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Facilitation and Interference from Formally Similar Word Primes in a Naming Task

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The naming of a word (e.g., CAVE) is delayed if participants first name a formally similar, but nonrhyming, prime (e.g., HAVE). Taraban and McClelland (1987) interpreted this effect in terms of competition between activated phonological codes, while Bradshaw and Nettleton (1974) argued that these interference effects are due to conflicting output codes and only arise when primes are named. Experiment 1 shows interference effects for nonrhyming primes read silently (e.g., HAVE-CAVE), contrary to Bradshaw and Nettleton's claim, but rhyming primes (e.g., NEED-WEED) produced no facilitation, contrary to predictions from Taraban and McClelland's model. In Experiment 2 participants named both prime and target, and both interference and facilitation were observed. In Experiment 3 formally dissimilar rhyming prime-target pairs (e.g., EIGHT-HATE) produced no facilitation even when primes were named. Both interference and facilitation effects seem to result from a complicated interaction of orthographic, phonological, and output codes.

Key Words: Priming; word naming; word recognition; orthography; phonology.

Skilled readers have little difficulty generating the phonological and semantic codes necessary to understand text. Despite appearances, however, generating a phonological code from a visual input is actually a rather complicated process. As such, there are now a number of models of the processes involved, each with a slightly different conceptualization of how phonology is derived. Dual-route models, for example, propose two possible ways to formulate a word's name from orthographic information (Coltheart, 1978; Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart & Rastle, 1994; Patterson & Morton, 1985). Many other theories, however, posit that for most words a single route is all that is necessary to successfully convert orthography to phonology (Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989; Van Orden, Pennington, & Stone, 1990).

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One finding that any theory of naming must explain is the regularity effect, that is, the finding that words with regular pronunciations (e.g.,MINT) are usually named more quickly than words with irregular pronunciations (e.g., PINT) (e.g., Baron & Strawson, 1976). What they must also explain, of course, is why the regularity effect is strongest for words that are low frequency, that is, why there tends to be an interaction of frequency and regularity in naming latencies (Brown, Lupker, & Colombo, 1994; Seidenberg, Waters, Barnes, & Tanenhaus, 1984, but see Jared, 1997, for evidence of regularity effects for high frequency words also).

Proponents of the dual-route model of naming have interpreted the regularity effect and its interaction with frequency as evidence that there are two separate routes involved in naming. According to the dual-route model, one way for a reader to generate a phonological code is to use grapheme-to-phoneme conversion (GPC) rules to generate a set of phonemes and then to assemble those phonemes into a complete code (the “assembly route”). This route must be used when naming unfamiliar letter strings. The other route is the “lexical route” in which a word’s phonological code is essentially looked up after the word’s orthographic code has allowed the word’s lexical entry to be selected.

According to the dual-route model, irregular words are named more slowly than regular words because, for irregular words, the assembly route produces an incorrect regularized phonological code which differs from the correct phonological code produced by the lexical route. Since it takes time to resolve the difference between the outputs from the two routes, irregular words take longer to pronounce than regular words. Further, since the amount of time it takes the lexical route to produce a code is an inverse function of frequency, the competition process and, by implication, the regularity effect, should be more noticeable for low frequency words, as is typically observed.

Single-route proponents, however, have suggested that the regularity effect (and hence the regularity by frequency interaction) is actually the result of the lack of consistency among the phonological codes activated by the orthography of an irregular word (e.g., Glushko, 1979; Jared, McRae, & Seidenberg, 1990). Consistency describes the extent to which words that share elements of their orthography (typically, their “body”) also share phonology. For instance, while GAVE and HAVE are orthographically similar, they are phonologically dissimilar. Thus, although GAVE is regular and HAVE is irregular, both are inconsistent. On the other hand, GATE is regular *and* consistent because all words ending in -ATE are pronounced similarly.

