

## Multiple Code Activation in Word Recognition: Evidence From Rhyme Monitoring

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Seidenberg and Tanenhaus reported that orthographically similar rhymes were detected more rapidly than dissimilar rhymes in a rhyme monitoring task with auditory stimulus presentation. The present experiments investigated the hypothesis that these results were due to a rhyme production-frequency bias in favor of similar rhymes that was present in their materials. In three experiments, subjects monitored short word lists for the word that rhymed with a cue presented prior to each list. All stimuli were presented auditorily. Cue-target rhyme production frequency was equated for orthographically similar and dissimilar rhymes. Similar rhymes were detected more rapidly in all three experiments, indicating that orthographic information was accessed in auditory word recognition. The results suggest that multiple codes are automatically accessed in word recognition. This entails a reinterpretation of phonological "recoding" in visual word recognition.

The role of sound-based codes in visual word recognition has been studied extensively by cognitive psychologists and reading researchers. There are a number of reasons for interest in this topic. In languages such as English, words are specified in both phonological and orthographic codes, although the phonological code is in some sense primary. The child's initial language experience is through spoken language, and in learning to read, the child is taught to map printed words onto existing phonological forms. Even mature readers often experience hearing words as they read. These intuitions are supported by numerous studies demonstrating that subjects make sound-based confusions to visually presented words and letters in recognition and recall tasks (R. Conrad, 1972).

The classic explanation for phonological

effects in visual word recognition is that the phonological code becomes available during a recoding stage impelled by limitations in working memory (Atkinson & Shiffrin, 1968). This explanation was partially based on the belief that working memory utilizes an acoustic and/or articulatory code.

A second explanation is provided by phonological-mediation models of visual word recognition. According to these models, visually presented words are translated into a phonological code. The phonological code is then used to search the mental lexicon for the entry of the word (Meyer, Schvaneveldt, & Ruddy, 1974a). However, phonological mediation models have proved extremely controversial, with many researchers arguing that the lexicon can be directly accessed through a visual code, without phonological mediation (Baron, 1973; Massaro, 1975).

An alternative explanation for phonological effects in visual word recognition is suggested by recent models of the lexicon in which the phonological and orthographic codes for words are closely integrated. This assumption is embedded in Morton's (1969) logogen model and in the Collins and Loftus (1975) spreading-activation model. In the logogen model each lexical item has a cor-

responding unit in memory, which contains a representation of its semantic, phonological, and orthographic codes. In the spreading-activation model, orthographic and phonological information are represented in a single lexical network. Both models imply that when a word is recognized, all of its codes become available. Thus both models can account for a sound-based code becoming available in visual word recognition.

The integrated representation of the sensory codes in these models has another implication. Just as the phonological code is accessed in visual word recognition, so should the orthographic code be accessed in auditory word recognition. Evidence supporting this somewhat counterintuitive prediction is provided by a recent study by Seidenberg and Tanenhaus (1979). In this study, subjects monitored a short list of spoken words for a word that rhymed with a cue word presented prior to each list. Rhyme monitoring latencies were approximately 50 msec faster when the cue and rhyming word were orthographically similar (e.g., *pie-tie*) than when they were orthographically dissimilar (e.g., *rye-tie*). Since subjects could in principle make rhyming decisions solely on the basis of phonological information, these results provide evidence that the orthographic code is accessed during auditory word recognition.

Since this study provides the most convincing evidence in the literature for the orthographic code being accessed during auditory word recognition, it is important to consider alternative explanations for the results. Recent research, reviewed by Cutler and Norris (1979), has indicated that the following dimensions influence response latencies in monitoring studies: word frequency (Foss & Blank, 1980), phonemic similarity (Newman & Dell, 1978), and syllable length (Mehler, Segui, & Carey, 1978). Seidenberg and Tanenhaus (1979) matched orthographically similar and dissimilar rhymes along all three of these dimensions. Furthermore, in two of their experiments, the same target word was presented with both orthographically similar and dissimilar cue words. There is, however, one potentially serious confound that was not considered. It seems likely that subjects may have tried to

predict the rhyme word on at least some proportion of the trials (see Tanenhaus & Seidenberg, in press, for evidence that predictability influences rhyme monitoring in sentences). If there were a production-frequency bias in favor of orthographically similar rhymes, this would have resulted in subjects generating more predictions that were orthographically similar than dissimilar to the cue word. Monitor latencies would be facilitated on trials in which the subject correctly predicted the target word. Thus a production frequency bias in favor of orthographically similar rhymes would result in faster monitor latencies to similar rhymes than to dissimilar rhymes.

