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Conspiracy Effects in Word Pronunciation

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According to what we call "conspiracy models" of word pronunciation, the pronunciation of a target word or nonword is influenced by the pronunciations of word "neighbors" orthographically similar to the target. Words with inconsistent neighbors should, therefore, be pronounced more slowly than words with consistent neighbors. In Experiment 1, we found that pronunciation latencies for exception words (words whose pronunciations are inconsistent with most of their neighbors) were indeed slow compared to consistent controls, but no such effect was obtained for regular inconsistent words (words whose pronunciations are consistent with most but not all of their neighbors). In Experiments 2 and 3, we preceded trials on target words or nonwords with priming trials using specific neighbors of the target, in an attempt to boost their influence on the pronunciation of the target. As predicted, Experiment 2 showed that preceding a target word with an exceptional neighbor does indeed produce an effect on the accuracy and latency of pronunciation of the target. Experiment 3 amplified the effect found in Experiment 2 by using pseudoword targets. Reliable effects were found for primes that shared the same vowel and final consonants with the target (_VCC primes), and for primes that shared the same vowel and initial consonants with the target (CCV_ primes). However, no reliable effect was found for primes that shared only the vowel with the target. These findings are consistent with predictions of conspiracy models. The general discussion considers the implications of the results for dual-route models, as well as various types of conspiracy models. © 1987 Academic Press, Inc.

The spelling-to-sound structure of English has often been described in terms of rules that relate letters (graphemes) to sounds (phonemes) (Chomsky & Halle, 1968; Venezky, 1970; Wijk, 1966). The regularity and irregularity that is present in this mapping from letters to pronunciation has usually been captured in dual-route models (Forster & Chambers, 1973). These models typically include a lexical look-up process and a rule process that operate in parallel (Baron & Strawson, 1976; Coltheart, 1978; Coltheart, Besner, Jonasson, & Davelaar, 1979; Frederiksen & Kroll, 1976; Mason, 1978; Stanovich & Bauer, 1978), with the pronunciation provided by the first of these processes to reach completion. The basic evidence favoring this sort of model has been faster pronunciation of "regular" words relative to "exception" words, where the former category refers to words that follow the rules, while the latter category refers to words that break the rules (Baron & Strawson, 1976; Gough & Cosky, 1977; Stanovich & Bauer, 1978). Regular words are pronounced more quickly, since their pronunciations can be accessed using either route, while exception words can only be pronounced using the lexical route (Coltheart et al., 1979).

A class of models that is distinctly different from dual-route models is what we will call conspiracy models, first proposed by Glushko (1979). In order to make

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Glushko's ideas more concrete, we present the following model, which is based on the interactive activation model (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982) in which similar ideas were applied to perceptual facilitation. Hereafter, the model we present will be referred to as the conspiracy model.

The model has three levels—a letter level, a word level, and a phonological level (Figure 1), and operates according to forward-going activation between levels and competitive inhibition within levels, in the following manner. The input activates units at the letter level, which in turn activate words. The words that get the greatest amount of activation from the letter level are those that are orthographically most similar to the input. Each activated word competes with all other activated words via mutual inhibition, and each active word attempts to activate the phonological features appropriate to its own pronunciation. The phonological string that is pronounced results from the effects of all active words. When more than one word is active, the pronunciation that results is essentially synthesized by the model from the simultaneous effects of all active words. Note that, unlike the interactive activation model of visual word perception, we do not stress the role of feedback connections. This is not because we do not believe in feedback, but only because the presence vs the absence of feedback is irrelevant to our account of conspiracy effects in pronunciation.

To the extent that the pronunciations of the activated words are *consistent*—for example, have the same primary vowel sound and very similar pronunciations, like the rhyming words *dish, wish,* and *fish*—the pronunciation will be easy to synthesize (Glushko, 1979, 1981). This is because the activated words share many of the same phonological features. These orthographic "neighbors" of the target—based on the identical spelling for the vowel and the consonant cluster ending—are phonological "friends" and tend to support the activation of the target pronunciation. An exception effect could result in the following way. When an exception word like *have* is the target, it supports its own activation, but also supports the activation of words that are visually similar to it, like *save, wave,* and *gave*—again, the similarity is based on the identical spelling of the vowel and consonant ending. *Gave, save,* and *wave* support the same vowel pronunciation, and they could "conspire" against the target word. These "conspirators" are "enemies" of *have* since they contain major phonological discrepancies with respect to the vowel and inhibit phonological features of this target word in favor of their own. Conspiracy relations of this sort could underlie longer processing times for exception words, since the exceptions must overcome the phonological interference from the conspirators. This explanation seems to fit the traditional exception effect that dual-route models attempted to explain, since the activated "friends" of an exception target word are, by definition, in the minority compared to their "regular" enemies that would also be activated by the target word. These "regular" words could

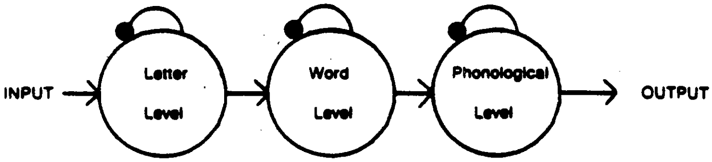

FIG. 1. Conspiracy model for pronunciation (directed arrows represent forward-going activation between levels, and loops represent competitive inhibition within levels).

constitute a formidable conspiracy to inhibit the activation of the target word.

The interactive facilitation and interference that characterizes the conspiracy model can explain the exception effect, but also suggests a reciprocal interference effect of exception words on their neighbors. Specifically, if *have* is difficult to pronounce because it activates orthographically similar words with pronunciations that are *inconsistent* with its own, like *save* and *gave*, then, according to this model, one might expect *have* to interfere with the pronunciation of *gave* or *save*, at least to some extent. Two studies have reported a reciprocal interference effect of this sort (Glushko, 1979; Seidenberg, Waters, Barnes, & Tanenhaus, 1984). These studies examined monosyllabic words that had the same pronunciation for the primary vowel sound and final consonant(s) as most of their neighbors with the same vowel and consonant spelling, and that had one or two exception neighbors. Words like *save* and *gave* that belong to the larger group of words that share the _ave spelling and pronunciation will be referred to here as "regular-inconsistent" words, as they have been in the earlier studies. These words are "regular" in that they exhibit the grapheme–phoneme correspondences typical of words that have the same vowel spelling and final consonants, but they have at least one neighbor that violates the typical correspondences.[1] In both studies, these regular-inconsistent words showed pronunciation latencies that were similar to exception words. Conspiracy models predict a disadvantage for these "regular" words with inconsistent neighbors, while dual-route models do not, and these results provide one of our main sources of support for such models.

Our purpose in the experiments reported in this paper was to examine in more detail the nature of the conspiracy effects that are characteristic of the conspiracy model. This research shares many features with ongoing work in speech perception (Cole & Jakimik, 1978, 1980; Marslen-Wilson & Tyler, 1980; Pisoni, Nusbaum, Luce, & Słowiaczek, 1985), including an interest in the relative importance of different parts of a word—beginning, middle, and end–for word recognition, and in the effects of word frequency. The first experiment was conducted in two parts. In Experiment 1A we tried to replicate previously reported effects for regular-inconsistent words, and in Experiment 1B we tried to amplify that effect, but both attempts were largely unsuccessful. There was evidence, though, that the number of "enemies" that an exception word has effects reading time and accuracy. In Experiments 2 and 3, we introduced a priming technique and were able to produce clear evidence of neighbor effects and to examine these more closely.

