Reading Ability and Knowledge of Orthographic Structure

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It has been well-documented that orthographic structure (spelling contraints) contributes to the perceptual processing of letter strings. The present paper continues this study by exploring the relationship between utilization of orthographic structure and reading ability. Fourth-graders of varying reading ability were given pairs of letter strings and asked to pick the string that most resembles English spelling. The letter strings were varied systematically in terms of lexical status, frequency of sublexical patterns, and rule-based regularity. The results revealed a significant positive relationship between reading ability and appropriate decisions about English spelling. Some constraints in English spelling are mentioned along with some suggestions about how classroom practice might be modified to facilitate the child's understanding of orthographic structure.

Reading involves the integration of the visual patterns on a page of text with the reader's knowledge. Students of reading seek to understand the processes involved in evaluating the visual patterns, the nature of the knowledge sources, and how the knowledge sources are integrated with visual processing. It is generally accepted that sentential constraints in the form of semantic and syntactic information are utilized in reading. Although it is not as obvious, knowledge of orthographic structure (the constraints or redundancy of written language) is also utilized in letter and word recognition.

The utilization of orthographic redundancy is not necessary for accurate letter recognition, but it allows reading to be much more efficient. Even though the page of text appears to be clear to the reader, all readers have tunnel vision. Only six or eight characters to the right and left of fixation are perfectly legible. In addition, the short duration of an eye fixation may not allow complete processing of all of the potentially legible letters. Orthographic structure supplements the relatively limited visual information available to the reader in a given eye fixation (Massaro, 1975).

Given that orthographic structure facilitates reading, it is important to describe the reader's form of knowledge of this structure. In previous work, Venezky and Massaro (1979) have distinguished between two categories of descriptions: statistical redundancy and rule-governed regularity. The first describes the reader's knowledge in terms of the frequencies of occurrence of letters and letter sequences in written

Visible Language, XVIII 4 (Autumn 1984), pp. 323-334.
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text. According to the second description, the reader acquires certain rules about the nature of letter patterns in words. The rules can be described by phonological constraints in spoken English and scribal conventions in the transcription of spoken English into writing.

One method of testing various descriptions of the reader's knowledge of orthographic structure is to ask the reader to process novel letter strings. In our work (Massaro, Venezky, & Taylor, 1979; Massaro, Taylor, Venezky, Jastrzembski, & Lucas, 1980; Massaro, Jastrzembski, & Lucas, 1981) we begin with real words and make anagrams of them to create strings that vary systematically according to various descriptions of orthographic structure. We have used two basic tasks in the study of the reader's processing of these letter strings. The first involves perceptual recognition of the letter strings, whereas the second requires an overt judgment about the orthographic structure of the strings. In a protracted series of experiments, we have found large effects of orthographic structure in both perceptual recognition and overt judgment tasks. Given these positive results, we were encouraged to assess how knowledge of orthgraphic structure relates to reading ability and how this knowledge develops over the time course of children learning to read.

Massaro and Taylor (1980) carried out a perceptual recognition task with college sophomores. A large introductory class in psychology was given the Nelson-Denny (1973) reading test. Students scoring in the top 15 percent were contrasted with their peers scoring in the bottom 15 percent of the sample. Although there was a large contribution of orthographic structure to perceptual recognition, this contribution was identical for good and poor readers. These adult readers appear to have mastered the utilization of orthographic structure in letter and word recognition even though they vary enormously in reading ability.

Three groups of sixth graders and one group of college students participated in a second experiment (Massaro & Taylor, 1980). Based on the comprehension subtest of the Gates-MacGinite (1965) reading test, the mean comprehension grade level for three groups of sixth graders was 5.0, 7.8, and 11.9, respectively. The effect of orthographic structure on perceptual recognition was 16 percent for adults, 10 percent for the good and average sixth-grade readers, and only 6 percent for the poor readers. This substantial interaction was not statistically significant because of the large range of orthographic structure effects observed within each of the four groups of readers. However, post hoc correlations between various descriptions of orthographic structure and performance on the 200 test items revealed significant differences due to reading level. A frequency-based description correlated .48, .46, .35, and .28, respectively, for the adults, good, medium, and poor sixth-grade readers. A description based on rule-governed regularity also discriminated among the four groups of readers. These experiments provide some evidence that the utilization of orthographic structure may be related to reading ability, but only for young readers.

