SYLLABIC CODING AND READING ABILITY IN WORD RECOGNITION

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Abstract. Two experiments were run in order to determine if fifth grade children use syllabic coding as a component of the word recognition process in reading. Contrary to results from previous studies, evidence for syllabic coding was found in a lexical decision task for high frequency words and, less strongly, for low frequency words. In a naming task, an effect of syllabic coding was found for pseudoword naming latency but not for high frequency words. However, syllabic coding effects were found on error measures for both pseudowords and high frequency words. Throughout both experiments, skilled readers performed better than less skilled readers but the syllabic coding effects were similar for both reading ability levels.

INTRODUCTION

The experiments presented here looked for evidence of effects on reading due to a major phonological variable, the syllable. Two questions were asked: (1) is the syllable a component of word recognition in reading and, if it is, (2) are skilled readers better than the others at utilizing syllabic information to recognize words?

Liberman and Shankweiler (1978) demonstrated that poor readers often fail to achieve awareness of the syllabic and phonetic structure of spoken language, an awareness that is necessary to use an alphabetic writing system effectively. How lack of awareness of the underlying structure of speech can lead to difficulties with reading is described systematically in the reading model of Laberge and Samuels (1974). (See also Estes, 1977, for a similar treatment.) Reading is seen as a process by which visual information is transformed in a series of processing stages involving visual, phonological, episodic memory and semantic memory systems. Some of the visual codes derived from print have their counterparts in phonological codes; letters, spelling-patterns and whole words in the visual system are in complex association with phonemes, syllables and words in a phonological system whose units are closely related to acoustic and articulatory inputs. The information flow is from subunits (for example, letter features) into large units (for example, letters) arranged in a hierarchical structure. For the skilled reader in the Laberge-Samuels model, reading becomes more efficient as the various sub-

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processes require less attention, i.e., become more automatic. Efficiency requires that the appropriate information processing structures evolve, and the beginning reader who attempts to map entire printed words directly into a phonological equivalent without first establishing a substructure based on the components of the spoken word (e.g., phonemes and syllables) will not become a skilled reader. It might be the case, then, that readers who have evolved processing structures without having been aware of the existence of syllables in speech when they began to learn to read might be destined to become less efficient readers. On the other hand, the less skilled readers might eventually restructure the process of mapping print into syllable units as their awareness of the spoken language matured, in which case, no trace of the earlier structure might be found.

In the experiments reported here, the major experimental manipulation is the degree of integrity of the syllable units in each stimulus. Two aspects of word recognition are studied: pronunciation and meaning. If syllabic information is used in either aspect, then disruption of the syllable unit should prove deleterious. The first experiment uses a naming task in an attempt to bias the subject toward the use of a phonological strategy for word identification. Although, to my knowledge, syllable unity has not been manipulated before, another syllable variable—the number of syllables—has sometimes been found to affect the latency of naming a printed word or pseudoword (Erickson, Pollack, & Montague, 1970); but negative evidence has also been found (cf. Fredriksen & Kroll, 1976). The second experiment attempts to bias the subject toward a search for the meaning of a stimulus; a lexical decision task is used. Although evidence for some kinds of phonological encoding of the stimulus has been found in the lexical decision task under certain conditions (e.g., Davelaar, Coltheart, Besner, & Jonasson, 1978), there appears to be no evidence of specific syllable effects (Fredriksen & Kroll, 1976).

In both experiments children of skilled and less skilled reading abilities are studied with regard to their use of syllabic information. Skilled readers were expected to perform better than less skilled readers. Of specific interest are the possible interactions of reader ability with syllable unity. As suggested above, it may be the case that less skilled readers do not use syllabic information in the same way as do the skilled readers.

