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DEVELOPMENTAL CHANGE IN PERFORMANCE OF A WORD SYNTHESIS TASK: EFFECTS OF SUBSYLLABIC SEGMENTATION AND SPEED OF PRESENTATION

BY

KAREN K. MCCLURE

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NAME OF AUTHOR: Karen K. McClure

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Karen K. McClure

1149 Rosewell Place

Winnipeg, Manitoba

R2G 1V8

May 29, 1992

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled DEVELOPMENTAL CHANGE IN PERFORMANCE OF A WORD SYNTHESIS TASK: EFFECTS OF SUBSYLLABIC SEGMENTATION AND SPEED OF PRESENTATION in partial fulfillment of the requirements for the degree of MASTER OF ARTS.

Dr. Gay Bisanz

Dr. Fernanda Ferreira

Dr. John Henderson

Dr. Bruce Derwing

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Abstract

The development of subsyllabic awareness as indexed by a word synthesis task was investigated in a study of children from kindergarten, grade 1, and grade 2. The children attempted to blend auditorily-presented CCVC word segments to produce words. Subsyllabic segmentation (CC-VC, C-CVC, CCV-C, and C-C-V-C) and presentation rate of the word segments (one per 1/2 s and one per 1 1/2 s) were varied, and the dependent measure was number correct in each condition. I also administered several tasks to measure the children's ability to associate visually-presented consonants, consonant clusters, rimes, and words with an appropriate unit of speech. Performance was best on words that were segmented between onset and rime, even for the kindergarten children, and performance on words that were segmented into phonemes was poorest. Performance on word segments that were presented at the fast rate was better than on those presented at the slow rate. Evidence was found for a developmental trend on all tasks. I discuss the implications of these results for models of reading acquisition, as well as reading instruction. I suggest that models of reading acquisition should reflect the reciprocal relationship between aspects of phonological awareness and the process of learning to read. I also suggest that because preliterate children are able to manipulate onset and rime units, it may be useful to emphasize those units in reading instruction.

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Developmental Change in Performance of a Word Synthesis Task: Effects of Subsyllabic Segmentation and Speed of Presentation

One critical area of research in cognitive development is the investigation of how young children learn to read (Curtis, 1980; MacLean, Bryant, & Bradley, 1987; Perfetti, Beck, Bell, & Hughes, 1987; Stanovich, 1986). Studying changes with age in the types of knowledge and component processes that are essential to beginning readers' performance is important to formulating models of the acquisition of skilled reading. These types of knowledge and component processes may not be emphasized in models of skilled reading in adults, but are critical for characterizing the development of reading skill. Within the last ten years, researchers have found evidence that awareness and processing of the phonological features of language (in this case, English) are important during the acquisition of early reading skill (for a review, see Wagner & Torgesen, 1987). Phonological awareness is defined as explicit knowledge of the phonological structure of language (e.g., Bryant & Bradley, 1985; Perfetti, Beck, Bell, & Hughes, 1987; Stanovich, Cunningham, & Cramer, 1984), or more specifically, as knowledge of correspondences between units of print and units of sound.

Stanovich, Cunningham, and Cramer (1984) administered ten different phonological awareness tasks to kindergarten children to investigate the relationships among the variety of skills that comprise phonological awareness.

These tasks required that children supply and choose rhyming words, select words that had the same initial or the same final consonant as the target word, select words that had a different initial or a different final consonant than a target word, and either delete or substitute the initial consonant of a target word. To address the issue of the relative predictive power of the spelling-sound correspondence tasks administered earlier, a standardized measure of reading ability was obtained from the same participants at the end of first grade.

Despite the differing task requirements, there were uniformly moderate to high correlations among the seven non-rhyming tasks. All of the non-rhyming spelling-sound measures were superior to an omnibus IQ test (Otis-Lennon IQ) in predicting first-grade reading ability (Stanovich et al., 1984). Children had the most difficulty when they were required to delete a single consonant from a target word and then say the resulting word. Children performed better on tasks where the critical sound contrast was at the beginning of the word than on those tasks where the contrast was at the end of the word. Children had the greatest success on tasks in which the response involved choosing or supplying a rhyming word, tasks that involved manipulating larger subsyllabic components than individual phonemes. They may have performed better on tasks involving the beginning of the word because this part is encoded first and thus less subject to interference. Indeed, Meyer and Schriefers (1991) have suggested that the phonological encoding of a syllable onset is initiated before the encoding of the rime.

Three general views have been advanced about the relationship between phonological awareness and learning to read. One view is that phonological awareness is a cognitive prerequisite to learning to read (e.g., Bradley & Bryant, 1983; Bryant & Bradley, 1985; Fox & Routh, 1984; Kirtley, Bryant, MacLean, & Bradley, 1989; Treiman, 1985); the second view is that phonological awareness is a product (e.g., Alegria, Pignot, & Morais, 1982; Morais, Cary, Alegria, & Bertelson, 1979). The third view, that the causal relationship between phonological awareness and reading acquisition is reciprocal, has been advanced by authors of recent reviews of the phonological awareness literature (Stanovich, 1986; Torgesen & Wagner, 1987).

In past discussions, the term phonological awareness generally has referred to knowledge of how letter units map onto individual phonemes. However, phonological units other than phonemes may be more salient to children (e.g., Bruck & Treiman, 1990; Bryant & Bradley, 1983; Kirtley, et al., 1989; Treiman, 1985; Wise, Olson, & Treiman, 1989). For example, four-year-olds and even some three-year-olds are able to make judgments about rhyme (e.g., that the vowel and final consonant of *pan*, *can*, and *man* but not *cat* are the same), but have problems when they have to isolate single phonemes.