EXPERIMENT 1

Experiment 1 used a modified version of the two studies that have reported an interference effect for regular-inconsistent words (Glushko, 1979; Seidenberg et al., 1984). Glushko (1979) found the effect in an experiment in which subjects saw exception words and their regular-inconsistent neighbors, thereby creating the possibility of unplanned cross-priming between items. Seidenberg et al. (1984) avoided potential cross-priming effects in their replication and did find a consistency effect with low-frequency exception and regular-inconsistent words. An examination of the Seidenberg et al. stimuli, though, shows that the initial phonemes in the set of target words differed from the initial phonemes in the set

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[1] We have followed Glushko (1979) in the practice of defining regularity with respect to the vowel spelling and final consonant cluster, rather than just the vowel spelling alone, since there are clear regular patterns that are conditioned by the nature of the final consonant cluster, such as, for example, the effect of final *-ll* or of final clusters beginning in *r*—compare /ae/ in cat, cam, and catch, to /a/ in car, bard, starch, etc.

of control words. This produces a potential source of differences in pronunciation latency due to different onset characteristics for these phonemes (/g/, for example, is more abrupt than /s/). Precautions to deal with both of these problems were incorporated into this experiment. The experiment used what we will call *vowel + ending* neighbors and designate as _VCC neighbors. These are the kinds of neighbors examined in the earlier studies (Glushko, 1979; Seidenberg et al., 1984). Two words are _VCC neighbors if they have the same vowel spelling and the same final consonant or consonant cluster. A vowel spelling can be a single vowel, a vowel cluster (e.g., *ai*), or V_e, as in *cake*. In Experiment 1B, degrading the first letter of the stimulus was used in an attempt to amplify the competition between _VCC neighbors. Since this letter contains critical information that would be required for selectively activating the target word relative to its _VCC neighbors, it was thought that this manipulation might enhance the relative activation of these competitors, and thereby produce enhanced conspiracy effects.

Method

Subjects. The subjects for Experiments 1A and 1B were Carnegie-Mellon University undergraduates who received course credit or $3 for participation. All the subjects were native speakers of English. Twenty subjects were tested in Experiment 1A and 36 others were tested in Experiment 1B.

Stimuli for Experiment 1A (intact words). The stimuli were all monosyllabic words. There were 24 test words of each of the following four types: high- and low-frequency exception words and high- and low-frequency regular-inconsistent words (see Appendix A). Mean word and bigram frequencies for each type are shown in Table 1. The categorizations that were used for word types in this experiment are similar to those in Glushko (1979) and Seidenberg et al. (1984), which are as follows. *Exception* words have an atypical pronunciation compared to their _VCC neighbors. *Regular-inconsistent* words have the most common _VCC correspondence among their _VCC neighbors,[2] and have at least one _VCC neighbor with a different _VCC correspondence. The number of _VCC neighbors with the same and alternate pronunciations is listed for each test word in Appendix A, based on a search of monosyllabic words in the Kucera and Francis (1967) word frequency book. The mean ratio of regular-inconsistent _VCC pronunciations to alternate _VCC pronunciations for words in this study is about 4 to 1. The mean and median number of "friends" and "enemies" in each of the categories is shown in Table 1. For each test word there was a *regular control* word. Each control word has the same consistent _VCC pronunciation as all of its monosyllabic _VCC neighbors.[3] The control words were closely matched to the test words for word frequency, initial phoneme, and length, and the mean bigram frequencies for test words and control words were similar. The mean number of _VCC neighbors for these control words is 8.7 and the median is 8.0, based on the Kucera and Francis (1967) corpus. These means and medians are listed by category in Table 1. Fifty additional words were used for practice and 50 more words were used as fillers. Neither the practice words nor the fillers were _VCC neighbors with any of the target words or control words, thereby reducing the probability of priming the vowel sound and terminal consonant of experimental words with the practice words or fillers.

Stimuli for Experiment 1B (intact and degraded words). The test and control

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[2] *Brood* is the only exception to this, due to a failure to consider a third alternate pronunciation for the _ood neighbors (see Appendix A).

[3] Actually, the control word *group* has a foreign word neighbor, *coup*, that violates the regular pattern.

TABLE 1

Mean Word and Bigram Frequencies, and Median and Mean Number of "Friends" and "Enemies" for Stimuli in Experiments 1 and 2

Word type	Mean word frequency	Mean bigram frequency	Median (mean) "friends"	Median (mean) "enemies"
High-frequency exception	1271	523	0.0 (0.5)	7.5 (8.7)
Control	1172	488	10.0 (10.0)	
Low-frequency exception	20	404	0.0 (0.9)	8.0 (8.5)
Control	20	331	9.5 (10.1)	
High-frequency regular-inconsistent	398	473	6.5 (7.7)	2.0 (2.5)
Control	409	372	9.0 (8.2)	
Low-frequency regular-inconsistent	11	424	6.0 (6.7)	1.0 (1.8)
Control	13	433	6.5 (6.6)	

Note. Word frequency is mean frequency per million tokens (Carroll, Davies, & Richman, 1971); mean bigram frequencies are based on the summed bigram frequency counts for all word-length and letter-position combinations in the Mayzner & Tresselt (1965) samples.

words from Experiment 1A were used in Experiment 1B. There were 48 practice words and 192 filler words. As in Experiment 1A, the practice and filler words were not _VCC neighbors to any test or control words. Each test and control word had an intact form, in which the standard font was used to display the word on a computer monitor, and a degraded form, in which 40% of the pixels for the first letter of the word were turned off before the word was displayed. Two independent judges rated randomly degraded versions of the letters on a five-point scale. All of the degraded letters used for test words were rated as "moderately degraded" by both judges. The "moderately degraded" rating was bracketed by the ratings "confuseable with another letter" and "readable." The same version of a degraded letter was assigned to a test word and to its associated control word, and the degrading for each pair of test and control words was different. Practice words were degraded on one of their first to fifth letters using a procedure that selected 40% of the pixels randomly. Fillers were degraded on their second to fifth letter so as to equalize the frequency of degrading letters in each position within the word across target and filler trials.

Apparatus. The following apparatus was used in all the experiments described in this paper. The stimuli were presented on an IBM XT. A clock accurate to 0.5 ms and interfaced with the computer measured the time between presentation of the stimulus and onset of pronunciation. The subject initiated the presentation of the stimuli by pressing a microswitch. The actual stimulus presentation began on the next 60-Hz monitor scan, which also started the RT clock. A voice key stopped the clock when the subject initiated a pronunciation. In Experiment 1B Hercules graphics hardware and Graph-X software routines were used to modify letters of the stimuli. The font for intact letters in Experiment 1B did not differ from that in Experiment 1A.

Procedure for Experiment 1A. Each subject pronounced 196 words, 48 of which were test words—12 words of each type described above—and 48 were matched control words, which were presented in random order. Any particular _VCC spelling was used only once for each subject, either with an exception word or with a regular-inconsistent word, and each word appeared an equal number of times across subjects. Each session began with 50 practice trials. Fifty fillers were interspersed in the main experimental list so that a test or control word was never preceded by a word with the same initial consonant or central vowel. Each subject controlled the pace of the experimental session. A trial began with the presentation of a fixation mark. When the subject pressed a microswitch, the fixation mark disappeared and a word appeared immediately. The subject was instructed to pronounce the word out loud as quickly as possible while still pronouncing it accurately. The word disappeared as soon as the subject initiated a pronunciation and was replaced by the fixation mark after a 2500-ms delay. Errors were transcribed by the experimenter.

Procedure for Experiment 1B. The procedure differed from Experiment 1A primarily in the use of degraded stimuli along with intact stimuli; the intact stimuli provided for a replication of Experiment 1A. Each subject saw 12 test words of each type and their associated control words, as in Experiment 1A. Half of the test words and half of the control words were in an intact form, and half were in a degraded form, with the form of each control word matched to the corresponding test word. A particular _VCC spelling for a test word was used only once for any particular subject, and each test word appeared in an intact and degraded form an equal number of times across subjects. A session began with 48 practice words. The test stimuli were organized in six blocks that included 1 test word for each of the following eight combinations (high vs low frequency × intact vs degraded × exception vs regular-inconsistent) with their control words and 32 filler words. These items were selected randomly and ordered randomly within each block, with the fillers used to satisfy the same constraints on consecutive initial consonants and vowels as in Experiment 1A.

Design. Subjects were exposed to all conditions in this experiment, resulting in a within-subjects factorial design with three factors in Experiment 1A, which were word Regularity (exception vs regular-inconsistent), test Type (test vs control), and word Frequency (high vs low), and an additional factor of Degrading (intact vs degraded) in Experiment 1B.