Recently, there has been support for the notion that both phonological and nonphonological (direct visual) codes of print can access the reader's internal lexicon, i.e., his memory for words. Coltheart, Davelaar, Jonasson, and Besner (1977) and Meyer, Schvaneveldt, and Ruddy (1974) agree that both phonological and nonphonological routes to the lexicon are possible; they differ in that Coltheart et al. suggest that mutual facilitation between routes is possible, while Meyer et al. do not allow for that possibility. Marcel and Patterson (1978) present data from studies of aphasics and normals that also support the dual channel notion. Levy (1977) found severe and stable deficits in reading comprehension when vocalization was required; no such deficits occurred in analogous listening comprehension tasks. However, Levy also found comprehension deficits unrelated to vocalization (thematicity effects) and concluded that both speech processing and visual processing are used in accessing the meanings of both individual words and sentences.
Experimenters who probe for evidence of phonological encoding in reading will miss finding certain visual codes used by a reader that are related to phonological codes; these visual codes may still preserve some characteristics of the original phonological encoding. Specifically, it may be the case that visual codes of spelling patterns exist that reflect a past association in the reader's experience of these spelling patterns with historically older phonological syllable codes. It might be expected that the information in these visual codes preserves the syllabic divisions present in the phonological codes that preceded them. If so, we would find a unitization of letter groups into syllable-like visual units. This visual, but syllable-like, encoding might or might not be merely a temporary stage in the evolution of visual reading codes; they might or might not be found in mature reading behavior as well as in children's reading. Either way, it may be the case that the reader (at least at some stage of development) visually parses words into syllables (among other parsings) because his overt and covert speech systems, which were operational in earlier reading acquisition, did so previously.

The present experiments were not designed to pinpoint the locus of syllable effects in either visual or speech codes. Rather, these studies look for any evidence of syllable effects on word recognition while using a technique that presumably can probe for a reader's sensitivity to the syllables in the words he or she is reading, whether that sensitivity depends on information in the visual mode or in the speech mode. The technique requires dividing a printed multisyllabic word with a nonalphabetic marker (a slash). Two types of division are used: division of the word that corresponds to correct syllabification, and division of the word that is incorrect with regard to syllabification. The words that are correctly syllabified should "look right" to any visual information encoder presented with the printed stimulus. If a visual syllabic code is used in accessing the name or meaning of a word, then such a code will be facilitated by correct syllabification compared to an incorrect division of the word.

If instead of (or in addition to) visual processing, speech modality codes are used in word recognition, then the stimuli that are correctly syllabified should again be easier to transform from print to speech. Finally, if syllable processing is not important to word identification, it will suggest that one kind of intraword phonological processing does not affect word recognition, even through the use of a related visual code. Note that the statement that syllabic coding exists does not imply that the structures of the word naming process or the lexical memory, etc., are to be viewed as syllabaries; the only implication to be made is the weaker one: that syllabic coding is utilized somewhere in the process of recognizing words.

EXPERIMENT 1

In order to encourage phonological processing (and therefore heighten potential syllable effects) subjects were required to respond to a stimulus item by pronouncing it (naming). Stimuli were divided (using a slash) either appropriately (Regular) or inappropriately (Irregular) and both skilled and less skilled readers were studied. In addition, word familiarity was varied; high frequency words were contrasted with orthographically and phonologically regular pseudowords.
The word-pseudoword variable was introduced to examine the possibility that high frequency words are not processed phonologically, but, rather, that their pronunciations are accessed lexically. Lexical access to pronunciation may occur in a manner similar to (and perhaps along with) access to semantics (cf. Forster & Chambers, 1973; Marcel & Patterson, 1978). However, there is no such memory of a pseudoword’s pronunciation; subjects are likely to pronounce them by applying phonological rules. Therefore, if one expects to find a syllable effect anywhere, it should occur at least with pseudowords. Nevertheless, it should be noted that subjects are not limited entirely to phonological processing in order to pronounce a pseudoword, because pronunciation can still take place, in part, by finding real word analogs to the printed pseudowords (or analogs to parts of the pseudoword) and lexically accessing the pronunciations of those analogs.

**Method**

**Subjects.** From a group of 51 fifth grade children, 25 skilled readers and 26 less skilled readers were chosen. The mean reading class levels on a scale of 0 – 9 and mean Comprehensive Test of Basic Skills reading grade equivalence were 6.6 and 8.7 for the skilled readers, and 3.2 and 5.1 for the less skilled. The children were tested in October and November of the school year and had been given the CTBS the previous June.

**Stimuli.** Forty-five high frequency two-syllable words were chosen from the 1,000 most frequent words in the Carroll, Davies and Richman (1971) norms. Each of forty-five pseudowords was constructed by first permuting the vowels of a high frequency real word. Often, this produced a pseudoword that was phonologically irregular or very unusual, and a new vowel was used instead. Examples of real words and their pseudoword counterparts are: letter – lutter, region – rogin, among – omang, coming – cimong, perhaps – parheps.