To account for these kinds of findings, Treiman (1985) has proposed that the smallest phonological units of which preliterate children are aware are the syllable onset and rime. According to a number of linguistic analyses, syllables have the constituent structure illustrated in Figure 1. The onset includes any and all consonants up to the vowel, and is optional in English. The remainder of the syllable is termed the rime, and is made up of two subconstituents: the nucleus, which includes the vowel, and the coda, which included any following consonant. One reason for supposing that children are aware of syllable onset and rime is that these are the units involved in rhymes: Two words rhyme when they differ in onsets but share the same coda. Recall that in studies like that of Stanovich et al. (1984) children performed well in tasks requiring them to supply or judge rhymes.

Insert Figure 1 about here

Treiman (1985) found that four-year-old children can isolate the first sound in a word more successfully if the word begins with a single consonant than if it begins with a consonant cluster. In the first instance, children isolate the whole onset (e.g., represented by the *c* in *cat*). In the second instance, children must isolate only part of the onset (e.g., represented by the *s* in *stir*), requiring them to break up a subsyllabic unit. Young children are also able to detect the initial phoneme of a word like *cat* (the letter *c*), presumably because this sound comprises the onset, a complete unit. Children have more difficulty with the final phoneme (the letter *t* in *cat*) because it is only part of the rime. Such evidence led

Treiman (1985) to suggest that some phonemes are easier to detect than others because of their linguistic environment.

Kirtley et al. (1989) investigated awareness of onsets, rimes, and phonemes in kindergarten, grade 1, and grade 2 children. The children were given classification tasks in which they had to judge whether a set of CVC words began or ended with the same consonant. The children were more often correct in the initial sound task. The children were successful when the phoneme to be detected represented the whole speech unit (the onset), but not when the phoneme was only part of the speech unit (a subunit of the rime). The results were taken as evidence that children can isolate some phonemes without training. While these results are consistent with an onset-rime explanation, they can also be interpreted as indicating that children are better at tasks that involve the beginning of the word than tasks that involve the end of the word. In a related study, Wise, Olson, and Treiman (1990) trained first grade children to read CCVC and CVCC words using onset-rime (CC-VC, C-VCC) and postvowel (CCV-C, CV-CC) segmentation during training. On post-training reading tests, there was greater improvement on those words that were trained using an onset-rime division.

Bruck and Treiman (1990) investigated word-initial consonant cluster effects on phonemic awareness in grade 1 and grade 2 children. Early researchers suggested that the serial position of a phoneme in a spoken word was critical to its accessibility (Bruce, 1964). However, more recent research has led experimenters to suggest that the linguistic status of a phoneme has effects on accessibility above and beyond those of serial position (Treiman, 1985). Bruck and Treiman (1990) used two different tasks to measure phonemic awareness: phoneme recognition and phoneme deletion. CCV, CVC, and VCV nonwords were used as stimuli.

Bruck and Treiman (1990) found that the initial consonant of the CCVs (e.g., /*sku*/) was more difficult to recognize than the initial consonant of the CVCs (e.g., /*suk*/) for both grades. Also, more errors were made on the CCV stimuli when the second rather than the first phoneme was to be recognized. Based on the results of the study, Bruck and Treiman suggested that the role of a phoneme in the syllable, and particularly its role in the onset, affects childrens' ability to access the phoneme. That is, the effects of linguistic structure go beyond those of the phoneme's serial position in the word. Bruck and Treiman have shown that the linguistic structure of a spoken stimulus affects childrens' performance on phonological awareness tasks.

Both the early evidence that performance on phonological awareness tasks is related to reading ability and the recent work on the structure of the syllable has motivated researchers to understand the component skills that are measured by these tasks. Phonological awareness tasks can be divided into two groups: those that require analysis of the phonological constituents of the words and those that require synthesis of separately presented phonological constituents to produce whole words (Torgesen et al., 1989). Synthesis tasks are critical for understanding how children blend the constituents of a letter string to identify a new word while learning to read. Children are sometimes taught to say the sound of individual letters in a word, and then use blending to help them identify the word. Thus, synthesis tasks mimic the blending process that children use to identify words.

For example, Torgesen et al. (1989) investigated the development of blending skill using a phoneme synthesis task. These researchers suggested that the most basic component required for children to blend is some degree of awareness that words are made up of a set of speech sounds that can be combined in different ways to form different words. However, these investigators claimed that children may have equal levels of phonological awareness but still exhibit differential performance in blending because of differences in ability to execute additional processing operations required in blending. These additional processing operations are described in the blending model originally proposed by Perfetti, Beck, Bell, & Hughes (1981). According to this model, blending requires the following four steps: a) individual phonemes must be represented and stored in working memory for further processing, b) segments are then combined into a word-like representation, c) the lexicon is searched for a real word that matches the phonological string that is produced, and d) candidates from the lexicon are compared to the blended string and a response alternative is selected.

Torgesen et al. (1989) investigated the contributions of the working memory and lexical search components of the blending task. Their purpose was to investigate whether individual differences are primarily due to variations in level of phonological awareness, in ability to store and manipulate phonemes in working memory, or in the ability to identify real words in the lexicon. The participants were children from kindergarten, grade 1, and grade 2. To investigate the role of working memory, children responded to phoneme synthesis tasks in which the rate of presentation of individual phonemes was one phoneme per 1/2 s or 1 1/2 s. In synthesis tasks, the faster rate of presentation should be less difficult than the slower rate because the child does not have to wait as long in order to obtain all components of the word. The faster the rate of presentation, the closer the presentation resembles an intact word in its working memory demands. To investigate the role of lexical search, both words and nonwords were used. The words and nonwords varied in length from 2 to 6 phonemes, and were presented to individual participants in live voice by an experimenter. There were multiple experimenters for each condition. Kindergarteners' performance was significantly lower than the performance of the other two groups, who did not differ significantly from one another. Real words in the fast presentation were the least difficult and nonwords in the slow presentation were the most difficult for all age groups. Torgesen et al. (1989) acknowledged that the most striking aspect of the developmental analysis of the synthesis task was the abrupt improvement in performance between kindergarten and grade 1, and the lack of a difference between grade 1 and grade 2.

