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Syllable Structure or Word Structure? Evidence for Onset and Rime Units with Disyllabic and Trisyllabic Stimuli

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Most of the evidence that English syllables are composed of onset and rime units comes from studies involving monosyllabic stimuli. Thus, the evidence may reflect word-based structure, words being divided into an initial onset and a remainder, rather than syllable-based structure. To distinguish between word-based and syllable-based structure, we carried out three experiments with disyllabic and trisyllabic stimuli. Students at two different universities learned word games in which a phoneme or group of phonemes was replaced with a fixed phoneme or group of phonemes. We asked whether games that involved an onset or a rime were easier to learn than games that did not involve these units. Results supported the syllable structure hypothesis except in the case of the easiest game for the students at the more selective university. Together with the findings of Fowler, Treiman, and Gross (*Journal of Memory and Language*, 1993, 32, 115–140), the results suggest that both syllable structure and word structure play a role in the processing of spoken words.

Many linguists and psycholinguists have argued that spoken English syllables are not just linear sequences of phonemes. Instead, the phonemes within a syllable are organized into two major units, the *onset* (the initial consonant or consonant cluster) and the *rime* (the vowel and any following consonants). Evidence for an onset/rime structure for syllables in English and closely related languages comes from many sources, including constraints on the distributions of phonemes in syllables, word games, speech production and perception, and errors in short-term memory for speech (Berg, 1989a; Claxton, 1974; Cutler, Butterfield, & Williams, 1987; Dow & Derwing, 1989; Fowler, 1987; Fudge, 1969, 1987, 1989; Hockett, 1967/1973; MacKay, 1972, 1974; Selkirk, 1982; Stemberger, 1983; Treiman, 1983, 1986, 1988; Treiman & Da-

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nis, 1988a; Yaniv, Meyer, Gordon, Huff, & Sevald, 1990). Given what appears to be strong evidence for an onset/rime view of syllable structure, researchers have applied this view in a number of different domains. Onset and rime units, it has been argued, are involved in the development of phonological awareness and literacy skills in children (Adams, 1990; Bowey & Francis, 1991; Bruck & Treiman, 1990; Goswami, 1986, 1988, 1991; Goswami & Bryant, 1990; Goswami & Mead, 1992; Hansen & Bowey, 1992; Kirtley, Bryant, Maclean, & Bradley, 1989; Schreuder & van Bon, 1989; Treiman, 1985, 1991, 1992, 1993; Treiman, Goswami, & Bruck, 1990; Treiman & Weatherston, 1992; Treiman & Zukowski, 1991; Wise, Olson, & Treiman, 1990; Wise, 1992). In addition, orthographic units that correspond to onsets and rimes have been argued to play a role in adults' recognition of printed words (Bowey, 1990, 1993; Levitt, Healy, & Fendrich, 1991; Taft, 1992; Treiman, 1994; Treiman, Mullennix, & Bijeljac-Babic, 1993; Treiman & Chafetz, 1987; Treiman & Zukowski, 1988).

However, all of these applications of the onset/rime view of syllable structure may rest on a weak foundation. In an important challenge to this view, Davis (1989) pointed out that many of the words that are involved in speech errors and most of the stimuli that have been used in experiments contain a single syllable. What appears to be a division between the syllable's onset and rime may in fact be a division between the first onset of the word (or morpheme) and the word's remainder. Thus, much of the evidence that has been taken to support syllable-based structure could equally well be taken to support word-based (or morpheme-based) structure.

Some support for Davis's (1989) claim comes from findings that the beginnings of words have a special status in adult language production (Berg, 1989b; Browman, 1978; Fowler, Treiman, & Gross, 1993; Shattuck-Hufnagel, 1987). For example, when people mistakenly exchange a consonant in one multisyllabic word with a consonant in another word, the exchanged consonants are usually at the beginnings of the words, as in "*r*icious *v*at" for "*v*icious *r*at." Despite the opportunities for exchanges of consonants that are not in the word onset, such errors formed less than 10% of all consonant exchanges in one study of speech errors (Shattuck-Hufnagel, 1987). As another piece of evidence that word onsets are special, consider a recent study with visually-presented stimuli (Fowler et al., 1993, Exp. 3B). In this experiment, a pair of nonwords such as *bepniz Kugfam* was presented on a computer screen. Subjects' task was to transpose a specified consonant from the second nonword into the corresponding position of the first nonword and say the result as quickly as possible. We refer to this task as the *phoneme shift task*. In the experiment under discussion, two types of trials were included. On some trials, the first consonant of the second nonword was capitalized, as above, indicating that it should be shifted to the first nonword. The response in the present example would be "kepniz." On other trials, the first consonant of the nonword's second syllable was capitalized (*bepniz kugFam*), meaning that "f" should be shifted to yield "bepfiz." Subjects shifted word-initial onsets faster and more accurately than syllable-initial onsets, suggesting that word onsets are not closely bound to the following phonemes in a disyllabic stimulus.

The findings just described suggest that there is in fact a division between the onset of the word and the remainder of the word, as Davis (1989) proposed. However, the word onset and the word remainder may not be the *only* constituents in polysyllabic words. Word structure and onset/rime syllable structure are not mutually exclusive (see Berg, 1989b). The word remainder unit within a polysyllabic word may itself contain onset and rime units.

To distinguish between word structure and syllable structure, one must use stimuli

that contain more than one syllable. Only in this way is it possible to differentiate the remainder-of-word unit from the syllabic rime. In several previous experiments (Fowler et al., 1993), we attempted to tease apart these two units by using disyllabic and trisyllabic stimuli. Two different tasks were employed. The first was the speeded phoneme shift task just described which involves visual presentation of stimuli. The second was a *word game task* involving auditory presentation of the stimuli. In our word game task (Fowler et al., 1993, Exp. 5), subjects heard one trisyllabic nonword on each trial. They attempted to learn a manipulation in which one (or two) phoneme(s) in the stressed middle syllable was (were) replaced with one (or two) phoneme(s) that remained fixed throughout the experiment. We compared subjects' ability to learn various types of word games. In one game, the initial consonant of the middle syllable was replaced with /g/, as when /ʃə'polhəð/ changed to /ʃə'golhəð/. According to the syllable structure hypothesis, this game should be easier to learn than one in which the final consonant of the middle syllable was replaced (e.g., /ʃə'polhəð/ changing to /ʃə'poghəð/). This is because the initial consonant forms a constituent of the syllable, the onset, whereas the final consonant, or coda, is part of the rime. However, if the only structure within a word is the division between the onset of the first syllable and the remainder of the word, the two games should not differ in difficulty. The game involving the initial consonant was in fact easier to learn than the game involving the final consonant, supporting the syllable structure hypothesis. In addition, a game involving the vowel and final consonant of the middle syllable (e.g., /ʃə'polhəð/ to /ʃə'pɛghəð/) was easier to learn than a game involving the initial consonant and vowel of this syllable (e.g., /ʃə'polhəð/ to /ʃə'gɛlhəð/). This result, too, supports the syllable structure hypothesis. Specifically, it suggests that the vowel and final consonant of the middle syllable form the syllable's rime whereas the initial consonant and vowel are not a constituent of the syllable.

For trisyllabic stimuli, we found support for the syllable structure hypothesis not only with the word game task but also with the phoneme shift task. Employing the phoneme shift task with trisyllabic stimuli, we showed that shifts involving onset and rime units were performed more rapidly than shifts involving units that do not correspond to linguistic constituents (Fowler et al., 1993, Exp. 4). The results with the phoneme shift task did not appear to be as strong as the results with the word game task, in that only in the word game task was there additional support for the syllable structure hypothesis in the nature of subjects' errors. Nevertheless, both tasks yielded clear support for an onset/rime structure in the stressed middle syllables of trisyllabic stimuli.

A different picture emerged for disyllabic stimuli. In two experiments using the phoneme shift task with disyllabic stimuli, our results were not consistent with the syllable structure hypothesis. Subjects in one of these experiments were not faster to shift onsets than codas and so did not show the pattern of results predicted by the syllable structure hypothesis (Fowler et al., 1993, Exp. 3A). Subjects in another experiment were not faster to shift vowel–final consonant units than initial consonant–vowel units (Fowler et al., 1993, Exp. 3C). The syllable structure hypothesis predicts such a difference. Thus, the results of Fowler et al. (1993) supported the syllable structure hypothesis for the stressed middle syllables of trisyllabic stimuli but not for disyllabic stimuli.