Each word was syllabified to produce a Regular and an Irregular version. Each word was syllabified appropriately using either a standard dictionary or the rules suggested by Speohr and Smith (1973). Each word was also divided inappropriately at a position that conformed to no standard rules of correct syllabification. The position of each appropriate division was matched by an inappropriate division of some word; i.e., the position of the division was balanced. A division was marked with an oblique slash that occupied one character space. The stimuli were placed on cards 10.16 x 15.24 cm using Chartpak Alternate Gothic 2 lowercase type. A quasi-random ordering of 90 Regular and Irregular stimuli was produced for words and an homologous one for pseudowords. If a Regular stimulus appeared in the first 45 trials, its Irregular counterpart appeared in the second 45 trials, and vice versa.

**Design.** A between-subjects design was used, with 11 skilled readers and 13 less skilled readers receiving real words, and 14 skilled and 13 less skilled readers receiving the nonword condition. Because of machine failure, one additional skilled reader was discarded.

**Procedure.** Subjects were run on a Gebrands three-channel tachistoscope. A fixation frame came on for 800 msec, followed by the stimulus for 1.5 sec, and a blank frame for 1 sec. Stimuli subtended approximately 2 degrees of visual angle. Subjects were told to say each word quickly when it appeared.
A voice operated relay was adjusted during five practice trials and then used to clock the interval between stimulus onset and the onset of vocalization. After practice, two dummy trials preceded, without a break, a run of 45 trials. There was a brief rest after trial 45 while the cards were changed for the second run of 45 trials. The interstimulus interval was controlled by the experimenter and was approximately 12 seconds.

Results and Discussion

Errors were classified into one of two types: incomplete utterances (e.g., partial vocalizations) and mispronunciations. Incomplete utterances were scored as such only when followed immediately by a correct pronunciation. Long hesitations between the two syllables were also scored as incomplete. With regard to scoring mispronunciations, the experimenter's criterion for a correct pronunciation was generous for both real words and pseudowords.

An analysis of variance was performed on the number of incomplete utterances, for each subject. The effect of reading ability was significant, with skilled readers making only 1.04 errors while the less skilled readers averaged 3.21 errors, $F(1,47) = 6.06, MS_e = 6.67, p = .018$. No other effects involving reading ability were significant. Fewer errors were made on real words than on pseudowords, $F(1,47) = 13.17, MS_e = 6.67, p < .001$, and fewer errors were made on regularly syllabified stimuli than on irregular stimuli, $F(1,47) = 6.05, MS_e = 4.29, p < .017$. The interaction of these two variables was also significant, $F(1,47) = 4.05, MS_e = 4.29, p < .05$, and is given in Table 1. Clearly, the disruptive effect of irregular syllabification was stronger for pseudowords than for high frequency real words, although a syllable effect exists for both.

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<th>Stimulus Division</th>
<th>Real Words</th>
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The results were slightly different for mispronunciations. There was no significant difference between skilled and less skilled readers on these errors, skilled readers making an average of 1.43 errors while less skilled readers made 1.96 errors. As above (see Table 1), there were significant effects for the word-pseudoword comparison $F(1,47) = 14.47, MS_e = 75.03, p < .001$ and the regular-irregular syllabification comparison, $F(1,47) = 8.65, MS_e = 20.17, p < .006$, but their interaction was not significant, unlike the result for incomplete utterances. The significant interaction for incomplete
utterances suggests that syllabification is more important for naming novel stimuli than for naming frequent words. Although the interaction leading to this suggestion is only marginally significant, the same interpretation is supported more strongly by the response latency data.

