RUNNING HEAD: ADULTS' KNOWLEDGE OF PHONEME–LETTER RELATIONSHIPS

Adults' Knowledge of Phoneme–Letter Relationships is Phonology-based and Flexible

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Abstract

Despite the importance of phonemic awareness in beginning literacy, several studies have demonstrated that adults, including teacher trainees, have surprisingly poor phonemic skills. Three experiments investigated whether adults' responses in phonemic awareness and spelling segmentation tasks are based on units larger than single letters and phonemes. Responses often involved large units, and they were influenced by sonority and syllable structure. Participants who performed a phoneme counting task before a spelling segmentation task produced significantly more phoneme-based responses and fewer onset–rime responses than participants who first counted words in sentences. This training effect highlights the flexibility of adults' strategies. Although adults are capable of phoneme-based processing, they sometimes fail to use it.

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One of the best documented findings in the study of literacy development is the importance of phonological awareness, particularly phonemic awareness, in the learning of alphabetic writing systems (e.g., Bradley & Bryant, 1983; Caravolas, Hulme, & Snowling, 2001). Beginning readers often have problems conceptualizing words as sequences of phonemes (e.g., Liberman, Shankweiler, Fischer, & Carter, 1974), and illiterate adults and readers of nonalphabetic writing systems also perform poorly in phonemic awareness tasks (e.g., Morais, Cary, Alegria, & Bertelson, 1979; Read, Zhang, Nie, & Ding, 1986). Because a degree of phonemic awareness appears necessary for the acquisition of alphabetic literacy, and because learning to read and spell in turn improves phonemic awareness, skilled readers have been assumed to possess good phonemic skills. However, several studies have revealed that adults do not always perform well in tasks of phonemic knowledge (e.g., Scarborough, Ehri, Olson, & Fowler, 1998; Scholes, 1993). Some of these studies have tested teacher trainees (e.g., Mather, Bos, & Babur, 2001; Moats, 1994; Serrano, Defior, & Martos, 2003), and their poor performance is especially worrisome. If literacy teachers are to foster children's phonemic skills, as research (e.g., Bryant, MacLean, Bradley, & Crossland, 1990; Hatcher, Hulme & Ellis, 1994) suggests that they should, then the results suggest that teachers may not be as phonemically aware as they should be in order to teach and evaluate young children.

If adults do not always use phonemes as their response units in phonemic awareness tasks, what do they do instead? Some researchers have claimed that adults often respond to oral phonemic awareness tasks on the basis of letters. Ehri (1985, p. 342) suggested that "the visual forms of words acquired from reading experiences serve to shape learner's conceptualizations of the phoneme segments in those words." Thus the spelling of a word could increase the salience of one phoneme or depress the prominence of another. Studies using several different tasks and participant populations support the notion of letter-based responding. The teacher trainees tested by Moats (1994) made a number of errors that appeared to reflect use of letters rather than phonemes. For example, participants probably counted two phonemes instead of three for *ox* because this word is spelled with two letters. Letter-based responses were also found by Ehri and Wilce (1980), who reported that fourth graders more often detected a /t/ in words such as *pitch* and *catch*, which include a *t* in their spellings, than in words such as *rich* or *much*; and by Ventura, Kolinsky, Brito-Mendes, and Morais (2001), for Portuguese speakers.

Adults' errors in phonemic awareness tasks are not always explained by use of letters, however. Sometimes adults use units that are larger than single phonemes. Scarborough et al. (1998) reported that eighth graders' errors in phoneme deletion and counting tasks almost always consisted of removing a portion larger than a single phoneme and undercounting phonemes. In a task in which participants had to underline the letters or letter groups that represented individual "sounds" in written words, Scarborough and colleagues found that adults did not systematically use either a letter- or a phoneme-based strategy. Rather, participants often marked as a unit letters that represented two or more phonemes. These responses appeared to respect such linguistic structures as onsets (initial consonant clusters) and rimes (vowel + final consonant units). Connelly (2002), who administered a similar task to university students, found that a group that received ten minutes of training on phoneme–grapheme correspondences beforehand made significantly more phonemic responses than an untrained control group, although neither group was close to ceiling. This result suggests that, although adults often prefer to use units larger than single phonemes and single letters, their strategies are flexible.

The research to date suggests that adults sometimes use units larger than single phonemes when linking sounds to spellings, but it has not systematically examined the linguistic factors that might explain these large-unit responses. At least two types of phonological attributes could be influential. The first is *sonority*, which refers to the loudness or vowel likeness of phonemes. Vowels are the most sonorant phonemes, followed in descending order by liquids (/r/, /l/), nasals

(/m/, n/, /ŋ/), and obstruents (fricatives, stop consonants). (See International Phonetic Association, 1999, for a key to the phonemic notation.) Several researchers (e.g., Stemberger, 1983; Treiman, 1984) have suggested that postvocalic liquids, such as the /l/ of *milk*, are linked with the vowel of the syllable. An obstruent, such as the /f/ of *gift*, it is more strongly bound to the following consonant. Thus, because of the way in which sonority organizes the syllable, a final consonant cluster is most likely to be processed as a unit when its first consonant is an obstruent. Postvocalic nasals are intermediate in their affinity with the phonemes preceding and following them. The studies mentioned above dealt with spoken words, however, and they do not answer our questions about adults' knowledge of phonological units that correspond to spellings. A second phonological factor that could contribute to adults' large-unit responses involves the names of letters. People may be especially likely to treat as units phonemes such as /ɛ/ and /l/ that make up the name of a letter. Supporting this view, Treiman and Cassar (1997) found that adults were more likely to judge that a two-phoneme sequence consisted of only one phoneme when that sequence was a letter name than when it was not.