Why did we find support for the syllable structure hypothesis in the case of trisyllabic stimuli but not in the case of disyllabic stimuli? The present experiments were carried out in an attempt to address this question and so to distinguish more accurately between the word structure hypothesis and the syllable structure hypothesis. The vary-

ing results within our previous series of experiments may reflect, in part, differences among groups of subjects. The experiment that showed the strongest evidence for syllable structure effects was the word game experiment with trisyllabic stimuli (Fowler et al., 1993, Exp. 5). The subjects in that experiment were students at Wayne State University. The other experiments in our earlier series of studies were carried out with students at Dartmouth College. As a private, Ivy League institution, Dartmouth has much more selective admissions standards than Wayne State, a public university. For example, 85% of Dartmouth students in a recent entering class graduated in the top 10% of their high school class. For Wayne State, about the same percentage of entering freshman reported graduating in the top half of their high school class. Average scores on the SAT (Scholastic Aptitude Test) for Dartmouth students in a recent year were 622 verbal and 682 quantitative; average SAT scores for freshmen entering Wayne State were 430 verbal and 460 quantitative. (These averages include scores on the ACT or Academic College Testing program test, which are converted to SAT equivalents by a formula supplied by the admissions offices.) For lower-ability students, holding the stimuli in memory and making the transformations may be quite demanding. Indeed, work by Hunt and his colleagues (Hunt, Frost, & Lunneborg, 1973; Hunt, Lunneborg, & Lewis, 1975) shows a link between verbal ability as measured by tests such as the SAT and ACT and the ability to retain and manipulate information in short-term memory. Lower-ability students may deal with the memory demands of the word game task by chunking the stimuli into groups of phonemes, including syllabic onsets and syllabic rimes. Students with larger memory capacities may be able to store long stimuli as sequences of phonemes and may not need to use intrasyllabic chunks. Thus, even though the Wayne State students in our previous study showed effects of syllable structure in the word game task with trisyllabic stimuli, Dartmouth students may not show such effects or may show them to a lesser degree than Wayne State students. Experiment 1 was designed to address this question.

Experiment 1

Method

Stimuli. The stimuli were identical to those used in the previous word game study with Wayne State University students (Fowler et al., 1993, Exp. 5, lax vowel condition). Specifically, the stimuli were 20 nonsense trisyllables with the structure /C_1V$'$$C_2VC_3$\$$C_4$V/. Primary stress was always on the second syllable of the nonword, which had a lax vowel. The stress on the second vowel attracts the preceding consonant, C_2, to this syllable (Treiman & Danis, 1988b). Thus, the break between the first and second syllables can be assumed to fall before C_2. Consonants were selected for the C_3 and C_4 positions that cannot belong to the same syllable in English, for example /t/ and /m/. Thus, one can assume that a syllable boundary separates these two consonants (Treiman & Zukowski, 1990). The first two phonemes of the stimuli were always /ʃə/. These phonemes were chosen to ensure that none of the stimuli began with a real English prefix. The last two phonemes were always /əð/, ensuring that no real suffixes occurred in the stimuli. Pilot work had shown that subjects could remember the stimuli better when the same phonemes occurred at the beginnings and the ends of all of the stimuli.

There were two rules in the one-phoneme substitution condition, the C_2 rule and the C_3 rule. In the C_2 rule, the first consonant of the middle syllable, the onset, changed to /g/. In the C_3 rule, the last consonant of the middle syllable, which is part of the rime, changed to /g/. For example, /ʃə'polhəð/ changed to /ʃə'golhəð/ by the C_2 rule and to /ʃə'poghəð/ by the C_3 rule.

The two-phoneme substitution condition

also involved two different rules. In the C_2V rule, the first consonant and vowel of the middle syllable changed to /gɛ/. In the VC_3 rule, the vowel and final consonant of the middle syllable changed to /ɛg/. Thus, the VC_3 rule involved a constituent of the syllable, the rime, while the C_2V rule did not. The stimulus /ʃə'polhəð/ changed to /ʃə'gɛlhəð/ by the C_2V rule and to /ʃə'pɛghəð/ by the VC_3 rule.

Procedure. The procedure for the Dartmouth students was the same as for the Wayne State students of the earlier study (Fowler et al., 1993, Exp. 5). Specifically, half of the subjects were assigned to the one-phoneme substitution condition and the other half were assigned to the two-phoneme substitution condition. Each subject participated in two sessions. Subjects in the one-phoneme substitution condition learned the C_2 rule in one session and the C_3 rule in the other session; subjects in the two-phoneme substitution condition learned the C_2V rule in one session and the VC_3 rule in the other session. The order of the rules was counterbalanced across subjects. At least one week elapsed between the two sessions. The order of the stimuli in a session was randomly chosen for each subject. All subjects were tested individually. For this and the other experiments, the experimenter at Wayne State University, like the vast majority of Wayne State students, was from the Detroit area. The experimenter at Dartmouth was from the Northeast United States, as were the majority of the Dartmouth subjects.

At the start of each session, the subject was informed that he or she would learn a word game involving nonsense words. The subject was told that all of the nonwords would change according to a rule. The subject was to try to discover the rule based on the examples that he or she would hear. On the first trial, the experimenter pronounced one of the stimuli, randomly chosen, and gave its transformation. On all subsequent trials, the experimenter pronounced the stimulus twice and the subject had to repeat it twice correctly. After repeating the stimulus, the subject was asked to try to apply the rule and pronounce the transformed stimulus. The experimenter provided the correct answer if the subject erred. All 20 trials were administered to each subject. We scored the subject's first complete response on each trial. If a subject responded incorrectly and then corrected him- or herself, the answer was considered wrong. All sessions were tape recorded for later verification of scoring.

Subjects. Forty undergraduate students at Dartmouth College participated in exchange for course credit. Two additional subjects were replaced due to experimenter error. The results of the Dartmouth students are compared to those of 40 students at Wayne State University whose results were reported in Fowler et al. (1993, Exp. 5, lax vowel condition). The Wayne State subjects included 26 undergraduates who received course credit for participation and 14 graduate students who were paid. Half of the Wayne State students at each academic level served in the one-phoneme condition and the other half served in the two-phoneme condition. One Wayne State subject was replaced due to experimenter error and two other subjects were replaced because their second session could not be scheduled within a reasonable period of time. All subjects at both institutions were native speakers of English.

Results

Figure 1 shows the proportion of correct responses on the 19 test trials for the Dartmouth students. The data are collapsed across rule order. In the one-phoneme condition, the beginning rule is the C_2 or onset rule and the end rule is the C_3 or coda rule. In the two-phoneme condition, the beginning rule is the C_2V or onset–vowel rule and the end rule is the VC_3 or rime rule. It is clear that the Dartmouth students did better on the beginning rule than the end rule in the one-phoneme condition but showed the opposite pattern of performance in the two-

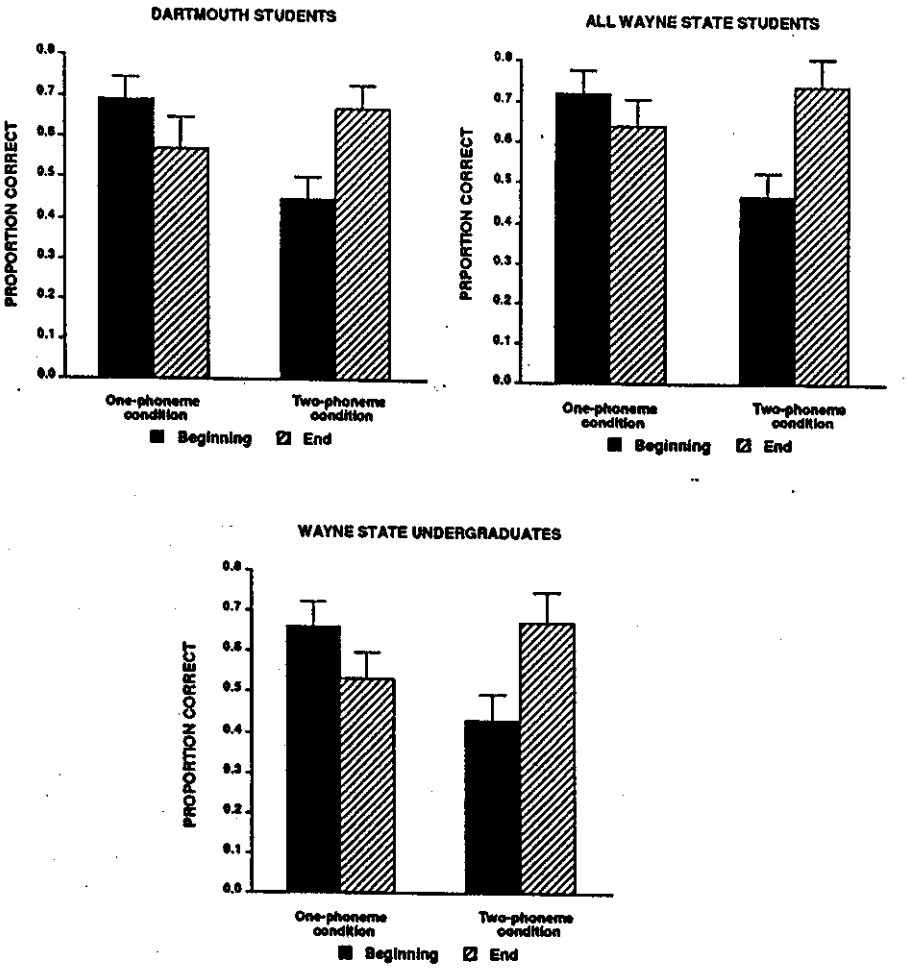

FIG. 1. Mean proportion of correct responses in Experiment 1 as a function of subject group, condition, and location of change. (Error bars represent standard errors.)

phoneme condition. For comparison, Figure 1 includes the results for all of the Wayne State students in the lax vowel condition of our earlier study, as well as the results for just the Wayne State undergraduates. These groups showed the same pattern as the Dartmouth students.

