonological Transparency
on the Speed of Word Recognition

Source	Degrees of Freedom	Mean Square	F Value
Group (G)	1	2.459	9.4**
Error	49	2.595	
Task Demand (TD)	1	13.963	26.6***
G x TD	1	8.507	16.2***
Error	49	.524	
Transparency (T)	1	7.649	33.3***
G x T	1	.940	4.1*
Error	49	.230	
TD x T	1	3.627	21.7***
G x TD x T	1	1.631	9.8**
Error	49	.167	

* $p < .05$; ** $p < .01$; *** $p < .001$

Table 4

Accuracy of Word Recognition in the Three Reader Groups as a Function of Task Demands and Phonological Transparency

Reader Group	Naming Task		Lexical Decision Task	
	Shift Words	Stable Words	Shift Words	Stable Words
PR	46.0 (19.2)	75.6 (16.5)	78.7 (15.2)	87.9 (11.7)
AVR	70.8 (17.5)	91.9 (11.3)	88.3 (12.9)	89.5 (11.6)
Adult Readers	98.4 (3.2)	100.0 (0)	98.8 (3.9)	100.0 (0)

Note. Entries are mean percent correct. Numbers in parentheses are standard deviations. PR= Poor readers; AVR = Average readers.

Table 5

Speed of the Three Reader Groups as a Function of Task and Phonological Transparency

Reader Group	Naming Task		Lexical Decision Task	
	Shift Words	Stable Words	Shift Words	Stable Words
PR	3.106 (1.937)	2.093 (.982)	1.665 (.794)	1.584 (.747)
AVR	1.625 (1.092)	1.270 (.569)	1.413 (.654)	1.242 (.550)
Adult Readers	.691 (.11)	.660 (.130)	.655 (.126)	.621 (.115)

Note. Entries are mean reaction times in seconds. Numbers in parentheses are standard deviations. PR= Poor readers; AVR = Average readers.

Table 6

Speed and Accuracy of Responses to Legal and Illegal Non-Words
for the Poor Reader and Average Reader Groups

Group	Legal		Illegal	
	Accuracy	Speed	Accuracy	Speed
PR	70.4 (13.8)	1.96 (.92)	92.7 (10.4)	1.43 (.81)
AVR	78.9 (14.0)	1.74 (1.00)	95.2 (8.4)	1.36 (.75)

Note. Standard deviations are given in parentheses; accuracy is mean percent correct, while speed is mean reaction time in seconds. PR= Poor readers; AVR = Average readers.

Table 7

Differential Contribution of Levels of Orthographic and Phonological Processing to Recognition of Shift and Stable Words for the Poor Reader Group

Regression Step/ Predictor	Multiple R ²	Beta	R ² Change	F-test/t-test
SHIFT WORDS				
Step 1	.799			63.70***
Illegal Nonwords		.894		7.98***
Step 2 ^a	.959		.159	57.78***
Illegal Nonwords		.085		.72
Legal Nonwords		.902		7.60***
STABLE WORDS				
Step 1	.797			62.87***
Illegal Nonwords		.893		7.93***
Step 2 ^a	.949		.152	44.81***
Illegal Nonwprds		.103		.78
Legal Nonwords		.881		6.69***

^aThe F-test reported for step 2 is the F to enter. *p < .05; **p < .01; ***p < .001

Table 8

Differential Contribution of Levels of Orthographic and Phonological Processing to Recognition of Shift and Stable Words for the Average Reader Group

Regression Step/ Predictor	Multiple R ²	Beta	R ² Change	F-test/t-test
SHIFT WORDS				
Step 1	.779			109.48***
Illegal Nonwords		.883		10.46***
Step 2 ^a	.792		.012	1.77
Illegal Nonwords		.605		2.69*
Legal Nonwords		.299		1.33
STABLE WORDS				
Step 1	.803			126.71***
Illegal Nonwords		.896		11.26***
Step 2 ^a	.806		.002	.35
Illegal Nonwords		.776		3.57**
Legal Nonwords		.129		.59

^aThe F-test reported for step 2 is the F to enter. *p < .05; **p < .01; ***p < .00.

