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READING ABILITY AND SENSITIVITY TO MEANING AT THE LEVEL OF THE MORPHEME

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ABSTRACT

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The study investigated letter detection in grade 4 good and poor readers as a function of the meaning, the morpheme content and the pronounceability of 6-letter groups. In the main experiment 2 groups of 16 boys matched on WISC Digit Span and Peabody Picture Vocabulary IQ and differentiated by reading ability were asked to detect the presence or absence of a target letter in a letter group presented simultaneously for 115 msec. in a tachistoscope. Stimuli were presented in 4 counterbalanced blocks; each block corresponded to a 24-item list composed of unpronounceable letter strings, 2-syllable nonsense words, 2-syllable single morpheme words, or 2-syllable double morpheme words. Good readers performed significantly better than poor readers. 6 planned orthogonal comparisons resulted in 3 significant main effects, indicating that meaningful word context, single morpheme words, and pronounceable nonsense words facilitated letter detection, as well as in 3 significant interactions showing a facilitating effect of meaning but no effect of morphemes for good readers, an effect of meaning restricted to single morpheme words and a facilitating effect of single morpheme words for poor readers, and a stronger facilitating effect of pronounceability for good than for poor readers. A second experiment with 12 good readers tested at 60 msec. confirmed the facilitating effect of meaning but no morpheme effect. Design of remedial reading measures stressing the morpheme content of words was suggested.

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READING ABILITY AND SENSITIVITY TO MEANING AT THE LEVEL OF THE MORPHEME

A survey of the literature suggests that reading disabled children, or dyslexics, exhibit deficiencies in certain areas of linguistic performance. It was the aim of the present study to investigate whether dyslexics differ from good readers in the use of one kind of linguistic information contained in written words: specifically whether poor readers differ from good readers in their sensitivity to meaning at the level of the morpheme. The experimental paradigm employed made use of a well-known phenomenon: the facilitating effect of context on tachistoscopic letter identification (for a recent critical review, see Krueger, 1975).

For the purpose of this study a dyslexic child was defined as one who "is unable to learn to read with proper facility despite normal intelligence, intact senses, proper instruction and normal motivation." (Eisenberg, in Money, 1962, p. 4). As here defined, the incidence of dyslexia is estimated at between 2 and 10% of the general population (Critchley, 1970). Dyslexia is much more frequently found in boys than in girls. The ratio of dyslexic boys to dyslexic girls is estimated to be between 4 and 10 to 1. (Bannatyne, 1971). Several hypotheses have been put forward as possible explanations of dyslexia, notably: failure to establish cerebral dominance (Orton, 1937); a maturational lag (Bender, 1958; Satz & Sparrow, 1970); a temporal or serial order processing deficit, (Bakker, 1970); and minimal brain dysfunction (Clements, 1966; Wender, 1971). It must be noted, however, that no agreement exists as to the actual cause or causes of dyslexia. On the basis of an extensive review of the literature, Gibson and Levin (1975) have pointed out that research into dyslexia has been concentrated on five main aspects of performance: poor perceptual-motor coordination; deficient sensory integration; reversals of letters and words; faulty serial ordering and temporal differentiation; and difficulties in sound segmentation. The present study, however, is most closely related to the small body of research which has investigated the relation between reading ability and linguistic capacity and which provides some evidence for a nonspecific language deficit in dyslexics.

A finding from a longitudinal study by DeHirsch, Jansky and Langford (1966) suggested that verbal fluency as measured by word count was related to reading achievement. The authors found that "richness of verbal output", quantified as the number of words used by preschoolers to tell a story, was one of the best predictors of reading achievement in second grade. The 53 children surveyed were of normal intelligence and showed no sensory deficits or psychopathology.

All were from English speaking homes and of predominantly lower middle-class background.

Fry, Johnson, and Muehl (1970) also studied oral language production in relation to reading achievement in grade 2 children. Social class and IQ were controlled for. Average or above average readers were found to have larger speaking vocabularies than below average readers, appeared to use more modification in the predicate position than in the subject position, and used less "existence" type sentences when telling a story about a picture.

Denner (1970) studied representational and syntactic competence of problem readers in three grade levels. The criteria for sample selection in this study were rather arbitrary (the teacher selected the low and average reading groups) and no IQ measures were available. Grade 1 poor readers and older (grade 3 and 5) poor readers did significantly worse on a linguistic synthesis task than average first-graders. The task consisted of reading a simple sentence by means of "logographs" (abstract graphic forms representing words), and then enacting that sentence. Poor readers approached the translation of the sentence into action by attempting to act out the meaning of each logograph unit. It seems that what was read was not a sentence as a unit, but a series of individual words. Poor readers thus failed to subordinate the meaning of individual words to the larger linguistic reality of the written sentence.

Denner concluded that children with reading disability lack syntactic competence in decoding written language. This lack, however, was not seen by him to constitute a general linguistic deficit, since oral language production, as far as could be observed in this sample, did not seem impaired (his subjects were good story tellers).

A study by Weinstein and Rabinovitch (1971) has been interpreted as suggesting that poor readers do not make use of syntactic cues as good readers do, although the findings are equally consistent with the existence of a language specific serial processing deficit in dyslexics. The authors investigated sensitivity to syntactic structure or word order in grade 4 good and poor readers, selected on the basis of test scores falling in the upper third or lower third of the grade 4 reading score distribution, respectively. The children learned strings composed of nonsense elements and grammatical markers which followed either normal or scrambled word order. Presentation of stimuli was auditory and recall was oral. The good readers learned syntactically structured strings (e.g., "When they sivoled the veg, they hanashed zalfly") in significantly fewer trials than unstructured strings (e.g., "Imi onucs, if tik, to hended parfing as"), while the poor readers learned strings of both types with equal difficulty. No differences were found between the good readers' and the poor readers' ability to learn the unstructured material. One methodological difficulty with this study, however, is that the good readers were significantly superior on IQ, and since the difference was only controlled statistically through analysis of covariance, interpretation of the findings is difficult.

One study of reading errors in beginning readers is consistent with the hypothesis that poor readers show a non-specific language deficit. Liberman, Shankweiler, Orlando, Harris, and Bell Berti (1971) found the major source of difficulty for poor grade 2 readers to be at the level of the word and not of the letter; the errors appeared to be context dependent. In this study poor readers made very few errors when asked to select a match for a tachistoscopically presented letter from a group of five letters presented on an answer sheet. (The target stimuli consisted of four reversible letters: "b"; "d"; "p"; and "g", and the letter "e" as a "reliability" check; the test items were apparently the same five letters in a different sequence on each trial.) On the other hand, when the children were required to read aloud a list of monosyllabic words composed of 2, 3, or 4 letters there were, beside vowel errors, errors representing confusions of b, d, p, and g, as well as other consonant errors involving omissions, additions, and substitutions. In addition, there were errors which represented reversals of sequence (e.g., "saw" for "was"). The number of errors made on the word list was highly correlated with errors made on paragraphs of connected text. Thus Liberman et al. suggested that "the problems of the beginning reader have more to do with word construction than with strategies for scanning connected text", and that "further exploration of the linguistic determinants of children's reading errors is likely to be profitable." (1971, p. 141). One implication of the Liberman et al. study is that an investigation focussing on a major linguistic characteristic of the word which might affect recognition of component letters may be a fruitful area for research into the nature of dyslexia. The most obvious linguistic cue at the word level, and one which has not yet been investigated in dyslexics, is that of meaning as defined by morpheme content. The purpose of the present study was therefore to investigate whether differences in sensitivity to this cue exist between poor and good readers. Meaning was defined in terms of morpheme content simply because the morpheme is the smallest unit of meaning according to psycholinguistic theory.