There were two problems with this study. First, the live-voice method of presentation may have led to inconsistencies across experimenters in the way in which the sounds were produced. Even sounds from one speaker will not be spoken in an identical manner each time they are produced. More importantly, experimenters' knowledge of the words and nonwords of which the phonemes were a part may have led to adjustments in the pronunciation of a phoneme to accommodate subsequent phonemes. Such coarticulation effects (Mills, 1980) distort the results because the purpose of the experiment is to mimic the job of the child attempting to blend. The child does not have the advantage of knowing the identity of the word, and so cannot make appropriate adjustments in the pronunciation of phonemes. A second concern was the appropriateness of the experimental task used to index blending skill, particularly for the youngest children. The stimuli were individual phonemes and an inspection of the results suggests that the task was extremely difficult for the kindergarten children. In each condition there were a number of kindergarten children who were unable to respond, yet none of the children in the other grades were unable to respond. One possible reason for the kindergarteners' poor performance may be that the stimuli presented to the children were individual phonemes. Newer work on syllable structure and recent evidence that preliterate children can manipulate subsyllabic units larger than the phoneme (e.g., Bruck & Treiman, 1990; Kirtley et al., 1989; Wise et al., 1989) suggests that the kindergarten subjects' performance may be dramatically improved if subsyllabic units were used instead of phonemes.

The present study was conducted to investigate children's subsyllabic knowledge and its development in the critical period from 5-7 years of age when most children are learning to read. A synthesis task, which mimics blending, was used to index subsyllabic awareness. Like Torgesen et al., (1989), I chose this procedure because production of words by blending is hypothesized to be an important strategy used by children to identify new words in the early stages of learning to read. However, my aim was to compose materials that were more likely to reveal subtle changes in the development of subsyllabic knowledge in this critical period, and to control more carefully the manner of stimulus presentation than did Torgesen et al. (1989).

It is evident from previous research that children can readily divide words into onset and rime (e.g., Bruck & Treiman, 1990; Kirtley, Bryant, MacLean, & Bradley, 1989; Treiman, 1985; Wise, Olson, & Treiman, 1989). This variable provides a means of examining developmental trends in childrens' awareness of structurally different subsyllabic units. All of the stimuli in the present study were real words of the form CCVC. They were segmented and spoken to the child in the following four ways: CC-VC, C-CVC, CCV-C, and C-C-V-C. In the CC-VC condition, words were divided into their onset and rime (e.g., *st-op*); in the C-CVC condition, the onset was divided (e.g., *s-top*); in the CCV-C condition, the rime was divided (e.g., *sto-p*); and in the C-C-V-C condition, the onset and rime were both divided (e.g., *s-t-o-p*) by presentation of all phonemes individually. It was predicted that words in the CC-VC (no violation of subsyllabic unit integrity) condition would be the least difficult to produce and that words in the C-C-V-C condition (onset and rime integrity violation) would be the most difficult. It was expected that this condition would be the most difficult not only because both the onset and rime were divided, but also because there were four units (phonemes) to blend.

The predicted order of difficulty for the C-CVC (onset violation) and the CCV-C (rime violation) conditions was less clear from a linguistic perspective. However, because both of these conditions divided a subsyllabic unit within a word, they were expected to be more difficult than the onset-rime condition. Additional factors, derived from psychological theory, might lead us to expect that the CCV-C condition will prove the more difficult of these two conditions. This difficulty may arise because the increased amount of information first presented (the CCV segment) may initiate a look-up procedure in the lexicon that interferes with maintenance of the segment in working memory, thus disrupting the blending process. A single phoneme initial segment is unlikely to initiate look-up, so maintenance of the initial segment in the C-CVC condition may be easier and should therefore not interfere with blending.

The second variable that was manipulated was the rate at which the segments of the words were presented: presentation was either fast (one unit per 1/2 s) or slow (one unit per 1 1/2 s). This manipulation allowed investigation of the effects of varying the processing load on working memory. The slow rate of presentation should be more difficult than the fast rate of presentation for all ages. It was expected that the slow rate of presentation would be especially difficult for the younger children, because a heavier load on working memory may be especially disruptive for them. Older children may have alternative strategies for coding and holding segments in working memory, and may therefore be less affected by the speed of presentation.

Four post-experimental tasks, three letter-sound correspondence tasks and a word reading task, were given to the participants after the experimental session. These tasks measured the children's preexisting ability to recognize visually-presented consonants, consonant clusters, rimes, and words. The tasks were given both to determine developmental changes in these types of knowledge, and to explore the relationship between performance on these measures and conditions of the synthesis task.

Method

Subjects

Participants were 32 children in kindergarten (mean age = 5:10; 15 girls, 17 boys), 32 children in grade 1 (mean age = 6:11; 13 girls, 19 boys), and 32 children in grade 2 (mean age = 7:10; 15 girls, 17 boys). These children were drawn from classrooms in middle-class schools in Edmonton, Alberta, in May and June of the school year.

The nine teachers of the students who participated in the study were given a questionnaire to help provide a picture of the children's reading programs. On a scale of one to seven where one represented a "pure whole language approach", seven a "pure phonics approach", and four a "perfect blend" of the two, the six first and second grade teachers on average rated their method of instruction as a two. Supplementary phonics stressed word families such as *man*, *pan*, and *can*, and was given within the context of reading and writing activities. Some teachers reported teaching consonant blends, but rarely did they report teaching grapheme-to-phoneme correspondence rules in which words were broken down into letter units corresponding to individual phonemes. Teachers estimated spending 50% of each school day on reading related activities. All teachers said they had a home reading program, and indicated that children had a variety of books to choose from to take home. All teachers reported having a writing program which consisted primarily of writing in personal journals. Also, all teachers reported having a spelling program that included invented spelling, personal dictionaries, and some use of word lists.