Table 9

Relations of Standardized Word Reading and Vocabulary, Naming, and Lexical Decision Measures

	WRAT Reading	WRMT WA	PPVT
Naming			
Shift Ac	.59***	.46***	.37**
Shift Speed	-.43***	-.31*	-.13
Stable Ac	.57***	.43***	.14
Stable Speed	-.45***	-.34*	-.24
Lexical Decision			
Shift Ac	.39**	.31*	.25
Shift Speed	-.25	-.09	-.12
Stable Ac	.23	.24	.15
Stable Speed	-.35*	-.24	-.16
Legal NW Ac	.23	.18	.09
Legal NW Speed	-.17	-.07	-.003
Illeg NW Ac	.17	.27*	.11
Illeg NW Speed	-.12	-.06	.02

Note. Ac = accuracy; NW = nonword; Illeg = illegal; WA= Word Attack; PPVT = Peabody Picture Vocabulary Test-R.

* $p < .05$, ** $p < .01$, *** $p < .001$

Appendix A

List of Words Used in the Two Word Recognition Tasks

STABLE	SHIFT
Cultural	Natural
Maturity	Majority
Security	Severity
Intensity	Serenity
Confession	Convention
Confusion	Precision
Conformity	Finality
Dependence	Confidence
Stupidity	Sincerity
Activity	Mortality
Oddity	Locality
Classical	Colonial
Difference	Preference