Although no studies directly investigating the relation between morpheme content and word perception in children were found in the literature, one study of tachistoscopic recognition in young normal readers (Gibson & Guinet, 1971) suggests that verb inflections, which are in fact a special class of morphemes, may function as a unit. The study was undertaken as a test of one aspect of Gibson's theory (1969; 1971) which classifies the distinguishing features of words into four types of information that are processed independently and sequentially: namely, graphological; phonological; semantic; and syntactic, and was interpreted as support for the independent processing of the syntactic features of words. The evidence of the study did not bear out the specific hypothesis that if verb inflections function as units they should therefore increase the length of words perceived by children. Gibson and Guinet argued, however, that inflections did tend to be treated as units, since they were often substituted in error for another inflection or another word ending. In the study stimuli consisting of real words (verb stems) and pronounceable and unpronounceable pseudowords, with or without the endings "s", "ed", and "ing", were exposed to grade 3 and 5 pupils (67 msec.) as well as to adults (33 msec.), who were then asked to write down all the letters they had seen. Comparison of errors on the last letters of inflected and uninflected words and pseudowords matched in length showed that only the "ing" ending was reproduced with significantly fewer errors. This effect was seen only in grade 3 pupils. While the appropriateness and sensitivity of the paradigm and the analysis used can be questioned, the conclusion that verb inflections (i.e., bound morphemes) may be treated as units and may function independently is of interest, since it carries the logical implication that stems or root morphemes may also function as units.

More recently evidence has been provided that, in adult subjects at least, meaning at the level of the morpheme is a relevant factor in word recognition. Murrell and Morton (1974) showed that tachistoscopic recognition of a word (e.g., "pained") was facilitated by pretraining with a word of the same morpheme root (e.g., "pains") but not by pretraining with a word which was similar both acoustically and visually (e.g., "paint"). They also found that suffixes such as "ing", were recognized substantially better than roots. They concluded that "the word recognition process, even in the absence of contextual or semantic stimulus information, involves assignment of the stimulus to a particular morpheme with its specific semantic associations." (1974,p. 966).

Although little is known about the relation between morpheme content and word perception in children, there is evidence that the context provided by a word facilitates letter recognition. Therefore, in the present study, it was decided to investigate morpheme processing in good and poor readers by using a paradigm manipulating context. What accounts for the word facilitation effect is not known although the phenomenon has been exhaustively studied in adults (for a review of this research, see: Massaro, 1975; Mason, 1975). To date no clear evidence exists that meaning as a cue contributes to intraword redundancy, as has been pointed out by Mason (1975). While cues such as pronounceability, orthographic structure, and transitional probabilities of individual letters have been shown to produce facilitation when embedded in meaningless words (Krueger, 1975; Massaro, 1975), the relative contribution of any cue to the word context effect is not known and may depend on the particular paradigm used, as well as on the age, reading ability, and differential sensitivity of the subjects studied.

The effect of word context on letter recognition has been clearly demonstrated in beginning readers. Lott and Smith (1970) found that grade 1 - 4 readers identified the component letters of 3-letter words at a lower contrast level when presented in the word than when presented individually with masking symbols in the other two letter positions. Krueger, Keen, and Rublevich (1974, Exp. 1) used a visual search paradigm to investigate context effects in adults and a small sample of ten grade 4 pupils, representing a wide range of reading ability. Each stimulus display consisted of a target letter centered above a column of five 6-letter items. In one type of display the items were either all words or nonwords; in a second, either third order pseudowords or nonwords. They found that both children and adults searched faster through words than through nonwords, but unlike the adults, children did not search significantly faster through pseudowords than through nonwords. On the other hand, they argued that grade 4 children make as much use of redundancy in near English and English letter sequences as adults because the relative reduction in search rate was essentially the same for children as for adults on both types of displays: 10% for words, but only 3% for third order pseudowords. Consistent negative correlations between measures of reading ability and search time indicated that good readers tended to locate the target letter faster in all types of materials, unrelated letters as well as words. There was no association, however, between reading ability and absolute or relative reduction in search time for words or pseudowords. A word context effect has, however, been recently demonstrated for good, but not for poor, grade 6 readers by Mason (1975, Exp.1). In this experiment a visual search paradigm similar to that of Krueger et al. was used, but the task was much more complex in that the displays consisted of five rows of 5-letter groups each. Thus, the task was very similar to an actual reading task. Good readers identified letters in word displays faster than in nonword displays, while poor readers did not. While good readers were superior to poor readers on word displays, the two groups did not differ on nonword displays.

The specific tachistoscopic letter detection paradigm used in the present study to investigate morpheme processing in good and poor readers was selected with a view to eliminating as much as possible extraneous factors which might affect the performance of poor readers adversely. Subjects selected for this study were 10-year-old grade 4 boys; good readers who were average or above average readers and poor readers who were at least 1½ years below grade level. This grade level was selected in order to prevent "slow starters" or "late bloomers" from being included as poor readers, and also because it is only at the grade 4 level that a clear and measurable difference in reading ability can be established. For a poor reader sample of the type described, it was believed advisable to eliminate from the detection task any memory component, as well as any demanding search comparison component, and finally to avoid any response requirement which placed a premium on coordination of motor responses involving the use of the right and left hand. Tasks such as those utilized by Krueger et al. or Mason make rather stringent demands on the subject. Specifically, subjects were instructed to search for the target letter systematically and as quickly as possible from top-to-bottom (Krueger et al, 1975), or left-to-right as well as top to bottom (Mason, 1975), and were required to respond by pressing a left or right hand button for affirmative or negative responses respectively. Accordingly, in the present study, in order to simplify the task as much as possible, a target letter and a 6-letter group were presented simultaneously, and subjects simply responded verbally "yes" or "no" upon detection of the presence or absence of the target letter. Accuracy, not latency of response, was the dependent variable of major interest.

In order to investigate morpheme processing it was decided to compare lists comprised of single and double morpheme words. Since most double morpheme words consist of two or more syllables, and the possibility exists that the syllable may also function as a perceptual unit, it was decided to use only 2-syllable words, and that the double morpheme words should be restricted to those segmentable into morphs at the syllable boundary. Single and double morpheme words of the kind studied differ from nonwords in that they are pronounceable as well as meaningful. Pronounceability has been shown to be relevant in context effects, at least for adults (Gibson, Pick, Osser, & Hammond, 1962). Thus a list of 2-syllable pronounceable nonsense words was included as a control. The effect of pronounceability has been variously attributed to the redundancy provided by orthographic structure (Gibson, Shurcliff, & Yonas, 1970; Massaro, 1975), or to the spatial frequency of individual letters (Mason, 1975). It is not clear to what extent the effect of pronounceability is related to these factors. For a study on young readers, however, pronounceability seemed a most appropriate control. The final list of unpronounceable letter strings was selected so that it could be compared with the list of pronounceable nonsense words in order to determine the effect of pronounceability per se, and also because these letter strings contained no higher order perceptual unit than the single letter.

In statistical terms the design was envisaged in terms of six orthogonal comparisons: three representing the subdivision of the main effect of stimulus list and three representing the subdivision of the interaction of reading ability and stimulus list. To test for the facilitating effect of meaning or meaningful words, performance of all subjects on single and double morpheme lists was to be compared with that on pronounceable nonsense words and letter string lists. This first comparison of meaningful words with nonwords would essentially test for a replication of the facilitating effect of word context on letter recognition in children. A second comparison was planned to test for an effect of morphemes; performance on the single morpheme list was to be compared to that on the double morpheme list. If the morpheme constitutes a perceptual processing unit, then processing double morpheme words would require processing two units of information as compared to only one bit for the single morpheme words, thus making the task of processing double morpheme words more difficult. A morpheme effect would therefore be demonstrated by better performance on the single than on the double morpheme list. If morphemes are not processed as units, however, but the perceptual processing unit is the single letter or the whole word, then no difference in performance between single and double morpheme words should appear. The third comparison was to test for an effect of pronounceability; performance on the list of pronounceable nonsense words was to be compared with that on the unpronounceable letter strings. Better performance on the pronounceable nonsense words would demonstrate an effect of pronounceability. This comparison was intended to investigate the contribution of pronounceability to any facilitating effect of word context that was found.