Stimuli

The stimuli consisted of 64 CCVC four-phoneme words drawn from Carroll, Davies, and Richman's (1971) word frequency book (given in Appendix A). The 64 words were divided into eight lists balanced for word frequency, bigram frequency and trigram frequency. Order of items was the same across lists. A potential concern was that some of the words formed a CVC word in the C-CVC condition (e.g., flip->lip, twin->win). This property may have provided an advantage in that condition. However, any potential advantage would work against the prediction that the onset-rime condition would be the least difficult. To equalize the potential effect of CVC lexicality, these words were distributed equally across the lists (and are marked with an asterisk in Appendix A).

Each phoneme and phoneme combination required for the set of stimuli was recorded on audio tape out of the context of the word in which it occurred. For example, for the word *stop*, the following segments were recorded: *st* and *op* for the CC-VC condition, *s* and *top* for the C-CVC condition, *sto* and *p* for CCV-C condition, and *s*, *t*, *o*, and *p* for the C-C-V-C condition. The consonants and consonant clusters were recorded with a following schwa. These sounds were then digitized at a 10 kHz rate using a waveform editor, and the schwa was digitally truncated to the extent possible while still maintaining intelligibility. The result was a set of segments to be used in any condition for which the segment was required (e.g., the /s/ of *stop* would also be used as the /s/ of *plus*). These sounds were then recorded back onto audio tape in the appropriate combinations of segmentation and speed of presentation. For example, for the CC-VC (slow) condition, 5 s of silence was recorded before the first segment, then *st* was recorded, then 1 1/2 s of silence followed by *op*. The same general procedure was followed for the words in all lists. The example refers to the CC-VC (slow) condition. To create the fast condition, 1/2 s intervened between the CC and VC. Five seconds of silence were recorded between stimuli, and this amount of time proved to be sufficient for the children to respond.

This procedure ensured that presentation of the phonemes to be synthesized was consistent across conditions and participants. However, this procedure resulted in somewhat unnatural transitions between the concatenated segments, because normal coarticulation could not occur between those segments. Thus, a further reason that the C-C-V-C condition might be worse than the others is that it contains three unnatural transitions rather than just one. However, children attempting to blend an unfamiliar word would also produce unnatural and variable transitions, because without knowledge of the word, they cannot predict upcoming phonemes.

Three adults performed the synthesis task to evaluate the quality of the stimuli. Performance was virtually errorless, with one adult making an error in the

C-CVC condition, and the other adults making a total of three errors in the C-C-V-C condition. Average percentage correct across conditions was 97.9%. Therefore, I am confident that the stimuli were intelligible.

On the post-experimental tasks, children were tested for their knowledge of spelling-sound correspondences and their word reading ability. The stimuli (shown in Appendix B) were selected from the synthesis task. The spelling-sound tasks consisted of 18 consonant clusters and the 14 individual letters that comprised these clusters. A random sample of 16 rimes and 16 words was selected to keep the experimental session at a duration that was reasonable for young children.

<u>Procedure</u>

The experimental task consisted of 64 trials, eight stimuli in each of the eight conditions of the synthesis task. The participants were required to listen to auditorily-presented phonemes and/or groups of phonemes and then attempt to produce the word. The experimental task was followed by the consonant, onset, rime, and word reading tasks in this order. For the first three tasks, the participants were shown index cards with individual letters or groups of letters printed on them. Children were instructed to say the sound or sounds corresponding to the letter or letters presented. On the word reading task, the children were asked to try to read the words. If they did not know a particular word, they were asked to guess. Children were tested individually in one twenty-five minute session. Sessions were tape-recorded for later coding and scoring.

Design

The experimental design was a 3 (grade) x 4 (segmentation) x 2 (speed) factorial. The first variable was between subjects and the rest were within. For the synthesis task, participants in each grade attempted to produce eight words in each of eight (2 rate x 4 segmentation) conditions for a total of 64 trials. Participants saw a single item in only one of its conditions, but across items received all conditions of the experiment. A latin-square procedure was used so that each word appeared once in each of the eight conditions, and the design was fully replicated across eight subjects.

Results and Discussion

Synthesis task. A trial was scored as correct if the children pronounced the word presented. If the children indicated that they did not know the word or produced only part of the word, the trial was scored as incorrect. An analysis of variance was performed on the mean number correct for each condition of this task, with grade as a between subjects variable, and subsyllabic segmentation and rate of presentation as within subjects variables.

As expected, there was a main effect of grade across all conditions, $F(2,93) = 100.42$, $p < .001$. Grade 2 children performed better (68%) than grade 1 children (58%), $F(1,93) = 3.50$, $p > .10$, who in turn performed better than kindergarten children (32%), $F(1,93) = 24.89$, $p < .001$. In addition, there was a main effect of subsyllabic segmentation, $F(3,279) = 278.62$, $p < .001$. The CC-VC condition was less difficult (69%) than the C-CVC condition (63%), which in turn was less difficult than the CCV-C (52%) condition. The C-C-V-C condition (32%) was more difficult than the latter. Post-hoc comparisons revealed each of these differences to be significant, $Fs(1,279) >= 25.05$, $ps < .001$.

There was a significant interaction between grade and subsyllabic segmentation, $F(6,279) = 3.90$, $p < .001$, which took the following form: Both kindergarten and grade one children performed better in the C-CVC condition than in the CCV-C condition (41 vs. 28% correct), $F(1,279) = 29.51$, $p < .001$, and (64 vs. 59%), $F(1,279) = 4.39$, $p < .05$, respectively. However, these conditions did not differ for the children in grade 2 (69.5 vs. 68.9%), $F(1,279) < 1$. This pattern is shown in Figure 2. Thus, the condition in which the rime was segmented was more difficult for the younger children than the condition in which the onset was segmented, a pattern that disappeared by grade 2.