In another study, Massaro and Hestand (1983) studied how the acquisition of knowledge of orthographic structure relates to grade level and reading ability as measured by the California Achievement Tests (1978). Rather than using a perceptual recognition task, an overt judgment task was utilized. The subject is shown a pair of letter strings and is asked to choose the letter string that looks more like a word. This task provides information about the extent to which knowledge of orthographic structure is available and capable of report. In each pair of items, one item did not violate any rules of a rule-governed description of orthographic structure, and the other had anywhere from one to four violations. First, second, and third graders at the end of the school year were tested. First graders averaged about 58 percent correct, second graders averaged about 69 percent correct, and third graders averaged about 79 percent correct. Performance correlated .5 with grade level. We also asked to what extent performance on our orthographic structure test varied with reading level, as measured by the California Achievement Tests. Performance correlated .66 with reading level based on vocabulary and comprehension tests. Therefore, reading level accounted for 17 percent more of the total variance than that accounted for by grade level.

Two other studies report similar results to the work in our laboratory. Allington (1978) required good and poor second and fourth graders to discriminate zero-order from fourth-order approximations to English (Miller et al., 1954). Performance was primarily a function of reading ability rather than grade level. Katz (1977) asked students to report a letter's most frequent position in a five-letter string. For example, given e_ _ _ _ and _ _ _ e _, which string has the letter *e* in its most frequent position in five-letter words? The results provided some evidence that good fifth-grade readers are better at reporting certain constraints in written English than are their poor-reader peers.

The present experiment extends these previous studies by including a much broader range of test items in the overt judgment task. The lexical status, the frequency, and the rule-governed regularity were systematically varied to assess the degree to which these sources of information are available to fourth-grade readers. The central question is whether reading ability is correlated with knowledge of spelling constraints. The subjects are given pairs of letter strings and asked to choose which letter string most resembles English spelling. Seven types of letter strings varying in lexical status, regularity, and log bigram frequency were paired with each other in the task. Consider the six-letter strings shown in Table I. For each word there are six anagrams varying in orthographic regularity and summed log bigram frequency. In addition, the words are either high or low in word frequency. Every category was paired with every other category, and each category could be paired with itself. Subjects chose the letter string "which looked most like English spelling." The degree to which subjects can discriminate among the types of items should reveal which aspect(s) of orthographic structure is (are) consciously available and capable of report.

Table I. The seven categories of items used in the judgment task.

Category of Items	Example Letter Strings	
Words	should	magnet
Regular-Very High (R-VH)	hosuld	gemant
Regular-High (R-H)	shulod	tamgen
Regular-Low (R-L)	lohuds	nemtag
Irregular-High (I-H)	dhouls	ntagem
Irregular-Low (I-L)	louhds	nagtme
Very Irregular-Very Low (VI-VL)	dlsuoh	tmngae

Method

Subjects. Forty-four fourth-grade students from the Madison, Wisconsin, School District participated as paid subjects. Of these, the data of seven were lost due to a computer malfunction. Requests for student volunteers were mailed to all fourth graders in three Madison schools. The subjects in the experiment were those who responded to the request for participants and whose parents agreed to release their child's reading test scores. The scores were for the STEP (1977) reading test which was administered near the completion of third grade. For the 30 students included in the data analysis, the STEP scores ranged from 14 to 50, with an average score of 40.5. The experiment was conducted near the end of the fourth-grade year and lasted about 45 minutes. Each child was paid $5.00.

Stimuli. Forty words and their corresponding six types of anagrams (R-VH, R-H, R-L, I-H, I-L, and VI-VL) were selected to produce 280 letter strings. Nearly all of the regular strings had zero irregularities; all of the irregular strings had two irregularities, the very-irregular items usually had three and sometimes four irregularities. The position-sensitive summed log bigram frequency could be very high, high, and low. This frequency measure and the regularity measure were independent of one another. Therefore, one level of one variable was independent of the level of the other variable (cf. Table I).