Results for Experiment 1A

The experiment produced a reliable effect for exception words, but only a hint of an effect for regular-inconsistent words. Exception words were 22 ms slower than their controls (598 ms vs 576 ms), while regular-inconsistent words were only 8 ms slower than their controls (581 ms vs 573 ms) (see Table 2). Subjects were also more likely to make an error when pronouncing an exception test word than when pronouncing its control word—7.4% vs 0.4%, but not when pronouncing regular-inconsistent test and control words—1.3% in both cases. Separate analyses of variance for exception and regular-inconsistent words were performed over subjects and items. Exception words showed a significant main effect for Type (test vs control), over subjects ($F(1,19) = 9.91, p < .01$) and over items ($F(1,92) = 4.88, p < .05$), and a main effect for Frequency (high vs low), over subjects ($F(1,19) = 30.25, p < .001$) and over items ($F(1,92) = 10.34, p < .005$). Though the effect of Type was larger for low-frequency words, the two-way interaction between Type and Frequency was not significant. *T* tests showed a significant difference between low-frequency exception test and control items, with a critical difference of 21 ms using subject means and 32 ms using item means exceeded in both analyses (32 and 36 ms, respectively), but not between high-frequency exceptions and their controls. (Critical differences reported in this paper are based on one-tailed *t* tests significant at the .05 level, using the relevant error term from the ANOVA analysis, and adjusted for the number of tests.) The analysis of regular-inconsistent words showed a marginal main effect for Type

TABLE 2
EXPERIMENT 1A MEAN RESPONSE LATENCIES (ms) AND PERCENTAGE ERRORS

Word type	Test	Control	Difference
High-frequency exception	573 (5.9)	560 (0.4)	+13
Low-frequency exception	623 (8.8)	591 (0.4)	+32
High-frequency regular-inconsistent	583 (1.3)	576 (0.9)	+7
Low-frequency regular-inconsistent	579 (1.3)	569 (1.7)	+10

($F(1,19) = 3.82$, $.10 > p > .05$) over subjects. No other effects or interactions were significant in analyses over subjects or items.

Analyses of errors similarly showed a strong effect for exception words and essentially no effect for regular-inconsistent words. The difference in errors on exception test and control words was significant over subjects ($F(1,19) = 26.72$, $p < .001$) and over items ($F(1,92) = 21.67$, $p < .001$). A critical difference of 3.9% for pairwise comparisons of test and control words in the subject analysis was exceeded by both the high-frequency (5.5%) and low-frequency (8.4%) exception words, as was the critical difference of 4.2% for the item analysis (5.5% for high-frequency words and 8.3% for low-frequency words). If we consider only those errors in which the subject pronounced an exception word like its regular-inconsistent neighbor, we find that these errors represent the majority of errors made on exception word stimuli (74%). However, there is only a small difference in the subjects' tendency to make these errors on high- or low-frequency exception words (5% vs 6% of all trials using exception words). The error rates showed no clear trend for the regular-inconsistent words, with no significant effects in either the subject or the item analyses. For both test words and control words the error rate tended to be very low. Over all the experimental trials, there were only two instances in which a regular-inconsistent word was pronounced like an exceptional neighbor: one subject pronounced *go* to rhyme with *to* and one subject pronounced *here* to rhyme with *were*.

Results for Experiment 1B

Degrading increased all response latencies by about 40 ms, but it did not provide the hoped-for effect of amplifying conspiracy effects, which would have been evidenced in significant interactions between Degrading and Type, Frequency, or both. There was a main effect of Degrading on response latencies for exception words ($F(1,35) = 29.47$, $p < .001$ over subjects and $F(1,92) = 34.18$, $p < .001$ over items) and for regular-inconsistent words ($F(1,35) = 77.78$, $p < .001$ over subjects and $F(1,92) = 49.08$, $p < .001$ over items) and a similar pattern of main effects for degrading in the error data, but in separate analyses of exception words and regular-inconsistent words over subjects and items, there were no significant interactions with Degrading and Type or Frequency. This was true for the response latency data as well as for the error data. Indeed, both intact and degraded stimuli produced results very similar to those found in Experiment 1A (see Table 3). Essentially the same pattern of significant effects was found in the response latency and error data for exception words as in Experiment 1A, but the hint of an effect in the response time data for regular-inconsistent words seems to have disappeared in this experiment. The only hint of evidence for conspiracies in the data for regular-inconsistent words can be found in the error data, where subjects were more likely to mispro-

TABLE 3
EXPERIMENT 1B MEAN RESPONSE LATENCIES (ms) AND PERCENTAGE ERRORS FOR INTACT STIMULI AND DEGRADED STIMULI

Condition	Test	Control	Difference
Intact stimuli			
High-frequency exception words	558 (3.7)	557 (0.5)	+1
Low-frequency exception words	597 (5.7)	563 (0.9)	+34
High-frequency regular-inconsistent words	565 (0.0)	561 (0.0)	+4
Low-frequency regular-inconsistent words	563 (3.2)	567 (0.0)	−4
Degraded stimuli			
High-frequency exception words	589 (6.5)	592 (6.0)	−3
Low-frequency exception words	635 (9.4)	597 (1.9)	+38
High-frequency regular-inconsistent words	603 (3.2)	602 (2.8)	+1
Low-frequency regular-inconsistent words	613 (6.2)	615 (2.8)	−2

nounce test words compared to control words (3.2% vs 1.4%). There was a main effect for Type in the subject analysis of the errors as well as in the item analysis ($F(1,35) = 10.07$, $p < .01$ and $F(1,92) = 4.56$, $p < .04$, respectively) and a significant two-way interaction in the subject analysis between Type and Frequency ($F(1,35) = 5.37$, $p < .05$) that was largely due to a slight increase in errors for low-frequency test words compared to control words. A difference of 3.3% between low-frequency test and control words in the subject and item analyses was exceeded by the critical difference in the subject analysis (2.3%) and equal to it in the item analysis. As in Experiment 1A, there were only two instances of a regular-inconsistent word pronounced like an exceptional neighbor: in both cases, *mush* was pronounced to rhyme with *push*.

Discussion of Experiment 1

In Experiments 1A and 1B there was a reliable difference in pronunciation times for exception words compared to matched control words. This difference appears greater for low frequency words, in keeping with the results for exception words reported by Seidenberg et al. (1984). Error analyses also showed a significant difference between high- and low-frequency exception test and control words. If we interpret these data according to a conspiracy model, they suggest that exception words pay a penalty for the inconsistent phonological information that their neighbors contribute. Longer processing times are required to resolve the competition between inconsistent pronunciations. In some cases lexical items with the "regular" pronunciation dominate the activation process, which results in the synthesis of the regular rather than exceptional pronunciation and, consequently, the production of an error. Regular words activate consistent phonological information, which makes their pronunciation easier to synthesize and less subject to error.

If the conspiracy interpretation of exception effects is correct, we should expect that exceptions with fewer regular neighbors would actually exhibit less interference than exception words with more such neighbors. However, Brown (1987) provides evidence against this prediction. He compared exception words (mean and median number of _VCC "enemies" 3.9 and 2.0, respectively, based on Kucera and Francis) and unique words (no _VCC neighbors), that were low frequency (mean, 40; median, 15; based on Kucera and Francis). Brown did not find a disadvantage for the words with enemies and from this argued that a word's enemies do not interfere with its pronunciation. In view of the importance of the predicted effect of enemies for a conspiracy account, we carried out a post hoc analysis of reading times for our own low-frequency words in the following manner. We took the 24 low-frequency exception target words and rank ordered them according to the number of enemies that they had. We began with the exception words with the most enemies and matched these with exception words with the least enemies, controlling for initial phoneme, word frequency, length, and the number of "friends."[4] This resulted in two groups of 10 words that differed only in the number of enemies that they had (high-enemy group, mean 11.6 and median 11.0; low-enemy group, mean 3.1 and median 3.5). Table 4 shows the mean reading times and error rates, by subjects, collapsed across Experiments 1A and 1B. The 20-ms penalty exhibited by high-enemy exception words was significant using a one-tailed test ($t(55) = 1.89, p < .05$); the 24-ms penalty in the item analysis was not, which is not surprising given the small *n*. Subjects also showed about a threefold increase in errors when pronouncing high-enemies compared to low-enemies, a difference that was significant in a one-tailed test by subjects ($t(55) = 3.98, p < .0005$) and by items ($t(18) = 1.79, p < .05$). These data suggest that the number of enemies that an exception word has affects accuracy and the amount of time required to initiate pronunciation, even after the facilitative effects of friends have been controlled for. This post hoc analysis is put forth with caution; however, its results are contrary to the Brown model, in which there is no interference for _VCC phonology from neighbors, and it is also contrary to predictions that one would make using a dual-route model, in which exception word pronunciations are read out directly from a lexical entry for the word.