In the first experiment reported here, we examined adults' performance in several tasks of phonemic knowledge, asking whether their responses were based on individual phonemes, individual letters, or larger units. One task we used was a spelling segmentation task modeled after that of Scarborough et al. (1998) and Connelly (2002). This task investigated adults' understanding of the links between the letters in printed words and the phonemes to which they correspond. We used monosyllabic words that varied in the sonority of the pre- and postvocalic consonants and in whether they contained letter-name segments. We hypothesized that liquids and nasals would be grouped with preceding vowels more often than obstruents and that letter-name sequences such as /ɛl/ would sometimes be treated as units. Such results would suggest that adults do not always conceive of letters in printed words as representing individual phonemes. They group phonemes into larger units in ways that are systematically influenced by phonological factors. The participants in Experiment 1 also performed two oral phonemic awareness tasks—phoneme deletion and phoneme counting. The stimuli, which were spelled with initial and final digraphs (two-letter sequences that correspond to a single phoneme, such as *sh*), were designed to test the idea that adults' errors in phonemic awareness tasks are primarily based on use of letters. If so, all phonemes spelled with digraphs would often be treated as made up of two units. If phonology is important, however, the different phonological characteristics of the phonemes spelled by the digraphs may lead to different patterns of performance across digraphs.

EXPERIMENT 1

Method

Participants

Data were analyzed from 60 undergraduate students who were native English speakers and received course credit for participation. For this experiment and the following ones, we excluded students who had taken classes in linguistics or speech science or assisted in teaching young children to read or spell. We did this because we wanted to test our hypotheses on participants who had not been required to explicitly reflect on the relations between letters and phonemes. The participants in Experiment 1 attended a highly selective university (America's Best Colleges 2005) located in the Midwestern United States.

Tasks

Spelling Segmentation Task

Stimuli. The stimuli for this task appear in Appendix A. To test the effect of sonority, we used 24 words with CCVC (C = consonant, V = vowel) and 24 words with CVCC phonological structure. The interior consonant of the cluster—the second element of the initial cluster or the first element of the final cluster—varied in sonority (/r/, /l/, nasal, or obstruent). The exterior member of the consonant cluster was almost always an obstruent, and the vowels were short.

To test the effect of CV letter names, such as /bi/ or /pi/, we used 6 words with CVC phonological structure that had a consonant letter name at the beginning, such as *beat* (*b*) and *peel* (*p*). Six control words had the same phonological structure but did not contain a consonant letter name (e.g., *boat*, *pail*). In all these items, the vowels were spelled as digraphs. VC letter names were tested by including 18 CVCC words in which the medial VC was a letter name (/ɑr/, /ɛl/, or /ɛn/), 6 items for each letter name (e.g., *bark*, *belt*, *dent*). The control items for these were the CVCC items that were also used to test sonority and did not contain letter names, described above (e.g., *fork*, *kilt*, *punt*). We also had 32 filler items such as *quench*, *rhythm*, and *choir*. All the fillers had complex phoneme–letter relationships to prompt participants to consider responses other than one-to-one correspondences.

Two forms of the task were given in a between-subjects design. In the free response version, participants were asked to circle the letters or letter clusters corresponding to phonemes in any way they preferred. In the multiple choice version, participants saw four alternative responses for each item in which the spellings had been segmented in different ways: phonemic (e.g., [s] [i] [l] [k]); onset–rime (e.g., [s] [ilk], [cl] [ip]); cluster (e.g., [s] [i] [lk]); V + C or C + V (e.g., [s] [il] [k], [c] [li] [p]); and for the letter-name and control items additionally letter-name (e.g., [dea] [n]). The participants picked the response they thought best.

Procedure. In the free response version the participants heard the following instructions: "Beginning readers are taught to sound out the letters in written words and to write letters for the sounds in words. Please listen to the pronunciation of the following words and look at the letters. Determine which letter or group of letters corresponds to individual sounds in the words and circle them." For the multiple choice version, the instructions were the same, except that the last sentence was: "Determine which of the four options best shows the way in which individual sounds in each word correspond to its letters; circle your choice." The practice items were *dog*, *Phil*, and *moon*. The experimenter pointed out that in the first word each "sound" corresponded to a single letter, while in the second word /f/ was represented by *ph*. The participant was asked to respond to the last practice item and received corrective feedback if required. The experimenter read out the words one by one as the participant performed the task.

Phoneme Deletion Tasks

Stimuli. The initial deletion task included 60 items with CCVC spellings, 30 real words and 30 pseudowords. We used items whose spellings began with *sh*, *th*, and *ch*, 6 items for each digraph. The final deletion task had 60 items with CVCC spellings in which the final digraphs were *sh*, *th*, and *ng*, 30 real words and 30 pseudowords. It was not possible to use the same digraphs for both initial and final versions of the task, since /tʃ/ is often spelled as *tch* rather than *ch* at the ends of words and /ŋ/ does not appear word initially. The control items for the digraphs were words with initial or final consonant clusters. Thus the words had similar spelling patterns, CVCC or CCVC, but for the digraph items the two adjacent consonants represented one phoneme, while for the cluster items they represented two phonemes. The interior consonants of the clusters were either sonorants or obstruents, and the exterior consonant was almost always an obstruent. We had 12 two- and three-phoneme filler words for both the initial and final deletion tasks. These stimuli appear in Appendix B.

Procedure. The participants were told that their task was to take off the first/last sound of the words that they heard. For example, deleting the first sound of *cat* produces /æt/. The experimenter demonstrated the procedure with three practice items (*cat*, *lap*, and *spin* for the initial phoneme deletion task; *sit*, *run*, and *gasp* for the final deletion task) and then asked the participant to try one practice item (*scale*, *must*) without help. It was pointed out that there were both real and made-up words and that deletion would sometimes produce a real word and sometimes not.

Phoneme Counting Task

The stimuli were the same as those for the phoneme deletion tasks, except that the fillers were one- and two-phoneme words (see Appendix B). The participants were asked to count the sounds in the words, and the experimenter demonstrated what she meant by a "sound" by explaining that /s/ had one sound, *up* two (/ʌ/ and /p/), *cat* three (/k/, /æ/, and /t/), and *mist* four (/m/, /ɪ/, /s/, and /t/). The experimenter let the participant determine the number of sounds in the last item him/herself.

Overall Procedure

The experiment started with the first half of the phoneme counting task, after which the participants pronounced some words as a filler task. The second half of the phoneme counting task followed and the spelling segmentation task was next. The initial and final phoneme deletion tasks were then given, in counterbalanced order. The items were pronounced by a native speaker of American English.