The main interest of the present study, however, lay in establishing whether differences between good and poor readers exist and hence in the three planned comparisons related to reading group by list interactions. To determine whether word context is more effective in facilitating letter identification for good readers than poor readers in the paradigm used, it was planned to compare performance on the combined word lists as opposed to the nonword lists separately for good and poor readers. On the basis of the research by Liberman et al. (1971) and Mason (1975), it might be expected that poor readers would show less facilitation of letter detection by word context than good readers. It should be noted, however, that Krueger et al. (1974) did not find an association between reading ability and the word context effect. To test for differential sensitivity to morphemes in good and poor readers, it was planned to compare the difference between the reading groups in performance on the single as opposed to the double morpheme word list. There was no basis for predicting whether or not the good readers would show a morpheme effect since the role of morphemes in the word facilitation effect was not known. Inferior performance by poor readers on the double morpheme list relative to the single morpheme list might be expected in view of the argument that morphemes constitute perceptual processing units, as well as on the basis of the poor readers' possible difficulties in the utilization of linguistic cues. The final comparison was designed simply to determine the differential effect of pronounceability on good and poor readers. Thus, performance of each group on the pronounceable nonsense words and the unpronounceable letter strings was to be compared. It was expected that any facilitating effect of pronounceability would be greater for the good than for the poor readers.

Experiment 1

Method

Subjects. Thirty-two grade four, right-handed boys, of middle-class background, whose first language is English, were screened for participation in this study in such a way as to obtain two groups of 16 subjects each. The poor readers group was retarded in reading ability by at least 1½ years below grade level. The good readers group was reading at grade level or above. Reading levels for poor and good readers in three schools were established using the Gates-MacGinitie Reading Test subtest of Comprehension.

At the other two schools Canadian Basic Skills Reading Comprehension subtest scores were available and were used to establish reading levels for the poor and good readers at those schools. The Gates MacGinitie Reading Test was given to seven good readers and thirteen poor readers, while the Canadian Basic Skills Test scores were available for nine good readers and three poor readers. Subjects were matched individually on the Peabody Picture Vocabulary Test (PPVT) and on the Forward Digit Span subtest of the WISC. All subjects were free of known neurological and emotional impairment, and had no uncorrected auditory or visual deficiencies. The characteristics of the groups are presented in Table 1.

Stimulus Materials and Apparatus. Stimuli were presented on 4 x 6 inch white cards using a portable one-field Cambridge tachistoscope. Each stimulus card contained a target letter typed above a letter group, e.g., $\overset{s}{\text{forest}}$, $\overset{k}{\text{uaefsn}}$. On half the cards the target letter was contained in the letter group (letter present), while on the other half it was not, different target letters being used (letter absent). An Underwood Primary typewriter was used to type the letters. The size of the individual letters was .5 cm, to subtend a visual angle of .75 degrees. The distances of the target letter and the letter group above and below the fixation point were .25 cm. each, to subtend a visual angle of .33 degrees each. The adaptation field card contained a

Table 1

IQ, Digit Span, Age, and Reading Level of Good and Poor Reading Groups

Characteristic	Reading Group	
	Good Readers	Poor Readers
PPVT IQ		
Mean	109.00	108.63
Range	81 - 146	82 - 146
Standard Deviation	13.8	13.6
WISC Forward Digit Span		
Mean	5.4	5.4
Range	4 - 7	4 - 7
Standard Deviation	.8	.8
Age in Months		
Mean	121.36	121.75
Range	114 - 139	115 - 136
Standard Deviation	5.82	5.48
Reading Grade Level		
Mean	5.4	2.8
Range	4.4 - 10.6	2.3 - 3.4
Standard Deviation	1.5	.3
N	16	16

dot in the center of the card, located midway between the target letter and the letter group. The illumination for the adaptation field card and the stimulus field cards was provided by two identical Westinghouse #WF6T5/CW fluorescent lamps.

Twelve lower-case printed letters were used as target letters and four sets of 48 6-letter groups corresponding to four lists as test items. The set of 12 target letters was chosen for their high frequency in grade 2 vocabulary words and low confusability with each other; it included the following letters: a, e, i, o, r, s, t, m, p, k, and v. The letter groups consisted of: 48 unpronounceable 6-letter strings (LS, e.g., wthnii); 48 pronounceable 6-letter groups composed of two nonsense words (PN, e.g., tacsle); 48 single-morpheme 6-letter 2-syllable words (SM, e.g., answer); and 48 double-morpheme 6-letter 2-syllable words (DM, e.g., likely). All items were used for pilot training sessions, but only 24 items of each type of letter group or a total of 96 items were used in the experimental session. The lists of experimental items are shown in Appendix A in the randomized order they were presented to subjects.

Pronounceability of letter groups was determined by the experimenter and one other judge. While syllable length was not controlled across lists, each list contained words with syllables of 2, 3, and 4 letters. There were 16 words on the SM list which consisted of two 3-letter syllables, but only 6 on the DM list; there were 19 such words on the PN list. The number of words with 2 and 4-letter syllables was 8 on the SM list; 18 on the DM list and 5 on the PN list. All 2-letter syllables constituted the first syllable of the word on the PN and SM lists, while on the DM list nine 2-letter syllables were at the beginning of the word and nine at the end. The double morpheme words were chosen in accordance with linguistic convention as expounded by Lyons (1968, pp. 80-81). All double morpheme words are segmentable at the syllable boundary into single morphemes (i.e., morphs) that contribute meaning to the word. In selecting double morpheme words, contractions from the single morpheme were allowed (e.g., name - naming), but phonetic transformations (e.g., write - wrote) were not. Single and double morpheme words were selected so as not to contain consonant clusters or diphthongs wherever possible.

Most real words used are listed in grade 2 level teaching materials used in the schools of the Protestant School Board of Greater Montreal. All words were selected from common word lists of "The Teacher's Word Book of 30,000 Words" by Thorndike and Lorge (1944), and were checked for familiarity with a group of 10 average readers in a grade 3-4 class. Although all words used were listed as having a frequency at least greater than one per million words in both the general count and in the juvenile book count, it must be noted that the Thorndike - Lorge norms refer mainly to root words and are sometimes misleading. Thus, some double morpheme words were not listed separately, but are included within the frequency count of their root. For example: "bigger" is counted under "big" which has the highest possible count of over 100 per million words, but no frequency count is available for "bigger". It need not be emphasized however that "bigger" is a common word. Conversely, some single morpheme word counts are excessively high, since they contain the double morpheme words they can form. For example: "finish" is listed with a frequency of over 100 per million words, but this count includes the words: "finished", "finishing", etc.

Letters constituting the words were used again to form other letter groups, so that for each target letter all test letters were used twice, once in word form and once in nonword form, thus keeping the frequency of test letters controlled. Each target letter was used twice per list, once in the letter present group and once in the letter absent group. The position of the target letter in the letter present groups was controlled so that each letter position was used four times in each list.

Following construction of the four stimulus lists, the spatial frequency redundancy of each item on each list was calculated using the Mayzner and Tresselt (1965, Table 1) counts for single letter frequency by letter position in

6-letter words. Subsequently t - tests confirmed that the single morpheme ($\bar{X}$ = 1226.8) and double morpheme ($\bar{X}$ = 1117.2) words did not differ significantly on this measure (t = 1.53, df = 46), and also that the mean spatial frequency per item of the combined word lists ($\bar{X}$ = 1172.0) did not differ significantly from the mean spatial frequency per item of the combined nonword lists ($\bar{X}$ = 1005.6), t = .50, df = 94. The spatial frequency of the letter strings ($\bar{X}$ = 845.4), however, was significantly lower than that of the pronounceable nonsense words ($\bar{X}$ = 1165.8), t = 10.53, as well as that of the single morpheme (t = 14.08) and double morpheme (t = 9.44) word lists; df = 46, $p < .001$ for each comparison.

A set of practice stimuli, identical in character to the experimental stimuli was also devised for the pilot sessions using the following target letters: b, c, d, f, g, n, u, w, and y, and containing 36 letter groups in each of the four stimulus categories, or a total of 144 practice items. Two sample stimulus cards were used to convey the instructions to the subject.