Since there were seven categories and each category could be paired with itself, there were 28 unique pairs of categories. These pairs were sampled randomly without replacement in each block of 28 trials. The actual letter strings from each of the categories were randomly selected with replacement for each group of subjects. Eventually, each subject was presented with 420 pairs for judgment. Accordingly, there were 15 trials of each of the 28 pairs of categories. The two strings of each pair were printed in lower-case and were arranged side-by-side. Each string subtended a visual angle of 2.5 degrees with 2.1 degrees between the two strings.

Procedure. The stimulus items were generated by a DEC LSI-11 computer under software control and presented on Tektronix Monitor 604 cathode ray tubes (CRT) (see Taylor, Klitzke, & Massaro, 1978). The alphabet consisted of lower-case nonserifed letters resembling Universe 55 type font.

The children were instructed about the experiment in two phases. In the first phase, two letter strings printed on 4 x 6-inch cards were held by the experimenter. The children viewed the letter strings and each raised one of their hands to indicate whether the letter string on the left or on the right looked most like English spelling. The children were encouraged to respond quickly, but to be accurate.

In the second phase all the children in a group stood in front of a CRT and were told to perform the same task as was performed with the index cards, but to press one of two response keys located beneath the CRT. Each child in the group attempted several trials while the others and the experimenter watched. They were told to be certain to respond, guessing if necessary. All children readily adapted to the computer equipment. After each child in the group had a turn, they were led to individual subject rooms for the start of the data collection session. Each of the 420 trials began with a 250-msec fixation point, followed by the two letterstrings. Subjects selected the one of the two strings which most resembled English spelling by pressing one of two keys located beneath the string. The strings remained on the CRT until all the subjects responded, or for a maximum of four seconds. The 420 pairs were presented in one session with a five-minute break after 210 trials. The experiment lasted about 45 minutes.

Results

Three groups of readers were defined on the basis of their STEP (1977) reading test scores. There were ten children per group. Ten readers with scores between 47 and 50 made up the good group, ten readers with scores between 41 and 44 made up the average group, and the poor group was made up of readers with scores between 14 and 38. For each subject, the proportion of times that each of the seven categories was chosen as most like English over the other six categories was computed. These proportions were used as dependent variables in an analysis of variance with instructions, category type, reader group, and subjects as factors. Figure 1 presents the percentage of choices of most like English as a function of category for each of the three reader groups. There was a large decrease in choices with decreases in orthographic structure $F(6, 162) = 192$, $p > .001$. The differences between adjacent categories in Figure 1 were also a function of reader group, $F(12, 162) = 5.10$, $p > .001$. The slope of the functions decreased with decreasing reading ability. This result shows that reading ability predicted to some extent the reader's sensitivity to differences in orthographic structure.

An analysis of variance also was conducted on the reaction times of all of the choice responses. Response type was included as a factor to assess the differences in reaction times between choosing a given category as most like English relative to the