Results

Spelling Segmentation

Scoring

We classified the participants' responses into six categories: (1) phonemic ([c] [l] [i] [p]); (2) consonant + vowel ([c] [li] [p]); (3) vowel + consonant ([m] [il] [k]); (4) cluster ([cl] [i] [p], [m] [i] [lk]); (5) onset–rime ([cl] [ip], [m] [ilk]); (6) letter name ([pea] [k]). Response type 2 only applied to CCVC items, response type 3 only to CVCC items and response type 6 only to CVC items; the other response categories applied to all types of items. Table 1 shows the mean proportion of responses of each type to the various types of stimuli, as well as the mean proportion of responses of each type pooled across stimuli. The results are pooled over the free response and multiple choice conditions because preliminary analyses showed no significant effects as a function of condition.

Please insert Table 1 about here.

Effect of Consonant Sonority

First we examined whether the sonority of the interior consonant of the cluster affected participants' tendency to group the corresponding consonant letter with the adjacent vowel letter or the other consonant letter of the cluster. The relevant types of responses for this analysis were consonant cluster, C + V, V + C, and onset–rime groupings. We ran a repeated-measures analysis of variance (ANOVA) on cluster responses using the within-subject factors of structure (CCVC, CVCC) and sonority (/r/, /l/, nasal, obstruent). In this and other analyses, we used Huynh-Feldt corrections when the assumption of sphericity was violated. There was a significant main effect of structure ($F(1,59) = 9.01$, $p = .004$), such that participants were more likely to give cluster responses for CCVC words than CVCC words. Also significant was the effect of sonority ($F(1,59) = 3.26$, $p = .025$). The interaction between structure and sonority failed to reach significance ($p = .12$), although sonority effects tended to be stronger for items with final clusters. Post hoc *t* tests revealed that the obstruent items produced significantly more cluster responses than the /l/, /r/ or nasal items, which did not differ reliably.

The groupings involving a consonant and a vowel were analyzed in a repeated-measures ANOVA, where grouping type (V + C, C + V) and sonority (/r/, /l/, nasal, obstruent) were within-subjects factors. There were significant main effects of grouping type ($F(1,59) = 12.27$, $p = .001$) and sonority ($F(2.4, 145.9) = 5.45$, $p = .003$), as well as an interaction ($F(2.4, 142.3) = 9.37$, $p < .001$). Post-hoc tests revealed that sonority did not significantly affect the rates of C + V groupings. However, V + C groupings were significantly more common when the postvocalic consonant was /r/ or /l/ than when it was a nasal or an obstruent. The difference between /r/ and /l/ was not significant, nor was the difference between nasals and obstruents.

The rate of onset–rime responses was very low, 1%, and no effects of sonority were found.

Effect of Letter Names

To assess the effect of VC letter-name segments, we counted the number of V + C responses in the letter-name items (e.g., *belt*) and the control items with the similar CVCC phonemic structure (e.g., *silk*). The data were analyzed with a repeated-measures ANOVA with condition (letter-name, control) and sonority (/r/, /l/, nasal) as within-subjects factors. There were significant main effects of condition ($F(1,59) = 4.85$, $p = .032$) and sonority ($F(1.8, 103.7) = 9.27$, $p < .001$), but no interaction. Participants gave reliably more V + C responses to letter-name items than control items. Post hoc tests demonstrated sonority effects similar to those in the previous analysis. That is, /r/ and /l/ items did not significantly differ from each other, and both produced significantly more V + C responses than nasal items. C + V + V responses in CVC words with CVVC spellings were very infrequent ($M = .01$ and 0.0 for letter name and control items, respectively), showing that the adults hardly ever considered the CV units to represent one sound. Thus, letter-name responses sometimes occurred when the letter name was part of the rime but they rarely occurred in such a way as to violate the onset–rime boundary.

Phoneme Deletion Task

Scoring

The responses were classified into three categories: letter-by-letter (deleting one letter of a digraph instead of a phoneme from the digraph CVC words, as in *t* from *thin* or *s* from *ship*); cluster (deleting a whole consonant cluster from CCVC/CVCC words, as in *sn* from *snob* or *nt* from *punt*), and phonemic (correctly deleting a phoneme from the word, as in *sh* from *ship* or *ng* from *sing*). A few responses were based on units larger than consonant clusters, but these were too infrequent for statistical analysis. Preliminary analyses revealed no significant differences between the real and pseudoword items, and so these conditions were pooled in the following analyses.

Letter-by-letter Responses

One question was whether the rate of letter-by-letter responses was uniform across the different types of digraphs, which would indicate the use of letters as response units, or whether different digraphs produced different rates of letter-by-letter responses. Table 2 shows the mean proportions of letter-by-letter responses. The data were analyzed by a repeated-measures ANOVA with digraph type (*sh*, *th*, *ch*/*ng*) as the within-subjects factor. Because the initial and final conditions did not use the same digraphs, we analyzed the two conditions separately. We found no significant differences among the initial digraphs but significant differences among the final digraphs ($F(2,118) = 113.60$, $p < .001$). Post hoc tests showed that final *ng* items produced significantly more letter-by-letter responses than either of the other final digraphs, and that final *sh* digraphs produced significantly more letter-by-letter responses than final *th* digraphs. Because the digraphs are all spelled with two letters, the results suggest that the phonological properties of digraphs affect adults' responses. Adults consider *ng* to consist of two phonemes much more often than the other digraphs.

Please insert Table 2 about here

Cluster Responses

Table 2 also shows data on cluster responses, in which participants deleted both consonants of a cluster instead of just the last phoneme. Given the results of earlier studies and of the spelling segmentation task, we anticipated that the cluster response rate would depend on the type of consonants in the cluster. Thus, we ran an ANOVA with position (initial, final) and sonority of the interior consonant of the cluster (sonorant, obstruent) as within-subjects factors. This showed significant main effects of position ($F(1,59) = 4.11$, $p = .047$) and sonority ($F(1,59) = 6.81$, $p = .011$), but no interaction. Deletions of whole clusters were more common for initial than final clusters, and more common when the interior consonant was an obstruent than when it was a sonorant. Thus, initial clusters, which make up the onset of the syllable, tend to group together more than final clusters, and clusters of two obstruents seem to be particularly cohesive.