Proponents of the single-route position have provided a number of demonstrations that consistency is empirically important by showing that it takes longer to name inconsistent words than consistent words even when those words are all regular (e.g., Jared et al., 1990). Although these findings are somewhat controversial, they are easily explained by single-route theories such as the PDP models of Plaut et al. (1996), Seidenberg and McClelland (1989) and Van Orden et al. (1990). Recent versions of the dual-route model (e.g., Coltheart et al., 1993; Coltheart & Rastle, 1994; Patterson & Morton, 1985) have mechanisms that, at least in theory, also allow these models to account for consistency effects. These mechanisms involve processing structures contained within the lexical route.

The prominent models of word naming, therefore, can all explain the effects of regularity, consistency, and frequency, making it somewhat difficult to discriminate among them on the basis of these effects. In the present research, we examined the viability of the models from a different perspective, by investigating the effects of priming by formally similar words in the naming task. This investigation extends the experiments conducted by Burt and Humphreys (1993). As Burt and Humphreys suggested, the effects that they observed appeared to pose a serious challenge for all of the prominent models.

EFFECTS OF PRIMING BY FORMALLY SIMILAR WORDS

The type of formal similarity we investigated involved only the sharing of a word body. A set of words that shares a word body will be said to constitute a body neighborhood. Thus, all words ending in -AVE (e.g., CAVE, WAVE, HAVE, etc.) make up such a neighborhood.[1] Within a neighborhood, it is possible for there to be both friends and enemies. Friends are words that have similar phonologies; that is, they rhyme (e.g., CAVE and WAVE). Enemies have different phonologies (e.g., WAVE and HAVE). Our examination centered on the effects on word naming of presenting either a friend or an enemy of a target word as a prime. Several previous studies have examined these issues using lexical decision tasks (e.g., Hanson & Fowler, 1987; Meyer, Schvaneveldt, & Ruddy, 1974; Pugh, Rexer, & Katz, 1994; Shulman, Hornak, & Sanders, 1978). However, we will restrict our attention to those studies that have used the naming task since the models under investigation are all models of the naming process.

The effects of priming target words with their enemies were first examined by Bradshaw and Nettleton (1974). In their Experiment 1, participants were required to rapidly name a sequence of visually presented word pairs that were body enemies (e.g., MOWN-DOWN, WART-MART, etc.). Participants took longer to name a sequence of words when enemies were adjacent to each other than when they were separated by neutral words. In subsequent experiments, Bradshaw and Nettleton found that when the first member of each pair was covertly identified but not articulated (Experiment 3), there was no effect on the pronunciation time for the second member of the pair. The authors took these findings to mean that it was necessary to name the prime aloud in order to observe interference from enemies in the body neighborhood.

Taraban and McClelland (1987) provided a more controlled examination of the effect of priming by enemies on the naming process. In their Experiment 2 the targets were regular words, and the primes were either enemies (e.g., PINT-TINT) or regular control words (e.g., TAPS-TINT). They found a small but significant (15 msec) interference effect for target naming latencies when participants named primes that were enemies of the targets.

Taraban and McClelland (1987) interpreted their results in terms of a conspiracy model. They based this model on the principles of interactive activation (see McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982) and thus proposed that the model include a hierarchical arrangement of three levels: a letter level, a word level, and a phonological level. Activation feeds forward from one level to the next. To the extent that phonological features are shared among the activated words, a pronunciation will be synthesized easily. Enemies in the neighborhood, however, can slow naming latency because those words' phonological features are incompatible with the phonological features of the target.

Using this model, Taraban and McClelland (1987) offered the following account of the interference produced by enemy primes. When a reader processes an irregular word like PINT as a prime, the representational structures for PINT become activated. When a regular neighbor target (e.g., MINT) is presented, the representational structures for PINT are further activated. Thus, the phonological features for PINT play a major (and interfering) role in the synthesis of the pronunciation for MINT. The result is a delay in the naming of MINT in comparison to when the prime is not a body neighbor of MINT.