The data for the Dartmouth students and the full group of Wayne State students were analyzed using the factors of university (Dartmouth or Wayne State), number of phonemes changed (one or two), and location of change (beginning or end of middle syllable). Analyses were carried out both by subjects and by stimuli. Here and elsewhere, only those effects for which $p < .05$ in both types of analyses are reported as significant. There was a main effect of location of change ($F1(1,76) = 6.75$, $p = .011$; $F2(1,19) = 9.29$, $p = .007$) and an interaction between number of phonemes and location of change ($F1(1,76) = 39.46$; $F2(1,19) = 114.28$; $p < .001$ for both). Planned comparisons revealed that substitution of the beginning consonant of the middle syllable, C_2, was easier than substitution of the end consonant of the middle syllable, C_3 ($F1(1,38) = 8.96$, $p = .005$; $F2(1,19) = 9.27$, $p = .007$). The proportion of correct responses was .70 for the C_2 rule as compared to .60 for the C_3 rule. This superiority for the C_2 or onset rule over the

C_3 or coda rule is predicted by the syllable structure hypothesis. Also as predicted by the syllable structure hypothesis, replacement of the entire rime of the middle syllable, VC_3, was easier than replacement of the beginning consonant and vowel, C_2V ($F1(1,38) = 31.73$; $F2(1,19) = 116.26$; $p < .001$ for both). The proportion of correct responses was .70 for the VC_3 rule as compared to .46 for the C_2V rule. There was no significant main effect of university and no interactions involving this factor. There was an unexpected tendency for Wayne State students to perform better than Dartmouth students but this trend was not significant.

Table 1 shows some additional measures of performance. First correct trial is the earliest test trial on which the subject's response was correct. Length of longest run is the longest string of consecutive correct responses given by the subject.

The results for first correct trial could be analyzed by subjects only since the stimuli were presented in a random order. The only significant effect was an interaction between number of phonemes and location of change ($F1(1,76) = 4.72$, $p = .033$). In the one-phoneme condition, subjects tended to achieve their first correct response earlier on the C_2 rule than the C_3 rule, although the difference was not significant ($p = .27$). In the two-phoneme condition, correct responses tended to occur earlier for the VC_3 rule than for the C_2V rule ($p = .062$).

The results for longest run of consecutive correct responses were also analyzed by subjects only. There was a main effect of location of change ($F1(1,76) = 5.67$, $p = .020$), an interaction between number of phonemes and location of change ($F1(1,76) = 22.68$, $p < .001$) and a three-way interaction involving number of phonemes changed, location of change, and university ($F1(1,76) = 5.29$, $p = .024$). Although runs were not reliably longer on the C_2 rule than

TABLE 1
RESULTS FOR LOCATION OF FIRST CORRECT TRIAL AND LENGTH OF LONGEST RUN IN EXPERIMENT 1

	First correct trial		Length of longest run	
		Dartmouth students		
One-phoneme condition	C_2 (onset) rule	C_3 (coda) rule	C_2 (onset) rule	C_3 (coda) rule
Mean	4.45	5.25	8.20	7.30
SD	3.19	4.90	4.26	6.25
Two-phoneme condition	C_2V (onset–vowel) rule	VC_3 (rime) rule	C_2V (onset–vowel) rule	VC_3 (rime) rule
Mean	6.50	4.20	5.60	7.70
SD	4.58	2.88	4.38	5.47
		All Wayne State students (from Fowler et al., 1993)		
One-phoneme condition	C_2 (onset) rule	C_3 (coda) rule	C_2 (onset) rule	C_3 (coda) rule
Mean	4.00	4.85	9.65	7.65
SD	4.28	4.86	4.60	5.94
Two-phoneme condition	C_2V (onset–vowel) rule	VC_3 (rime) rule	C_2V (onset–vowel) rule	VC_3 (rime) rule
Mean	5.70	4.95	4.40	11.00
SD	3.11	5.60	3.87	6.27
		Wayne State undergraduates only (from Fowler et al., 1993)		
One-phoneme condition	C_2 (onset) rule	C_3 (coda) rule	C_2 (onset) rule	C_3 (coda) rule
Mean	4.62	5.69	7.85	5.31
SD	4.98	5.60	3.98	4.77
Two-phoneme condition	C_2V (onset–vowel) rule	VC_3 (rime) rule	C_2V (onset–vowel) rule	VC_3 (rime) rule
Mean	5.46	5.85	4.62	9.85
SD	3.38	6.41	4.70	7.22

Note. Maximum possible score for longest run is 19.

the C_3 rule ($p = .10$), subjects produced longer runs on the VC_3 rule than the C_2V rule ($p < .001$). As reflected in the three-way interaction, the superiority of the VC_3 rule over the C_2V rule was significant only for the Wayne State students. Dartmouth students showed a trend in the same direction but it was not significant.

So far, the results show that word games which kept the linguistic units of onset and rime intact were learned more easily than games that broke apart these linguistic units. This held true for both students at Wayne State University and students at Dartmouth College. Only in the analysis involving longest runs of consecutive correct responses was there a reliable difference between the two groups of subjects. In this analysis, Dartmouth students showed smaller effects of syllable structure than Wayne State students.

Because the Wayne State subjects included both graduate and undergraduate students, whereas the Dartmouth subjects included only undergraduates, we carried out additional analyses of the Wayne State data using the factor of academic status (graduate versus undergraduate) as well as the factors of number of phonemes and location of change. The Wayne State undergraduates did significantly worse than the graduate students in terms of proportion correct ($F1(1,36) = 6.26$, $p = .017$; $F2(1,19) = 56.31$, $p < .001$) and length of longest run ($F1(1,36) = 7.12$, $p = .011$). There was no main effect of academic status in position of first correct trial ($p = .19$). In none of the analyses did academic status interact significantly with other variables. The graduate students' better performance on two of the three dependent variables could reflect their higher levels of verbal ability. Alternatively, because the graduate students were paid for participation whereas the undergraduates received course credit, the differences could reflect the greater motivating effect of monetary payment.

The results for the Wayne State undergraduates may be compared to those of the Dartmouth students, who were also undergraduates who participated in exchange for course credit. Statistical analyses comparing the Wayne State undergraduates to the Dartmouth undergraduates showed no significant effects of university. Now, though, the trends were in the direction of better performance for the Dartmouth students.

Error analyses. To further evaluate the effects of syllable structure on performance, we examined subjects' errors in learning the games. According to the syllable structure hypothesis, people should be more likely to replace the vowel along with the specified consonant when learning the C_3 rule than when learning the C_2 rule. This should happen because the vowel and the C_3 (or coda) form a constituent of the syllable, the rime, whereas the vowel and the C_2 (or onset) do not form a constituent. For the C_3 rule, the proportion of errors that involved a change of the vowel in addition to a change of C_3 to /g/ was .13 (22 of 164). None of the 118 errors on the C_2 rule involved a change of the vowel as well as a change of C_2 to /g/. These data were analyzed using the factors of phoneme position and university; the results of four subjects who made no errors in learning one of the games were omitted from the by-subjects analysis. There was a main effect of phoneme position ($F1(1,34) = 11.93$; $F2(1,38) = 59.82$; $p < .001$ for both), a main effect of university ($F1(1,34) = 7.24$, $p = .011$; $F2(1,38) = 9.29$, $p = .004$), and an interaction between phoneme position and university ($F1(1,34) = 4.47$, $p = .042$; $F2(1,38) = 6.14$, $p = .018$). The main effect of university arose because the errors in question formed a higher proportion of the total for Wayne State students than for Dartmouth students. Although the difference between the C_2 and C_3 rules in vowel-changing errors was significant for both groups of subjects, it was larger for the Wayne State students than for the Dartmouth students. In this case, then, both groups of subjects made errors of the kind predicted by the

syllable structure hypothesis but these errors were more common among the Wayne State students.