TABLE 4
EXPERIMENT 1 MEAN RESPONSE LATENCIES (ms) AND ERROR RATES FOR HIGH- AND LOW-ENEMY WORDS

High-enemy		Low-enemy	
RT	% Error	RT	% Error
623	11.0	603	3.9

While the results for exception words are completely consistent with a conspiracy account, the results for regular-inconsistent words provided only marginal support for a conspiracy interpretation. In Experiment 1A the difference between regular-inconsistent test and control words was in the right direction but was only marginally significant by subjects; no additonal support was found in the error data. In Experiment 1B there was no effect for regular-inconsistent words in the pronunciation latency data, but there was some support for the effect in the error data, suggesting, perhaps, a speed–accuracy trade-off for a small regular-inconsistency effect in the data overall. The main result of Experiment 1B is that degrading the first letter of the stimulus did not have the predicted effect of increasing the consistency effect. Degrading clearly slowed responses down, but it did so uniformly for test words and control words.

Upon closer consideration of a conspiracy model, it is not clear why the effects for regular-inconsistent words should be as large as the effects for exception words, as has been previously reported (Glushko, 1979; Seidenberg et al., 1984), given the asymmetry in the distribution of friends and enemies for these two types of words. If a conspiracy interpretation of the pronunciation process is correct, then, in general, a single exception word, perhaps with support from one other exception word that shares the same pronunciation, competes with an activated neighborhood

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[4] In a few cases we were able to use the control word for the exception word instead of another exception word. In most cases the number of friends associated with the control word could not be matched to the exception word.

of regular-inconsistent words that is much larger. The situation is reversed for regular-inconsistent words. They receive considerable support from activated consistent neighbors and a much smaller decrement from one or two exception words that might be activated.

Let us suppose for a moment that we were unable to detect the competitive interference of exception neighbors with the pronunciations of regular-inconsistent words because the support provided by the "friends" of regular-inconsistent words masked the interference that might have been present from exception "enemies." Examining the effects of one or two exception words on their larger associated regular-inconsistent neighborhoods, then, would seem to require boosting the activation of the exception neighbors so that their effects might be observed. In the next experiment we tried to do just this by preceding the pronunciation of regular-inconsistent target words with the pronunciation of an exceptional neighbor. If our reasoning is correct, this should preactivate the exceptional neighbors of the regular-inconsistent words and should produce a larger competitive effect of the kind that we have predicted.

EXPERIMENT 2

Method

Subjects and stimuli. Eighteen new subjects from the same undergraduate population were tested. The stimuli were identical to the intact words in Experiment 1B.

Procedure. The procedure was similar to Experiment 1A. The major difference was that the 48 regular-inconsistent test words were immediately preceded by either their associated exception word or the control word for the associated exception word, creating a "primed" and "unprimed" condition for the pronunciation of the regular-inconsistent test words. For each subject a particular test word appeared in either the primed or the unprimed condition, but not both. Each subject pronounced an equal number of primed and unprimed high- and low-frequency test words, and each word appeared an equal number of times in both conditions across subjects. Each subject also pronounced all the corresponding control words. The test pairs and control words were presented in random order, and filler words were used to assure that a control word was never preceded by a word with the same initial consonant or that had the same vowel. The test and control words were mixed in with the filler words with no special demarcation of item type in the trial sequence. The same instructions as those used in Experiment 1 were used for this experiment.

Design and analysis. This experiment used a within-subjects factorial design with three factors: Type (test vs control), Frequency (high vs low), and Prime (primed vs unprimed). Although it was possible to separate control words into two types, those that were paired with a "primed" test word for a given subject, and those that were paired with an "unprimed" test word, there was no conceptual reason for doing so. A single mean was computed for control words for each subject and test words were compared to control words separately for the primed and unprimed conditions, rather than in a fully factorial analysis.[5]

Results

The results of this experiment show a significant interference effect for regular-inconsistent words compared to their regular control words in precisely those conditions in which their exceptional neighbors were preactivated. Whereas primed test

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[5] A check that was performed on control words to verify that no significant difference in pronunciation times would have resulted had they been subdivided into "primed" and "unprimed" categories (566 ms vs 569 ms) showed no effect for this subcategorization $F(1,17) = 0.58$, ns.

words showed a 19-ms increment in pronunciation latencies compared to their control words, unprimed test words showed a small 4-ms increment (see Table 5). The difference between primed test words and control words was significant over subjects ($F(1,17) = 13.63$, $p < .005$) and over items ($F(1.92) = 7.22$, $p < .01$), with a critical difference of 15 ms in the subject analysis exceeded by high (16 ms)- and low (22 ms)-frequency words, and a critical difference of 19 ms in the item analysis exceeded by low-frequency words (23 ms). The 15-ms difference between primed and unprimed test words (586 ms vs 571 ms) was significant ($F(1,17) = 5.15$, $p < .05$) by subjects and a 14-ms difference (586 ms vs 572 ms) was significant by items ($F(1,46) = 5.06$, $p < .05$). The difference between unprimed test and control words was not significant. In the analyses of primed and unprimed words, neither Frequency nor the interaction between Frequency and Type was significant. Error rates were slightly higher for the low-frequency primed and unprimed conditions, but in general they were all very low. The analyses of errors over subjects and over items showed no significant effects or interactions.

Discussion of Experiment 2

A basic principle of a conspiracy model would have a word that is read activate other words that are orthographically similar to it. Whether this similarity does in fact bring together the forces of the two types of orthographically-similar words used in this experiment and in Experiment 1 is important in assessing the accuracy of this model. There was only scanty evidence in Experiment 1 specifically for the competition posed by exception words to their _VCC regular-inconsistent neighbors, which is one kind of interaction that would be characteristic of a conspiracy model for reading these words. By preactivating the exception competition, as we did in this experiment, it seems that we were able to amplify the competitive effects of these exception words to a level at which they could be examined reliably. The significant interference effects in this experiment suggest that "exception" words and "regular" words in a lexicon are not isolated from each other and incapable of influencing one another. Rather, they seem highly interconnected, as, for example, in the McClelland and Rumelhart (1981; Rumelhart & McClelland, 1982) word perception model. The effects in this experiment are small, yet the results are promising. The priming technique seems to afford us a way of more clearly drawing out interactive effects between lexical items and examining a fuller range of these effects. We exploit the priming technique in the next experiment.

TABLE 5
EXPERIMENT 2 MEAN RESPONSE LATENCIES (ms) AND PERCENTAGE ERRORS

Condition		Difference
High-frequency regular-inconsistent words		
Primed	580 (0.5)	+16
Unprimed	568 (0.5)	+4
Control	564 (0.5)	
Low-frequency regular-inconsistent words		
Primed	592 (1.9)	+22
Unprimed	574 (1.9)	+4
Control	570 (0.5)	

EXPERIMENT 3

The results of Experiment 2 suggest that it is possible to manipulate the effects of the neighbors of words by selectively preactivating them. In this experiment we will explore these priming effects more fully and test a number of predictions of a conspiracy account. One prediction that the model makes is that conspiracy effects will not be limited to the _VCC neighbors examined in Experiments 1 and 2. One purpose of this experiment is to examine the role of another type of monosyllabic neighbor, which we will call *vowel + be-*

ginning neighbors and designate as CCV_ neighbors. CCV_ neighbors share the same vowel spelling, including a final *e* if there is one, and the same consonant or consonant cluster that precedes the vowel. For example, words like *deal* and *deaf* are CCV_ neighbors. Since the visual similarity on which lexical activation in a conspiracy model is based is not limited to the vowel–consonant cluster that comes at the end of a word, other neighborhoods, like the CCV_ neighborhood, should show effects that are similar to those of _VCC neighborhoods.

As should be evident, being a _VCC or a CCV_ neighbor involves sharing the same vowel spelling as well as the same consonant context for the vowel. Previous research has not directly examined whether the consonant context is critical to the kinds of interference effects that have been reported. Earlier work related to dual-route models (e.g., Coltheart, 1978; Meyer, Schvaneveldt, & Ruddy, 1974) proceeded as if the consonant context were not critical, while work related to conspiracy models (Glushko, 1979; Seidenberg et al., 1984) has assumed that it is. So it is not clear whether any interference results from two words simply sharing the same vowel but not a common consonant context. In order to examine this issue more closely we included another type of word in this experiment that is visually similar to a target word, which we will call vowel-same and designate as _V_-same. A word will be considered to be _V_-same to a target word if it shares the same vowel spelling with the target but has no consonants in common with the target. A conspiracy model predicts little or no effect of these words on the pronunciation of a target word. This is because competition with a target is not viable when only a very few features are held in common (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). Since the similarity of _V_-same words to the target is small, they receive little bottom-up activation, so the target word is likely to quickly drive down the activation of these words in favor of neighbors that have more features in common with it.