Phoneme Counting Task

Scoring

Based on the number of phonemes that the participants indicated each word to contain, we classified the responses as letter-by-letter or phonemic. For digraph words such as *ship*, a count of 4 was a letter-by-letter response, since participants presumably counted the phoneme spelled with a digraph as two segments. A count of 3 was a phonemic response, where participants counted the phoneme spelled with a digraph as a single unit. For cluster words such as *clan*, which consisted of 4 phonemes spelled with 4 letters, 4 was a phonemic response, as every letter of the word was counted as a single unit. A count of 3 was a cluster response, since two phonemes were counted as a unit. Virtually all responses that did not fall into the letter-by-letter category were phonemic and are therefore not reported separately. Table 3 shows the proportion of letter-by-letter responses for the different digraphs in the initial and final conditions.

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Letter-by-letter Responses

Our aim in the phoneme counting task was to determine whether digraphs differ in how often they prompted the counting of letters instead of phonemes. The means show a pattern very similar to the phoneme deletion task. The response rates in the initial condition resemble each other, while letter-by-letter responses in the final condition are much more common for *ng* than for the other digraphs. A repeated-measures ANOVA showed a main effect of initial phoneme type ($F(1.59, 109.5) = 3.67$, $p = .032$), and post-hoc tests showed that letter-by-letter responses were significantly but not substantially more frequent for *sh* than *th*. A similar analysis for the final condition revealed a main effect of phoneme type ($F(1.2, 68.9) = 88.63$, $p < .001$). Post hoc tests showed that, while there was no significant difference between final *th* and *sh*, participants counted *ng* as two phonemes significantly more often than either *sh* or *th*. As in the phoneme deletion task, then, *ng* behaves quite differently than other digraphs.

Discussion

One goal of this experiment was to examine adults' performance in the spelling segmentation task, asking how often participants responded on the basis of individual phonemes as opposed to larger units and whether their use of larger units was influenced by the phonological factors of sonority and letter names. A surprisingly high proportion of adults' responses involved units larger than single letters and single phonemes. Even though our participants were excellent readers and spellers, their responses were not always based on phonemes. Consistent with our hypotheses, the larger units that adults used were influenced by sonority and letter names. Specifically, participants tended to group sonorant consonants with the vowel of the syllable and obstruent consonants with other consonants. These results fit well with earlier findings on consonant sonority (Stemberger, 1983; Treiman, 1984), extending these findings to adults' judgments of phoneme–letter relationships. Moreover, adults tended to respect initial consonant clusters. These findings agree with the trends evident in the data of Scarborough et al. (1998) and show that adults' respect for onsets generalizes beyond the few one-syllable items in that study. However, the rate of actual onset–rime responses was only about 1% in the present study, suggesting that adults do not often process words in terms of whole onsets and rimes.

The results of the phoneme deletion and counting tasks provide further support for the importance of phonology. Responses in which a phoneme that was spelled with a digraph was counted as two units or in which participants only deleted one letter of a digraph occurred at different rates for different phonemes. By far the highest rates of letter-by-letter responses were seen for /ŋ/. If adults responded to these tasks purely on the basis of letters, all digraphs should have produced similar results. Reasons why /ŋ/ differed from other phonemes will be considered in the General Discussion.

Given the longstanding assumption that alphabetically literate adults are proficient with phonemes, the frequent use of larger units that was observed in this experiment is surprising. Our results suggest that these responses are systematic and governed by phonological factors; they are not random errors. One limitation of Experiment 1 is that the participants were students at a highly selective university who were likely to have high verbal skills. To determine whether the results generalize beyond this group, Experiment 2 tested students from several different universities that were chosen to obtain a larger range of language skills. Students completed a spelling segmentation task very similar to that of Experiment 1, allowing us to examine the effects of sonority and letter names with a broader population. We tested participants' language skills, specifically their vocabulary knowledge, and asked whether patterns of performance varied as a function of vocabulary.

EXPERIMENT 2

Method

Participants

The participants were from universities that differed widely in the selectivity of student admissions. Thirty-nine undergraduate students attended a highly selective university, the same one from which participants in Experiment 1 were drawn, and an additional 39 students attended less selective universities (America's Best Colleges 2005). All of the universities were located in the Midwestern United States. All students received course credit in exchange for their participation and were native English speakers. None of the participants in Experiment 2 had taken part in Experiment 1.

Tasks

Participants were tested in groups of about ten. They received a pack of testing materials and, after general instructions, worked at their own pace. The order of experimental materials was the following: background questionnaire, spelling segmentation (part 1), a filler task, spelling segmentation (part 2), and a vocabulary task.

Spelling Segmentation Task

The spelling segmentation task used the same stimuli as in Experiment 1, except for small changes to the fillers as noted in Appendix A. All participants received the multiple choice version of the spelling segmentation task, and the experimenter did not read the words aloud. The task was split into two parts, with a filler task in between, to reduce monotony. Both parts of the task included written instructions that were the same as those for the spelling segmentation task of Experiment 1. There were two versions in which the experimental items were in different orders.

Vocabulary Task

This task required participants to circle the real words from a list of both real and pseudowords. The list contained 40 fairly uncommon real words and 40 pseudowords and came with the following instructions: "Below you will see a list of 80 items. Some of the items on this list are real English words. Other items are not real words in the English language. You are to read the items and circle the ones that you know to be real words. Do not guess, but only circle those items that you know are real English words. You can circle an item if you are not sure of its exact meaning." We scored the vocabulary test by counting the number of real words circled and subtracting a point for each nonword incorrectly circled.