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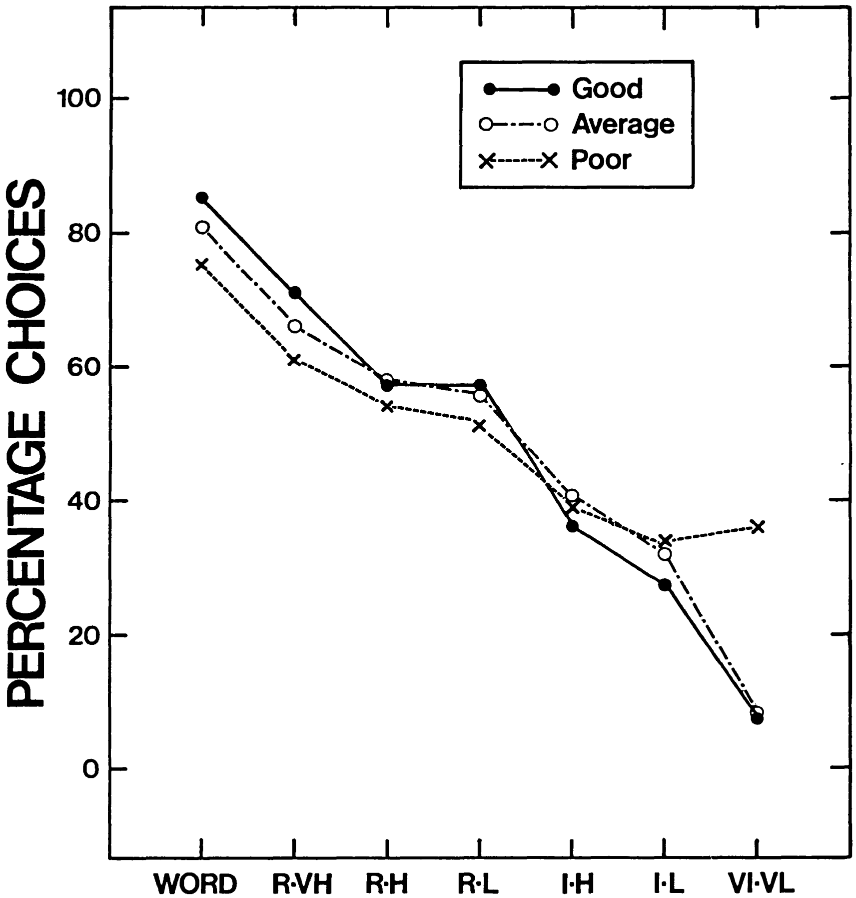
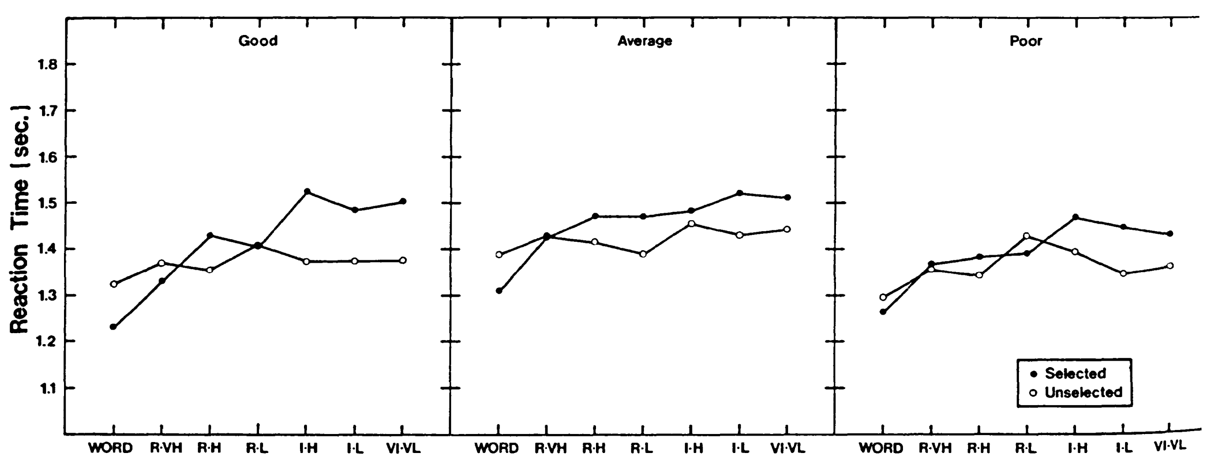


Figure 1. Percentage of choices of the letter string "that looks most like English spelling" as a function of category type, reading ability is the curve parameter.

Figure 2. Reaction times for choosing each of the category types (selected) and for choosing the alternative member of the pair (unselected) for the three levels of reading ability.



average reaction time for choosing the other six categories. As an example, the reaction times to the "word" category corresponds to all those trials having a word as one member of the test pair. The "selected" reaction time to the "word" category would be the average reaction time on those trials when a word was chosen as the item that looked most like English spelling. The "unselected" reaction time to the "word" category would be the average reaction time on those trials when the other item from any of the other six categories was chosen as the item that looked most like English spelling. Therefore, there are two reaction times for each category; the "selected" reaction time is the average time to respond with the item from that category alternative. The "unselected" reaction time is the average time to respond with the other six categories when they are paired with the designated category.

Figure 2 presents the reaction times as a function of response type, category, and reader group. "Selected" reaction times should increase with decreases in orthographic structure since it should not only be less likely but it should take longer to choose an item as most like English spelling when it is low in orthographic structure. We would not expect systematic differences in the "unselected" reaction times since they are pooled across six different categories that can have either more or less orthographic structure than the designated category. Following this expectation, reaction times increased with decreasing orthographic structure, $F(6, 162) = 22$, $p > .001$, and primarily for the selected response when that category was chosen as the item most like English, $F(6, 162) = 4.56$, $p > .001$. However, reaction times did not vary as a function of the three levels of reading ability. Accordingly, although reading ability was related to the choices of items differing in orthographic structure, it did not influence the time to respond in the task.