The issue is perhaps analogous to the production-frequency confound in the classic study by Collins and Quillian (1969). They argued for a hierarchical model of semantic memory in which properties of a concept are stored only at the highest possible node in the semantic structure. For example, the property *can fly* would be stored with the concept *bird* and not the concept *robin*, since *bird* is a superordinate of *robin*. Collins and Quillian found that reaction times to verify the proposition *birds can fly* were faster than verification times to the proposition *robins can fly*, apparently confirming the cognitive economy assumption. Subsequent work by C. Conrad (1972), however, demonstrated that Collins and Quillian had confounded production frequency and hierarchical level. Conrad found that reaction times in verification tasks are inversely related to the frequency with which the subject assigns a property to a particular category. When production frequency was controlled, Conrad was unable to find evidence supporting this version of the cognitive economy assumption.

Rhyme production-frequency norms collected from 80 Wayne State University undergraduates increased the plausibility of a production-frequency bias explanation for orthographic effects in rhyme monitoring. The stimuli used to collect the norms were taken from 48 word triples such as those (e.g., *pie, rye, tie*) used by Seidenberg and Tanenhaus (1979). Each triple contained two cue words and a target word. Two lists of words were formed by assigning the cue

words from each triple to different lists. Subjects received booklets containing a column of words followed by five blanks. Their task was to try to generate five rhymes for each word, preserving the order in which the rhymes came to mind. Production frequencies for rhyme associates were determined by collapsing across the five positions to compute the total number of times a word was given as a rhyme associate to the cue word. Overall, 55% of the five rhyme associates generated most frequently for each cue word were orthographically similar to the cue word. An orthographic bias was particularly evident for the first rhyme associate, with 65% of the first rhyme associates being orthographically similar.<sup>1</sup>

A production-frequency bias was verified in the Seidenberg and Tanenhaus study by using the norms to compute the production frequency for each cue-target pair. Production frequency was defined as the percentage of subjects generating the target as a rhyme associate of the cue. Orthographically similar cue-target pairs were found to be more predictable than dissimilar cue-target pairs. Mean production frequencies were 37.5% for the orthographically similar pairs and 18% for the dissimilar pairs.

Given the well-known relationship between production frequency and reaction time, it seemed likely from these norms that orthographic effects in rhyme monitoring might simply be due to a production-frequency bias in favor of orthographically similar rhymes. Experiment 1 was conducted to investigate this possibility.

## Experiment 1

### Method

**Subjects.** Twenty-two Wayne State University students participated as unpaid subjects.

**Stimulus materials.** Stimuli for all trials were taken from monosyllabic rhyme triples such as *boat-vote-goat*.<sup>2</sup> Each triple contained a cue word and two rhyming target words, one orthographically similar and the other orthographically dissimilar to the cue word. Predictable rhymes (e.g., *down-town*), unusual spellings, uncommon words, homophones, homographs, and homonyms were avoided. Within test triples, production frequency was controlled, as nearly as possible, by using the rhyme production-frequency norms previously described. Within a test triple, the orthographically similar target and the orthographically dissimilar target had been generated with equal frequency as a rhyme associate to the cue

word. For example, the target words *goat* and *vote* were both generated equally often as rhyme associates of the cue word *boat*. For these stimuli, mean production frequencies for the orthographically similar and dissimilar targets were 8.00 and 8.75, respectively. The mean Kučera and Francis (1967) word frequencies for orthographically similar and dissimilar targets and cue words were 44, 44, and 42, respectively.

To ensure that orthographically similar and dissimilar cue-target rhymes did not differ in phonemic similarity, the mean number of phonemes shared by cues and targets and the mean number of differing phonemes were calculated. For example, *boat* and *goat* share two phonemes, [o] and [t], and differ by two phonemes, [g] and [b]. Orthographically similar cue-target pairs shared 2.0 phonemes and differed by 2.4 phonemes, whereas dissimilar pairs shared 2.0 phonemes and differed by 2.1 phonemes.

Monitor lists of three semantically unrelated monosyllabic words were constructed. Each list contained a target that rhymed with the cue. All of the words in a target list were similar in length, frequency, and number of syllables. The two nontargets in each list were neither orthographically nor phonologically similar to the target words. Each word including cues and targets was presented only once during the experiment.

On test trials, the target word occurred in the second position of the monitor list. Only the second position was used because data from the second position are the most stable. Monitor times to first-position targets are affected by shifts in attention, and monitor times for third-position targets are unusually short due to expectancy effects.

Distractor trials used to vary the position of the targets were constructed in a similar manner to test trials and were divided equally between similar and dissimilar orthography conditions. The cue-target pairs used in distractor trials were different from the cue-target pairs used in test trials.

**Procedure.** On each trial, subjects heard a single word in isolation (the cue), followed 2 sec later by an auditorily presented list of three semantically unrelated monosyllabic words. The subject's task was to detect the single word in the list that rhymed with the cue.

Two versions of the stimuli were recorded with each target word appearing once in each version. For each triple, the orthographically similar target appeared in one version and the orthographically dissimilar target in the other. Each subject heard only one version and, therefore, either the *boat-goat* or *boat-vote* combination but not both. Each version contained a total of 24 test trials, 12 orthographically similar and 12 orthographically dissimilar cue-target pairs. Each version contained 48 distractor trials. On test trials, the target word was the second in the three-word list. On the distractor trials, the target appeared equally often at each of the other two positions.