Results

We did a median split according to the participants' vocabulary scores, and Table 4 shows the results for each group. As before, we were interested in whether the sonority of the consonants that preceded or followed the vowel of the experimental items influenced participants' responses. The relevant response types for considering the effect of sonority were consonant cluster, C + V, V + C, and onset–rime groupings. To analyze the cluster responses, we used a repeated-measures ANOVA with the within-subject factors of structure (CCVC, CVCC) and sonority of the interior consonant of the cluster (/r/, /l/, nasal, obstruent) and the between-subjects factor of vocabulary skill (high, low). As in Experiment 1, we found significant main effects of structure ($F(1, 76) =$

25.92, $p < .001$) and sonority ($F(3, 228) = 4.48$, $p = .004$). There was also an interaction between these factors ($F(3, 228) = 6.71$, $p < .001$). Only a trend toward an interaction had been observed in Experiment 1, possibly because cluster responses were less common in that experiment. Post-hoc tests revealed that sonority had no effect on initial cluster responses, but postvocalic consonants were significantly more often grouped with the final consonant if they were obstruents than if they were /r/ or /l/. Postvocalic nasals did not differ reliably from postvocalic obstruents, although they were significantly more often grouped with the final consonant than liquids were. There were no effects of vocabulary skill on cluster responses.

Please insert Table 4 about here

A repeated-measures ANOVA with the within-subjects factors of grouping type (C + V, V + C) and sonority (/r/, /l/, nasal, obstruent) and the between-subjects factor of vocabulary (high, low) was used to analyze responses that grouped together a vowel and a consonant. There were significant main effects of grouping type ($F(1, 76) = 38.74$, $p < .001$) and sonority ($F(2.8, 211.3) = 3.83$, $p = .013$). Also, grouping type and sonority interacted ($F(3, 228) = 2.71$, $p = .046$). Although sonority had no effect on C + V responses in CCVC words, postvocalic consonants in CVCC words were significantly more often grouped with the vowel if they were liquids or nasals than if they were obstruents. There were no significant differences between liquids and nasals. Finally, participants with lower vocabulary scores were significantly more likely to give responses that grouped together a vowel and a consonant ($F(1, 76) = 4.441$, $p = .038$).

The rate of onset–rime responses was much higher than in Experiment 1: 18% – 33% depending on condition and participant group. To examine these responses, we did a repeated-measures ANOVA where position of cluster (initial, final) and sonority (/r/, /l/, nasal, obstruent) were the within-subjects factors and vocabulary (high, low) was the between-subjects factor. A significant main effect of position emerged ($F(1, 76) = 8.69$, $p = .004$), as words with initial consonant clusters gave rise to more onset–rime responses than words with final clusters. This interacted with vocabulary skill ($F(1, 76) = 6.30$, $p = .014$), and post-hoc tests demonstrated that participants with lower vocabularies were more likely to give onset-rime responses for words with initial consonant clusters.

V + C responses were not significantly more common for VC letter-name items than control items, unlike in Experiment 1. However, such responses were affected by students' vocabulary scores, being more common among those with lower vocabularies, and by sonority. Confirming these observations, repeated-measures ANOVA with condition (letter name, control) and sonority (/r/, /l/, nasal) as the within-subjects factors and the between-subjects factor of vocabulary (high, low) found significant main effects of sonority ($F(2, 152) = 5.35$, $p = .006$) and vocabulary ($F(1, 76) = 5.24$, $p = .025$). We also examined the number of C + V + V responses in the CVC letter name words with CVVC spellings. Although responses grouping the initial consonant letter and the following two vowel letters were slightly more frequent when they made up a letter name than when they did not, the difference was not significant for either participant group.

Discussion

Experiment 2 was designed to extend the spelling segmentation results of Experiment 1 to a student population with a broader range of language skills, measured here as vocabulary knowledge. We asked whether responses were affected by sonority and letter names, as in Experiment 1, and whether groups of students who differed in their vocabulary skills showed different patterns of performance. The sonority effects found in Experiment 2 replicated those of Experiment 1. However, the letter-name effect found in Experiment 1 did not replicate. The linguistic variable of sonority affected participants with higher and lower vocabulary scores in largely similar ways. Overall, however, students with smaller vocabularies were more likely to treat letters corresponding to several phonemes as units in the spelling segmentation task.

The group with larger vocabularies included mostly students from the highly selective university, but some students from the less selective universities as well. Nor was the low vocabulary group restricted to students from the less selective universities. When the analyses were repeated splitting the participants by the type of university they attended (highly selective vs. less selective), the only difference was that that students from selective universities were slightly but significantly less likely to use consonant + vowel groupings. Thus, the differences seen here appear to reflect the students' vocabulary skills more so than the type of university they attended. Because we did not test linguistic abilities other than vocabulary, we can draw no conclusions about which other linguistic skills may be related to performance in these tasks. No previous studies have reported differences in spelling segmentation performance as a function of linguistic skill, and one goal of Experiment 3 was to replicate this new and potentially important finding.

Unexpectedly, there was a striking difference between Experiments 1 and 2 in the rates of phonemic responses relative to large-unit responses. In Experiment 1, 80% of the responses for the CVCC and CCVC items were based on phonemes, while in Experiment 2 the overall rate was only 48%. As far as large-unit responses are concerned, onset–rime responses constituted only 1% of the responses in Experiment 1 but 21% in Experiment 2. Cluster responses occurred at a rate 7% in Experiment 1 as compared to 17% in Experiment 2. The differences remain even when cross-experiment comparisons are restricted to the students from the highly selective university. Approximately 54% of these students' responses in Experiment 2 were phonemic, as compared to 80% for Experiment 1.

The most likely explanation for these differences between Experiments 1 and 2 is the linguistic experience of the participants just prior to the spelling segmentation task. In Experiment 1, the participants did the phoneme counting task first, followed by word reading and then spelling segmentation. In contrast, participants in Experiment 2 did the spelling segmentation task first.