Procedure. Preliminary testing took place in order to assign subjects to groups. Reading tests were administered where necessary, and selected subjects were then tested individually on the Peabody Picture Vocabulary Test and on the WISC Digit Span. Each child was then tested individually in three separate sessions during school hours and on school grounds. Two pilot sessions were held one week apart, while the experimental session took place two weeks later. The two pilot training sessions of approximately one hour duration were conducted in order to familiarize the subjects with the task, as well as to establish an optimal exposure time for all subjects. Before each stimulus list was presented, 36 practice trials with practice stimulus cards were given, starting at an exposure time of 500 msec. and gradually reducing (or increasing) the stimulus exposure duration in order to find the exposure duration corresponding to approximately 75% correct responses on that type of stimulus list for a particular subject. The stimulus list was then presented at that exposure time. Only two stimulus lists could be shown during any one pilot session, because of the long testing time required. Exposure times ranged from 20 to 700 msec. and varied over lists. Some subjects required additional manipulation of the exposure time during the presentation of the first half of the stimulus lists. The median exposure duration for subjects on the single morpheme list, corresponding to approximately 75% correct responses (115 msec.), was chosen as the experimental exposure time. For the third session, the experimental testing session, 24 items per stimulus category were used in order to keep testing time below one hour while presenting all four lists in one session.

The four stimulus lists were administered in blocks in order to maximize the use of strategy by subjects. Stimuli within lists were presented in the same order to all subjects. Presentation order of the four stimulus lists was counter-balanced over subjects using a Latin Square once over the two pilot sessions and again for the experimental session. During the experimental session poor and good readers were matched on the order of presentation so that each poor reader and his matched good reader received the identical presentation order.

At the beginning of each session each child was shown the two sample cards and given one practice trial with feedback. During the testing sessions no feedback was given. For all testing sessions subjects were told that the procedure involved finding a letter in a group of letters, and that the letter would appear briefly when the experimenter pressed a button. On each trial the fixation point was displayed until the experimenter initiated stimulus exposure. Subjects were asked to report verbally whether the letter was present or absent during each trial. When subjects complained that they "could not see" the stimuli, guessing was encouraged.

The instructions are included in Appendix B.

<u>Results.</u>

The mean number of correct responses made on each list by the two groups in the experimental session is shown in Table 2. The raw data is included in Appendix C.

A one-between one-within factor design analysis of variance of correct responses was first performed with reading ability as the between factor and stimulus list as the within factor. The source table for the analysis of variance is shown in Appendix D. A significant main effect was obtained for reading ability, $\underline{F}(1, 30) = 8.40$, $p < .01$. Good readers performed significantly better than poor readers, making an average of 19.81 correct responses to the poor readers' average of 17.11 correct responses.

The main effect of list was divided into three orthogonal components in order to assess the effects of: (1) meaning, (2) morphemes, and (3) pronounceability. The means for the various list effects are shown in the last column of Table 2. All three orthogonal comparisons of list effects were statistically significant. Correct responses were more frequent for meaningful lists than for nonsense lists, $\underline{F}(1, 90) = 170.83$, $\underline{p} < .001$; for single morpheme words than for double morpheme words, $\underline{F}(1, 90 = 18.34$, $\underline{p} < .001$; and for pronounceable nonsense words than for unpronounceable letter strings, $\underline{F}(1, 90) = 9.96$, $\underline{p} < .005$. All these main effects were qualified by an interaction indicating differences between good and poor readers.

The reading ability by stimulus list interaction was divided into three orthogonal components: (1) meaning by reading ability; (2) morphemes by reading ability; and

Table 2

Means and Standard Deviations for Correct Responses

List	Reading ability				
	Poor readers		Good readers		Mean
	$\bar{X}_p$	(SD)	$\bar{X}_g$	(SD)	$\bar{X}$
Nonsense					
Unpronounceable (LS)	16.44	(3.04)	17.00	(2.37)	16.72
Pronounceable (PN)	16.81	(3.47)	18.56	(2.34)	17.69
Nonsense means	16.63		17.78		17.21
Meaningful					
Single morpheme (SM)	18.81	(3.49)	21.81	(2.01)	20.31
Double morpheme (DM)	16.38	(3.12)	21.88	(2.19)	19.13
Meaningful means	17.60		21.85		19.72
Group means	17.11		19.81		18.46

(3) pronounceability by reading ability. The means for the list by reading ability interactions are shown in the first two columns of Table 2, and are illustrated graphically in Figures 1, 2 and 3. All three orthogonal comparisons were statistically significant. As Figure 1 shows, the facilitating effect of meaning on letter detection is much more marked in good readers than in poor readers, $F(1, 90) = 62.25$, $p < .001$. The significant morpheme content by reading ability interaction, $F(1, 90) = 20.33$, $p < .001$, illustrated in Figure 2, is attributable to the performance of the poor readers. For good readers, the meaningful context of words facilitated performance with both single and double morpheme words, but for poor readers, the effect of meaning was limited to the single morpheme list. As may be seen from Table 2, the poor readers' performance on the double morpheme words was actually slightly lower than on the two types of nonsense strings. As shown in Figure 3, pronounceability facilitated letter detection more for the good readers than for the poor readers, $F(1, 90) = 4.59$, $p < .05$.

Analyses of variance were then performed separately on the hits (correct positive responses) and on the correct rejections (correct negative responses) in order to investigate the possibility of response biases. The method of analysis for the hits and the correct rejections was the same as that used for the correct responses. The

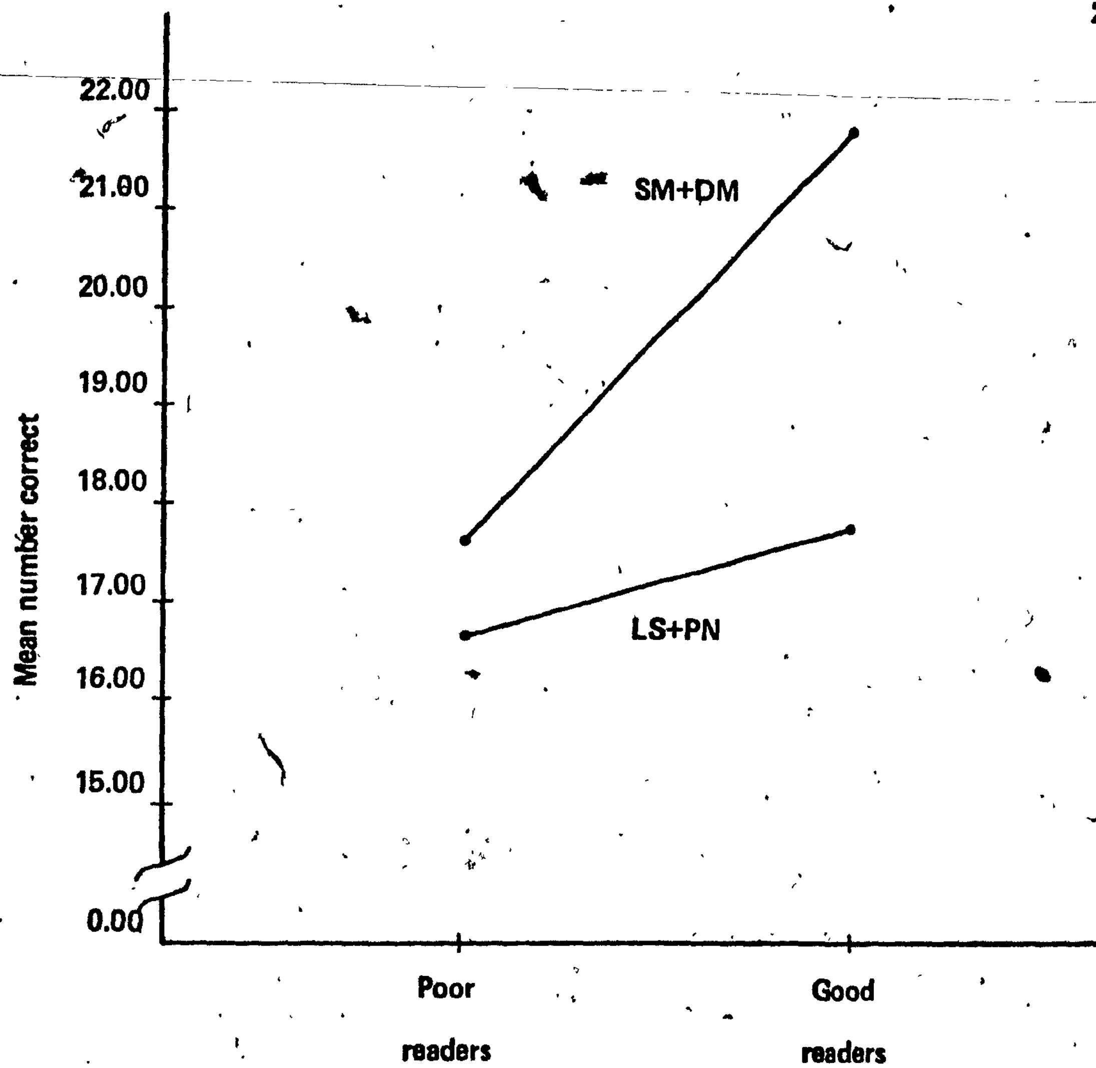

Figure 1. Meaning by reading ability interaction.