Pseudowords, rather than words, were used as targets in this experiment. Our prediction is that pseudowords should produce a large conspiracy effect, relative to the size of the effect found in Experiment 2. This prediction follows from the fact that the person does not have a specific detector for the target string. A conspiracy model predicts a larger role for the activated neighbors of the pseudoword since there is no single strongly active item that can suppress the activation of neighbors and drive the activation of a pronunciation by itself.

Method

Subjects. Forty-eight new subjects from the same undergraduate population participated for course credit.

Stimuli. The test stimuli consisted of 45 pseudowords, each with three associated prime words—an exception word, a regular-inconsistent word, and a regular control word (see Appendix B for the full list). There were three groups with 15 pseudowords in each, with each group assigned to one of the following three conditions: _VCC-, CCV_-, and _V_-same, where "same" refers to the visual similarity between a pseudoword target and its associated prime. The pseudowords for each condition were created as follows, using monosyllabic exception words. In the _VCC-same condition, the initial consonant or consonant cluster of an exception word was replaced with another consonant or consonant cluster. A similar procedure was followed for the CCV_-same condition by replacing the final consonant or consonant cluster. In the _V_-same condition, all the consonants in the associated exception word were replaced, leaving only a vowel, vowel + *e*, or vowel digraph (like oo or ai) in common with the associated exception word. Paired with each exception word prime, there was a regular-inconsistent prime that had the same ending, beginning, or vowel as the exception prime, and thus bore the same similarity to the pseudoword target as the exception prime. A control prime had no letters in common with the associated pseudoword. In addition to the test items, 24 words and 24 pseudowords were used for practice, and 135 words and 135 pseudowords were used as fillers. The prime-target pairs were thus embedded among the fillers, as in Experiment 2, without special demarcation in the trial sequence. None of the practice or filler items shared the same two first or last letters as a test-prime or test item.

Procedure. Each subject pronounced each of the 45 pseudowords, with 5 pseudowords from each combination of the three prime types (exception, regular-inconsistent, control) and the three similarity conditions (_VCC-same, CCV_-same, _V_-same). A Latin square design was used to assign primes to pseudowords, and then the prime-test pairs for each subject were selected randomly under the constraint that each pseudoword appear with each type of prime and in each similarity relation an equal number of times across subjects. The stimuli were organized into blocks of 24 items. The first two blocks were used for practice. Each subsequent block had three prime-test pairs, nine word fillers, and nine pseudoword fillers. The fillers were used to assure that two prime-test pairs did not appear consecutively. The subject initiated the presentation of a block by pressing a microswitch. A fixation mark appeared for 500 ms and then the experimental item was presented. There was a 2500-ms delay between the subject's initiation of the target pronunciation and the display of the fixation mark for the next trial. At the start of the experiment the subjects were told that some of the letter strings that would appear on the screen were not words. They were asked to pronounce each letter string as soon as they could after it appeared on the screen, to be accurate in their pronunciation of the words, and to pronounce pseudowords the way they thought they would be pronounced if they were words. The experimenter transcribed the pronunciations of pseudowords and noted errors in pronouncing the primes. In addition, all the trials were recorded using an audiocassette recorder.

Design. Subjects were exposed to all conditions in this experiment creating a within-subject factorial design with two factors: the type of Prime word (exception vs regular-inconsistent vs control) and the type of prime-target Overlap (CCV_-same vs _VCC-same vs _V_-same).

Results

The use of pseudowords in this experiment produced the predicted large effects on pronunciation, compared to the results in Experiment 2 where words were used. The question of primary interest in this experiment was whether _VCC and CCV_ neighbors would both have an effect on pronunciation, and further, whether vowel similarity was, by itself, capable of producing an effect. In addressing these issues, we first consider naming latencies in those instances when pseudowords were pronounced using major (regular) spelling-sound correspondences (i.e., assonant with the regular-inconsistent prime); we will then consider the frequency with which these correspondences were used.

The latency results show that _VCC neighbors and CCV_ neighbors both strongly influenced the pronunciations of orthographically similar pseudowords, while _V_-same words did not. The particular way in which we assessed the effects of these neighbors on "regular" pronunciations was by comparing the condition in which exception neighbors were primed to the condition in which regular-inconsistent neighbors were primed. There is a substantial 59-ms difference between these two conditions for _VCC neighbors and a 36-ms difference for CCV_ neighbors, based on subject means (see Figure 2). In both cases, the pseudowords preceded by regular-inconsistent primes were pronounced more quickly, a result that is in accord with the relative facilitation pseudowords would have in this condition according to a conspiracy account. The difference in pronunciation latencies for pseudowords primed by exception _V_-same words compared to regular-inconsistent _V_-same words is a mere 12 ms, again in accord with a conspiracy model which predicts little or no effect of low-similarity primes. The main effect of Overlap in the pronunciation data was significant over subjects (*F*(2,94) = 6.47, $p < .005$) and over items (*F*(2,42) = 4.12, $p < .05$), as was the main effect of Prime type (*F*(1,47) = 22.04, $p < .001$) over subjects, and (*F*(1,42) = 10.25, $p < .005$) over items. A critical difference of 30 ms for comparisons between the priming conditions in the subject analysis was exceeded for _VCC and CCV_ neighbors, but not for _V_-same words, as was the critical difference of 64 ms for the item analysis, which was exceeded in both the CCV_-same condition (74 ms) and the _VCC-same condition (69 ms), but not in the _V_-same condition (16 ms). Further, the two-way interaction between Overlap and Prime was significant in the subject analysis (*F*(2,94) = 3.75, $p < .03$) (though not in the item analysis (*F*(2,42) = 1.25, ns)), suggesting that these differences were not equally significant across the three Overlap conditions. Planned contrasts were used in order to examine these differences more carefully. Equally weighted differences in the _VCC and CCV_ conditions compared to the _V_ condition showed a significant difference (*F*(1,94) = 5.75, $p < .03$) by subjects, but not by items (*F*(1,42) = 2.48, $.25 > p > .10$), while the difference between the _VCC and the CCV_ conditions was nonsignificant by subjects (*F*(1,94) = 1.69, ns) and by items (*F*(1,42) = 0.01, ns), largely supporting the conspiracy model predictions of a difference between the _VCC and the CCV_ conditions compared to the _V_-same condition and no difference between the _VCC and the CCV_ conditions.

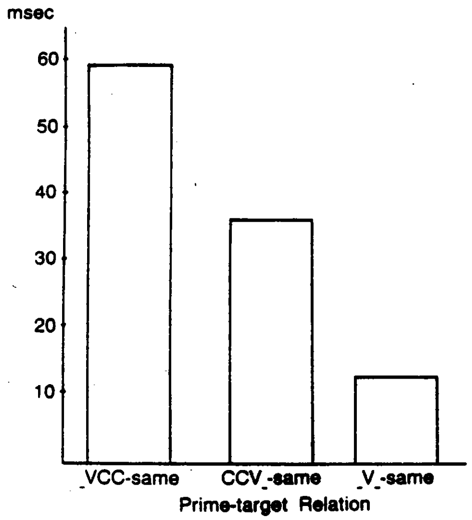

FIG. 2. Experiment 3 pronunciation latency differences (*Y* values in ms represent the difference between latencies for pseudowords with exception primes and pseudowords with regular-inconsistent primes for the three types of prime-target relations in this experiment).