The experience in counting phonemes and the instructions about what was meant by phonemes may have focused the Experiment 1 participants on smaller units of sound, which they might not otherwise have used. It is noteworthy that, despite this experience, the participants in Experiment 1 still often used units larger than single phonemes, such as clusters or vowel + consonant units. This outcome supports the idea that highly literate adults do not always respond in terms of phonemes when explicitly asked about the relations between letters and sounds. However, the possibility that such a short and implicit experience of phonemes could influence performance in the spelling segmentation task suggests that adults' strategies in such tasks are relatively flexible. Connelly's (2002) training study, discussed in the Introduction, is consistent with this suggestion. As a direct test, we manipulated implicit phonemic training as a between-subjects variable in Experiment 3. Half of the participants were assigned to an experimental group that did phoneme counting as their first task. For the control group, the first task was counting words in sentences. The spelling segmentation task followed for both groups.

EXPERIMENT 3

Method

Participants

Data were collected from 55 undergraduates who were assigned to either the experimental (28 students) or the control group (27 students). Given the results of Experiment 2, the groups were chosen so that their mean vocabulary scores were statistically indistinguishable.[1] All participants were native speakers of English from the same university as in Experiment 1, and none had participated in earlier experiments in this series. The participants chose whether they wished to receive course credit or $10 for their participation.

Tasks

The first task for both groups was a counting task. The experimental group did a phoneme counting task, which was exactly as in Experiment 1 and required the participants to count the number of phonemes in monosyllabic words. The control group did a word counting task in which they had to count the number of words in sentences read by the experimenter. The number of words varied between 4 and 13, and each sentence contained at least one compound word that either was or was not typically hyphenated (e.g., *redhead*, *state-of-the-art*). There were 50 sentences in the word counting task, which was designed to take about the same amount of time as the phoneme counting task. Thus, both the experimental and control groups had to analyze linguistic units into their components and count the components, although the sizes of the components differed. The nature of the tasks meant that the experimental group received implicit practice in phonemic analysis while the control group did not. The spelling segmentation task and the vocabulary task were the same as in Experiment 2. To avoid participant fatigue, the background questionnaire was done midway through the counting task and the vocabulary task midway through the spelling segmentation task.

Results and Discussion

The spelling segmentation task was scored as in Experiments 1 and 2. We tested our hypothesis that implicit phonemic training increases the proportion of phonemic responses by comparing the proportion of such responses for the experimental group and the control group. Phonemic responses were significantly more frequent for the experimental group, 71%, than for the control group, 48% ($t(53) = 2.85$, $p = .006$). Onset–rime responses, on the other hand, were significantly more common for the control group, 16%, as compared to the experimental group, 6% ($t(50.8) = 2.42$, $p = .019$, adjusting for violation of the assumption of homogeneity of variance). There were no significant differences between the experimental and control groups in the proportions of responses grouping together the consonants of a consonant cluster, vowels with consonants, and letter-name sequences. These responses showed effects of sonority similar to those seen in Experiment 2.

To investigate the relationship between vocabulary and use of particular response units, we did partial correlations, controlling for training group. The results largely replicated the findings of Experiment 2. Students with higher vocabulary scores produced significantly fewer responses that grouped vowels and consonants ($r = -.35$, $p = .009$) and significantly fewer letter-name responses ($r = -.40$, $p = .003$) than students with lower vocabulary scores. In addition, the partial correlation between vocabulary and phonemic responses was nearly significant ($r = .27$, $p = .052$). These findings support the idea that there are subtle differences in the processing strategies of people with varying linguistic abilities, and they further suggest that these differences remain even after a brief period of implicit phonemic training.

GENERAL DISCUSSION

Given the surprising finding that literate adults sometimes fail to respond on the basis of phonemes in tasks tapping phonemic awareness and knowledge of phoneme–letter relations (e.g., Scarborough et al., 1998; Scholes, 1993), we set out to investigate the nature of adults' nonphonemic responses. Do these responses reflect letter-by-letter processing or random error, or can they be explained by phonological factors? Our results strongly support the idea that phonological factors and units larger than single phonemes are important.

Phoneme sonority influences how adults group letters when they explicitly assess the relations between letters and phonemes. Responses that grouped two consonants together were particularly common with obstruent consonants, whereas responses that grouped a vowel and a consonant were most common when the consonant was a liquid. In all three experiments, differences as a function of sonority were particularly pronounced for consonants that occurred after the vowel. This is consistent with previous findings involving spoken words (e.g., Stemberger, 1983; Treiman, 1984) and agrees with the sonority effects observed in the deletion task of Experiment 1. Our results further show that adults are reluctant to break up onset clusters, as in previous studies (e.g., Stemberger, 1983; Treiman, 1983). Cluster responses in the spelling segmentation task were significantly more common for CCVCs than CVCCs, and deletions of entire consonant clusters were significantly more common in the initial than the final deletion task. Responses that divided the syllable into onset and rime units were relatively common in Experiment 2 and the control condition of Experiment 3, suggesting that under some circumstances adults treat syllables in terms of these units.

Further support for the importance of phonology comes from the different rates of letter-based responses that we observed for different phonemes in the deletion and counting tasks—from as low as 8% to as high as about 70% for *ng* (/ŋ/). If phonology did not matter, we would expect all phonemes spelled with two letters to be treated alike. The difference between *ng* and other digraphs appears to reflect the phonological characteristics of /ŋ/, together with the way in which its spelling relates to its sound. Except at the end of a word or morpheme, /ŋ/ appears only before a velar stop: /k/ (as in *tank* /tæŋk/) or /g/ (as in *finger* /fɪŋgɚ/). Speakers may be inclined to believe that the /ŋ/ of a word such as *hang* is likewise followed by a velar stop. Knowledge of spelling may reinforce the idea that words like *hang* end with /ŋg/. In words like *tank* and *finger*, the pronunciation /ŋ/ is carried by the letter *n*. By analogy, people may come to believe that the *n* at the end of a word like *hang* spells /ŋ/, leaving the *g* to spell /g/.

The results of Experiments 2 and 3 suggest that vocabulary skills are linked to the tendency to use units larger than single phonemes. College students with smaller vocabularies were more likely to use large units than those with bigger vocabularies. The effects were not large, but they were observed in two separate experiments. To our knowledge, such findings have not previously been reported. Examining these differences, and their origins, is a topic for future research.