In the two-phoneme condition, the syllable structure hypothesis predicts that the vowel would erroneously remain unchanged more often in the C_2V condition than in the VC_3 condition. That is, subjects asked to change the syllable's onset and vowel would sometimes change only the onset. In the C_2V condition, the proportion of errors in which C_2 changed to /g/ and the vowel remained the same was .11 (24 of 210). The corresponding figure in the VC_3 condition was .03 (4 of 125). These data were analyzed using the factors of phoneme position and university; the results of three subjects who made no errors in learning one of the games in the two-phoneme condition were omitted from the by-subjects analysis. The main effect of phoneme position was not significant, although the trend was in the predicted direction.

We also examined "whole-syllable" errors. These are errors in the two-phoneme condition in which subjects replaced the third phoneme of the syllable as well as replacing the two specified phonemes in the appropriate manner. On an onset/rime view of syllable structure, such errors should be more common in the C_2V condition than in the VC_3 condition. This prediction follows from the idea that the phoneme that does not participate in the substitution is more closely tied to the involved phonemes in the C_2V condition, where the non-involved phoneme is part of the rime, than in the VC_3 condition, where the non-involved phoneme is the onset. In the C_2V condition, the proportion of whole-syllable errors was .16 (34 of 210). In the VC_3 condition, the proportion of whole-syllable errors was .03 (4 of 125). These data were analyzed using the factors of phoneme position and university; the results of three subjects who made no errors in learning one of the games had to be omitted from the by-subjects analysis. There was a main effect of phoneme position ($F1(1,35) = 14.89$; $F2(1,38) = 27.17$; $p < .001$ for both) and no other significant effects. Whole-syllable errors were more frequent in the C_2V than in the VC_3 condition. This result provides further support for the cohesiveness of the rime unit for both the Wayne State students and the Dartmouth students.

The error results for the Wayne State students were broken down by academic status, undergraduate versus graduate. No significant effects of academic status were observed.

Discussion

In the present study, we examined Dartmouth students' ability to learn word games involving phoneme substitutions in the stressed middle syllables of trisyllabic stimuli. In our earlier work, we found syllable structure effects in this task for students at Wayne State University (Fowler et al., 1993, Exp. 5). Specifically, a word game involving a substitution of the initial consonant of the middle syllable, the onset, was easier to learn than a word game involving a substitution of the final consonant of this syllable, which is part of the rime. In addition, a game involving a substitution of the whole rime was easier to learn than a game involving a substitution of the syllable-initial consonant and vowel. The Wayne State students' errors in the word game task also showed effects of syllable structure.

The main goal of Experiment 1 was to determine whether students at Dartmouth College would also show effects of syllable structure in the word game task with trisyllabic stimuli. As discussed in the introductory remarks, there was reason to think that Dartmouth students might not show the effects, or might show them less strongly, because of their greater verbal abilities. However, Dartmouth students, like Wayne State students, demonstrated effects of syllable structure in their learning of the word games and in the nature of their errors. In most of the analyses, there were no significant main effects of university and no sig-

nificant interactions involving university. Thus, effects of syllable structure on the learning of word games with trisyllabic stimuli are not confined to Wayne State students. The effects also occur with Dartmouth students, attesting to their generality across a wide ability range.

Although the two groups of subjects showed similar patterns of results, the effects of syllable structure were significantly smaller for the Dartmouth students than for the Wayne State students in two of our analyses. The Dartmouth students also showed a nonsignificant tendency to perform better overall than the Wayne State students when the analyses were restricted to undergraduates. One interpretation of these differences is that higher verbal ability is associated with better performance and smaller effects of syllable structure in the word game task. To further test this interpretation, it would be necessary to run two groups of subjects who differ in verbal ability under identical conditions. Although this has not yet been done, the main conclusion to be drawn from Experiment 1 is clear. Effects of syllable structure on the learning of word games with trisyllabic stimuli are not limited to one population of students.

Experiment 2

In Experiments 2 and 3, we turned to disyllabic stimuli. As discussed earlier, we did not find effects of syllable structure in our previous studies with disyllabic stimuli (Fowler et al., 1993). These studies employed a phoneme shift task with visual presentation of the stimuli. Dartmouth students did not move onset consonants faster than coda consonants in the phoneme shift task with disyllabic stimuli (Exp. 3A). Nor did they shift vowel–final consonant units faster than initial consonant–vowel units (Exp. 3C).

There are several possible reasons why syllable structure effects may not have appeared in our earlier studies with disyllabic stimuli. One reason concerns the nature of the task. In our phoneme shift task, the stimuli are presented visually rather than auditorily. The left-to-right scanning that is necessitated by this visual presentation may mask effects of syllable structure. Also, the visual presentation of the stimuli may reduce the role of phonological processes in the task. People may perform the task on a visual basis rather than by translating the stimuli into their phonological forms and performing the task phonologically. Supporting the idea that the nature of the task is important, syllable structure effects in the middle syllables of trisyllabic stimuli appeared to be weaker in the phoneme shift task (Fowler et al., 1993, Exp. 4) than in the word game task (Fowler et al., 1993, Exp. 5). The nature of the subject population could also play some role. Although the Wayne State and Dartmouth students performed similarly in Experiment 1, the Wayne State students showed larger effects of syllable structure in a few of the analyses. Our use of Dartmouth students as subjects in the previous studies with disyllabic stimuli may have contributed, together with other factors, to the lack of syllable structure effects.

To address these issues, Experiments 2 and 3 were word game analogues of our previous phoneme shift studies with disyllabic stimuli (Fowler et al., 1993, Exps. 3A and 3C). In these word game studies, the stimuli were presented auditorily and subjects attempted to learn rules that changed the stimuli in various ways. The subjects for Experiments 2 and 3 included both Wayne State undergraduates and Dartmouth undergraduates, allowing us to compare the two groups.

In Experiment 2, we compared subjects' ability to learn two different word games involving disyllabic stimuli. One manipulation involved a syllable-initial single consonant—an onset. The other manipulation involved a syllable-final single consonant—a coda, or part of a rime. According to the syllable structure hypothesis, the former game should be easier to learn than the lat-

ter because it involves a syllable constituent. Although this result was not found in the speeded phoneme shift task of Fowler et al. (1993, Exp. 3A), we expected that subjects in the word game task would show a sensitivity to syllable structure.

Method

Stimuli. The stimuli were 20 disyllabic nonwords with the structure /C_1VC_2\$ C_3VC_4/. Consonants were selected for the C_2 and C_3 positions that could not legally belong to the same syllable. Both vowels were lax. Across the set of stimuli, the consonants that appeared in C_2 position were exactly the same as those that appeared in C_3 position. The stimuli did not contain English prefixes or suffixes, nor were their individual syllables real words. The final consonants were chosen from the set of reduction-blocking consonants listed by Fudge (1984) (e.g., /b/, /k/), ensuring that the vowels in the second syllables were not reduced to /ə/. There were no repeated phonemes within a nonword. In the first-syllable stress condition, the stimuli were pronounced with primary stress on the first syllable. In the second-syllable stress condition, the stimuli were pronounced with primary stress on the second syllable.

Two rules were compared, the C_2 rule and the C_3 rule. For the C_2 rule, the second consonant of each stimulus (the coda of the first syllable) changed to /g/, as when /dæpfɛb/ yielded /dægfɛb/ and /nɛfbɪk/ yielded /nɛgbɪk/. For the C_3 rule, the third consonant (the onset of the second syllable) changed to /g/. Thus, /dæpfɛb/ became /dæpgɛb/ and /nɛfbɪk/ became /nɛfgɪk/.

Procedure. Half of the subjects at each institution were assigned to the first-syllable stress condition and the other half were assigned to the second-syllable stress condition. Each subject participated in two sessions, learning one rule in each session. The order of the two rules was counterbalanced across subjects. In all other respects, the procedure was the same as that of Experiment 1.

Subjects. Twenty undergraduate students from Dartmouth College and twenty undergraduate students from Wayne State University participated. Most of the students received course credit in exchange for participation; several of the Wayne State students were unpaid volunteers. One Wayne State student did not complete her second session because she felt "humiliated" at being unable to figure out the rule. She was replaced with another subject. One Dartmouth subject was replaced due to experimenter error. All of the subjects were native speakers of English.