Each subject's pseudoword pronunciations were rated by two independent judges for the use of regular and alternate pronunciations, with initial agreement between the two judges on 96% of all the pronunciations and eventual agreement on discrepant ratings. For the initial analysis, the experimenter transcribed pronunciations during the experimental sessions and the second rater transcribed pronunciations using the tape recording of the experimental sessions; the final analysis was done using the tape recording. The particular form of the pronunciation that a subject produced provides further insight into the effects of neighbors. The probability that the regular pronunciation would be used for pronouncing a pseudoword was much lower when pseudowords were primed by exception _VCC neighbors (.63) than when they were primed by regular-inconsistent _VCC neighbors (.96); the same effect was also observed, though in somewhat attenuated form, when they were primed by exception CCV_ neighbors compared to regular-inconsistent CCV_ neighbors (.79 vs .89). In contrast, there was essentially no difference in the probability that a regular pronunciation would be used with exception _V_-same primes compared to regular-inconsistent _V_-same primes (.93 vs .94) (see Figure 3). An analysis of these differences showed the same basic pattern of effects as the pronunciation data. The main effect of Overlap was significant in the subject analysis ($F(2,94) = 21.46, p < .001$) and item analysis ($F(2,42) = 4.75, p < .02$), as was the main effect of Prime type over subjects ($F(1,47) = 65.35, p < .001$) and over items ($F(1,42) = 38.38, p < .001$) and the interaction between Overlap and Prime type over subjects ($F(2,94) = 16.63, p < .001$) and over items ($F(2,42) = 14.99, p < .001$). A critical difference of .07 for specific comparisons between prime types in the subject analysis was exceeded by pseudowords with exception primes and regular-inconsistent primes in the CCV_-same condition (.10) and in the _VCC-same condition (.33), but not in the _V_-same condition (.01); a critical difference of .09 in the item analysis was equaled in the CCV_-same condition (.09) and exceeded in the _VCC-same condition (.34) but not in the _V_-same condition (.03). Analyses using planned contrasts, similar to those used for the pronunciation data, showed a difference between CCV_ and _VCC differences compared to _V_ differences in the subject analysis ($F(1,94) = 16.75, p < .001$) and in the item analysis ($F(1,42) = 13.12, p < .001$) in accord with the predictions of a conspiracy model. There was also a difference between _VCC and CCV_ conditions in the subject analysis ($F(1,94) = 15.97, p < .001$) and in the item analysis ($F(1,42) = 17.06, p < .001$), a difference that was not anticipated.*

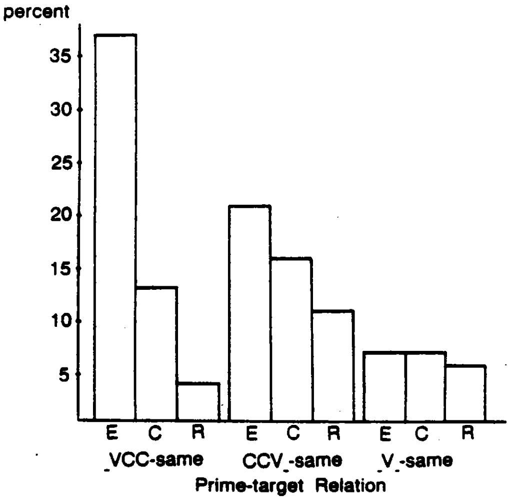

FIG. 3. Experiment 3, percentage use of correspondences that differed from *major* correspondences (E, exception prime; C, control prime; R, regular-inconsistent prime).

The control-prime condition in this experiment provided a baseline for the difficulty of our pronunciation task. These primes were visually unrelated to the target word, so we did not expect them to bias the neighbors of the pseudoword. We could then compare the results in this condition to the priming condition expected to produce relative facilitation (regular-inconsistent prime) and to the condition likely to produce relative interference (exception prime). Our expectation was that for the control-prime condition pronunciation latencies and the use of regular pronuncia-

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* *Note added in proof.* Rebecca Treiman has pointed out that a number of CCV_ targets and primes share a consonant after the vowel (pint/pink/pinf, bush/bust/busk, pull/pulp/pulf). A reanalysis of our data without these items showed the same pattern of significant effects in reading times and error rates for the CCV_ stimuli, over subjects and items. In the analysis by subjects, a 47 msec difference for Prime type (688 msec vs 641 msec) exceeded a critical difference of 30 msec; a difference of 71 msec (723 msec vs 652 msec) exceeded the critical difference of 66 msec in the item analysis. The error rates varied by only 1% in the subject analysis. These results suggest that these items were not inflating our results for the CCV_ stimuli.

tions would lie somewhere between the high interference effects of exception primes and the relative facilitation of regular-inconsistent primes. This was clearly the case in both the _VCC-same and the CCV_-same conditions, where the differences between the exception-prime condition and regular-inconsistent prime condition were large. This was not true in the _V_-same condition, but here the differences between the exception-prime condition and regular-inconsistent prime condition are small, so it is not clear that there is the same relative facilitation and interference and that we should expect to find control-prime results bracketed by the exception-prime and regular-inconsistent prime results. The control-prime condition thus provided a check on our stimuli that was borne out (see Table 6).

Discussion of Experiment 3

The results from this experiment suggest that a word that a person reads aloud partially activates visually similar neighbors. These neighbors interact with each other and with the target and contribute to the synthesis of a pronunciation. Our results here suggest that these interactive effects are indeed present and able to shift the course of pronunciation, providing facilitation and interference and affecting the form of the pronunciation that is eventually chosen. These results support a conspiracy model for the pronunciation process.

Our results show that neighborhood effects are not limited to the influence of *vowel + ending* neighbors but also include *vowel + beginning* neighbors. This finding agrees with the basic operation of a conspiracy model, since this model does not place restrictions on which particular segments of an input can activate words in the system (McClelland & Rumelhart, 1981). The question of what other conjuncts of orthographic information in a target word are capable of initiating the activation and interaction of neighbors is open to further empirical investigation. There is some evidence, as well, for a greater influence of *vowel + ending* neighbors, in that the priming effects observed in Experiment 3 tended to be stronger for *vowel + ending* primes than for *vowel + beginning* primes —this trend was particularly clear in the choice of pronunciations, and less so in the reaction times for regular pronunciations. Under General Discussion, we will consider possible accounts for this difference in the size of the priming effect between the _VCC and the CCV_ conditions.

Finally, our results suggest that the context of any particular letter in the input is critical to the effect that the letter has. It is letters in context that underlie the activation and support of words in a conspiracy model. This is because words are activated when there is a substantial amount of orthographic overlap with the input, and are inhibited when the overlap is small. In this experiment, words that shared the same vowel and initial consonant spelling or vowel and final consonant spelling influenced one another. When the similarity

TABLE 6

EXPERIMENT 3 MEAN RESPONSE LATENCIES (ms) AND PERCENTAGE USE OF CORRESPONDENCES THAT DIFFERED FROM "MAJOR" CORRESPONDENCES

	Prime-target similarity relation		
Type of prime word	CCV_-same	_VCC-same	_V_-same
Exception	686 (21)	684 (37)	642 (7)
Regular-inconsistent	650 (11)	625 (4)	630 (6)
Control	674 (16)	662 (13)	626 (7)

was limited to the vowel spelling there was no reliable effect.[6]

GENERAL DISCUSSION

Dual-Route Models Reconsidered

A conspiracy model is quite different from a dual-route model, and it might be worth considering here what implications the effects that we found in our experiments have for dual-route models. The effects of "enemies" on the pronunciation of exception words in isolation and the consistent set of priming results reported above argue against the independent "rule" and lexical components in dual-route models. We say this with some qualification, since there may be versions of a dual-route model that could account for the kinds of results found in our experiments. Below we will argue that a person does not typically use an explicit representation of "pronunciation rules" when pronouncing a word, although rule-like effects can appear in the data as a result of the words that a person knows, and we will also consider the nature of the rules that a more comprehensive dual-route model would need to use.

Let us begin by considering a version of a dual-route model that uses only regular grapheme–phoneme correspondences (GPCs) in the rule component (Coltheart, 1978; Coltheart et al., 1979). Presumably, these are like the "major correspondences" in Venezky (1970) for single letters, vowels, and digraphs. Exception words can only be pronounced using a lexical route (Baron & Strawson, 1976; Coltheart, 1978; Coltheart et al. 1979; Mason, 1978; Stanovich & Bauer, 1978), since there are no rules in the rule component for the atypical vowel correspondence in these words. On this model, there is no apparent reason why the number of "enemies" should affect the pronunciation of an exception word, as found in Experiment 1, nor is it evident why an exception-word prime would affect the pronunciation of a regular-inconsistent word that followed, as found in Experiment 2, since regular-inconsistents follow major correspondences just as regular words do, and should therefore benefit from the dual-routes for pronunciation as much as regular words benefit.