Mean latencies were computed for correct responses on regular stimulus trials and irregular stimulus trials for each subject. An analysis of variance performed on mean latency produced a pattern of results similar to the analysis performed on incomplete utterances, but more highly significant. The mean latencies, in ms, were 771 for skilled readers and 915 for less skilled readers, $F(1,47) = 13.23, MS_e = 39784$, $p < .001$. No other effects involving reading ability were significant. Table 1 presents the mean latencies for regularly and irregularly syllabified words and pseudowords, averaged over both reading ability groups. Not surprisingly, real words were pronounced faster than pseudowords, $F(1,47) = 89.53, MS_e = 39784$, $p < .001$, and the effect of regularity is also significant, $F(1,47) = 13.28, MS_e = 1148$, $p < .001$. However, the interaction of the two variables clearly accounts for the main effect of regularity; irregular syllabification is detrimental only when pronouncing pseudowords, $F(1,47) = 12.32, MS_e = 1148$, $p < .001$. The finding of a syllable effect on the naming of pseudowords is striking in the light of negative evidence for syllable involvement in naming either words or pseudowords from Henderson, Coltheart, and Woodhouse (1973), Forster and Chambers (1973) and Fredriksen and Kroll (1975). However, these investigations varied the number of syllables in the stimulus rather than the integrity of the syllable unit and that difference with the present experiment may be the critical one. One possibility is that phonological processing of pseudoword (or novel) stimuli occurs, but such processing is unlike inner speech in that it is not necessarily distributed in time; the various syllables are processed in parallel. The technique of syllable disruption used in the present experiment, however, may delay the onset of that phonological processing that is dependent on a syllabic partitioning of the stimulus. The data are clear with respect to the effect of syllable regularity on pseudoword naming; both errors and latencies indicate that regularly syllabified stimuli are easier to process than irregular stimuli. The results for real words are contradictory; syllable effects are indicated by both types of error responses but not by latencies. While it is possible that subjects were attempting to maintain a constant response latency and were trading-off speed against errors, this hypothesis does not gain plausibility from the low error rates.

With respect to reader ability differences in the processing of syllable information, the experiment found no interactions between reader ability and syllable regularity. Therefore, the substantial reader ability differences that were found appear to be unrelated to the processing of syllable information.

The appropriateness of articulation as a measure of phonological processing may be questioned. Fredriksen and Kroll (1975) accept such an equation between the phonological representation of a letter string and the articulatory representation of the string, but Davelaar et al. (1978) do not. Fredriksen and Kroll assume that, in word naming, phonological encoding is completed first and that this encoding then determines the articulatory coding for the response. Davelaar et al. point out that the articulation of a letter string may, in fact, begin before the entire string is phonologically encoded,
and, therefore, a distinction must be made between the final phonological and articulatory codes. Forster and Chambers (1973) go somewhat further and suggest that, if a phonological code is used, the code used for naming is not necessarily the same as the phonological code used for lexical access. In the present experiment, there is some evidence to support Davelaar et al.; the incomplete utterances appear to be overt examples of articulation that began before phonological coding was completed. The likelihood of a difference between the code used for articulation and the code (possibly phonological) normally used to access the meaning of a word in natural reading is, perhaps, enhanced by the present paradigm in which rapid articulation is required, but access to meaning is not.

**EXPERIMENT 2**

The second experiment was designed to require processing for meaning, thereby including an important component of natural reading. In addition, Experiment 2 extended the study of real words to include low frequency words as well as high frequency words. The finding of syllable effects on latencies for pseudowords but not for high frequency words in Experiment 1 suggested that, if a similar result were obtained in Experiment 2, low frequency words would be found to behave more like pseudowords, i.e., low frequency words would show evidence of syllable processing on latencies. A lexical decision task was chosen as the experimental paradigm. In the lexical decision task, word frequency effects are typically found and those were expected here; reaction times to high frequency words were expected to be faster than low frequency words, and words were expected to be faster than pseudowords. As in the previous experiment, I studied both skilled and less skilled reader groups. Of primary interest were the questions of (1) whether the regularity of syllabification would affect reaction times to high and low frequency words as well as to pseudowords and (2) whether these syllabification effects would interact with reader ability.

**Method**

**Subjects.** From a group of fifth grade children, 51 skilled readers and less skilled readers were selected. From this set, 18 skilled and 18 less skilled readers were chosen for the major analyses on the basis of response error criteria discussed below. Unless noted otherwise, all remarks apply to the final group of 36 children. The children had been classified previously into one of 10 reading classes using the Comprehensive Test of Basic Skills together with teachers' recommendations. Skilled readers were selected from reading classes 7-9 and less skilled readers from the range 0-4. The mean reading class levels and CTBS reading grade equivalence were 8.56 and 10.4 for the skilled readers and 2.67 and 6.3 for the less skilled readers. The children were studied in the experiment in May and June and were given the CTBS in June. Therefore, as expected, their CTBS scores were somewhat higher than those of the children in the first experiment (run earlier in the school year) whose CTBS scores date from the end of the previous school year.