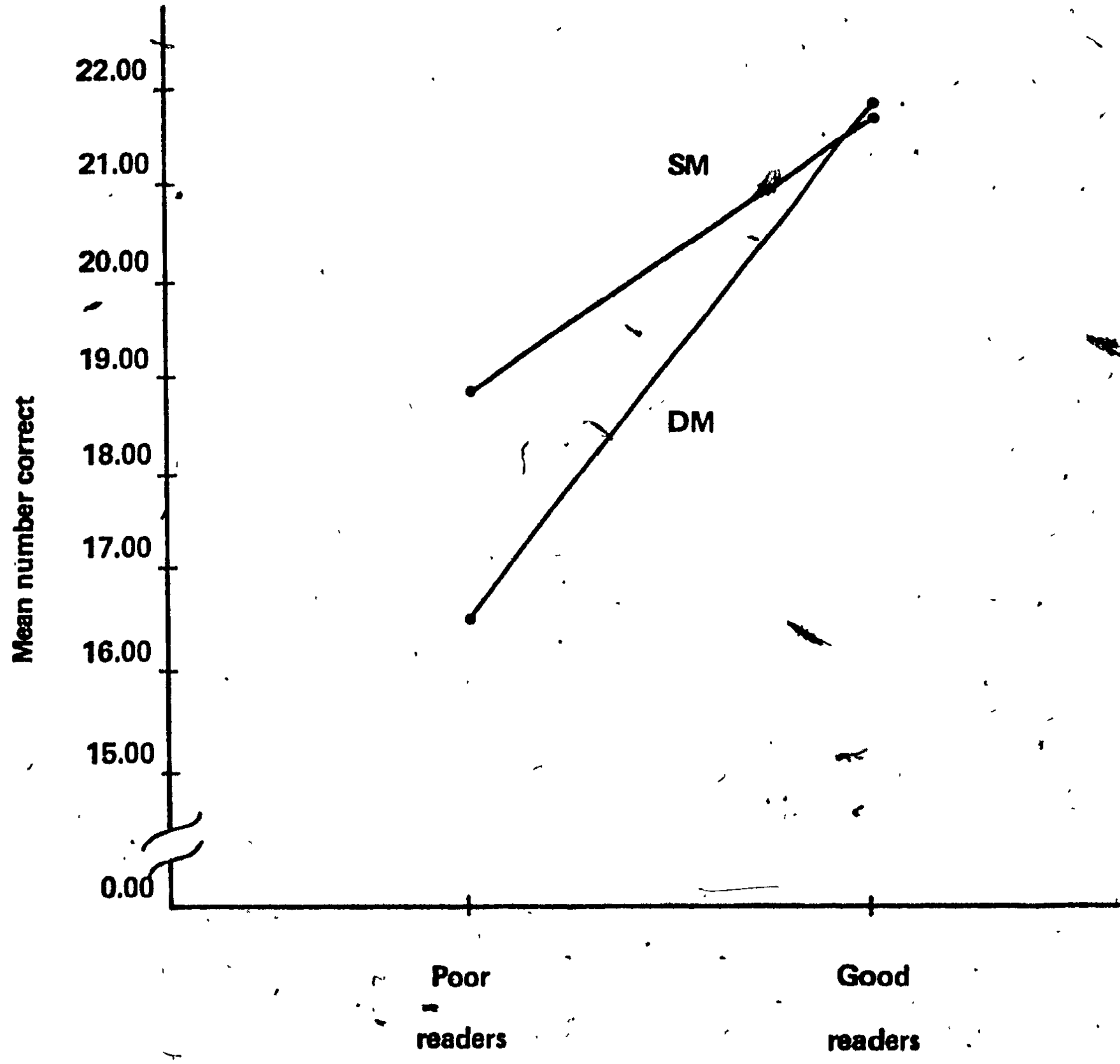

Figure 2. Morpheme by reading ability interaction.

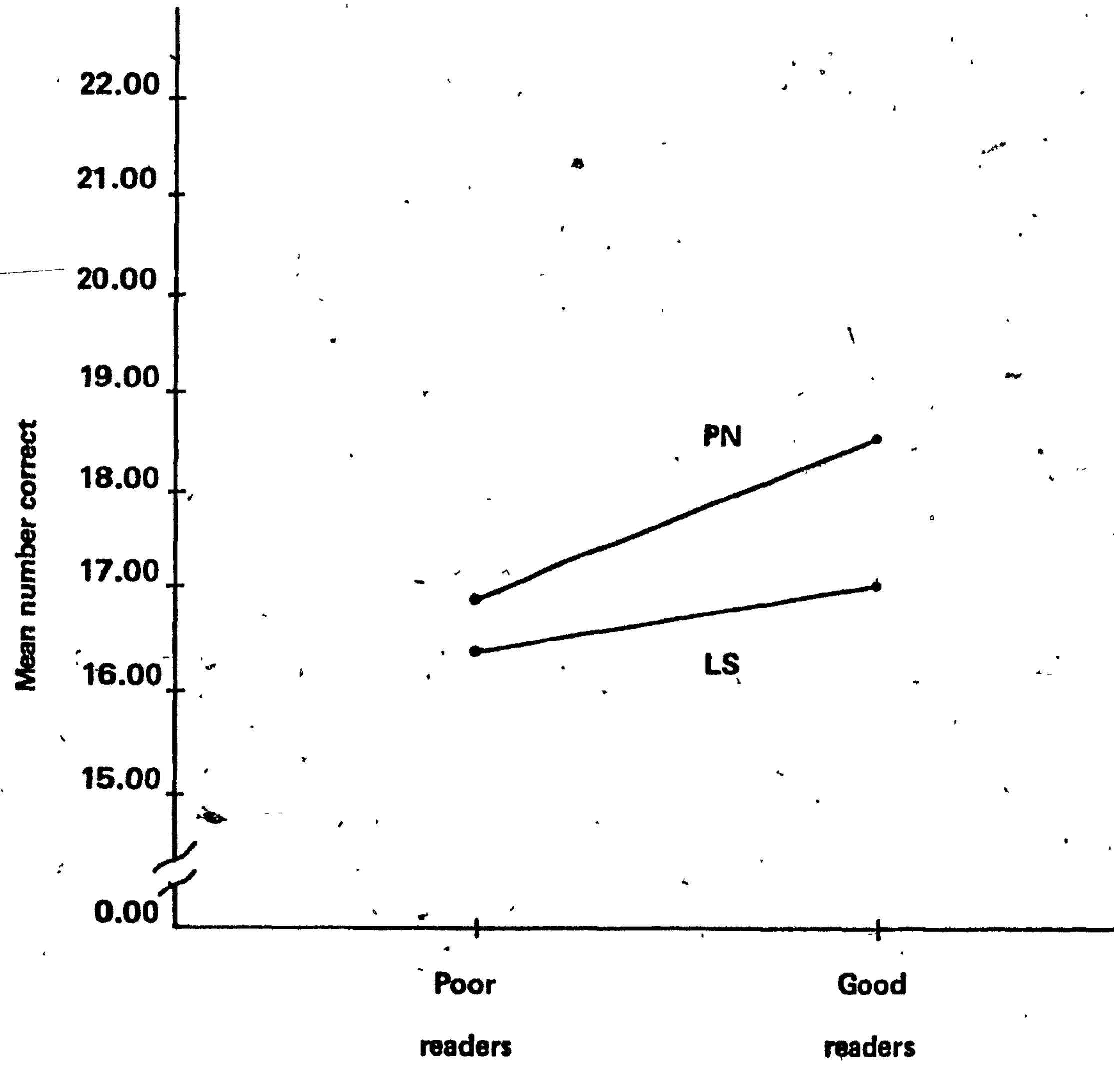

Figure 3. Pronounceability by reading ability interaction.

significant findings were the same as those obtained in the analysis of correct responses with the exception of the effect of pronounceability. The main effect of pronounceability was not significant and no significant interaction was present when hits only were analyzed, and while this main effect was significant when the correct rejections were analyzed, it showed no significant interaction with reading ability. The mean number of hits and correct rejections and the analysis of variance source tables for the hits and the correct rejections are shown in Appendix E. The raw data is included in Appendix G.