Insert Figure 2 about here

In addition, post-hoc comparisons of the patterns of performance across grades indicated that grade 2 children performed better than grade 1 children in all conditions, except in the C-CVC condition, $Fs(1,372) > 6.98$, $ps < .001$, where the trend was in the predicted direction, $F(1,372) = 2.63$ $p > .10$. Grade 1 children outperformed the kindergarten children in all conditions, $Fs(1,372) > 47.26$, $ps < .001$.

As expected, speed affected performance, $F(1,93) = 79.21$, $p < .001$. Overall, the slow rate of presentation proved to be more difficult (50%) than the fast rate (55%). In addition, there was a significant grade x speed interaction, $F(2,93) = 4.15$, $p < .019$. At each grade, performance was slightly better in the fast condition compared to the slow condition: 70.7 vs. 65.3% for the grade 2 children, $F(1,93) = 17.02$, $p < .001$, 59.4 vs. 56.7% for the grade 1 children, $F(1,93) = 4.25$, $p < .05$, and 34.9 vs. 28.6% for the kindergarteners, $F(1,93) = 23.16$, $p < .001$. However, as indicated by the means, the interaction occurred because improvement in performance in the fast presentation condition was not as great for the grade 1 children as it was for the others. The reasons for this attenuated effect are not apparent.

There was also a significant segmentation x speed interaction, $F(3,279) = 5.14$ $p < .002$. A difference in favour of the fast presentation condition was observed in the CC-VC condition, 72.1 vs. 66.7 %, $F(1,93) = 14.59$, $p < .001$, the C-CVC condition, 61.7 vs. 53.6%, $F(1,93) = 28.59$, $p < .001$, and the C-C-V-C condition, 33.2 vs. 29.4%, $F(1,93) = 9.33$, $p < .001$, but not in the CCV-C condition (52.9 vs. 51.2%), $F(1,93) = 2.33$, $p > .1$. It would appear that the unique difficulty associated with the CCV-C condition -- that presentation of the

CCV unit may initiate lexical lookup -- eliminated the advantage provided by the faster rate of presentation. There was no three-way interaction, $F(6, 279) = 1.71$, $p < .119$.

Post-experimental tasks. A response on any of these tasks was scored as correct if the child pronounced the segment that was visually presented. If children did not produce the entire stimulus or indicated that they did not know the item, the item was scored as incorrect. A separate analysis of variance was performed on the mean number correct for each task, with grade as the between subjects variable. The mean percentage correct for each task is shown in Table 1.

Insert Table 1 about here

Main effects of grade were found in all three spelling-sound correspondence tasks: $F(2,93) = 17.67$, $p < .001$, for the consonant, $F(2,93) = 77.77$, $p < .001$, for the consonant cluster, and $F(2,93) = 80.86$, $p < .001$, for the rime task, respectively. Except in the consonant task, children in grade 2 performed better than children in grade 1, $F(1,93)$s > 4.12, ps $< .05$., who in turn performed better than children in kindergarten, $F(1,93)$s > 40.30, ps $< .001$. In the consonant task, however, grade 2 children performed only marginally better than children in grade 1, $F(1,93) = 1.90$, $p > .10$.

There was an effect of grade on the word reading task, $F(2,93) = 65.43$, $p < .001$ (see Table 1). Again, grade 2 children performed better than grade 1 children, $F(1,93) = 74.28$, $p < .001$, who in turn performed better than kindergarten children, $F(1,93) = 56.35$, $p < .001$. This result was most likely due to variation in the amount of reading instruction and other literacy experiences these children may have had.

The spelling-sound correspondence tasks tapped children's ability to associate graphemes with an appropriate unit of speech, an operation children must perform before blending. Children in grade 2 and grade 1 performed very well on the consonant identification task, but the kindergarten children also performed at a surprisingly high level. The kindergarten children had clearly mastered many individual consonant sounds, but their performance dropped substantially in the consonant cluster and the rime tasks, where they had to identify and produce the sounds of two phonemes together. Children in grade 1 had less difficulty on these tasks than kindergarteners, and grade 2 children performed the best of all. Recall that in the synthesis task, all children performed better when they heard clusters of phonemes rather than individual phonemes, with the onset division easier than the rime. Ironically, the reverse situation would seem to exist here.

Because children's ability to associate graphemes with an appropriate unit of speech is a precursor to blending, this pattern suggests that kindergarteners' ability to associate letters with individual phonemes is a kind of inert knowledge that they are unable to use effectively to blend words. This finding has important implications. Because the children did so well on the segmentation task in the CC-VC (onset-rime) condition, it might be suggested that children be trained to use an onset-rime blending strategy by first teaching them associations between visually presented letters and onset/rime units. However, the findings for single phonemes might lead one to be sceptical of such a suggestion, because performance on the consonant task did not predict performance on the segmentation task. Alternatively, perhaps this lack of correlation is due to the particular unnaturalness of phonemes as units for preliterate children.

Correlations. For each grade, correlations were computed between all conditions of the synthesis task and all post-experimental tasks. Since lists were counterbalanced over conditions, these results must be interpreted with caution. However, the overall pattern of correlations between the conditions of the synthesis task and the word reading task is of interest. The pattern is best illustrated by examining the correlations significant at the .01 level. These correlations are shown in Table 2.

Many positive correlations were found between the synthesis task conditions and the word reading task, particularly for the kindergarten children.

For the grade 1 children, there were significant positive correlations between both the slow and the fast CCV-C conditions and the word reading task. There were no significant correlations for the grade 2 children. Across grades, there were few significant correlations between conditions of the synthesis task and the other post-experimental tasks and the patterns were not of interest.

Insert Table 2 about here

Considering just correlations among the post-experimental tasks, performance by the kindergarten children on the consonant cluster and the rime tasks were correlated, $r = .78$, $p < .001$ as were the consonant cluster and the word reading task, $r = .52$, $p < .001$. For the grade 1 children, there was a positive correlation between performance on the rime task and performance on the word reading task, $r = .45$, $p < .01$. There were no significant correlations among the post-experimental tasks for the grade 2 children. I have no particular account of these last correlations, and so will not discuss them further.