On the other hand, when a friend, such as TINT, is presented as a prime, the appropriate phonology for the target should be preactivated and therefore pronunciation of the target should be facilitated. Thus, Taraban and McClelland's account of phonological interference also leads to the prediction of phonological facilitation from friend primes. In fact, Taraban and McClelland did report facilitation from friend primes, however, they only investigated this effect for nonword targets. In contrast, Lupker and Colombo

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[1] For the sake of brevity, we will often refer to body neighborhoods simply as "neighborhoods" and body neighbors as "neighbors." The reader should keep in mind, however, that our use of these terms is slightly different than the more common use described by Coltheart, Davelaar, Jonasson, and Besner (1977).

(1994) found virtually no evidence that word naming was facilitated by friend primes except when the target was a low frequency irregular word (e.g., WASH-SQUASH).

More recently, Burt and Humphreys (1993) also investigated interference effects from enemy primes in a naming task. In their studies, participants were required to name an irregular prime (e.g., BUSH) and subsequently to name a regular target (e.g., MUSH). As in previous studies, they reported interference when the prime immediately preceded the target. This effect, however, was also found when the prime was presented ten trials earlier. Burt and Humphreys concluded that their delayed phonological interference was inconsistent with Taraban and McClelland's (1987) conspiracy model. The conspiracy model's explanation is based on the prime's activation and thus one would predict that interference would be relatively short-lived. Certainly, phonological interference should not survive the presentation of a number of intervening stimuli that are also named. Since Burt and Humphreys found that interference effects survived a prime-target delay of 10 trials they suggested their results were more compatible with Seidenberg and McClelland's (1989) PDP model (although, as will be discussed, even this model requires new assumptions to account for the delayed interference effect).

According to PDP-type models (e.g., Plaut et al., 1996; Seidenberg & McClelland, 1989), naming words involves the computation of phonological codes that are characterized as patterns of activation distributed over representational units. A single process can compute a phonological code from an orthographic input for all words and nonwords. The model itself consists of a network of interconnected orthographic and phonological units and a mediating level of hidden units. Connections between orthographic and phonological units are weighted. These weights change as a consequence of experience with words and their pronunciations. With repeated exposure to a word, the connection weights between the word's orthographic and phonological units (and mediating hidden units) are adjusted in the correct direction. Thus, with increased experience, the pattern of phonological activation more closely approximates the correct pattern of activation. This learning model differs from an activation model like Taraban and McClelland's (1987) in that, unlike activation that presumably dissipates rapidly unless consciously maintained, connection strengths are not altered until another stimulus that recruits the relevant units is processed.

Although the assumptions of the PDP-type models are consistent with delayed phonological interference effects, Burt and Humphreys (1993) argued that Seidenberg and McClelland's (1989) model, as implemented, could not actually account for Burt and Humphreys' effects. Learning rules in the model do not allow a single exposure of a prime to produce weight changes substantial enough to affect pronunciation of a target. That is, simulations with the model revealed that the single presentation of the irregular word PINT produced negligible changes in weights and thus should have little effect on the pronunciation latency for MINT. An interference effect would only be expected after repeated presentations (Seidenberg & McClelland, 1989, pp. 540–541). Similarly, it would only be after repeated exposures that the regular prime TINT would facilitate naming of the target MINT.

As noted, the main alternative to single-route models like Seidenberg and McClelland's (1989) model is the dual-route model. The most recent version of the dual-route model—the Dual-Route Cascaded (DRC) model (Coltheart et al., 1993; Coltheart & Rastle, 1994)—accounts for consistency effects in terms of the lexical route. The idea is that a word will activate not only its own word detector but also word detectors for neighbors. These detectors in turn feed activation forward to the phonological output lexicon and the phoneme system. If the phonology for these neighbors is inconsistent (i.e., if there are enemies in the neighborhood), the information produced by the lexical route will be less helpful in deriving the ultimate pronunciation. Thus, regular-inconsistent words may be named more slowly than regular-consistent words depending on factors such as how inconsistent the neighborhood is and how much the lexical route actually contributes to the naming of regular-consistent words.