Discussion

The results showed a strong facilitating effect of words but no sensitivity to morphemes for the good readers, while for the poor readers the word facilitation effect was restricted to the single morpheme words. Although no morpheme effect was apparent for the good readers, five good readers reached a ceiling in performance on one or the other of the meaningful lists. When hits only are considered, seven good readers and one poor reader reached a ceiling in performance. Since it had been necessary to select a single exposure time (115 msec.) for both good and poor readers, and the perceptual processing time required for word recognition may be inversely related to reading ability, the possibility had to be considered that the morpheme effect might become apparent in good readers at shorter exposure times.

Experiment 2

Experiment 2 was conducted in order to determine whether the morpheme effect would be present in good readers if the stimuli were presented at a faster exposure rate than in Experiment 1.

Method

Subjects. Twelve grade four male good readers were selected from one of the schools which supplied subjects for Experiment 1. Four children had participated in Experiment 1, while eight had not. As assessed by the Gates MacGinitie Reading Test the mean reading level of the group was 5.67; reading levels ranged from 4.3 to 8.8 with a standard deviation of 1.21. The mean PPVT score was 115.08, while scores ranged from 99 to 137. The standard deviation for these scores was 9.83.

Stimulus Materials and Apparatus. The stimuli and equipment were identical to those in the experimental session of Experiment 1.

Procedure. The procedure was identical to that used in the experimental session of Experiment 1, except for the exposure duration for each stimulus card, which was set at 60 msec., or approximately half the stimulus exposure duration of 115 msec., used in Experiment 1. Presentation order of the four stimulus lists was counterbalanced over subjects using a Latin Square. One practice trial with feedback using one of the two sample cards was given at the beginning of the experimental session.

Results

The shorter exposure time seemed appropriate for detecting a morpheme effect of the kind seen in the poor readers in Experiment 1, since only two subjects reached ceiling performance of 24 items correct and that was on the single morpheme list. An analysis of variance was performed on correct responses. The mean number of correct responses on each list is shown in Table 3. The source table for the analysis of variance is shown in Appendix G. The main effect of list was divided into three orthogonal components in order to assess the effects of: (1) meaning, (2) morphemes, and (3) pronounceability, as in Experiment 1. Correct responses were more frequent for meaningful lists than for nonsense lists, $F(1, 33) = 140.15$; $p < .001$, and for pronounceable nonsense words than for unpronounceable letter strings, $F(1, 33) = 5.96$, $p < .05$. No significant morpheme content effect was found.

Analyses of variance were then performed separately on the hits and on the correct rejections. The significant findings were the same as those obtained in the analysis of correct responses, with the exception of the effect of pronounceability which was significant only for the hits. The means and standard deviations and the analyses of variance source tables for the hits and the correct rejections are included in Appendix G.

Table 3

Experiment 2. Means and Standard Deviations for Correct Responses

List	Mean	SD
Nonsense		
Unpronounceable (LS)	16.42	2.02
Pronounceable (PN)	17.58	1.44
Nonsense mean	17.00	
Meaningful		
Single morpheme (SM)	20.75	2.14
Double morpheme (DM)	21.25	1.14
Meaningful mean	21.00	

Discussion

The results of Experiment 2 confirm the results of Experiment 1 for good readers. The mean score for this group of good readers was virtually identical to that of the group of good readers in Experiment 1, $\bar{X}$ = 19.00, vs. $\bar{X}$ = 19.81, despite a shorter stimulus exposure duration of 60 msec. in Experiment 2 vs. that of 115 msec. in Experiment 1. The results of the analysis of variance and the orthogonal comparisons for Experiment 2 are similar to those for Experiment 1, confirming the presence of a strong word facilitation effect and the lack of a morpheme effect for the good readers, even for a shorter stimulus exposure duration. Experiment 2 also eliminates the possibility that the results of Experiment 1 concerning the absence of a morpheme effect in good readers may have been due to a ceiling of performance on the two meaningful lists.

General Discussion

The results of the main experiment showed a significant effect of reading ability on letter detection: the good readers' performance was generally superior to that of the poor readers. A possible contributing factor to the differences in performance between the two reading groups is that of the perceptual processing time required for the recognition of words. Evidence from several studies suggests that this factor may be inversely correlated with reading ability. Thus, Gilbert (1959) found that better adult readers identified a higher percentage of test words at a 125 msec. exposure duration than poor readers did at 250 msec. Katz and Wicklund (1971) found that reaction times in word recognition when the word is included in a sentence were longer for poor than for good grade 5 readers. Replications of the present study at several different stimulus exposure durations may help clarify the contribution of the perceptual processing time factor to the above results.

While differences between reading groups were to be expected on any task associated with the reading process, the results, as qualified by the orthogonal comparisons, showed that the differences between the two reading groups depended in part on the type of materials they were required to process. A post hoc test (Scheffé) showed that the two reading groups did not differ when processing meaningless unpronounceable letter strings; this finding rules out simple feature extraction, grapheme-by-grapheme decoding, or single letter recognition as explanatory factors for the inferior performance of the poor readers on the other three types of stimuli. It was when linguistic cues were present in the stimuli that the differences between good and poor readers became apparent.

The meaningful context of words was found to greatly facilitate letter detection in Experiment 1 and Experiment 2. This result provides a replication of the findings of Lott and Smith (1970) and Krueger et al. (1974) which indicated the existence of a word context effect in children. The data of Experiment 1 indicated, however, that word facilitation is much stronger for good than for poor readers, as was also shown by Mason (1975). A significant morpheme effect was demonstrated, but could be attributed only to the inferior performance of the poor readers on the double morpheme words. The existence of a morpheme effect indicated that, at least for the poor readers, the morpheme constitutes a perceptual processing unit in word recognition, as has been suggested by Murrell and Morton (1974). The inferior performance of the poor readers on the double morpheme words also suggests that one of the differences between good and poor readers lies in the utilization of linguistic cues provided by the morpheme content of words. The fact that the good readers did not show a morpheme effect may be due to the particular task used in the present study. The possibility exists that a morpheme effect will appear in good readers at exposure times shorter than 60 msec., since Murrell and Morton used exposure times between 20 and 60 msec.; it must be mentioned, however, that they used a different task, and their subjects were adults.

The good readers' superior performance on meaningful words can be attributed in part to the effect of pronounceability, which was found to provide some facilitation for the good readers, but less for the poor readers. It must be mentioned, however, that the effect of pronounceability, when no cues were provided by meaning, was equivalent to that of spatial frequency redundancy, as was also suggested by Mason (1975), since the comparison of letter strings with pronounceable word items showed spatial redundancy to be significantly higher on the pronounceable nonsense words. It was clear, however, that the highly significant facilitation of letter detection provided by the context of words when compared to nonwords was due to the cues provided by meaning, since the comparison of meaningful with nonmeaningful items on spatial redundancy was not significant. Notwithstanding Mason's suggestion to the contrary (1975, p. 145), meaning is a factor whose contribution to the facilitating effect of words cannot be underestimated. Even though the poor readers' performance on the double morpheme words was not better than that on the meaningless stimuli, a post hoc test (Scheffé) showed that their performance on the single morpheme words was significantly better than on all the other lists: this result suggests that meaning at the level of the morpheme provided some facilitation for the poor readers as well.