Results

Figure 2 shows the proportion of correct responses for students at each university, collapsed across rule order. The data were analyzed using the factors of university (Dartmouth versus Wayne State), stress (first-syllable stress versus second-syllable stress), and rule type (C_2 or coda versus C_3 or onset). There was a main effect of university ($F1(1,36) = 16.26$; $F2(1,19) = 115.29$; $p < .001$ for both). Dartmouth students produced more correct responses than Wayne State students. Also, there was a three-way interaction involving university, stress, and rule ($F1(1,36) = 4.69$, $p = .037$; $F2(1,19) = 12.62$, $p = .002$). The interaction arose because Wayne State students showed an effect of rule type, performing significantly better on the C_3 rule, which involved the onset of the second syllable, than the C_2 rule, which involved the coda of the first syllable. For Wayne State students, the proportion of correct responses was .65 for the C_3 rule and .52 for the C_2 rule ($F1(1,18) = 5.21$, $p = .035$; $F2(1,19) = 12.33$, $p = .002$). This is the pattern of results predicted by the syllable structure hypothesis. The Dartmouth students did not show this pattern. Instead, they showed an interaction between stress and rule ($F1(1,18) = 6.61$, $p = .019$; $F2(1,19) = 8.85$, $p = .008$). The Dartmouth students performed better on the onset (C_3) rule than the coda (C_2) rule in the first-

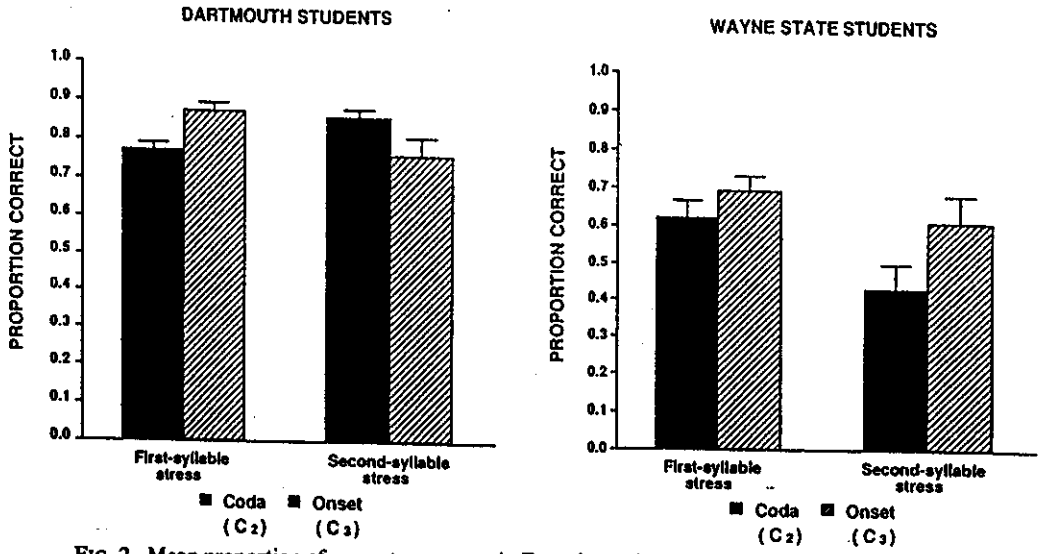

FIG. 2. Mean proportion of correct responses in Experiment 2 as a function of subject group, stress, and rule type. (Error bars represent standard errors.)

syllable stress condition ($F1(1,9) = 6.93$, $p = .027$; $F2(1,19) = 4.34$, $p = .051$). They showed a nonsignificant trend in the opposite direction in the second-syllable stress condition. This pattern of results is unexpected. Possibly, since polysyllabic words with stressed first syllables are more common than polysyllabic words with unstressed first syllables (Cutler & Carter, 1987), the effects of rule type were less marked with the less natural-sounding stimuli.

Data on position of first correct trial and length of longest run are shown in Table 2. For first correct trial, there was a main effect of university ($F1(1,36) = 14.48$, $p = .001$), a main effect of rule ($F1(1,36) = 11.71$, $p = .002$), an interaction between

TABLE 2
RESULTS FOR LOCATION OF FIRST CORRECT TRIAL AND LENGTH OF LONGEST RUN IN EXPERIMENT 2

	First correct trial		Length of longest run	
	C_2 (coda) rule	C_3 (onset) rule	C_2 (coda) rule	C_3 (onset) rule
		Dartmouth students		
First-syllable stress				
Mean	2.90	2.80	7.50	12.20
SD	.88	1.55	2.72	5.07
Second-syllable stress				
Mean	2.50	2.50	10.70	8.60
SD	.85	.71	3.53	4.86
		Wayne State students		
First-syllable stress				
Mean	5.00	4.00	6.70	8.00
SD	2.71	1.63	3.30	4.00
Second-syllable stress				
Mean	9.20	5.40	4.60	7.30
SD	6.46	3.41	3.98	6.52

Note. Maximum possible score for longest run is 19.

university and rule ($F1(1,36) = 10.78$; $p = .002$), and a three-way interaction involving university, rule, and stress ($F1(1,36) = 4.10$, $p = .05$). Again, Dartmouth students did significantly better than Wayne State students. Wayne State students showed the pattern of results predicted by the syllable structure hypothesis, achieving their first correct trial earlier when learning the C_3 (onset) game than when learning the C_2 (coda) game ($F1(1,18) = 12.68$, $p = .002$). This tended to be especially true when the syllable containing C_3 (the second syllable of the stimulus) was stressed, as shown by a marginally significant interaction between stress and rule ($F1(1,18) = 4.31$, $p = .052$). Indeed, the superiority for the C_3 rule over the C_2 rule was significant when the second syllable was stressed ($F1(1,9) = 11.05$, $p = .009$) but did not reach significance when the first syllable was stressed. Dartmouth students did not show any significant effects of rule or stress on the position of the first correct trial.

The results for length of longest run were analyzed in the same manner. There was a main effect of university ($F1(1,36) = 7.77$, $p = .008$) and an interaction of university, rule type, and stress ($F1(1,36) = 6.07$, $p = .019$). Overall, Dartmouth students produced longer runs of correct responses than Wayne State students. Dartmouth students showed an interaction between rule type and stress such that performance was better on the C_3 (onset) game than the C_2 (coda) game when the first syllable of the stimulus was stressed ($F1(1,9) = 7.82$, $p = .021$). When the second syllable was stressed, there was a nonsignificant trend in the reverse direction. Wayne State students did not show significant effects of rule or stress on length of longest run.

Error analyses. According to the syllable structure hypothesis, people should be more likely to replace the syllable's vowel along with the specified consonant when learning the C_2 (coda) rule than when learning the C_3 (onset) rule. This is because C_2 and the vowel of its syllable form a constituent, the rime. In contrast, the onset C_3 does not form a constituent with the vowel of its syllable. We therefore calculated the proportion of errors in which the consonant was appropriately changed to /g/ but the vowel of the same syllable also changed (and there were no other errors in the response). These data were analyzed using the factors of university, stress, and rule type. The results of one Wayne State student and five Dartmouth students had to be deleted from the by-subjects analysis because these subjects made no errors in one of the cells. A by-items analysis could not be performed because, after omitting those items for which no errors occurred in one or more of the cells, there were some cells in which the percentage of errors of the type in question was zero for all items. There was a main effect of rule type ($F1(1,30) = 12.00$, $p = .002$). Overall, the errors in question were more frequent for the C_2 (coda) rule than the C_3 (onset) rule, as the syllable structure hypothesis predicts. However, rule type appeared to interact with university ($F1(1,30) = 4.06$, $p = .053$). For Wayne State students, .19 of the errors in the C_2 condition (34 of 181) involved a change of the vowel as well as a change of C_2. In contrast, only .02 of the errors in the C_3 condition (2 of 133) changed the vowel as well as C_3. The effect of rule type was significant for the Wayne State students ($F1(1,17) = 11.24$, $p = .004$). However, Dartmouth students did not show significant effects of rule type or stress. For Dartmouth students, the proportion of errors in the C_2 condition that involved a change of the vowel as well as a change of the consonant was .07 (5 of 70). The proportion of such errors in the C_3 condition was .06 (4 of 70). Thus, the results of the error analysis confirm those of the preceding analyses in showing effects of syllable structure for Wayne State students but not for Dartmouth students.

Discussion

In a word game task with auditorily presented disyllabic stimuli, Wayne State University students made more correct re-

sponses on a game involving replacement of an onset consonant than a game involving replacement of a coda consonant. This pattern of results is consistent with the idea that the first consonant of the second syllable forms a unit on its own, the onset, whereas the last consonant of the first syllable is part of a larger unit, the rime. Although both of these consonants were in the remainder-of-word unit, they behaved differently for the Wayne State students. The nature of the errors made by the Wayne State students further supported the syllable structure hypothesis. The Dartmouth students, in contrast, did not show the pattern of results predicted by the syllable structure hypothesis. There was an unexpected interaction involving the stress pattern of the stimuli, but pooling over the two stress patterns there was no significant difference between the onset and coda rules for the Dartmouth students.