This DRC account is actually quite similar to the account provided by the conspiracy model of Taraban and McClelland (1987). As such, the DRC model would appear to make the same predictions. That is, the DRC model, construed this way, would predict the interference observed when a target like MINT is preceded by an enemy prime like PINT. However, it would also predict that this effect should not be particularly long-lasting, since it is based on activation of representational structures, and that the naming of a target like MINT would be facilitated when preceded by a prime like TINT.

THE PRESENT PARADIGM

In the present research we attempted to address two issues. First, we wished to take a closer look at the time course of the interference effects from priming by enemies and the (potential) facilitative effects from priming by friends in the naming task. Previously, investigators have examined the interference effects only for targets presented at least 1 s, and sometimes more than 3 s, after the prime (e.g., Burt & Humphreys, 1993; Kay & Marcel, 1981; Taraban & McClelland, 1987). However, the models under investigation all suggest that the priming processes are automatic in nature and, therefore, should be active at much shorter stimulus onset asynchronies (SOAs). To our knowledge, this issue has never been examined.

Second, to what extent are the interference effects dependent on naming the prime (as well as the target)? Bradshaw and Nettleton (1974) suggested that interference from enemy primes only occurs if the prime is named aloud. With the exception of some of Bradshaw and Nettleton's experiments, in studies investigating phonological interference in naming, participants have always been required to name the prime aloud (e.g., Burt & Humphreys, 1993; Seidenberg et al., 1984; Taraban & McClelland, 1987). If Bradshaw and Nettleton are correct and priming only occurs when primes are named aloud, then these priming effects may actually be due to overlapping output or articulatory processes and not to the phonological code generation process. On the other hand, if interference can be obtained when primes are read silently, then it would seem more likely that this effect is at least partly due to the phonological code generation processes. To resolve this issue, in the present experiments we first investigated whether phonological interference can be obtained without prime naming. We then contrasted the interference effects obtained when only the targets are named aloud with those in a condition in which both the primes and targets are named aloud.

To investigate these issues we used a modified version of Taraban and McClelland's (1987) methodology. Specifically, we included enemy (e.g., HAVE-CAVE), friend (e.g., WAVE-CAVE), and control (e.g., TAPS-CAVE) primes. In an attempt to maintain consistency across stimulus pairs, for enemy primes what we deemed to be the irregular word of the pair was selected to be the prime. Henceforth, this condition will be referred to as the irregular prime condition (with the friend prime condition being referred to as the regular prime condition). In a few pairs involving enemies where it was unclear which was the irregular word and which was the regular word the designation of prime and target was somewhat arbitrary. However, given the strong parallels between priming regular words with irregular words and irregular words with regular words reported by Burt and Humphreys (1993), the question of which word was the prime and which was the target would seem not to be an important one. In any case, as will be noted subsequently, removing these pairs from the analysis did not change any of the results.

A weakness in Taraban and McClelland's (1987) and Burt and Humphreys's (1993) designs was noted and corrected. These authors used what is technically an inappropriate control condition. Trials with related irregular primes were compared to a control condition with unrelated regular primes. When the prime is an irregular word, the control condition should also involve an irregular prime. More generally, there is some indication in the literature that processing time for the prime is an important determinant of processing time for the target regardless of whether there is a relation between prime and target (Lupker & Williams, 1989; Vanderwart, 1984). Thus, when possible, it is important that the same primes be used in the related and unrelated conditions with their pairings being interchanged in the two conditions. As such, in our first two experiments four types of priming conditions were used: irregular related, irregular unrelated, regular related, and regular unrelated. Based on similar considerations, the frequency of the primes was controlled by dividing the primes into high and low frequency sets and manipulating prime frequency in both the related and unrelated conditions. This allowed us to control for effects of prime frequency. In all three of the experiments the targets were low frequency regular words.