**Stimuli.** Six two-syllable high frequency and six two-syllable low frequency words were selected from the Carroll et al. (1971) fifth grade norms. The high frequency words had a range of from 145 to 959 occurrences in a sample of 634,283 tokens with a mean frequency of 411. The low frequency
words ranged from a frequency of 1 to 10 occurrences, with a mean of 3.5. Each low frequency word was required to be similar in length to a specific high frequency word and to preserve morphemes such as -er and -ing in the high frequency word. For each high and low frequency word, a control pseudoword was constructed by changing one or more consonants or vowels in the word. Some of the words were composed of suffixes attached to stems that were themselves words (e.g., poster, wanted). For the set of low frequency words, the word frequency of the stem was always lower than the entire word; for the set of high frequency words, the stem was always more frequent than the entire word.

Pilot testing established a pool of words and pseudowords that were reliably judged correctly. In pilot tests, stimuli were printed on a sheet of paper and fifth grade poor readers were asked to circle those stimuli that were real words. The final set of stimuli is presented in Table A of the Appendix. Thus the 24 stimuli may be viewed as divided into six sets of four conditions each, each set consisting of a high frequency word, a low frequency word, and two pseudowords. Within each set, the four stimuli are structurally similar with regard to orthography and syllabification; the similarity is greater between a pseudoword and its real word counterpart. Each stimulus was syllabified once regularly and once irregularly by means of a slash, as in the previous experiments, to produce 48 stimuli.

Two lists, each containing all 24 original stimuli, were constructed. For List A, three of the six stimuli in each of the four conditions (high and low frequency words, pseudoword controls for high and low frequency words) were syllabified regularly and three were divided irregularly. Each list contained a quasi-random sequence of conditions. List B was identical to List A, except that a stimulus that was divided regularly in List A was divided irregularly in List B, and vice versa (see Table A in the Appendix). Stimuli were placed on 10 x 15 cm tachistoscope cards as in Experiment 1. As in Experiment 1, each stimulus subtended approximately 2 degrees of visual angle.

**Design.** Nine skilled and nine less skilled readers received List A followed by List B, while the remaining nine children in each reader ability group received the reverse order of lists. Randomized within each list were the factorial combinations of the four conditions (high and low frequency words, two pseudoword controls) by two levels of syllable regularity.

**Procedure.** Subjects were told to decide whether each stimulus displayed was a real word or not, based on their knowledge of the meaning. If they did not know the meaning of a stimulus, they were told to judge it as not a word. The experimenter showed the child four cards representing real and pseudowords, two divided regularly and two divided irregularly. The slash in each stimulus was explained as the experimenter's way of making the task more challenging for the child. Then four practice trials were given. The child pressed a telegraph key with his or her dominant hand to make a "word" response, the other hand being used for a "not word" response. The first list was then presented, preceded without interruption by a dummy trial. The cards were changed after the first list; and then the second list, preceded by a dummy trial, was presented.
Each trial began with an 800 msec fixation frame, followed by the stimulus frame for 1500 msec, followed by an all-white frame for 1 sec.

Results and Discussion

Errors were frequent. They consisted mainly of wrong key presses ("word" instead of "not word" or vice versa) even though the subject often knew the correct identity of the stimulus. Such responses were usually followed immediately by the correct key press or by a remark that the subject momentarily confused which key went with which decision. A score of five errors or less (out of 48 trials) was chosen as a criterion for including a child in the final latency data analysis and subjects were run until the quota for each cell of the design was filled with criterion subjects. A total of 51 children was run in order to obtain a final set of 36 criterion children. Of the rejected subjects, six were skilled readers and nine were less skilled readers.