Experiment 2 was based on an earlier study using a phoneme shift task with visually presented disyllabic stimuli (Fowler et al., 1993, Exp. 3A). In that study, which was carried out with Dartmouth students, we compared shifts of onsets and shifts of codas. No significant difference between onsets and codas was found either in the analysis of response times or the analysis of errors. Based on the earlier results, one might be tempted to conclude that the individual syllables of disyllabic stimuli do not show an onset/rime structure. If it is only the stressed middle syllables of trisyllabic stimuli that show such a structure, onset/rime structure may be restricted to stressed syllables, as Brady, Fowler, and Gipstein (1994) suggested, or to foot-initial syllables. However, the results of the Wayne State students in the present experiment show that such a conclusion would be incorrect. Evidence for syllable structure *can* be found for both the stressed and unstressed syllables of disyllabic stimuli. Although stress may modulate the pattern of results, in that the superiority for onsets over codas appeared to be greater when the syllable containing the onset was stressed than when this syllable was not stressed, the overall pattern of results was similar for stressed and unstressed syllables.

The results of Experiment 2 show clear differences between Wayne State and Dartmouth students. The Dartmouth students performed significantly better than the Wayne State students and did not do better overall on the onset rule than the coda rule. Evidence for syllable structure was confined to the Wayne State students. These results contrast with the findings of Experiment 1. In that experiment, the Dartmouth undergraduates did not perform significantly better than the Wayne State undergraduates, although there was a nonsignificant trend in this direction. Both groups of subjects in Experiment 1 showed clear effects of syllable structure, although the effects were stronger for Wayne State students than for Dartmouth students in a few of the analyses.

The different patterns of results in the two experiments could reflect the difficulty levels of the tasks for the two groups of students. Comparing overall levels of performance in Experiments 1 and 2, it appears that the Dartmouth students found the Experiment 2 word games involving disyllabic stimuli easier than the Experiment 1 games involving trisyllabic stimuli. The Dartmouth subjects showed effects of syllable structure only in the harder task. For the Wayne State undergraduates, the word games with disyllabic stimuli (Experiment 2) were comparable in difficulty to the word games with trisyllabic stimuli (Experiment 1). The Wayne state students appeared to treat the stimulus syllables in terms of onset and rime units in both situations.

Experiment 3

Experiment 3 was modeled on our earlier study using the phoneme shift task in which Dartmouth students shifted CVs and VCs in the first and second syllables of visually presented stimuli (Fowler et al., 1993, Exp. 3C). In that study, we did not find support

for syllable structure, in that VCs were not moved more rapidly or accurately than CVs. In Experiment 3, we used a word game task involving auditory presentation of the stimuli. We asked whether this word game task would reveal evidence of syllable structure that was not found in the phoneme shift task. We also asked whether Wayne State students and Dartmouth students would show similar or different patterns of results.

Method

Stimuli. The stimuli were 20 disyllabic nonwords with the structure /C_1VC_2\$ C_3VC_4/. Consonants were selected for the C_2 and C_3 positions that could not legally belong to the same syllable in English. Both of the vowels in each stimulus were lax. The stimuli did not contain real English prefixes or suffixes. We tried to minimize the number of syllables that were real words. The final consonants were selected from the set of reduction blocking consonants listed by Fudge (1984), ensuring that the vowels in the second syllables did not reduce to /ə/. Phonemes were never repeated within a nonword. Across the set of stimuli, the same CVs occurred in the first syllable and the second syllable and the same VCs occurred in the two syllables. In the first-syllable stress condition, the stimuli were pronounced with primary stress on the first syllable. In the second-syllable stress condition, the stimuli were pronounced with primary stress on the second syllable.

We compared two rules in the first-syllable condition. In the CV rule, the initial consonant and vowel of the first syllable were replaced with /gɛ/. In the VC rule, the vowel and final consonant of the first syllable were replaced with /ɛg/. The rules in the second-syllable condition were similar except that units in the second syllable of the nonword were replaced. In the first-syllable condition, for example, /tʃæpfɪb/ became /gɛpfɪb/ according to the CV rule and /tʃɛgfɪb/ according to the VC rule. In the second-syllable condition, the CV rule yielded /tʃæpgɛb/ and the VC rule yielded /tʃæpfɛg/.

Procedure. Half of the subjects at each institution were assigned to the first-syllable condition and the other half were assigned to the second-syllable condition. Within each condition, half of the subjects received each stress pattern. Each subject participated in two sessions, learning the CV rule in one session and the VC rule in the other session. The order of the two rules was counterbalanced across subjects. In other respects, the procedure was like that of Experiment 1.

Subjects. The subjects included 32 students from Wayne State University and 32 students from Dartmouth College. All were undergraduates who participated in exchange for course credit, with the exception of one Wayne State undergraduate who was an unpaid volunteer. Two additional Wayne State students were replaced because they did not return for their second session. Both of these students had done very poorly in the first session. One Dartmouth subject had learned English as a small child but was not a native speaker. Because he was fluent at English and because his results were similar to those of the other subjects, he was retained.

Results

Figure 3 shows the proportion of correct responses in the various conditions of the experiment. The data, collapsed across order, were analyzed using the factors of university (Dartmouth versus Wayne State), stress (first-syllable stress versus second-syllable stress), syllable (substitution in first syllable or substitution in second syllable) and rule type (CV versus VC). There was a main effect of rule type ($F1(1,56) = 31.95$; $F2(1,19) = 94.89$; $p < .001$ for both). Subjects generally did better on the VC rule than the CV rule. However, this main effect was qualified by an interaction with syllable ($F1(1,56) = 15.91$; $F2(1,19) = 24.45$; $p < .001$ for both). In the first syllable, the superiority for the VC game over the CV

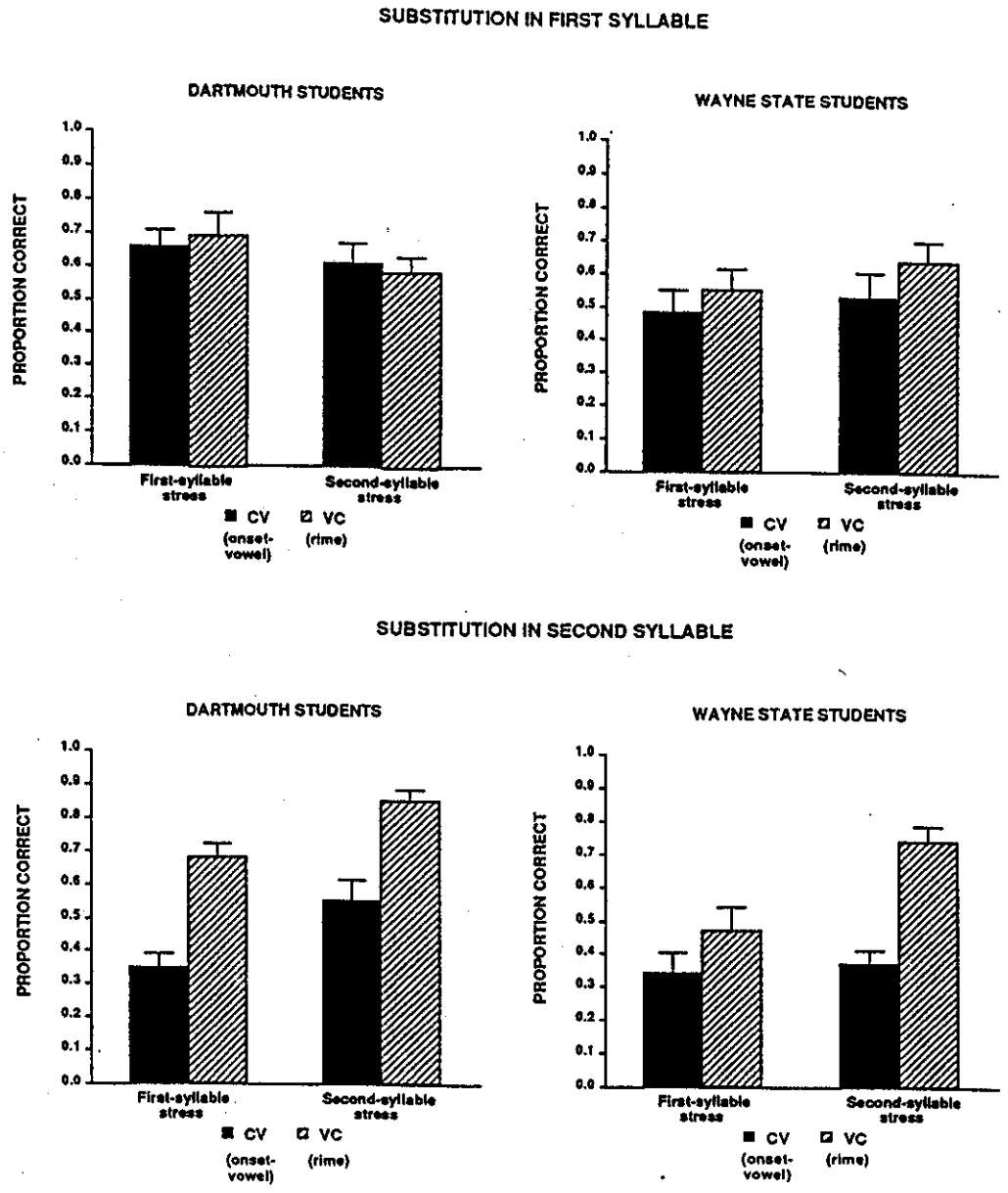

FIG. 3. Mean proportion of correct responses in Experiment 3 as a function of subject group, stress, syllable, and rule type. (Error bars represent standard errors.)

game was not statistically reliable. The mean proportion correct was .62 for the VC game as compared to .57 for the CV game. In the second syllable, there was a large and statistically significant superiority for the VC game over the CV game. The mean proportions of correct responses for substitutions in the second syllable were .69 for the VC game and .40 for the CV game ($F1(1,31) = 39.34$; $F2(1,19) = 110.83$; $p < .001$ for both). There were no significant effects involving university or stress.