The fact that poor readers cannot efficiently process double morpheme words might be attributed to a difficulty in segmenting and encoding (i.e., "chunking") written words at the level of the morpheme when information content is high, since each additional morpheme in a word is seen as adding to that word's information content. Another possible explanation would take into account the morphological composition of the two word lists. Thus, the list of double morpheme words consisted mostly of root morphemes and affixes, while the single morpheme words are by necessity composed of only root morphemes. The poor readers performed better on the single morpheme words; it thus seems reasonable to suppose that some of the poor readers' difficulties reside in the processing of affixes and syntactic endings, as suggested by Weinstein and Rabinovitch (1971) in the interpretation of their study. This explanation is also consistent with the views of Gibson and Guinet (1971) and Murrell and Morton (1974) that root morphemes and affixes are processed independently.

An alternative explanation of the morpheme effect is based on the assumption that poor readers have difficulty segmenting words at the syllable boundary. In order to extract meaning from, and thus be facilitated by them in word recognition, the double morpheme words must be segmented at the morpheme or syllable boundary, which coincide in this study. In order to extract meaning from the single morpheme words, this segmentation is not necessary. This explanation would also clarify the fact that pronounceability provided little facilitation for the poor readers. In order to process pronounceable nonsense words better than unpronounceable letter strings, the subjects had to syllabicate.

The extent to which the various explanatory factors contribute to the differences between the good and poor readers remains to be determined by further research. It must be emphasized, however, that these differences became apparent only when processing words, not unrelated letters. The findings of the present study are thus in agreement with the suggestion of Liberman et al. (1971) that the problems of the beginning reader reside at the level of the word, and that poor readers do not seem to be sensitive to some linguistic cues provided by word context.

The contribution of the present study consisted of developing a letter detection paradigm which, while suitable for the exploration of the reading process in general, is particularly appropriate for the investigation of various factors involved in dyslexia. Through the use of the appropriate paradigm, this study succeeded in delineating a specific problem area at the word level: the poor readers' difficulty in processing double morpheme words. Therefore, this study has implications for the design of remedial reading measures that could be specifically directed toward the poor readers' problems exposed here. Since poor readers were found to have difficulty in using the linguistic cues provided by meaning as defined by the morpheme content of words, remedial materials should be designed to emphasize these cues. Such materials should stress the explicit and implicit morpheme content of words, since it is easy to speculate that if poor readers show difficulties when processing words that are clearly segmentable into morphemes, they would find words that are not easily segmentable even harder to process.

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Appendix A

Stimulus Lists

Letter Strings

Target Letter	Letter Group	+ Letter Present - Letter Absent
l	wloefr	+
v	drlhya	-
o	ngniee	-
k	yllkie	+
m	rpltya	-
s	npdnai	-
v	eielrv	+
s	yooujs	+
m	pmriee	+
a	rlrleo	-
p	aeoptt	+
r	gjnlue	-
e	klcsiy	-
i	ietcsu	+
l	ihisnf	-
i	rblmue	-
a	llcrae	+
e	rwrgeo	+
p	wthnii	-
t	trproa	+
o	rvoecl	+
k	uaefsn	-
t	wsrnae	-
r	rtleut	+

Pronounceable Nonsense Words

Target Letter	Letter Group	+ Letter Present - Letter Absent
o	lolvey	+
e	tacsle	+
a	retmoh	-
s	fosret	+
r	lacler	+
p	montem	-
l	ainild	+
s	teinum	-
a	loldar	+
k	nosrep	-
t	pelayr	-
v	tisnel	-
i	gibreg	+
o	ulsufe	-
i	ke[illegible]re	-
p	pelnic	+
r	lesmyf	-
m	muises	+
k	mektar	+
m	nifreg	-
e	dowsha	-
t	nogtiw	+
v	lervis	+
l	epkupe	-

Single Morpheme Words

Target Letter	Letter Group	+ Letter Present - Letter Absent
o	clover	+
e	castle	+
k	person	-
p	pencil	+
i	lumber	-
o	engine	-
p	moment	-
k	market	+
s	minute	-
m	finger	-
t	parrot	+
v	silver	+
e	shadow	-
m	empire	+
r	jungle	-
l	flower	+
t	answer	-
s	forest	+
i	insect	+
a	mother	-
v	listen	-
r	turtle	+
a	dollar	+
l	finish	-

Double Morpheme Words

Target Letter	Letter Group	+ Letter Present - Letter Absent
o	lovely	+
i	bigger	+
k	unsafe	-
v	hardly	-
t	replay	-
l	inlaid	+
e	[illegible]ickly	-
e	grower	+
v	relive	+
i	retake	-
p	teapot	+
a	recall	+
l	upkeep	-
t	towing	+
r	caller	+
m	misuse	+
r	myself	-
s	joyous	+
m	partly	-
o	useful	-
k	likely	+
p	within	-
s	unpaid	-
a	roller	-

Appendix B

Instructions

Instructions

I will show you some cards that have a single letter typed above a group of letters. (Show samples of appropriate stimulus cards). When you look into the instrument you will first see a dot. (Show sample of adaptation field card). When I press this button the letter card will appear for a short time. Look just at the dot. The single letter will appear just above the dot and the letter group just below the dot. Sometimes the single letter is in the letter group and sometimes it is not. When I press this button I will say "Now". Tell me each time I press the button whether the single letter is in the letter group or not. Say "Yes, it's there" if the letter is in the group, and "No, it's not there" if it is not in the group.

Appendix C

Raw Data for Experiment 1 and Experiment 2

Experiment 1. Raw data: Correct Responses

Poor Readers

	Stimulus List			
Subject	LS	PN	SM	DM
1	21	23	22	21
2	17	18	19	16
3	15	13	16	15
4	19	18	20	18
5	20	21	23	21
6	18	19	20	18
7	11	14	11	11
8	15	17	22	18
9	13	14	15	13
10	15	15	18	14
11	20	22	24	20
12	16	17	20	17
13	20	19	22	19
14	12	11	16	12
15	16	13	17	14
16	15	15	16	15

Experiment 1. Raw data: Correct Responses

Good Readers

Subject	Stimulus List LS	PN	SM	DM
1	15	21	22	21
2	21	22	24	23
3	17	19	23	24
4	20	20	23	24
5	14	19	22	22
6	19	20	24	24
7	17	22	23	23
8	18	17	23	22
9	18	17	23	22
10	18	20	22	23
11	18	18	21	22
12	14	14	17	17
13	17	18	21	21
14	19	19	23	24
15	14	16	20	21
16	13	15	18	17

Experiment 1. Raw data: Hits

Poor Readers

Subject	LS	PN	SM	DM
	Stimulus List			
1	10	12	12	11
2	10	9	10	8
3	8	8	11	9
4	10	10	10	9
5	10	11	12	11
6	10	9	10	9
7	5	6	6	5
8	8	10	11	9
9	4	8	5	5
10	9	7	9	7
11	10	11	12	12
12	7	7	10	6
13	9	9	11	11
14	8	5	8	7
15	12	9	10	10
16	9	8	9	7

Experiment 1. Raw data: Hits

Good Readers

Subject	LS	PN	SM	DM
	Stimulus List			
1	10	11	12	11
2	11	11	12	11
3	10	10	12	12
4	10	11	12	12
5	8	10	12	12
6	10	10	12	12
7	9	11	12	12
8	10	7	12	12
9	9	9	12	11
10	8	10	11	11
11	10	10	11	10
12	5	5	7	9
13	10	10	12	11
14	9	9	12	12
15	8	8	10	10
16	8	8	9	10

Experiment 1. Raw data: Correct Rejections

Poor Readers

Subject	Stimulus List LS	PN	SM	DM
1	11	11	10	10
2	7	9	9	8
3	7	5	5	6
4	9	8	10	9
5	10	10	11	10
6	8	10	10	9
7	6	8	5	6
8	7	7	11	9
9	9	6	10	8
10	6	8	9	7
11	10	11	12	8
12	9	10	10	11
13	11	10	11	8
14	4	6	8	5
15	4	4	7	4
16	6	7	7	8