The phonological units that adults use are also affected by recent experience. Although training effects are not unexpected, it is remarkable that such brief and implicit training as ours had such strong effects. Exposure to phoneme counting instructions and the subsequent experience of counting phonemes, which preceded the spelling segmentation task for the experimental group in Experiment 3, caused adults to shift from larger to smaller phonological units. Thus, adults' strategies are not fixed but depend on the situation. Adults possess a phonemic competence that is not always put into full use, and even implicit training can modify adults' strategies. Explicit instruction, such as the ten-minute rule-based instruction that Connelly (2002) provided to his experimental group, is not necessarily required.

Our results suggest that concern about teachers' (or adults' in general) phonemic skills may have been premature. Depending on the circumstances, and with very little training, adults can adopt a largely phonemic strategy. However, such a strategy is not necessarily natural for all skilled readers. Given the importance of phonemic awareness in teaching and children and evaluating their errors, we need to make sure that teachers are aware of different types of strategies in phonological processing and know when to use each one. For example, a teacher who observes a young child spelling *ox* as "oks" needs enough access to the phonemic level to realize that this misspelling plausibly represents each of the phonemes in the spoken word.

Although learning to read probably requires and fosters a certain level of phonemic awareness, advanced reading skills may promote use of letter chunks that represent units larger than single phonemes. Ehri (1995) proposed that these multi-letter chunks can correspond to morphemes, syllables, or subsyllabic units such as onsets and rimes; she did not specify whether and how specific phonological characteristics might determine the types of units that readers form. The present findings suggest that sonority is one organizing principle for multi-letter units. Use of multi-letter chunks may be more prominent in English than other alphabetic languages because English often lacks one-to-one mappings between phonemes and letters. For example, readers of English may link the multi-letter unit *ook* with the pronunciation /ʊk/ because *oo*, on its own, is typically pronounced as /u/. Larger units may be less important for languages with one-to-one correspondences between letters and phonemes, such as Finnish. Such an outcome would be consistent with the psycholinguistic grain size hypothesis, according to which the size of units that readers use depends on the consistency of the writing system (Ziegler & Goswami, 2005).

Our findings suggest that full phonemic awareness is not necessarily the endpoint of literacy development in English. Phonemic awareness and phoneme-based processing are vital to learning to read because they help learners understand how the alphabet works. As learners gain an understanding of the relations between written and spoken language, they develop strategies in addition to phonemic ones. This includes an understanding that writing does not always represent the precise phonemic structure of words. Teaching children to read and spell English may require teaching them some fictions, for example that the "true" sounds of unstressed vowels are the ones with which they are spelled or that blending the syllables /bə/, /æ/, and /tə/ produces *bat*, rather than *buhahtah* (Ehri, Wilce, & Taylor, 1988). Efficient reading is best served by the levels of phonological analysis that provide the most accurate understanding of the relationship between the sound structure of words and the spellings conventionally used to represent them.

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Footnote

[1] One additional student was tested, but her vocabulary score was considerably lower than all others’, and including her data would have made the vocabulary scores of the two groups differ significantly. Therefore, her data were dropped.

Appendix A

Stimuli for Spelling Segmentation Task of Experiments 1, 2, and 3

CCVC items: *crab, crib, gram, drab, brag, grid; sled, slug, clip, clan, glum, flap; snag, snub, smug, snap, snob, snug; stab, spat, scum, stun, skim, stag.*

CVCC items: *cord, tort, fork, cork, dorm, lord; hulk, silk, kilt, colt, gulp, mal;, monk, punt, bump, damp, lamp, ramp; dusk, mask, raft, gust, mast, loft.*

CVC letter name items: *beat, beef, deep, dean, peel, peat.*

CVC control items: *boat, bail, nail, moat, pail, tail.*

CVCC letter name items: *carp, tart, bark, yard, harp, lark; belt, helm, pelt, melt, yelp, welt; rent, hemp, dent, vend, tend, mend.*

Fillers for Experiment 1: *fetch, rock, whip, mulch, might, wheat, rhythm, chaos, luck, rich, sketch, choir, check, whoop, quench, frown, draw, ring, song, draught, sham, shun, shot, thug, thud, Thor, gash, dash, gosh, bath, math, moth.*

Fillers for Experiments 2 and 3: *fetch, rock, whip, mulch, might, wheat, rhythm, chaos, luck, rich, sketch, chord, check, whoop, quench, frown, draw, squawk, chirpy, church.*

Appendix B

Stimuli for Phoneme Deletion and Phoneme Counting Tasks of Experiment 1

Initial digraph real words: *sham, shut, shun, ship, shot, shed; than, thud, thug, this, Thor, thin; chap, chug, chum, chin, chop, chit.*

Initial digraph pseudowords: *shan, shup, shum, shid, shon, shig; thap, thun, thup, thig, thob, thid; chag, chud, chut, chim, chog, chib.*

Final digraph real words: *gash, rush, posh, rash, dash, gosh; bath, myth, moth, path, math, Goth; hang, lung, tong, gang, fang, song.*

Final digraph pseudowords: *pash, fash, cosh, dosh, dush, vash; nath, dath, foth, poth, luth, sath; cang, mang, vong, nong, cung, jang.*

Initial cluster real words: *skim, stun, stab, spat, scum, stag, clan, sled, snag, snob, brag, crib.*

Initial cluster pseudowords: *stug, stam, spod, scag, spug, scop, snop, sneg, flet, drob, clun, crub.*

Final cluster real words: *dusk, gust, mask, mast, raft, loft, gulp, cork, dorm, punt, colt, lamp.*

Final cluster pseudowords: *fust, lusp, lusk, dask, moft, paft, bult, fump, hulp, fank, gorm, horp.*

Fillers for phoneme deletion task: *sun, lip, om, ug, tan, hum, ut, in, tag, tub, im, we, bit, top, ag, ad, pot, mad, ab, it, pun, son, ip, he.*

Fillers for phoneme counting task: *a, ap, om, at, we, i, on, ut, in, ar, o, up, im, ab, ug, e, ag, ob, to, ad, id, no, ub, of, it, ip, as, un, is, he.*

Table 1

Mean Proportions of Different Responses in Spelling Segmentation Task of Experiment 1 as a Function of Sonority of Interior Consonant of Cluster (Standard Deviations in Parentheses)