EXPERIMENT 1

In Experiment 1 we attempted to determine whether interference and facilitation effects can be obtained without prime naming and, if so, the time course of those effects. Thus, in Experiment 1 the primes were not named and SOA was manipulated. To accomplish this, there were three SOA conditions in Experiment 1: in Condition A the SOA was 129 ms, in Condition B the SOA was 314 ms, and in Condition C the SOA was 814 ms. These SOA values approximate the SOAs used in Lupker and Colombo's (1994) Experiment 1 and thus should allow a comparison with their results.

Method

Participants

The participants in Experiments 1 were undergraduate students at the University of Western Ontario. Thirty-six participants were tested in Condition A, 24 new participants were tested in Condition B, and 30 new participants were tested in Condition C.

In each of the experiments reported here, participants were paid or received partial course credit in an introductory psychology course for their participation. All participants considered English to be their first language and had normal or corrected-to-normal vision.

Apparatus

Stimuli were presented on a computer monitor on which letters were approximately 0.60 cm high and at eye level for participants. Participants sat approximately 50 cm from the monitor screen. Naming times were recorded by a microphone connected to an electronic voice key relay which is triggered by vocal responses.

Stimuli

Thirty-two formally similar prime-target pairs were selected such that the prime and target were regular (rhyming) words (e.g., NEED-WEED). For 16 pairs the prime frequency was greater than 60 per million ($M = 280.9$, Median $= 128.0$), and for the remaining 16 pairs the prime frequency was less than 55 per million ($M = 11.2$, Median $= 6.5$) (Kučera & Francis, 1967). Frequency for all targets was less than 55 per million ($M = 9.6$, Median $=$ 6.5 for targets paired with high frequency primes; $M = 6.4$, Median $= 3.0$ for targets paired with low frequency primes).

Another 32 formally similar prime-target pairs were selected such that the prime was an irregular word and the target was a regular word, e.g., WHAT-CHAT. For 16 pairs the prime frequency was greater than 60 per million ($M = 615.2$, Median $= 322.0$) and for the remaining 16 pairs the prime frequency was less than 55 per million ($M = 10.5$, Median $= 7.0$).[2] Frequency for all targets was less than 55 per million ($M = 10.9$, Median $= 7.0$ for targets paired with high frequency primes; $M = 10.9$, Median $= 4.0$ for targets paired with low frequency primes). A complete list of the primes and targets is presented in the Appendix.

The ideal stimulus set for this experiment would involve only regular inconsistent targets; that is, regular words with body neighborhoods in which at least one word has an irregular pronunciation. Unfortunately, there are too few inconsistent word bodies to accomplish this (and, at the same time, to use the same primes in

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[2] These averages are based on 31 of the 32 pairs because after Experiments 1 and 2 had been completed, we discovered that the prime "SAID" had been misclassified as a low frequency word. In addition, some questions were raised about the use of "WIND" as a target, since it is a homograph, and about the regularity of "DON," "STEIN," "TOLL," and "BOMB." To address these issues, the analyses in Experiments 1 and 2 were also performed with these stimuli removed. In no instance did this change the results.

both the related and unrelated conditions) without considerable repetition of word bodies. Because targets in the irregular prime condition must be inconsistent, many (26 of 32) of the targets in the regular prime condition were consistent. As discussed below, there is no reason to believe that this compromise affected the results of these experiments.

To ensure that each target was presented in both the related and unrelated conditions, two lists of stimuli were created. Targets paired with a related prime in List A (e.g., NEED-WEED) were paired with an unrelated prime in List B (e.g., HELP-WEED). The unrelated pairs were created such that there was minimal overlap in orthography between the prime and target. For the majority of unrelated pairs, there were no overlapping letters. In some cases there was one overlapping letter (as in the HELP-WEED example) and in one case (involving a five-letter prime) there were two overlapping letters. The mean overlap between primes and targets in the unrelated condition was 0.23 letters.