The stimuli were recorded in a quasirandom order with the first six trials being fillers, and the only other

<sup>1</sup> Of course, this procedure may slightly overestimate a similar orthography bias in rhyme production, since it requires a written response.

<sup>2</sup> The test stimuli used in Experiments 1-3 are given in the Appendix Tables A1, A2, and A3.

constraint being that no more than two trials from either orthography condition occurred successively. The distribution of items from these conditions was counterbalanced by halves. The stimuli were recorded on the left channel of a stereo tape. A 500-Hz timing tone was placed on the right channel so as to coincide with the beginning of each target rhyme. The tone, which was not heard by the subjects, was input to a voice-operated relay that started a Gebrands digital timer. The timer stopped when the subject pressed a telegraph key.

### Results and Discussion

Of the 528 possible monitor latencies, 12 were randomly distributed errors.

Mean latencies for each subject were computed by collapsing across the 12 targets in the orthographically similar and dissimilar conditions. Mean latencies for each item were computed by collapsing across the scores of the subjects who received each target word in orthographically similar and dissimilar conditions.

Analyses were performed on both the subject and item latencies for reasons given in Clark (1973). The mean monitor latency was 527 for similar rhymes and 580 for dissimilar rhymes. The effect of orthography was significant by subjects,  $F(1, 20) = 42.18$ ,  $MS_e = 740.48$ ,  $p < .001$ , and by items,  $F(1, 23) = 7.02$ ,  $MS_e = 4,675.55$ ,  $p < .05$ . The  $F'_{min}$  was also significant,  $F'_{min}(1, 30) = 6.02$ ,  $p < .025$ . There was no significant effect of version ( $F < 1$ ) by subjects nor a significant Orthography  $\times$  Version interaction ( $F < 1$ ).

The results indicate that with production frequency controlled, orthographically similar rhymes are detected faster than orthographically dissimilar rhymes. However, to obtain precise matching in production frequency, it was necessary to use different target words in the similar and dissimilar conditions. As a consequence, it is possible to attribute the results of Experiment 1 to differences between the orthographically similar and dissimilar target words. In Experiment 2, the same target word was preceded by either an orthographically similar or dissimilar rhyme.

## Experiment 2

### Method

**Subjects.** Twenty-two Wayne State University students served as unpaid subjects.

**Stimulus materials, design, and procedure.** The de-

sign, task, and procedure were largely the same as those in Experiment 1. Monosyllabic rhyme triples (e.g., *boat, vote, goat*) were constructed as before; however, one cue word was also orthographically similar to the target (*boat*), whereas the other was not (*vote*). Test triples were constructed such that the target word bore the same production frequency to both the orthographically similar and dissimilar cues. For example, the target word *goat* was generated as a rhyme associate of *boat* as often as it was to *vote*. For test trials, mean production frequencies for orthographically similar and dissimilar cue-target pairs were 6.58 and 6.08, respectively. The mean Kučera and Francis (1967) word frequencies for orthographically similar and dissimilar cue words and targets were 31, 28, and 23, respectively. Similar cue-target pairs shared 2.1 phonemes and differed by 2.4 phonemes. Dissimilar cue-target pairs shared 2.0 phonemes and differed by 2.4 phonemes.

Two versions of the stimuli were recorded with each target word appearing once in each version. Target words that were preceded by orthographically similar cues in one version were preceded by orthographically dissimilar cues in the other version. Each subject heard only one version.

### Results and Discussion

Of the 528 possible monitor latencies, 7 were errors and 2 were lost due to mechanical failures. Ten scores over 1,000 msec were entered in the analyses as 1,000 msec.

As in Experiment 1, rhyme monitor latencies were faster to orthographically similar rhymes than to dissimilar rhymes. The mean monitor latency was 492 for similar rhymes and 542 for dissimilar rhymes. The 50-msec effect was comparable to the 53-msec effect found in Experiment 1. Both analyses revealed a significant effect of orthography,  $F(1, 20) = 39.99$ ,  $MS_e = 703.22$ ,  $p < .0001$ , in the subject analyses, and  $F(1, 23) = 6.37$ ,  $MS_e = 5,156.06$ ,  $p < .01$ , in the item analyses. The  $F'_{min}$  was also significant,  $F'_{min}(1, 30) = 5.49$ ,  $p < .025$ .

By-subject analyses revealed no significant effect of version ( $F < 1$ ) and a marginally significant Orthography  $\times$  Version interaction,  $F(1, 20) = 3.69$ ,  $MS_e = 703.22$ ,  $.05 < p < .10$ .

The results of the preceding experiments clearly demonstrate that when rhyme production frequency for orthographically similar and dissimilar rhymes is equated, similar rhymes are still detected more rapidly than dissimilar rhymes. These results, in conjunction with the experiments reported by Seidenberg and Tanenhaus (1979), provide strong support for the claim that word rec-