In order to better account for our effects, one might imagine a dual-route model that included a wider range of grapheme–phoneme rules. This sort of model would be similar to the encoding-bias model set forth by Meyer et al. (1974) for lexical decision, in that their model includes typical and atpyical grapheme–phoneme correspondences. The _V_-same primes in Experiment 3 provided a test of this possibility. If an encoding-bias account is correct, it seems that the regular-inconsistent prime should have facilitated the typical vowel pronunciation and the exception prime should have facilitated the atypical pronunciation. The *ai* in *said,* for example, should have biased an atypical rule for the pronunciation of a pseudoword like *raim* resulting in a greater use of that rule relative to the case where *raim* was biased by the regular rule represented by the prime *sail.* This was clearly not the case—the rates at which atypical pronunciations were used in these two conditions did not differ (7% vs 6%), and there was no reliable difference in the pronunciation times. Now, let us contrast the _V_-same primes to the CCV_-same and the _VCC-same primes. In all three cases, the same typical and atypical vowels were primed, but the CCV_-same and _VCC-same primes included a consonant context for the vowel. The additional agreement between, for example, the

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[6] In this experiment, the overall effects were larger than for words in Experiment 2. Since the _V_-same condition did not produce a priming effect here, it is unlikely to have done so for words if used in Experiment 2.

initial consonants in *come*, *cope*, and *coze* should not have changed the relative biases of the exception and regular-inconsistent primes that an encoding-bias model would predict, since both primes had the same benefit of an additional grapheme-phoneme agreement with the pseudoword target. Since there was no difference between pseudowords primed by exceptions and regular-inconsistents in the _V_-same condition, one would not expect to find a difference in the CCV_-same and _VCC-same conditions. And yet, as the results show, there was a large difference in these latter conditions. The fact that we got significant results with CCV_ and _VCC primes suggest that our manipulation was sensitive to priming effects and that these effects depended on a substantial conjunction of visual information, that is, on putting the vowel in a consonant context.[7] The conjunctive effects suggest that grapheme–phoneme relations, which are relations between small units of information, do not adequately capture something essential about a pronunciation mechanism.

In order to account for conjunctive effects, one might imagine a dual-route model with very specific and detailed context for spelling-sound rules (Parkin, 1984; Patterson & Morton, 1985; Stanhope & Parkin, 1987). This sort of model might adequately account for the data, but it seems that the number of rules in such a model would need to be quite large just to accommodate the "neighbor" effects that we found in this study, and indeed, a conspiracy model (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982) suggests that there are probably other neighbors that could have effects similar to those that we found. In some cases activating these rules would be equivalent to activating the words that embody them. For example, in order for the *eaf* in *deaf* or the *ave* in *have* to affect pronunciation, a person would need to have rules for these segments based on the single instances that embody them—the words *deaf* and *have*. A conspiracy model provides for word and subword information without replicating that information in distinct, independent components, as a dual-route model does.

Conspiracy Models

Our results support two major features of a conspiracy account. First of all, priming effects were found for items that have a substantial overlap with the prime, but not with those that only have the vowel spelling in common with it, as expected on the conspiracy account. On the conspiracy model, this comes about because the primed item only falls inside the set of items substantially activated by the target when there is considerable overlap. When there is less overlap, the primed item receives little bottom-up support from the target stimulus, and is therefore suppressed quickly, contributing little to the resulting pattern of activation. A second source of support for the conspiracy model comes from the fact that the priming effect is not limited to *vowel + ending* overlap primes, but includes *vowel + beginning* overlap primes as well. It is important to the conspiracy model that priming should be found in both cases, since the model treats all kinds of overlap as equally important. It seems plausible to suppose that other patterns of overlap that have not been examined in this paper would produce priming effects, as well. Another prediction of the conspiracy model that has been confirmed is the prediction that the size of the priming

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[7] It is interesting to note that an examination of the Meyer et al. (1974) stimuli showed that their study used primes and targets that not only included typical and atypical vowel pronunciations, but that also preserved the context for these vowels in the relation between prime and target—for example, *grown crown*, *cash wash*. Although the results of their study, which concerned phonemic recoding in lexical decision, are not directly relevant here, the authors did not consider the facilitative effects of the conjunction of *vowel + context* and interpreted their "active" unit as a grapheme.

effects obtained should be much larger for pseudoword targets relative to word targets; this prediction follows from the fact that for pseudoword targets there is no preexisting word unit to dominate the pattern of activation and therefore swamp the effects of the competition.

While several aspects of the results support the conspiracy account, there is one aspect of the findings that seems to fall outside the scope of a conspiracy account. This is the fact that the priming effects found in Experiment 3 are considerably stronger for the _VCC prime condition than for the CCV_ prime condition. If _VCC targets had fewer regular neighbors than CCV_ targets, the primed _VCC exception would have less competition, and so would be expected to exert a stronger influence. Unfortunately, the neighborhood statistics of the targets used in Experiment 3 do not indicate that this is the case. The _VCC targets have slightly more regular neighbors on average than the CCV_ targets (11.9 vs 10.1), and the fraction of regular to total neighbors is virtually identical in the two cases (72% vs 73%). If anything, then, we would expect a slightly larger priming effect on the CCV_ targets than on the _VCC targets, quite the opposite of the effect that was obtained.

A question arises, then. How should the differential priming effects be interpreted? One possibility is that rhyme is a potent factor in the response formulation process. There might simply be a tendency to produce responses that rhyme with the preceding word, and this response tendency might be partially responsible for the priming effects observed in the _VCC priming condition. An alternative suggestion, due to Treiman and Chafetz (1987), is that CCV_s are not natural orthographic units, but _VCCs are. The phonological realization of a vowel is more predictable from the vowel + ending than from either the vowel alone or from the vowel + beginning (see Venezky, 1970). Furthermore, Treiman and Chafetz (1987) have reported considerable evidence supporting a role for _VCC units, including, for example, the finding that presenting a word parsed into CC + VCC clusters (e.g., STR ENGTH) is less disruptive to reading than presenting it parsed into CCV + CC groups (STRE NGTH). One might, then, propose that subjects use a processing mechanism that captures phonological correspondences between context sensitive letter groups, and that _VCC groups play a larger role than CCV_ groups. The theoretical problem would be to integrate this notion into a processing system that would at the same time produce the kinds of lexically based effects that we and others have observed in word reading experiments. These include, for example, the fact that exception effects are stronger for less frequent words (our Experiment 1; Seidenberg et al., 1984; Waters, Seidenberg & Bruck, 1984), and the fact that priming effects are stronger for nonword targets than for word targets.

A Distributed Model of Single-Word Reading

What appears to be required is a model that combines a sensitivity to particular lexical items with a sensitivity to the internal structure of a word and allows these factors to be integrated in a sensible and coherent way. One possibility would be a version of the conspiracy model in which lexical units were augmented by useful subword units such as initial consonant clusters and _VCC units (Glushko, 1979). Such a model could provide a means for capturing regularities that are present in the single letter, multiletter, and whole word units. In such a model, however, a key question that arises is the coordination of such units so that they act together in such a way as to produce predominantly correct performance in normal reading as well as the detailed pattern of effects obtained in this and other experiments. An alternative approach is to use connectionist learning procedures (Rumelhart, Hinton, & Williams, 1986) to train a parallel distribution processing network to read words aloud (Rosenberg & Sejnowski, 1986). Simulation experiments with a model similar to Rosenberg & Sejnowski's are underway to see if this approach is capable of accounting for our present findings.

CONCLUSION

Both the interactive model and the distributed model differ from the dual-route models in storing knowledge of regular and irregular patterns in the same set of connections, and both attribute learning to read regular and irregular patterns, not to an explicit rule-formation process, but to a gradual strength accumulation process based on experience reading particular words. This kind of view has important implications for our understanding of how best reading might be taught. During recent decades, a number of rule-based programs have been proposed for reading instruction. Given the results reported here, it would be important, it seems, to more carefully examine the effect of the particular word ensembles used for teaching reading, under the assumption that children are primarly learning about neighbors, and not grapheme–phoneme rules. For example, a single lesson on the vowel digraph *oo* in the Lippincott reading series (McCracken & Walcutt, 1963) includes words corresponding to the following neighbors: _oot (boot, hoot, loot, root, toot), _ool (cool, pool, tool, stool, spool), _oom (room, bloom, boom, gloom, broom), too_ (too, tool, toot, tooth), coo_ (coo, coop, cool), boo_ (boot, boom, boost), and loo_ (loop, loot, loose). Perhaps the reported success of these programs is due more to the words that children typically learn in these programs than to the spelling-sound rules that are taught. If this were true, there might be an opportunity to improve these programs by simply choosing example words judiciously.