Each participant was to respond to each target only once, so two groups of participants were required in order to complete the counterbalancing. Participants were assigned to the conditions by the order in which they appeared for the experiment such that the odd-numbered participants were assigned to one group and the even-numbered participants were assigned to the other group.

Procedure

Participants were told that they would be presented with a series of stimulus pairs on the computer screen, and their task for each pair would be to silently read the first word and to pronounce the second word aloud, as quickly and as accurately as possible. Participants first completed eight practice trials; one for each of the conditions in the experiment. Then the 64 experimental trials were presented.

Each trial began with a 1000 ms fixation cross. Then the prime appeared and remained on the screen for 86 ms in Condition A, 271 ms in Condition B, and 771 ms in Condition C. After a 43 ms interstimulus interval (ISI), the target appeared and remained on the screen until the participant responded. Thus, the SOA was 129 ms in Condition A, 314 ms in Condition B, and 814 ms in Condition C. The intertrial interval was 2000 ms.

Results and Discussion

Condition A

Naming latencies. In this and each of the following experiments a trial was considered an error, and was excluded from the latency analyses, if the naming latency was longer than 1100 ms or shorter than 250 ms (2.9% of all trials), or if the target was mispronounced (4.2% of all trials). Mean naming latencies are presented in Table 1. The correct naming latencies were submitted to a two (Relatedness) by two (Prime Regularity) by two (Prime Frequency) by two (Participant Group) ANOVA, with Relatedness, Prime Regularity, and Prime Frequency as within-subject factors and Participant Group as a between-subjects factor. In addition, in this and all subsequent experiments, the data were analyzed with both subjects and items analyses (F_1 and F_2, respectively).[3]

The latency analyses revealed three significant main effects: Relatedness ($F_1(1,34) = 14.78$, $p < .05$, $MSe = 1127.8$; $F_2(1,56) = 5.45$, $p < .05$, $MSe = 1148.6$), Prime Regularity ($F_1(1,34) = 57.26$, $p < .001$, $MSe = 1870.2$; $F_2(1,56) = 20.13$, $p < .001$, $MSe = 2619.3$), and Prime Frequency ($F_1(1,34) = 10.26$, $p < .05$, $MSe = 1114.8$; $F_2(1,56) = 1.14$, $p > .05$, $MSe = 2619.3$). The main effects were qualified by a Relatedness by Prime Frequency interaction ($F_1(1,34) = 4.68$, $p < .05$, $MSe = 1020.2$;

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[3] The words used in these experiments were not selected "randomly" in any sense of the term. Rather, they were selected because they met an extensive set of criteria. Further, across the three experiments, the set of items used virtually exhausts the entire population of inconsistent word bodies. The implication is that "items" really should not be treated as a random factor in any of these analyses because to do so would be to violate a number of assumptions underlying the ANOVA model (see Wike & Church, 1976). Further, because the items were not randomly selected, significant effects obtained in an ANOVA treating items as a random factor would not allow us to "generalize over items" in any case. Concerns about generalizability over items are, however, addressed by the virtually identical results in the three experiments even though different item sets were used.

TABLE 1

Mean Naming Latencies (ms) and Naming Error Percentages (in Parentheses) for Targets in Experiment 1, Conditions A, B, and C, as a Function of Prime Frequency, Prime Regularity, and Relatedness

Prime type	Related	Unrelated	RT effect	Error effect
		Condition A (SOA = 129 ms)		
High frequency				
Regular	568 (1.3)	560 (0.4)	−8	−0.9
Irregular	622 (11.2)	583 (6.2)	−39*,**	−5.0*,**
Low frequency				
Regular	582 (1.8)	572 (1.8)	−10	0.0
Irregular	617 (7.6)	613 (3.6)	−4	−4.0*,**
		Condition B (SOA = 314 ms)		
High frequency				
Regular	568 (0.5)	574 (2.1)	+6	+1.6
Irregular	613 (10.4)	592 (5.2)	−21*	−5.2*,**
Low frequency				
Regular	578 (1.6)	587 (2.1)	+9	+0.5
Irregular	622 (6.2)	601 (3.1)	−21*	−3.1*,**
		Condition C (SOA = 814 ms)		
High frequency				
Regular	553 (0.0)	555 (0.0)	+2	0.0
Irregular	618 (7.3)	579 (2.1)	−39*,**	−5.2*,**
Low frequency				
Regular	567 (0.0)	570 (0.0)	+3	0.0
Irregular	629 (4.9)	583 (1.7)	−46*,**	−3.2*,**

*$p < .05$ by subjects.
**$p < .05$ by items.