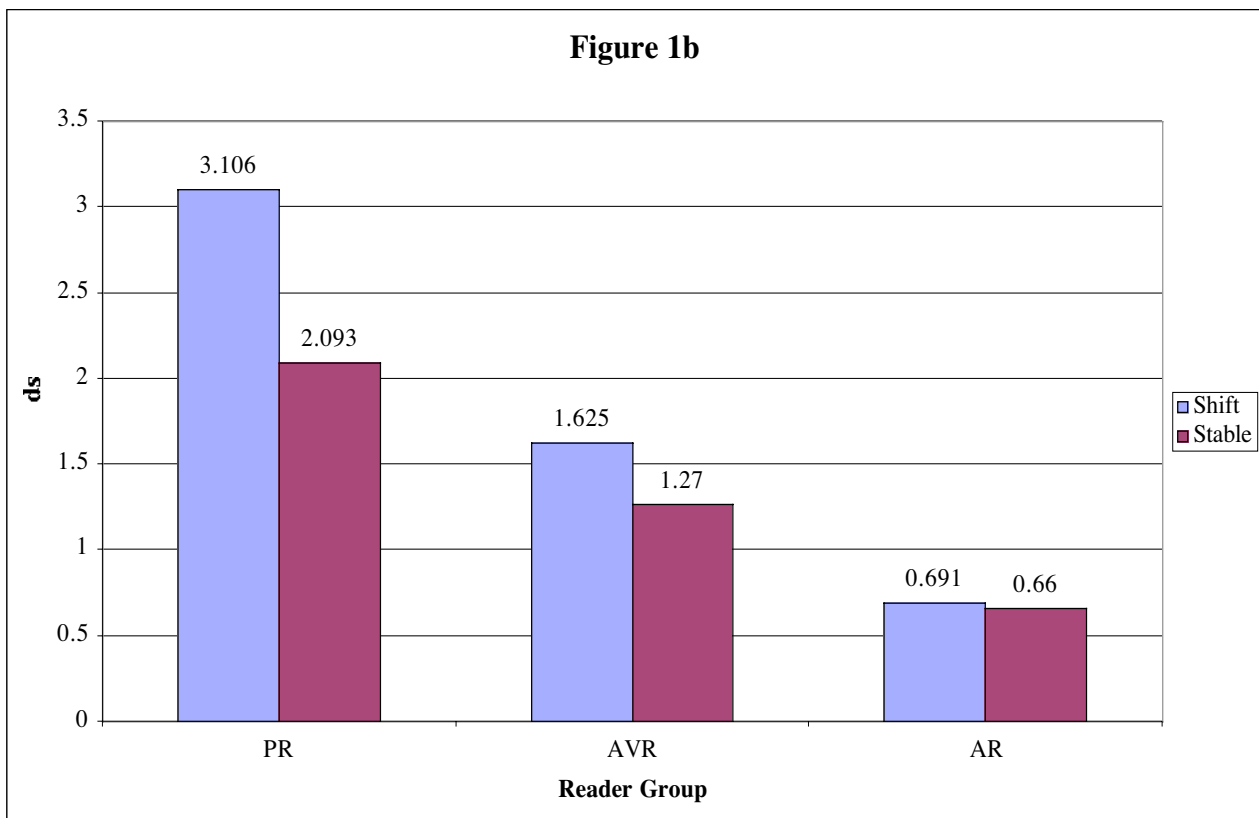
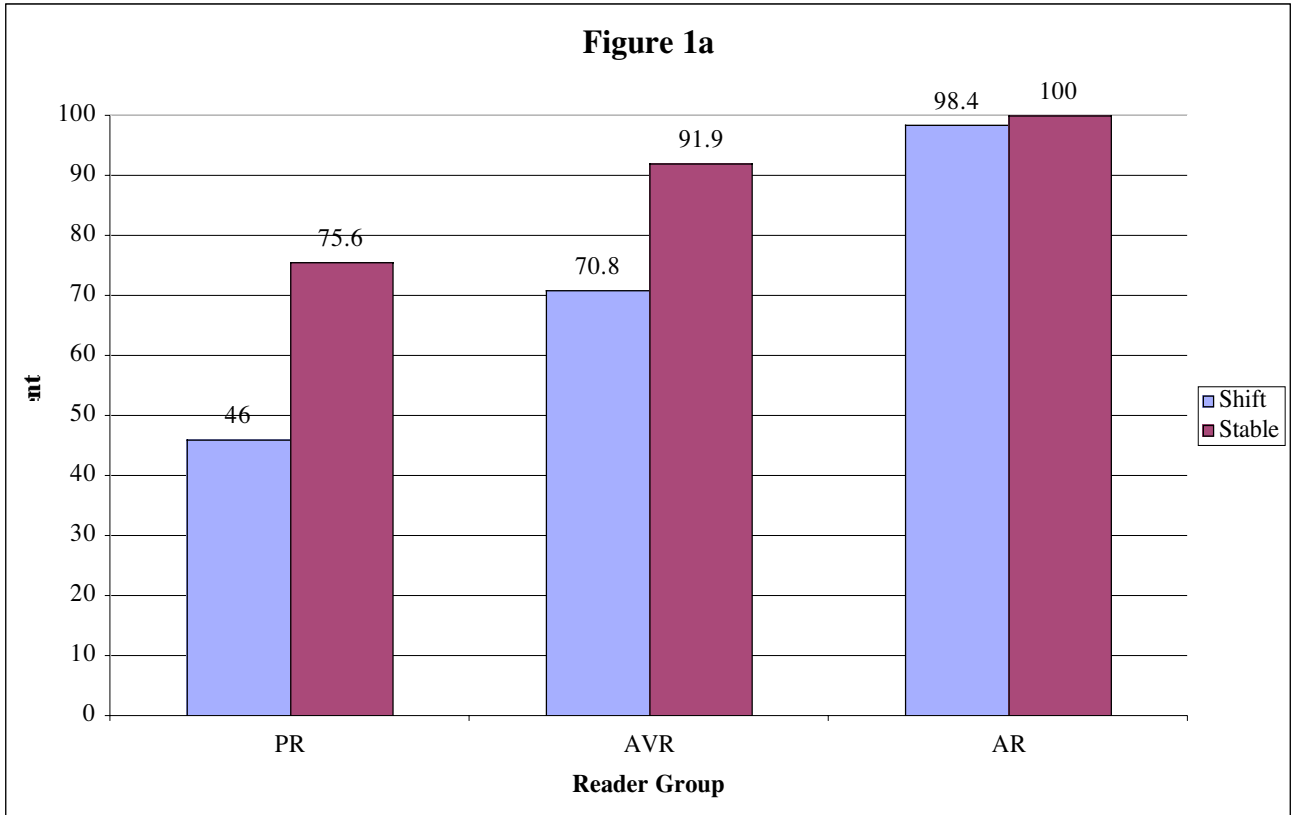
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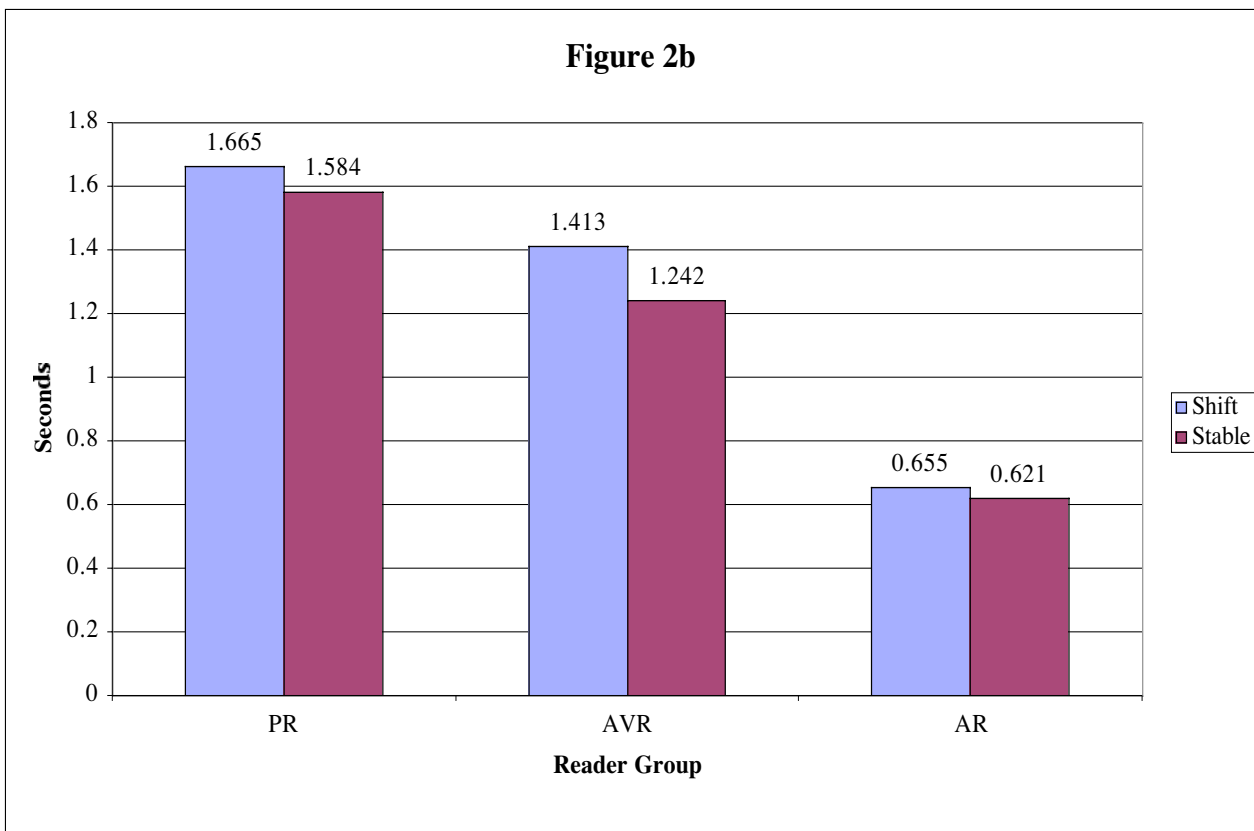