In kindergarten, it appears that greater skill at blending in the segmentation conditions and at both speeds is associated with identifying a greater number of visually presented words. In grade 1, there is some relationship between ability to deal with factors uniquely associated with the CCV-C conditions and a greater sight vocabulary. One possibility is that some children in this grade can inhibit a lexical look-up before sufficient information is available, and this skill is associated with a larger sight vocabulary. By grade 2, children may have acquired a broad base of knowledge and alternate strategies such that factors associated with performance on the synthesis task are no longer positively correlated with their ability to read single syllable words. Of course, these suggestions are highly speculative, but an explanation of this form would be required to account for this pattern of correlations.

General Discussion

The purpose of the present experiment was to investigate children's subsyllabic knowledge and its development. I studied the effects of subsyllabic segmentation and speed of presentation on the ability of young children to synthesize words from auditorily-presented segments. I also investigated children's knowledge of the associations between visually-presented subsyllabic word segments and words. Not surprisingly, evidence was found to support a developmental trend: Performance improved with each grade studied on these tasks.

More interesting was the effect of segmentation on children's ability to perform the synthesis task. Children in all grades performed better on the CC-VC condition compared to the C-CVC and CCV-C conditions. For example, although kindergarten children performed less well in all conditions, they performed best with the words segmented into onset and rime. Because of this CC-VC division advantage, an inference can be made that onset and rime are psychologically real units. It appears from the results that even preliterate children are aware of onset and rime, and for all grades these units are easier to manipulate than segments that violate either the onset or the rime. These results are consistent with conclusions that have been drawn by other researchers in this area (e.g., Kirtley et al., 1989: Treiman, 1985). These researchers have also demonstrated the difficulty that preliterate children have with subsyllabic units smaller than onset and rime.

Performance in the C-C-V-C condition was the worst for all grades. Kindergarteners did especially poorly in this condition. I propose that there may be at least three reasons for this result: First, children had difficulty with conditions with either the onset or rime segmented, so problems in the C-C-V-C condition are not surprising, because both onset and rime were divided. Also, children in the C-C-V-C condition had to blend four individually-presented phonemes. This was difficult for even the oldest children, because maintaining four individual phonemes before blending them together increases working memory load to a disruptive level. Finally, because of the manner of stimulus production and presentation, transitions between each of the phonemes did not have the coarticulation properties found in normal spoken language. The fact that the C-C-V-C condition had three such transitions may have contributed to the difficulty of this condition.

Although overall developmental patterns were similar in each grade, differences were found between the C-CVC and the CCV-C conditions across grades. The C-CVC condition was less difficult than the CCV-C condition for kindergarten and grade 1 children, meaning that onset division was not as disruptive as rime division. By grade 2, however, this difference disappeared. Children in the earlier grades may be aware of the onset and rime division, but by grade 2 may also become knowledgeable of a lower tier below the onset and rime. Children in the later grades may be aware of the separability of the rime into its constituent parts--the nucleus and the coda.

This developmental trend may also be explained by a combination of two factors: the differing amount of information in the first presented segment and the formation of candidate word look-up and rehearsal strategies. For the youngest children, the C-CVC condition may have been easier because it was only necessary to maintain one phoneme (part of the onset) in working memory while waiting for the next segment. However, in the CCV-C condition, the first segment (the onset plus the nucleus of the rime) may have been more difficult to maintain because it contained parts of two units and three individual phonemes. In the C-CVC condition, receipt of one phoneme may not have been enough to initiate look-up, but the initial segment in the CCV-C condition may have initiated look-up. This look-up may have interfered with maintenance of the initially-presented segment which is already a greater processing load on working memory. By grade

2, look-up strategies may no longer disturb maintenance of the larger initially-presented segment, thus resulting in improved performance.

Overall, I found an effect of speed, such that performance on segments presented at a faster rate was better compared to a slower rate. In all grades, performance was better in those conditions in which the segments were presented at a fast rate. This is consistent with previous research that has used a speed manipulation to investigate processing load on working memory (Torgesen et al., 1989). Fast presentation was less difficult for the children because they did not have to hold segments in working memory as long before they received all of the segments. This lessened processing load and afforded them more resources to put toward synthesizing these segments. There was a fast condition advantage for all segmentation conditions except the CCV-C condition. I propose that the unique difficulties associated with this task may have eliminated the advantage provided by the faster rate of presentation.

The post-experimental tasks were designed to investigate children's knowledge of visually-presented subsyllabic word segments and words. On these tasks, children were to associate visually-presented graphemes with an appropriate unit of speech. Although the grade 1 and grade 2 children did better than the kindergartners, all children performed best on the individual consonant task. Yet all children performed the worst on the C-C-V-C condition of the synthesis task, so children were aware of the sounds that correspond to individual graphemes but had difficulty with a synthesis task requiring them to blend individual phonemes.

On the other three tasks, the kindergarteners' performance was poor. Kindergarten children could produce individual phonemes, but could not produce these same phonemes when they were presented with others. For older children, the order of difficulty for the remaining tasks from hardest to easiest was as follows: consonant cluster, word, and rime. Performance on the rime task may have been facilitated because the children identified the rimes as pronounceable "word-like" units. The reason for difficulty on the consonant cluster task is less clear. Many children inserted a vowel between the two consonants of the cluster, and perhaps this indicates the difficulty the children had with identifying two graphemes together without a vowel. Although children had some difficulty recognizing and producing onsets and rimes, they could use these units successfully when they were presented auditorily. These discrepancies are important because they clearly show the importance of sound segmentation ability as a precursor to the ability to recognize the equivalent printed segment.