Response type	/r/	/l/	Nasal	Obstruent	Mean
Consonant cluster responses					
CCVC (e.g., [sl] [u] [g], [cr] [i] [b])	.15 (.28)	.13 (.26)	.12 (.25)	.15 (.29)	.14 (.25)
CVCC (e.g., [f] [o] [rk], [s] [i] [lk])	.02 (.08)	.03 (.11)	.04 (.09)	.08 (.15)	.04 (.09)
Responses grouping together consonants and vowels					
C + V (e.g., [s] [lu] [g], [c] [ri] [b])	.05 (.15)	.08 (.20)	.09 (.24)	.06 (.15)	.07 (.17)
V + C (e.g., [f] [or] [k], [s] [il] [k])	.23 (.35)	.19 (.29)	.13 (.26)	.09 (.20)	.16 (.24)
Onset–rime responses					
CCVC (e.g., [sl] [ug], [cr] [ib])	.01 (.05)	.01 (.04)	.01 (.03)	.01 (.04)	.01 (.03)
CVCC (e.g., [f] [ork], [s] [ilk])	.01 (.02)	.01 (.03)	.01 (.04)	.01 (.02)	.00 (.00)
VC letter-name responses					
Letter-name (e.g., [b] [ar] [k], [b] [el] [t])	.24 (.35)	.24 (.35)	.16 (.29)	-	.21 (.31)
Control (e.g., [f] [or] [k], [s] [il] [k])	.23 (.35)	.19 (.29)	.13 (.26)	-	.18 (.28)

Phonemic responses					
CCVC (e.g., [s] [l] [u] [g], [c] [r] [i] [b])	.78 (.34)	.78 (.34)	.77 (.37)	.78 (35)	.78 (.33)
CVCC (e.g., [f] [o] [r] [k], [s] [i] [l] [k])	.73 (.39)	.76 (.34)	.82 (.32)	.81 (.31)	.78 (.31)

Table 2

Mean Proportions of Different Types of Responses in Phoneme Deletion Task of Experiment 1 (Standard Deviations in Parentheses)

Response type	Initial	Final
Letter-by-letter responses		
sh	.19 (.35)	.14 (.31)
th	.17 (.33)	.08 (.26)
ch	.17 (.34)	-
ng	-	.71 (.37)
Cluster responses		
Interior obstruent (e.g., skim, dusk)	.08 (.16)	.04 (.14)
Interior sonorant (e.g., sled, gulp)	.04 (.11)	.02 (.04)

Table 3

Mean Proportions of Letter-by-letter Responses for Different Digraphs in Phoneme Counting Task of Experiment 1 (Standard Deviations in Parentheses)

Digraph	Initial	Final
sh	.17 (.31)	.18 (.33)
th	.12 (.26)	.17 (.30)
ch	.15 (.30)	-
ng	-	.68 (.35)

Table 4

Mean Proportions of Different Responses in Spelling Segmentation Task of Experiment 2 as a Function of Sonority of Interior Consonant of Cluster (Standard Deviations in Parentheses)

Response type	Vocabulary skill	/r/	/l/	Nasal	Obstruent	Mean
Consonant cluster responses						
CCVC (e.g. [sl] [u] [g], [cr] [i] [b])	High	.27 (.31)	.24 (.33)	.26 (.31)	.26 (.28)	.26 (.28)
	Low	.25 (.25)	.27 (.28)	.29 (.30)	.22 (.24)	.26 (.23)
CVCC (e.g., [f] [o] [rk], [s] [i] [lk])	High	.08 (.19)	.07 (.16)	.11 (.17)	.18 (.22)	.11 (.16)
	Low	.08 (.13)	.13 (.20)	.20 (.19)	.21 (.20)	.15 (.14)
Responses grouping together consonants and vowels						
C + V (e.g., [s] [lu] [g], [c] [ri] [b])	High	.08 (.15)	.10 (.23)	.06 (.17)	.07 (17)	.08 (.16)
	Low	.13 (.23)	.14 (.23)	.15 (.22)	.12 (.18)	.13 (.17)
V + C (e.g., [f] [or] [k], [s] [il] [k])	High	.22 (.26)	.20 (.23)	.18 (.27)	.13 (.16)	.18 (.20)
	Low	.32 (.34)	32. (.28)	.28 (.25)	.24 (.23)	.29 (.25)

Onset–rime responses						
CCVC (e.g., [sl] [ug], [cr] [ib])	High	.18 (.29)	.20 (.27)	.21 (.28)	.20 (.28)	.20 (.25)
	Low	.24 (.27)	.28 (.31)	.27 (.32)	.33 (.31)	.28 (.26)
CVCC (e.g., [f] [ork], [s] [ilk])	High	.18 (.29)	.22 (.31)	.18 (29)	.19 (.26)	.19 (.26)
	Low	.21 (.28)	.18 (.21)	.18 (24)	.18 (.23)	.19 (.21)
VC letter-name responses						
Letter-name (e.g., [b] [ar] [k], [b] [el] [t])	High	.22 (.26)	.25 (.28)	.13 (.24)	-	.20 (.21)
	Low	.38 (.33)	.32 (.31)	.29 (.25)	-	.33 (.26)
Control (e.g., [f] [or] [k], [s] [il] [k])	High	.22 (.26)	.20 (.23)	.18 (.27)	-	.20 (.22)
	Low	.32 (.34)	.32 (.28)	.28 (.25)	-	.31 (.27)
Phonemic responses						
CCVC (e.g., [s] [l] [u] [g], [c] [r] [i] [b])	High	.46 (.43)	.46 (.45)	.46 (.42)	.47 (.43)	.46 (.42)
	Low	.38 (.36)	.31 (.38)	.29 (.36)	.32 (.38)	.33 (.35)
CVCC (e.g., [f] [o] [r] [k], [s] [i] [l] [k])	High	.51 (.42)	.52 (.43)	.53 (.42)	.50 (.42)	.52 (.40)
	Low	.39 (.41)	.37 (.39)	.34 (.35)	.38 (.36)	.37 (.35)