APPENDIX A

Test and Control Words for Experiments 1 and 2

F, frequency expressed in occurrences per million tokens (Carroll et al., 1971); S, number of additional words in Kucera and Francis (1967) with the same _VCC pronunciation as the associated word (excluding archaic forms, like *shrove*); MFA, number of words with the more frequent alternate _VCC pronunciation; LFA, number of words with the less frequent alternate _VCC pronunciation, if any; AE, the associated exception word.

High-frequency exception	F	S	MFA	LFA	Regular control	F	S
1. are	6743	0	17	0	out	2335	12
2. both	512	0	4	0	big	612	11
3. break	97	1	10	0	best	362	14
4. choose	125	0	3	0	class	206	9
5. come	837	1	5	0	came	853	11
6. do	2440	2	4	0	did	1307	8
7. does	814	0	7	1	tell	686	14
8. done	288	2	12	1	dark	197	8
9. foot	158	1	7	0	fact	174	4
10. give	607	1	7	0	got	429	16
11. great	687	0	12	2	group	286	1
12. have	4346	0	12	0	him	1762	13
13. move	292	1	9	4	main	165	16
14. put	739	0	8	0	place	799	8
15. pull	100	2	6	0	page	430	7
16. said	2469	0	6	1	see	1634	14

17. says	184	0	14	0	stop	200	16
18. shall	177	0	12	0	soon	389	5
19. want	488	0	7	0	which	2678	1
20. watch	178	0	8	0	week	149	7
21. were	3200	0	3	2	with	5933	2
22. what	3350	0	15	0	when	3103	10
23. word	830	0	5	0	write	994	10
24. work	835	0	4	0	will	2438	22

Low-frequency exception	F	S	MFA	LFA	Regular control	F	S
1. bowl	52	0	6	0	bus	59	4
2. broad	51	0	4	0	broke	68	10
3. bush	19	1	10	0	beam	21	8
4. deaf	8	0	2	0	deed	4	14
5. doll	24	1	5	0	dots	30	10
6. flood	21	1	4	3	float	21	6
7. gross	3	0	9	0	grape	2	6
8. lose	48	1	8	1	lunch	53	5
9. pear	5	4	14	0	peel	4	8
10. phase	5	1	4	0	fade	6	9
11. pint	5	0	9	0	pitch	1	9
12. plow	12	9	15	0	pump	17	14
13. rouse	1	3	5	0	ripe	18	5
14. sew	6	0	14	6	slip	24	19
15. shoe	26	0	8	0	sank	13	17
16. spook	1	0	8	0	slam	1	13
17. swamp	10	0	10	0	stunt	5	7
18. swarm	4	1	4	0	swore	4	17
19. touch	74	0	4	0	trunk	74	11
20. wad	1	0	12	0	wit	5	16
21. wand	1	0	12	0	weld	1	2
22. wash	46	0	18	0	wax	14	5
23. wool	36	0	6	0	wing	26	14
24. worm	11	0	3	0	wake	19	14

High-frequency regular-inconsistent	F	AE	S	MFA	LFA	Regular control	F	S
1. base	144	(phase)	3	2	0	bird	144	2
2. bone	42	(done)	11	3	1	bag	63	12
3. but	3620	(put)	7	1	0	by	3924	14
4. catch	121	(watch)	7	1	0	clean	94	6
5. cool	88	(wool)	5	1	0	corn	96	7
6. days	380	(says)	13	1	0	draw	243	13
7. dear	67	(pear)	13	5	0	dust	59	9
8. flew	64	(sew)	13	6	1	fish	282	2
9. flat	113	(what)	14	1	0	fine	198	15
10. five	309	(give)	6	2	0	fast	212	7
11. form	471	(worm)	2	1	0	feet	463	9
12. go	1008	(do)	3	3	0	get	1070	11
13. goes	173	(does)	6	1	1	girl	195	2
14. grow	244	(plow)	14	10	0	gold	157	9
15. here	794	(were)	2	2	1	help	739	2
16. home	612	(come)	4	2	0	high	420	3
17. meat	88	(great)	11	2	1	mile	57	8
18. paid	68	(said)	5	1	1	plate	53	16
19. plant	158	(want)	6	1	0	piece	206	1
20. roll	48	(doll)	4	2	0	rod	39	9

21. root	58	(foot)	6	2	0	rice	57	12
22. sand	110	(wand)	10	1	0	sent	138	10
23. small	663	(shall)	11	1	0	such	795	1
24. speak	119	(break)	9	2	0	skin	112	16

Low-frequency regular-inconsistent	F	AE	S	MFA	LFA	Regular control	F	S
1. brood	3	(flood)	2	4	2	brisk	4	2
2. cook	38	(spook)	7	1	0	code	22	3
3. cord	18	(word)	4	1	0	cane	17	7
4. cove	2	(move)	8	4	2	cope	2	2
5. cramp	1	(swamp)	9	1	0	clang	1	8
6. dare	14	(are)	16	1	0	dime	14	5
7. fowl	3	(bowl)	5	1	0	fawn	3	5
8. gull	3	(pull)	5	3	0	gong	3	7
9. harm	19	(swarm)	3	2	0	hide	42	11
10. hoe	4	(shoe)	8	1	0	hike	6	5
11. lash	1	(wash)	17	1	0	loom	6	7
12. leaf	36	(deaf)	1	1	0	leg	57	4
13. loss	29	(gross)	8	1	0	luck	31	13
14. mad	27	(wad)	11	1	0	mix	16	2
15. moose	7	(choose)	3	1	0	mole	5	8
16. moth	8	(both)	3	1	0	mist	9	7
17. mouse	32	(rouse)	4	4	0	moist	18	1
18. mush	2	(bush)	10	2	0	math	2	5
19. pork	7	(work)	3	1	0	pail	12	16
20. pose	1	(lose)	7	2	1	peep	2	11
21. pouch	5	(touch)	3	1	0	peach	11	6
22. rave	1	(have)	12	1	0	reef	7	1
23. tint	1	(pint)	8	1	0	taps	2	14
24. toad	12	(broad)	3	1	0	tend	17	9

APPENDIX B

Prime Words and Pseudowords for Experiment 3

1, Exception prime; 2, regular-inconsistent prime; 3, control prime.

Prime-target relation:	End-same		Beginning-same		Vowel-same	
	1. come	zome	come	coze	come	vole
	2. home		cope		cope	
	3. trip		trip		trip	
	1. done	vone	done	dofe	done	fode
	2. bone		dole		dole	
	3. sick		sick		sick	
	1. have	mave	have	hane	have	nafe
	2. gave		hate		hate	
	3. prop		prop		prop	
	1. lose	fose	lose	lole	lose	vope
	2. pose		lobe		lobe	
	3. math		math		math	

1. move	hove	move	mobe	move	sofe
2. cove		mode		mode	
3. knit		knit		knit	
1. pear	zear	pear	peam	pear	neak
2. dear		peal		peal	
3. gift		gift		gift	
1. dead	yead	dead	deab	dead	leam
2. bead		deal		deal	
3. risk		risk		risk	
1. deaf	heaf	deaf	deag	deaf	yeap
2. leaf		dean		dean	
3. mock		mock		mock	
1. break	preak	steak	steab	steak	freap
2. creak		steam		steam	
3. hound		hound		hound	
1. soot	noot	soot	soog	soot	moop
2. boot		soon		soon	
3. club		club		club	
1. good	zood	good	goom	good	voon
2. food		goof		goof	
3. beep		beep		beep	
1. said	yaid	said	saip	said	raim
2. paid		sail		sail	
3. fuzz		fuzz		fuzz	
1. pint	rint	pint	pinf	pint	tish
2. tint		pink		pink	
3. clay		clay		clay	
1. bush	nush	bush	busk	bush	hund
2. lush		bust		bust	
3. gram		gram		gram	
1. pull	sull	pull	pulf	pull	suft
2. gull		pulp		pulp	
3. mend		mend		mend	

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