Correlations were found between conditions of the synthesis task and the post-experimental tasks. For kindergarten children, there were several positive correlations between the conditions of the synthesis task and the word reading task. These positive correlations suggest that for the kindergarten children, greater skill at blending in conditions of the synthesis task was associated with identifying a greater number of visually-presented words. This may be due to variability in the kindergarten children's prior phonological knowledge and their ability to read words, such that the few children in this grade that could read could also manipulate subsyllabic segments. For grade 1 children, the ability to synthesize units with rime violation was correlated with word reading. One possibility previously discussed is that some children in this grade can inhibit a lexical look-up before sufficient information is available, or hold two segments in memory more readily, and this skill is associated with a larger sight vocabulary. By grade 2, performance on any conditions of the synthesis task is no longer positively correlated with ability to read single syllable words. By grade 2, children may have a variety of strategies to use, and their ability to read words may be related to many factors other than their ability to manipulate subsyllabic units.

Evidence for the psychological reality of the onset and rime division in English is clearly shown in the results of this study. As discussed, even kindergarten children seem to exhibit awareness of this division, and all children performed best on conditions using this type of segmentation. Researchers must account for the salience of these linguistic divisions, because verifying the existence of these units has important implications for models of reading acquisition and reading instruction.

According to models of word recognition in children like those proposed by Frith (1985) and Marsh, Friedman, Welch, and Desberg (1981), reading progresses through three stages. These authors propose a logographic stage which is characterized by the recognition of a small number of whole words. The alphabetic stage is identified by the "sounding out" of small words phoneme by phoneme. A morphophonemic stage is proposed in which word meanings and stems can be used to identify words. Seigler (1986) has proposed an alternate framework for understanding the development of word recognition skills. Rather than passing through a series of stages in which only one strategy is employed, children may have access to a variety of back-up strategies, and be differentially competent at executing them different times, so that the probability of using a given strategy could change with age and skill. Within this framework, "stages" are simply a product of observing frequently utilized strategies at a given age and level of skill. The default strategy is always to retrieve a word directly.

These models of the development of reading skill must take into account the evidence that some aspects of phonological awareness are precursors to reading and some are products of reading. For example, it seems clear that awareness of subsyllabic units at the level of onset and rime occurs before the development of reading skill. Models of the development of word recognition skills should reflect this new understanding. If, for example, it could be shown that children could recognize words by using an onset-rime blending strategy, it may be necessary to revise the alphabetic stage proposed by Frith (1985) and Marsh et al. (1981) by adding an onset-rime substage.

Accounting for this new understanding within the framework proposed by Seigler (1986) requires consideration of both the changing nature of word representations in the lexicon and the emergence of back-up strategies. Consider the situation facing the child in the earliest phases of learning to read English. The child learning to read English may have lexical entries with a whole-word or perhaps a syllabic phonological representation, but it could be that no subunits below these levels are represented phonologically. The few visually-represented words ("sight words") the young child is able to retrieve are connected to this rather high level of phonological representation. As exposure to speech and print increases with age and the child becomes better able to use back-up strategies, existing phonological representations may be enriched by redundant phonological information at the subsyllabic and phonemic levels (Perfetti, 1986) and new entries may be acquired. The task for developmental psychologists interested in early word recognition becomes one of attempting to characterize the changing nature of the lexicon, identifying the emergence of back-up strategies, and examining the links between these phenomena.

Given the results of this study and others supporting the facility that young children have manipulating onset and rime units in auditory tasks, one interesting question is whether children can be instructed to use a strategy that involves identifying these larger subsyllabic units in print. This approach may prove to be effective in enriching and strengthening the connections between phonological and visual representations in the lexicon. However, instructional research will be needed in order to determine the validity of this suggestion.

Additional research like the type presented in this paper, using carefully controlled and presented stimuli, will help extend knowledge about the development of phonological awareness. This kind of research will further inform models of reading acquisition and instruction. By testing older children and adults, and using other stimuli types such as three-consonant onset clusters, multiple consonant rimes, and multisyllabic words, it will be possible to further characterize linguistic divisions and their contribution to the development of reading skill.

Table 1

Mean Percentage Correct on Posttests by Grade

GRADE	Consonant	Onset Cluster	Rime	Word
K	71	7	8	7
1	94	34	44	34
2	99	50	75	65

Table 2

Correlations between Synthesis Task Conditions and the Word Reading Posttest

GRADE	CC-VC Fast	CC-VC Slow	C-CVC Fast	C-CVC Slow	CCV-C Fast	CCV-C Slow	C-C-V-C Fast	C-C-V-C Slow
K	.67**	.48*	.55**	.58**	.44*	.39	.67**	.56**
1	-.08	-.02	.18	.15	.42*	.45*	.22	.36
2	.02	.20	-.01	.02	-.02	-.01	.19	.13