Experiment 1. Raw data: Correct Rejections

Good Readers

Subject	LS	PN	SM	DM
	Stimulus List			
1	5	10	10	10
2	10	11	12	12
3	7	9	11	12
4	10	9	11	12
5	5	9	10	10
6	9	10	12	12
7	8	11	11	11
8	8	10	11	10
9	9	8	11	11
10	10	10	11	12
11	8	8	10	12
12	9	9	10	8
13	7	8	9	10
14	10	10	11	12
15	6	8	10	11
16	5	7	9	7

Experiment 2. Raw Data: Correct Responses

Subject	LS	PN	SM	DM
	Stimulus List			
1	15	16	18	21
2	13	17	24	22
3	19	19	21	22
4	15	17	21	21
5	17	17	20	21
6	16	16	19	20
7	18	18	21	21
8	16	18	21	21
9	15	16	17	19
10	15	17	22	21
11	20	20	24	23
12	18	20	22	23

Experiment 2. Raw Data: Hits

Subject	LS	PN	SM	DM
	Stimulus List			
1	9	9	10	10
2	7	10	12	10
3	10	10	10	11
4	8	7	10	11
5	7	9	11	12
6	8	9	11	11
7	10	10	10	10
8	9	10	10	10
9	7	9	7	10
10	9	10	11	11
11	10	11	12	12
12	7	11	11	12

Experiment 2. Raw Data: Correct Rejections

Subject	Stimulus List LS	PN	SM	DM
1	6	7	8	11
2	6	7	12	12
3	9	9	10	11
4	7	10	11	10
5	10	8	9	9
6	8	7	8	9
7	8	8	11	11
8	7	8	10	11
9	8	7	10	9
10	6	7	11	10
11	10	9	12	11
12	11	9	11	11

Appendix D

Experiment 1. Analysis of Variance Source Table for Correct Responses

Table A

Analysis of Variance of Correct Responses as a Function of Reading Ability and List

Source	df	SS	MS	F
Reading ability (R)	1	233.80	233.80	8.40**
Error between	30	834.30	27.80	
List (L)	3	240.08		
C_1 meaning (mn)				
LS + PN vs. SM + DM	1	202.51	202.51	164.64***
C_2 morphemes (mr)				
SM vs. DM	1	22.56	22.56	18.34***
C_3 pronounceability (pr)				
LS vs. PN	1	15.02	15.02	12.21**
R x L	3	107.20		
C_1 mn x R				
[(LS + PN)poor + (SM + DM)good]				
vs.				
[(LS + PN)good + (SM + DM)poor]	1	76.57	76.57	62.25***
C_2 mr x R				
[SMgood + DMpoor]				
vs.				
[DMgood + SMpoor]	1	25.00	25.00	20.33***

Table A

Source	df	SS	MS	F
C_3 pr x R				
[LSgood + PNpoor]				
vs.				
[LSpoor + PNgood]	1	5.64	5.64	4.59*
Error within	90	110.40	1.23	

*$p < .05$

**$p < .01$

***$p < .001$

Appendix E

Experiment 1. Means, Standard Deviations, and Analysis of Variance Source Tables for Hits and Correct Rejections

Table A

Means and Standard Deviations
for Hits

List		Group	
		Poor readers	Good readers
LS	Mean	8.69	9.06
	Standard deviation	2.02	1.44
PN	Mean	8.69	9.38
	Standard deviation	1.89	1.67
SM	Mean	9.75	11.25
	Standard deviation	2.02	1.44
DM	Mean	8.50	11.13
	Standard deviation	2.19	0.96

Table B

Means and Standard Deviations
for Correct Rejections

List		Group	
		Poor readers	Good readers
LS	Mean	7.75	7.94
	Standard deviation	2.24	1.77
PN	Mean	8.13	9.19
	Standard deviation	2.16	1.17
SM	Mean	9.06	10.56
	Standard deviation	2.11	0.89
DM	Mean	7.88	10.75
	Standard deviation	1.89	1.53

Table C

Analysis of Variance of Hits as a Function of Reading Ability and List

Source	df	SS	MS	F
Reading ability (R)	1	53.8	53.8	5.50*
Error between	30	290.1	9.7	
List (L)	3	54.26		
C_1 meaning (mn)				
LS + PN vs. SM + DM	1	46.32	46.32	55.14***
C_2 morphemes (mr)				
SM vs. DM	1	7.56	7.56	9.00**
C_3 pronounceability (pr)				
LS vs. PN	1	0.39	0.39	0.46
R x L	3	24.23		
C_1 mn x R				
[(LS + PN)poor + (SM + DM)good] vs. [(LS + PN)good + (SM + DM)poor]	1	18.76	18.76	22.33***
C_2 mr x R				
[SMgood + DMpoor] vs. [DMgood + SMpoor]	1	5.06	5.06	6.03*

Table C

Source	df	SS	MS	F
C_3 pr x R [LSgood + PNpoor] vs. [LSpoor + PNgood]	1	0.39	0.39	0.46
Error within	90	75.21	0.84	

*$p < .05$

**$p < .01$

***$p < .001$

Table D

Analysis of Variance of Correct Rejections as a Function of Reading Ability and List

Source	df	SS	MS	F
Reading ability (R)	1	63.30	63.30	6.7*
Error between	30	280.60	9.40	
List (L)	3	69.68		
C_1 meaning (mn)				
LS + PN vs. SM + DM	1	55.13	55.13	50.57***
C_2 morphemes (mr)				
SM vs. DM	1	4.00	4.00	3.67
C_3 pronounceability (pr)				
LS vs. PN	1	10.56	10.56	9.69**
R x L	3	30.14		
C_1 mn x R				
[(LS + PN)poor + (SM + DM)good				
vs.				
(LS + PN)good + (SM + DM)poor]	1	19.53	19.53	17.92***
C_2 mr x R				
[SMgood + DMpoor]				
vs.				
[DMgood + SMpoor]	1	7.56	7.56	6.94**

Table D

Source	df	SS	MS	F
C_3 pr x R [LSgood + PNpoor] vs. [LSpoor + PNgood]	1	3.06	3.06	2.81
Error within	90	98.15	1.09	

*p < .05

**p < .01

***p < .001

Appendix F

Experiment 2. Analysis of Variance Source Table for Correct Responses

Table A

Analysis of Variance of Correct Responses as a Function of List

Source	df	SS	MS	F
Subjects (S)	11	87.00		
List (L)	3	201.67		
C_1 meaning				
LS + PN vs. SM + DM	1	192.00	192.00	140.15**
C_2 morphemes				
SM vs. DM	1	1.50	1.50	1.09
C_3 pronounceability	1	8.17	8.17	5.96*
Error (L x S)	33	45.33	1.37	

*$p < .05$

**$p < .001$

Appendix G

Experiment 2. Means, Standard Deviations, and Analysis of Variance Source Tables for Hits and Correct Rejections

Table A

Means and Standard Deviations for Hits and Correct Rejections

List	Hits		Correct Rejections	
	Mean	SD	Mean	SD
LS	8.42	1.24	8.00	1.71
PN	9.58	1.08	8.00	1.04
SM	10.42	1.31	10.25	1.36
DM	10.83	0.83	10.42	1.00

Table B

Analysis of Variance of Hits as a Function of List

Source	*df*	*SS*	*MS*	*F*
Subjects (S)	11	23.55		
List (L)	3	40.89		
C_1 meaning				
LS + PN vs. SM + DM	1	31.69	31.69	31.69**
C_2 morphemes				
SM vs. DM	1	1.04	1.04	1.04
C_3 pronounceability				
LS vs. PN	1	8.17	8.17	8.17*
Error (L x S)	33	32.87	1.00	

$^*p < .01$

$^{**}p < .001$

Table C

Analysis of Variance of Correct Rejections as a Function of List

Source	df	SS	MS	F
Subjects (S)	11	31.17		
List (L)	3	65.50		
C_1 meaning				
LS + PN vs. SM + DM	1	65.33	65.33	49.12*
C_2 morphemes				
SM vs. DM	1	0.17	0.17	0.13
C_3 pronounceability				
LS vs. PN	1	0.00	0.00	0.00
Error (L x S)	33	45.33	1.33	

*$p < .001$