Discussion

Before discussing the implications of the results it is necessary to give a brief defense of using the overt judgment task as an index of the utilization of orthographic structure in letter and word recognition in reading. The overt judgment task requires decisions about English spelling after letters are recognized rather than assessing the utilization of knowledge of English spelling in letter and word recognition. Reliable judgments about English spelling in the overt judgment task does not necessarily mean that this knowledge is utilized in letter and word recognition. Similarly, readers might have and utilize knowledge in reading but may not be able to perform appropriately in the overt judgment task. The primary argument for the validity of the overt judgment task as an index of utilization of orthographic structure in reading is the high correlation between performance on the overt judgment task and performance in perceptual recognition tasks (Massaro et al., 1980, 1981). Caution in generalizing these results to natural reading is still necessary, however, since perceptual reports might not be valid measures of psychological processes (Marcel, 1984).

The present experiment, as well as those reviewed in the Introduction, demonstrates a significant relationship between reading ability and knowledge of orthographic structure. We cannot state from this research how important utilization of knowledge of orthographic structure is for good reading. Although good readers may read better because they have learned to utilize orthographic structure, it is also possible that sensitivity to orthographic structure is dependent on skilled reading. However, the significant findings encourage us in the belief that it may be worthwhile to modify classroom practice to more directly facilitate the child's understanding of orthographic structure. There are some strong constraints in English orthography and these might be taught in a game format in the classroom (Massaro & Taylor, 1980). It is encouraging that the constraints in English orthography do not change significantly with the reading level of the text. We have found very high correlations among letter and letter-pattern occurrences in texts sampled from grades three to nine (Carroll, Davies, & Richman, 1971) and texts for adult readers (Kucera & Francis, 1967). Some of the major constraints are differences in terms of where consonants and vowels occur in words. Vowel sounds are relatively infrequent in initial and final position in English words and therefore the reader can expect most words to begin and end with consonants. Overall, constraints are greatest at beginnings and ends of words. Syllable boundaries in the middle of words permit almost any pair of letters to occur in medial positions. There are also major constraints on the possible consonant and vowel clusters and where they can occur in English words.

The games involve the child in determining which letters and letter patterns occur and where they occur in English words. In one game students are given a list of letter strings and asked to search for a particular letter or cluster of letters. If the child knows where letters and letter clusters normally occur, the search through the list will be much easier. An important aspect of the game is to discuss what rules of thumb are helpful in determining where letters and letter clusters might be found. In another game the child arranges letters and letter clusters on a magnetic board to create new words. The goal is to create the words visually rather than orally. A game modeled after the overt judgment task is to categorize letter strings as possible or impossible words. Whenever a letter string is judged to be impossible, the student indicates what is wrong with it and how it might be corrected. A popular game is a version of hangman; the student is told the number of letters of a mystery word and must guess what the word is. The participant guesses one letter at a time and is shown the position(s) in the mystery word of correct guesses. Playing these games, students might be made aware of the constraints in English orthography.

A relevant issue has to do with the form of the knowledge of orthographic structure. We have described the form in terms of sublexical letter patterns and rules (Massaro et al., 1980; Venezky & Massaro, 1979), although the knowledge may be represented at only the lexical level (Baron, 1977; Brooks 1975; Glushko, 1979). A test between these two forms of representastion might be possible within the context of the training programs just described. Training programs could be devised to teach primarily sublexical rules and spelling patterns or to teach whole words. The question would be which program would lead to more substantial and rapid gains in reading skill.

In summary, our work has encouraged our belief in the important contribution of orthographic structure in reading and learning how to read. Although phonics instruction is now generally accepted, little reading instruction directly teaches orthographic structure. Classroom programs incorporating instruction on orthographic structure might allow us to assess the role this knowledge plays in learning to read.

The research reported in this paper was supported in part by funds from the National Institute of Education, Department of Health, Education, and Welfare. The contributions of J. E. Jastrzembski and P. A. Lucas are gratefully acknowledged and Ken Paap made helpful comments on the paper and the research enterprise.

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