Additional measures of performance are shown in Table 3. For position of first cor-

TABLE 3
RESULTS FOR LOCATION OF FIRST CORRECT TRIAL AND LENGTH OF LONGEST RUN IN EXPERIMENT 3

	First correct trial		Length of longest run	
	CV (onset–vowel) rule	VC (rime) rule	CV (onset–vowel) rule	VC (rime) rule
		Dartmouth students		
Substitution in first syllable				
First-syllable stress				
Mean	4.00	4.75	7.88	10.50
SD	2.00	4.06	6.20	6.09
Second-syllable stress				
Mean	4.63	5.25	6.00	6.38
SD	4.31	2.61	4.21	3.02
Substitution in second syllable				
First-syllable stress				
Mean	5.75	4.13	3.38	7.38
SD	3.06	1.64	2.97	3.82
Second-syllable stress				
Mean	5.38	3.13	6.00	14.00
SD	4.84	1.64	4.14	4.31
		Wayne state students		
Substitution in first syllable				
First-syllable stress				
Mean	4.75	7.25	6.25	7.63
SD	2.61	4.71	5.65	5.18
Second-syllable stress				
Mean	8.50	4.13	6.50	8.50
SD	6.99	1.89	5.63	5.58
Substitution in second syllable				
First-syllable stress				
Mean	10.13	7.38	3.50	5.63
SD	6.71	4.69	3.02	4.17
Second-syllable stress				
Mean	6.75	2.88	4.13	9.88
SD	3.88	1.13	2.64	5.36

Note. Maximum possible score for longest run is 19.

rect trial, there was a main effect of university ($F1(1,56) = 6.26$, $p = .015$). Dartmouth students achieved their first correct trial earlier than Wayne State students. There was also a significant main effect of game ($F1(1,56) = 4.32$, $p = .042$). Subjects achieved their first correct trial earlier for the VC game than the CV game. No other main effects or interactions were significant.

For length of longest run, there was a main effect of game ($F1(1,56) = 29.01$, $p < .001$) and an interaction between game and syllable ($F1(1,56) = 7.67$, $p < .001$). Overall, subjects produced longer runs of correct responses on the VC game than the CV game. The superiority for the VC game over the CV game was not statistically reliable in the first syllable of the stimuli (8.25 vs 6.66). In the second syllable, however, people produced significantly longer runs of correct responses for the VC game than for the CV game (9.22 vs 4.25; $F(1,31) = 31.28$, $p < .001$). In addition, there was an interaction between stress and syllable ($F1(1,56) = 5.77$, $p = .02$). When the first syllable of the stimulus was stressed, substitutions of units in the first syllable led to

significantly longer runs of correct responses than did substitutions of units in the second syllable ($F1(1,30) = 4.40$, $p = .044$). When the second syllable was stressed, there was a nonsignificant trend in the opposite direction.

Error analyses. We looked first at errors in which the specified consonant was correctly changed to /g/ but the vowel remained unchanged. According to the syllable structure hypothesis, such errors should form a higher proportion of the total when subjects are learning the CV rule (where the C involved in the rule is in a different constituent of the syllable than the V) than when subjects are learning the VC rule (where the two phonemes involved in the rule are in the same constituent of the syllable). A by-subjects analysis was carried out using the factors of university, stress, syllable, and rule type; the results of three Dartmouth students were eliminated because they did not make any errors on one of the rules. An items analysis could not be performed because, after eliminating those nine items on which no errors were made in one or more of the cells, there was no variability in one of the cells. The only significant effect was the interaction between rule type and university ($F1(1,53) = 4.77$, $p = .033$). For Wayne State students, .17 of the errors in learning the CV rule (60 of 345) involved a failure to change the vowel coupled with a correct change of the consonant. The figure was .08 (20 of 243) for the VC condition. The difference between the two conditions was significant, supporting the syllable structure hypothesis ($F1(1,31) = 12.61$, $p = .001$). For Dartmouth students, .12 of the errors on the CV rule (32 of 279) involved a failure to change the vowel as compared to .10 of the errors on the VC rule (18 of 180). This difference was not significant. In this analysis, then, it appears that Wayne State students were affected by syllable structure in a way that Dartmouth students were not.

In a second analysis, we looked at whole-syllable errors. As in Experiment 1, these are errors in which the appropriate vowel and consonant were replaced with the appropriate phonemes but the other consonant of the syllable was also replaced with a single consonant. According to the onset/rime hypothesis, such errors should be more common when subjects are learning the CV rule (where the C not involved in the rule belongs to the same syllable constituent as the V) than when subjects are learning the VC rule (where the C not involved in the rule belongs to a different syllable constituent, the onset). The results of three Dartmouth students were eliminated from the by-subjects analysis because they made no errors on one of the rules. An items analysis could not be carried out because, after eliminating those nine items on which no errors were made in one or more of the cells, there was no variability in two of the cells. The only significant effect was the main effect of rule type ($F1(1,53) = 20.97$, $p < .001$). The proportion of whole-syllable errors was higher in the CV condition than in the VC condition, .30 (187 of 624) as compared to .09 (38 of 423). This difference supports the syllable structure hypothesis.

Discussion

The results of this experiment provide evidence for onset/rime structure in disyllabic stimuli. In general, word games involving a vowel and a following consonant (which form a rime) were easier to learn than word games involving a vowel and a preceding consonant (which do not form a constituent of the syllable according to the onset/rime view). Further support for the syllable structure hypothesis is that errors were more likely to involve the whole syllable in the CV condition than in the VC condition. These effects of syllable structure were found among both groups of subjects, the Dartmouth students as well as the Wayne State students. The findings support the suggestion of Experiment 2 that the individual syllables of disyllabic stimuli have an onset/rime structure.

The syllable structure effects in Experiment 3 were modified by word edge effects, however. When the two-phoneme unit that was involved in the substitution was at the very beginning or the very end of the stimulus (the CV rule in the first-syllable condition and the VC rule in the second-syllable condition), performance tended to be better than otherwise expected. When the two-phoneme unit involved in the substitution was in the middle of the stimulus, performance was not as good as otherwise expected. Presumably, isolating the unit to be changed is more difficult when it is in the middle of the stimulus than when it is at the edge. No such edge effect was seen in Experiments 1 and 2 because none of the manipulations in those experiments included phonemes that were at the very beginning or the very end of the stimulus.

The Dartmouth students tended to perform better than the Wayne State students in this experiment, although this trend was significant in only one of the analyses. Recall, however, that two Wayne State students who did very poorly in their first session did not return for their second session; if these subjects had participated in a second session the observed differences between the groups might have been larger. In most cases, the Dartmouth and Wayne State students showed similar effects of syllable structure. In one of the error analyses, however, the Wayne State students showed effects of syllable structure that the Dartmouth students did not. Thus, the overall picture of Experiment 2 is one in which both groups of subjects showed effects of syllable structure but the better-performing group, the Dartmouth students, sometimes showed weaker effects. This picture is similar to that seen in Experiment 1, where the Dartmouth undergraduates tended to perform better than the Wayne State undergraduates (although the difference was not significant in that experiment) and where the Dartmouth students showed weaker effects of syllable structure in a few of the analyses. The pattern of results in Experiment 3 differs from that of Experiment 2 in that the Dartmouth students showed no significant effects of syllable structure at all in Experiment 2.