* $p < .01$, 1-tailed

** $p < .001$, 1-tailed

Figure 1
Subsyllabic Division of the Word *stop*

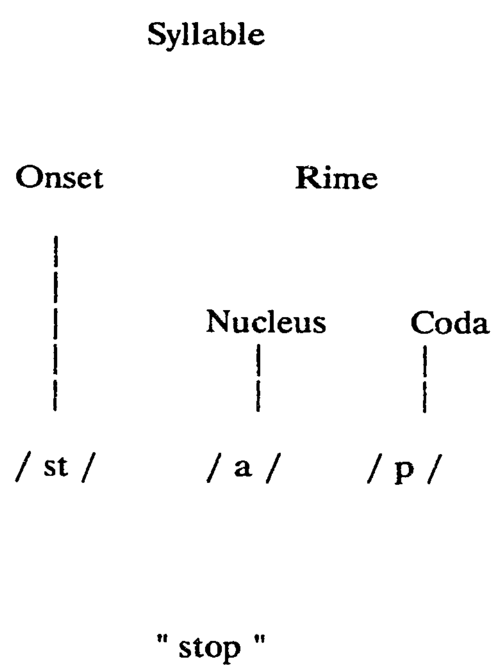
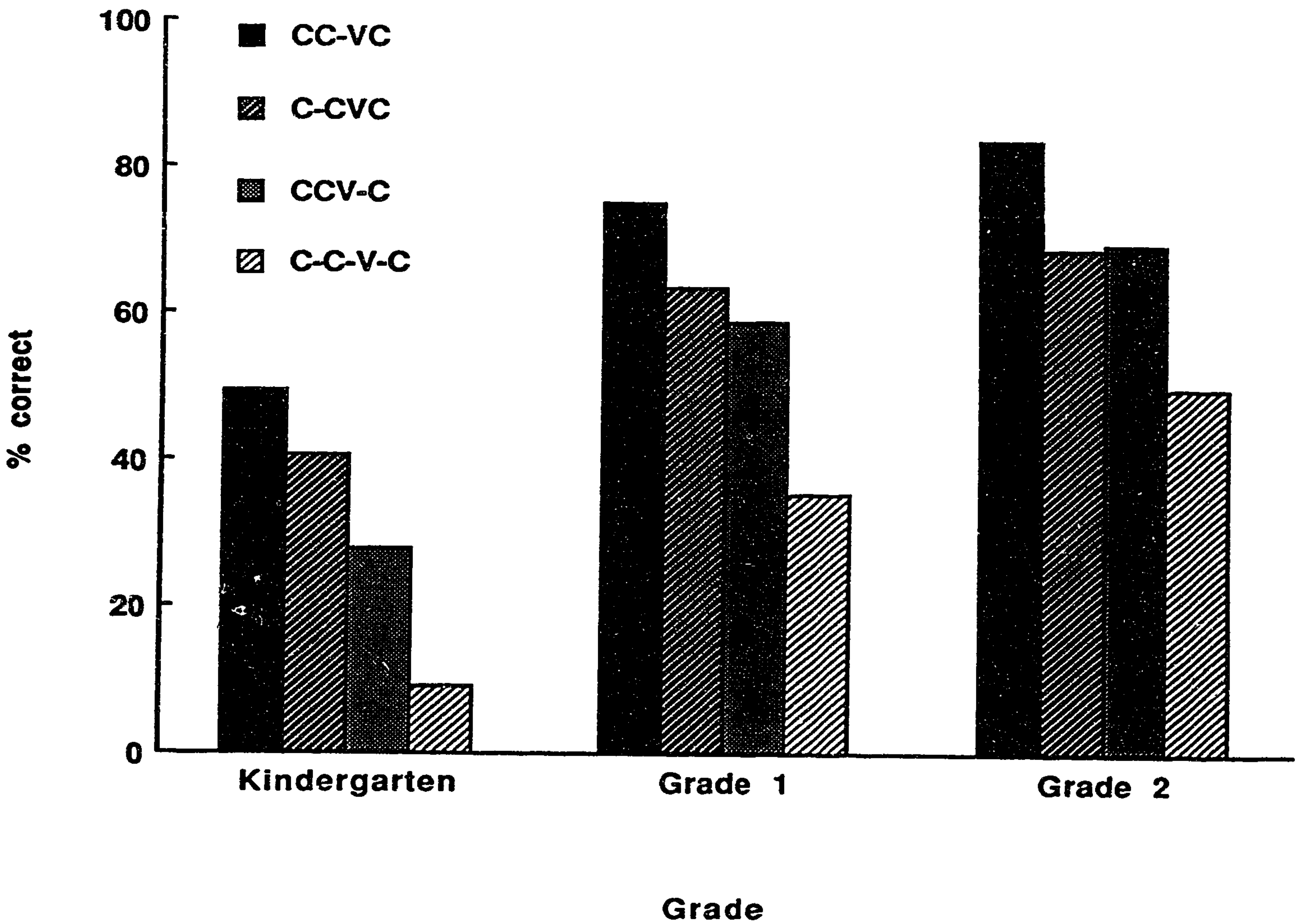


Figure 2

Percentage Correct on Segmentation Conditions of the Synthesis Task

(Collapsed across Speed of Presentation) by Grade



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Appendix A

Words Used in Synthesis Task and Word Frequency Means by List

List 1
1. blur
2. drum*
3. fret
4. prop
5. snug
6. span*
7. spur*
8. stem mean = 59.8

List 2
1. blob
2. drag*
3. flop
4. plus
5. prim*
6. skip
7. slam
8. sled* mean = 59.4

List 3
1. crop
2. flip*
3. gram
4. grin
5. plot*
6. plum
7. prom
8. slab* mean = 59.5

List 5
1. club
2. grit
3. slop
4. snip*
5. stab*
6. stir
7. swap
8. trim* mean = 57.8

List 6
1. clam
2. drug*
3. grab
4. slim
5. slug*
6. snub
7. swam
8. twin* mean = 57.6

List 7
1. frog
2. grid*
3. plod
4. skim*
5. slip*
6. sped
7. swan
8. swum mean = 58.6

<u>List 4</u>
1. clan
2. drab
3. flap*
4. grim*
5. smog
6. swim
7. trot*
8. twig*

mean = 59.6

<u>List 8</u>
1. crab
2. flag*
3. plop
4. plug*
5. slum
6. spun*
7. swat
8. trek

mean = 57.1

* three-letter words when the first letter is removed.

Appendix B

Stimuli for Posttests

1. Spelling-Sound Correspondence

   A. Single Consonants Task

      L, M, D, F, K, G, N, W, R, C, T, S, B, P

   B. Consonant Clusters Task

      DR, SN, SM, FL, SK, GR, SL, TR, SW, PL, FR, ST, CL, TW, SP, BL, PR, CR

   C. Rimes

      IG, ID, OT, OB, UG, AP, OG, IP, AB, EK, UR, OP, IM, ET, AG, UB

2. Word Reading

1. BLOB
2. SNUG
3. SWAN
4. GRIM
5. SLIP
6. GRAM
7. PLOD
8. CLUB
9. SWUM
10. STIR
11. STEM
12. PLUG
13. DRAG
14. SWAP
15. PLOP
16. FLAP