Error analyses were performed both on the total set of 51 children and on the criterion set of 36. Analyses on the larger set provided less clear results (e.g., less regular data, lower F-ratios) than analyses on the criterion set. For the criterion set of subjects, an analysis of variance was performed on the mean number of errors in each combination of condition (high frequency words, pseudoword controls for high frequency words, pseudoword controls for low frequency words), syllable regularity (regular, irregular), and time (first stimulus list, second list) for each subject in each reader ability group (skilled, less skilled). There were large effects of reader ability, $F(1,34) = 15.5$, $MS_e = .179$, $p < .001$. The mean total number of errors for skilled readers was 1.8 (3.7%) and for less skilled readers was 4.0 (8.3%). The effect of time was also significant, with an average of 3.7 errors the first half of the session and 2.0 errors the second half; $F(1,34) = 11.8$, $MS_e = .150$, $p < .002$. Condition was also significant, $F(3,102) = 6.12$, $MS_e = .146$, $p < .001$. The mean errors for conditions were: high frequency words, 1.44, low frequency words, 3.89, pseudoword high frequency controls, 2.22, pseudoword low frequency controls, 4.0. The effect of syllable regularity was not significant. The interaction of time, condition and regularity was the only significant interaction, $F(3,102) = 3.21$, $MS_e = .180$, $p < .03$. The interaction data appear to concern low frequency words. For that condition, subjects were more likely to make errors on regularly syllabified words than irregularly divided words in the first half of the session and then reversed that pattern for the second half. Compared to the three strong main effects that were obtained, the interaction result appears to be minor. The analysis of variance of errors based on the larger set of 51 children, which included both criterion and noncriterion subjects, gave similar results to the analysis of variance on the criterion set of subjects, with one exception: viz., the three-way interaction of time, condition and regularity was not significant. Of most interest to the present experiment is the fact that in neither analysis were the effects of syllable regularity or its interactions significant. However, both analyses produced F-ratios for the interaction of regularity and conditions that were nearly identical and approached significance ($p < .08$). These marginally nonsignificant results are of interest only because the same interaction turned out to be highly significant in the analysis of reaction times.
An analysis of variance was performed for reaction times on correct responses. As in the error analyses, the three main effects of reader ability, time, and condition were significant, while the main effect of syllable regularity was not. Only one interaction was significant, syllable regularity by condition. No other terms approached significance. The reader ability mean latencies were 900 msec for skilled readers and 1036 msec for less skilled readers, $F(1,34) = 6.21$, $MS_e = 426,433, p = .018$. For the factor of time, the mean first and second half latencies were 1011 and 925 msec, respectively. Figure 1 presents the mean latencies for the combinations of syllable regularity and condition. For the condition main effect, $F(3,102) = 47.47$, $MS_e = 23,321, p < .001$. For the interaction, $F(3,102) = 6.26$, $MS_e = 10,394, p < .001$.

Figure 1 shows that latencies for the four conditions are ordered from fastest to slowest as follows: high frequency words, low frequency words, pseudoword controls for high frequency words and pseudoword controls for low frequency words. An interpretation of the interaction of syllable regularity and conditions appears to be straightforward upon inspection of Figure 1. For the word conditions, latencies to regularly syllabified words were faster than to irregularly divided words while for the pseudoword conditions, the reverse was the case. Moreover, it appears that the magnitude of the regularity difference is greatest for the high frequency word condition. The reason for the absence of a main effect of syllable regularity and the significance of its interaction with conditions is clear. A word is more easily identified if it has a phonologically correct syllable division, while a pseudoword is more easily identified as such if it has a phonologically incorrect division. Thus, it appears that phonological processing is part of the lexical decision process; both words and pseudowords appear more wordlike when they are regularly syllabified.

For the previous analysis, the basic datum was the average of (up to) three correct latencies per subject for the three stimuli in each combination of time, condition and regularity. Two additional analyses were performed, both of which were concerned with controlling for specific stimulus effects. For the first analysis, stimuli were grouped in pairs such that both members were the same word or pseudoword but differed in regularity, one being the regularly syllabified form and the other the irregularly divided form. For this analysis of variance of latencies, a response was included in the analysis only if responses to both members of a pair were correct. Thus, if certain stimuli were more easily judged by subjects than other stimuli (because of differences in orthography or for other reasons), they would not contribute unsystematically to the regularity effect or its interactions. Table A in the Appendix contains the mean latencies for each stimulus in each experimental condition. A child contributed to the regular and irregular mean latencies of a stimulus only if he or she was correct on both. The number of subjects contributing to each pair is given in parentheses. The analysis of variance of these latency data produced results quite similar to the original latency analysis, although generally with slightly lower (but still strongly significant) F-ratios. In particular, the conditions by regularity interaction was again significant, $F(3,102) = 6.31$, $MS_e = 9114, p < .001$.