The findings of Experiment 3 suggest that the emergence of syllable structure effects depends on the nature of the task as well as on the nature of the subjects. When comparing CV and VC manipulations in the first and second syllables of disyllabic stimuli using the phoneme shift task, we did not find evidence for syllable structure effects with Dartmouth students (Fowler et al., 1993, Exp. 3C). In the present word game task, however, both Dartmouth and Wayne State students showed the effects. There are several reasons why syllable structure effects may be stronger in the word game task than the phoneme shift task. Modality of stimulus presentation is one reason. The stimuli are presented orally in the word game task but visually in the phoneme shift task. In the phoneme shift task, subjects may adopt the strategy of transposing letters in the orthographic representations of the stimuli and pronouncing the result rather than translating the printed stimuli into their phonological forms and then transposing the phonemes. The left-to-right scanning that is necessitated by the visual presentation of the stimuli in the phoneme shift task may lead to segments earlier in the stimuli being shifted more rapidly than segments later in the stimuli. This difference may swamp effects of syllable structure in many cases. Indeed, we found evidence for such scanning effects in our earlier studies using the phoneme shift task (Fowler et al., 1993). Finally, memory may play a larger role in the word game task than the phoneme shift task. Subjects have to remember the stimulus on each trial of the word game task; the stimulus is not present before them as it is in the phoneme shift task. Subjects also have to remember the unit involved in the substitution across trials of the game. Monosyllabic CVC stimuli seem to be coded in terms of an initial consonant unit and a final vowel–consonant

unit in short-term memory (Treiman & Danis, 1988a). To the extent that short-term phonological memory plays an important role in the word game task, onset and rime units may be used in this task as well.

General Discussion

As discussed in the introductory remarks, a large body of linguistic and psycholinguistic evidence suggests that syllables in English and related languages have a hierarchical internal structure. The two main constituents of the syllable in this view are the onset, the initial consonant or cluster, and the rime, the vowel and any following consonants. However, Davis (1989) posed an important challenge to the onset/rime view by arguing that the evidence for syllable-based structure is not altogether compelling. Because much of the existing data comes from monosyllabic words, the findings may be equally well interpreted in terms of word-based structure. Specifically, words (or morphemes) may be divided into a word onset, consisting of the initial consonant or cluster, and a word remainder, consisting of the vowel and the following phonemes of the word. Given the variety of claims about phonological processing, reading, and related topics that have been based on the onset/rime view of syllable structure, it is important to take Davis's criticisms seriously.

A strong version of Davis's (1989) view is that word onsets and word remainders are the *only* structural units in monosyllabic and polysyllabic stimuli. If the remainder unit is a linear string of phonemes, one should not find evidence for an onset/rime structure in the individual syllables of disyllabic or trisyllabic stimuli (except for the word-initial onsets of these stimuli). A weaker version of Davis's (1989) view, which is compatible with Berg's proposal (1989b), is that both syllable-based and word-based structure are important. The initial onset has a special status but, beyond this, the individual syllables of polysyllables contain onset and rime units.

Our data speak against the strong version of Davis's (1989) view. Were the initial onset and the remainder the only important units in stimuli of more than one syllable, we should not have found evidence for onset and rime structure in any of our experiments with disyllabic or trisyllabic stimuli. For example, because both the /f/ and /p/ of /dæpfɛb/ are part of the word remainder, a substitution of /f/ should be no easier or harder to perform than a substitution of /p/. However, the Wayne State students in Experiment 2 found it easier to learn a game in which a phoneme was substituted for /f/ than a game in which a phoneme was substituted for /p/. This result is consistent with the idea that /f/, being the onset of the second syllable, is more detachable from the stimulus as a whole than is /p/, which is part of the first syllable's rime. As another example, a strong version of Davis's view predicts no superiority for games involving VC substitutions over games involving CV substitutions with disyllabic stimuli. We found such a difference in Experiment 3, suggesting that the VC has a special status even when it is not everything but the word onset.

Although our results do not support a strong version of Davis's (1989) view, they are compatible with a weak version. That is, even though word-based structure is not the only structure in stimuli of more than one syllable, it is important. For example, evidence discussed earlier indicates that word beginnings have a special status in adult language production (Berg, 1989b; Browman, 1978; Fowler et al. 1993; Shattuck-Hufnagel, 1987). Further support for word-based structure comes from children's early sensitivity to rhymes that share the word-remainder unit, such as "mountain" and "fountain" (Brady et al., 1994). Although there appears to be a cut between the word onset and all that follows, our data lead to the important suggestion that the "all that follows" is not always treated as an unstructured string of phonemes.

The extent to which onset/rime structure

emerges in the word remainder unit appears to depend on the nature of the task that is used to elicit this structure, the nature of the stimuli, and the nature of the subjects. Table 4 summarizes the results of the present study and of our earlier study (Fowler et al., 1993) with respect to this issue. A task effect may be seen in that just one of the experiments using the phoneme shift task with Dartmouth students (the experiment with trisyllabic stimuli) showed evidence for onset/rime structure. Using the word game task, two of the three analogous experiments with Dartmouth students found such evidence. As we have discussed, the auditory presentation of stimuli in the word game task together with the stress on phonological memory may promote onset/rime coding in this task. Also, the left-to-right scanning that is necessitated by the visual presentation of stimuli in the phoneme shift task may cause phonemes near the beginnings of stimuli to be shifted faster than phonemes near the ends of stimuli, overriding any syllable structure effects.

The nature of the stimuli also appears to play a role in the emergence of onset/rime structure. All of our experiments involving the stressed middle syllables of trisyllabic stimuli showed evidence for onset/rime structure. For disyllabic stimuli, the evidence was mixed. Two factors may cause onset/rime structure to be more salient in the stressed middle syllables of trisyllabic stimuli than in the first or second syllables of disyllables. First, edge effects are eliminated with trisyllabic stimuli. As we saw in Experiment 3, word games that involve the beginning or end phonemes of words tend to be easier than those that involve the middle phonemes of words. Such edge effects can counteract syllable structure effects but are eliminated when none of the phonemes involved in the manipulation are at the edge of the stimulus. Also important may be the

TABLE 4
SUMMARY OF RESULTS PERTAINING TO ONSET/RIME STRUCTURE IN DISYLLABIC AND TRISYLLABIC STIMULI

Experiment	Task	No. of syllables in stimuli	Subjects	Comparison	Evidence for onset/rime structure?
Fowler et al. (1993), Exp. 3A	Phoneme shift	2	Dartmouth	last C of first syllable vs first C of second syllable	No
Fowler et al. (1993), Exp. 3C	Phoneme shift	2	Dartmouth	VC vs CV of first or second syllable	No
Fowler et al. (1993), Exp. 4	Phoneme shift	3	Dartmouth	first C vs last C of middle syllable; VC vs CV of middle syllable	Yes
Exp. 2	Word game	2	Dartmouth, Wayne State	last C of first syllable vs first C of second syllable	Dartmouth—No Wayne State—Yes
Exp. 3	Word game	2	Dartmouth, Wayne State	VC vs CV of first or second syllable	Dartmouth—Yes Wayne State—Yes
Exp. 1; Fowler et al. (1993), Exp. 5	Word game	3	Dartmouth, Wayne State	first C vs last C of middle syllable; VC vs CV of middle syllable	Dartmouth—Yes Wayne State—Yes

fact that the middle syllables of our trisyllabic stimuli received primary stress. There are indications in the literature (Berg, 1989b; Browman, 1978; Shattuck-Hufnagel, 1987) that stressed onsets have a special status. For example, in both speech errors (Shattuck-Hufnagel, 1987) and tip-of-the-tongue errors (Browman, 1978), the onsets of stressed non-initial syllables, such as the "l" of "alone," appear to participate in errors as if they were distinct units. The onsets of unstressed noninitial syllables, such as the "l" of "only," show no special tendency to be involved in speech errors or to be preserved in tip-of-the-tongue errors.

Finally, the nature of the subject population also appears to influence whether syllable structure effects, will emerge. In Experiment 2, for example, the Dartmouth students did not show any syllable structure effects, whereas the Wayne State students did. Also, the Dartmouth students showed higher overall levels of performance than the Wayne State students in this experiment. In Experiments 1 and 3, both groups of students showed syllable structure effects. In at least some of the analyses, however, the effects were weaker for the Dartmouth students than for the Wayne State students. Also, the Dartmouth undergraduates tended to perform better than the Wayne State undergraduates. One possible interpretation of these data is that people with higher verbal abilities can perform the easier word game tasks on a phoneme-by-phoneme basis. They do not need to employ onset/rime coding of the stimuli. This may have been particularly true for the Dartmouth students in Experiment 2, where only one phoneme of the stimulus changed on each trial. For people of lower verbal abilities or for harder tasks, chunking of phonemes into onset and rime units may become important. In these cases, units that correspond to onsets and rimes are easier to deal with than units that do not.

As we have discussed, the view of syllables as composed of onset and rime units has been applied to a number of different phenomena, ranging from literacy acquisition in children to speech perception and production in adults. Because most studies have used monosyllabic stimuli, the existing evidence for onset/rime structure could reflect the combined effects of syllable structure and word structure. Each of these types of structure seems to be important; their relative effects may well vary across tasks and subject populations. It is crucial, then, to examine the units involved in the processing of words of more than one syllable. Only by so doing can we tease apart the influences of syllable structure and word structure.

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