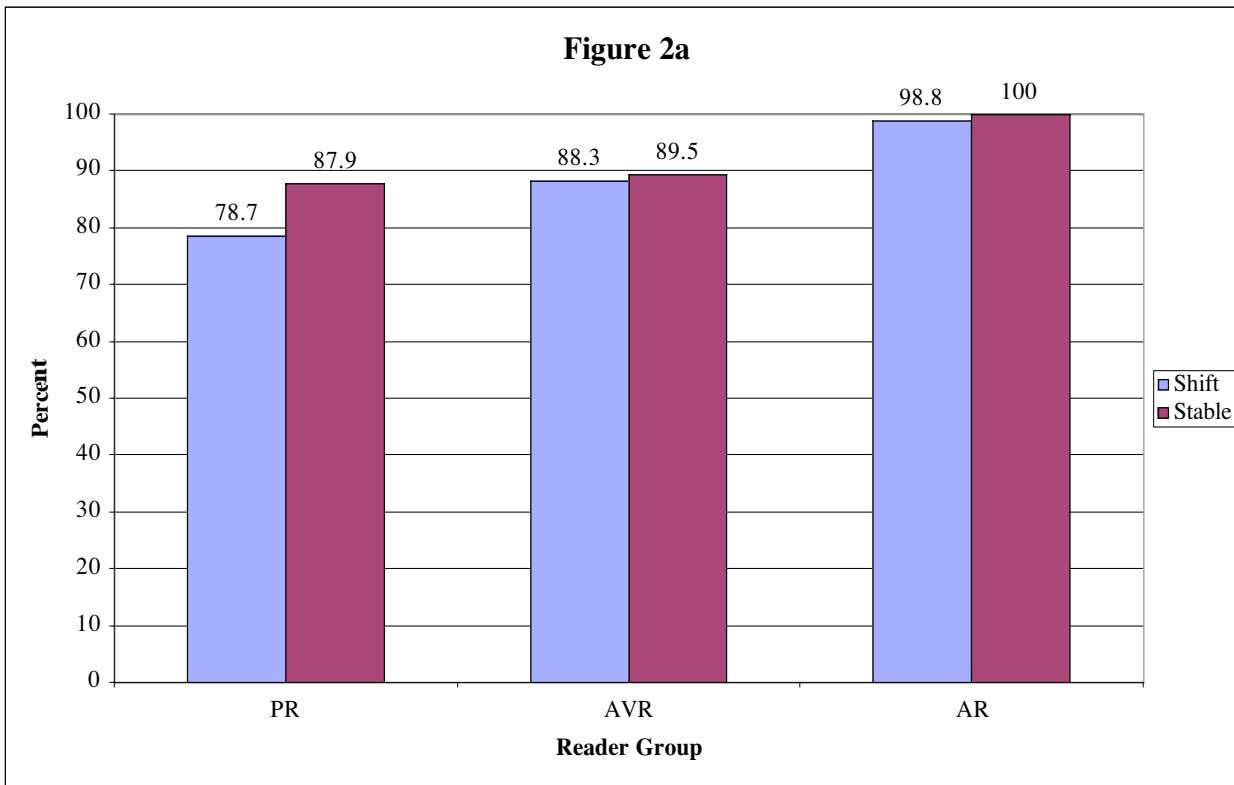
Figure 1A: Accuracy of Naming Words on the Word Naming Task

Figure 1B: Speed of Naming Words on the Word Naming Task

Figure 2A: Accuracy of Recognizing Words on the Lexical Decision Task

Figure 2B: Speed of Recognizing Words on the Lexical Decision Task





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