The second analysis for specific stimulus effects was concerned with the generality of the findings with the present stimuli. The analyses done so far
Figure 1. Mean reaction times for regularly and irregularly divided words and pseudowords in each condition (Experiment 2).
did not analyze for a random effects factor of stimulus differences within cells of the design (cf. Clark, 1973) because there were too many missing data points for such an analysis to give reasonable results. However, some measure of stimulus generality was obtained by averaging latencies over subjects for each of the six stimuli (correct responses only) in each of the four conditions. Averaging was done separately for regular and irregular forms of each stimulus and for skilled and unskilled readers. An analysis of variance was performed with stimulus as the unit of analysis (instead of the more common unit of analysis, i.e., the subject), with condition as a between-units factor and reader ability and syllable regularity as within-units factors. For this analysis, reader ability was significant, $F(1,20) = 72.75$, $MS_e = 6279$, $p < .001$, as was the factor of conditions, $F(3,20) = 8.26$, $MS_e = 30341$, $p < .001$ and no other terms were significant. In particular, the regularity by conditions interaction was not significant, $F(3,20) = 1.116$, $MS_e = 9448$, $p < .37$. The lack of more significant effects can, in part, be explained away by the large number of missing data points. This meant that subjects contributed unsystematically to cells of the design and there was no way to take subject effects into account. Nevertheless, the results of this conservative analysis suggest that some caution should be placed on the interpretation of stimulus generality for the present experiment.

**GENERAL DISCUSSION**

The present study was initiated in order to determine if information about the syllabic structure of a word is a component of word recognition in reading. In addition, the study asked if children of different reading abilities would utilize syllabic information differently. Experiment 2 found that correct syllabic information speeded the decisions for words in a lexical decision task while retarding the decisions of pseudowords. The effectiveness of correct syllabic information was greatest for high frequency real words. Experiment 1, which required only that children articulate the printed stimulus, found regular syllabic information effective only in speeding vocalization of novel pseudowords but not high frequency real words. However, regular syllabic information was effective for both pseudowords and real words when errors were measured; fewer errors occurred on regularly syllabified pseudowords and words than on irregularly divided items.

The results of Experiment 1 suggest that the children who were given pseudowords to pronounce did so by using a procedure based on syllable divisions. Nevertheless, one should not assume that this necessarily indicates the use of phonological rules to completely specify the pronunciation. The pseudowords may have been articulated, in part, on the basis of analogies with real words whose spelling was similar to that of the pseudowords. The pronunciation of the real word analogs could have been accessed lexically, rather than derived from phonological rules. However, the lexical access hypothesis is less plausible than the explanation based on phonology.

Use of the lexical mode of pronunciation would appear to be a somewhat more plausible explanation for the lack of an effect of syllabic information for the high frequency words in Experiment 1. Under this explanation, children who received high frequency words would have accessed the words' pronunciations lexically without first coding syllabic information. That is, lexical access would have been achieved through a direct visual route without
a prior phonological encoding. However, this explanation contrasts with both
the error data of Experiment 1 and the outcome of Experiment 2, which required
lexical access yet demonstrated the presence of syllabic coding on latencies.
Moreover, it would be difficult to explain why a lexical mode would be the
preferred mode when the response required was overt articulation (Experiment
1), while a phonological mode would be preferred when the response was a
covert semantic one (Experiment 2); if anything, the reverse would be
expected. Or one might expect no syllable effect at all in either the naming
or lexical decision tasks, based on the negative findings of Fredriksen and
Kroll (1976), Forster and Chambers (1973) and others that were treated above
in the discussion following Experiment 1. Finally, the use of a phonological
code may have been disguised by a discrepancy between the final phonological
code and the earlier information that determined the onset of articulation;
the advantage of a phonologically correct stimulus (e.g., correctly syllabi-
ified) may be lost when the response required is a fast articulation
(cf. Davelaar et al., 1978, and the present paper's discussion following
Experiment 1).

The clearest evidence that syllabic information is utilized in lexical
search comes from Experiment 2. It appears that children used syllable units
(or units related to the syllable) while searching for the presence of a
stimulus in memory. The syllable code was effective in searching for real
words, presumably because addressing based on this code is consonant with the
structure of the lexicon. For pseudowords, syllabic coding was counterproduc-
tive and slowed correct responses. Because the pseudowords were regular in
terms of orthography and phonology, individual syllables of these stimuli
would be likely to find matches in the lexicon, biasing a decision incorrectly
in favor of "words;" only the combination of the two pseudoword syllables
would have no entry in the lexicon. Thus, the decision that the stimulus was
not a word would be delayed. I found a related result (Katz, Note 1) in a
lexical decision task where the pseudowords varied in their orthographic
similarity to English; the more English-like the pseudoword, the longer it
took to decide it was not a word.

Why are high frequency words affected more by syllabic information than
low frequency words? The explanation depends on the notion that syllables can
become functional units in the Laberge-Samuels (1974) and Estes (1977) sense.
By a functional unit, it is meant that the letters within a given syllable are
associated with a unique code. Although several letters are inputs to the
encoder, there is but a single output that does not contain specific letter
information. It is this unique syllable code that is used to search memory
(along with other possible phonological and nonphonological codes). Assume
that high frequency words contain more high frequency syllables than do low
frequency words and that high frequency syllables are more likely to be
unitized. Therefore, when the unity of a high frequency syllable is disrupted
by an incorrect syllable division, the result is more disastrous to the
encoding of the syllable than when a low frequency syllable is incorrectly
divided. Incorrect syllabification of a low frequency syllable is not as
disruptive because it is less likely that there exists such a unitized
syllable whose encoding can be disrupted.

Note that the important information in the search process described may
be visual in modality; it may be more important that the syllables look the
same than sound the same. However, the present experiments make no statement about the modality of the syllabic information used except to point out (as discussed in the Introduction) that phonological codes may have counterparts in visual codes because of the intimate connection between speech codes and visual codes in reading acquisition.

The results of both experiments were clear with respect to reader ability differences. In naming and in lexical search, skilled readers were faster than less skilled readers. In none of the experiments did reader ability interact with syllabification; none of the interactions even approached significance. Therefore, it appears unlikely that the reading skill of the children studied depends on the ability to process syllabic information. Rather, it appears that both skilled and less skilled readers can competently use syllabic information, at least by the fifth grade. Inspection of the protocols of the least able readers supported this suggestion. It may well be the case that younger readers differ in their competency to use syllabic information in word recognition, but the present data suggest that no trace of an earlier ability difference in this area (if it exists) can be found by grade five. Clearly, the present investigations should be extended to younger children to look for early effects; it is possible that early difficulties with syllabic information lead to other problems that persist long after the reader has solved the syllable problem.

In conclusion, evidence for syllabic coding in children's word recognition was found. Whether or not such coding is common in natural reading for fifth grade children was not determined. Although general reader ability differences were found in word recognition, these differences were not related to the use of syllabic information. Additional study is needed of younger and poorer readers who may not have developed efficient syllabic processing structures. Also, the nature of the syllabic processing mechanism in reading needs to be explored. In particular, it is important to determine if its structure is represented solely in a visual modality, primarily in a speech modality, or in a more abstract mode prior to exploring the syllabic parsing and retrieval processes themselves. Knowledge of the operating modality of the syllable processor (and other processors of phonological or phonologically derived information) will constrain the plausible mechanisms hypothesized for its operation.

REFERENCE NOTE


REFERENCES


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Appendix

Table A

Latencies in msec and number of correct responses for skilled and less skilled readers when subject was correct on both the regular and irregular forms of a stimulus. Within each block of four words, the order is high frequency to low frequency and regular to irregular. For pseudowords, the order is high frequency control to low frequency control and regular to irregular.

<table>
<thead>
<tr>
<th>Word</th>
<th>Skilled</th>
<th>Less Skilled</th>
<th>Skilled</th>
<th>Less Skilled</th>
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<td>808 (18)</td>
<td>954 (17)</td>
<td>952</td>
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<td>814</td>
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<td>883 w/osler</td>
<td>827 (17)</td>
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