$F_2(1{,}56) = 1.66$, $p = .20$, $MSe = 1148.6$) and, more importantly, by a three-way Relatedness by Prime Regularity by Prime Frequency interaction ($F_1(1{,}34) = 4.71$, $p < .05$, $MSe = 1272.1$; $F_2(1{,}56) = 1.72$, $p = .19$, $MSe = 1148.6$), although neither of these effects were significant in the items analysis. No other effects approached significance.

Using planned comparisons we examined the differences between naming latencies in the related and unrelated conditions for each type of prime-target pair. Target naming was significantly slowed by high frequency irregular primes (t_1 (35) = 4.77, $p < .001$, one-tailed; t_2 (15) = 2.27, $p < .05$, one-tailed) but not by low frequency irregular primes ($t_1 < 1$; $t_2 < 1$). The small interference effects for high frequency regular and low frequency regular primes were not significant ($t_1 < 1$; $t_2 < 1$ in both cases).

Naming errors. Naming errors occurred if participants mispronounced word targets. Three types of mispronunciations were included: (1) a participant "regularized" the word; for instance, pronounced "SOOT" as "SUIT;" (2) a participant mispronounced the word in another way; for instance, pronounced "BROOD" as "BRODE;" and (3) a participant stuttered during their pronunciation.

Mean percentages of errors for each condition are presented in Table 1. The error data were submitted to the same analyses as the latency data. Results showed significant main effects of Relatedness ($F_1(1{,}34) = 8.31$, $p < .01$, $MSe = 35.0$; $F_2(1{,}56) = 10.16$, $p < .005$, *MSe* = 24.3) and Prime Regularity ($F_1(1,34) = 37.81$, $p < .001$, *MSe* = 34.7; $F_2(1,56) = 13.41$, $p < .001$, *MSe* = 93.2). The Relatedness by Prime Regularity interaction was also significant ($F_1(1,34) = 8.61$, $p < .001$, *MSe* = 34.7; $F_2(1,56) = 7.78$, $p < .01$, *MSe* = 24.3). No other effects were significant.

Planned comparisons showed that there were significantly more errors in the related condition for both high frequency irregular primes (t_1 (35) = 3.59, $p < .001$, one-tailed; t_2 (15) = 2.33, $p < .05$, one-tailed) and for low frequency irregular primes (t_1 (35) = 2.87, $p < .005$; t_2 (15) = 2.02, $p < .05$, one-tailed). The small effects for high frequency regular and low frequency regular primes were not significant ($t_1 < 1$; $t_2 < 1$ in both cases).

The results of Condition A show clear interference for target naming when primed by high frequency irregular primes, some evidence of interference when primed by low frequency irregular primes, and no facilitation from high or low frequency regular (rhyming) primes. The fact that the interference (at least for high frequency irregular primes) arose at such a short SOA suggests that this effect was due to automatic prime processing. Further, the fact that this interference arose when participants read the primes silently provides strong evidence against Bradshaw and Nettleton's (1974) claim that phonological interference effects only arise when primes are named. On the other hand, the interference effect is consistent with Taraban and McClelland's (1987) conspiracy model which views the naming process as dependent on the interactions among neighbors.

Taraban and McClelland's (1987) conspiracy model does, however, have some difficulty with our finding that rhyming primes did not facilitate target naming. According to the conspiracy model, facilitation in naming should occur when primes and targets share both orthography and phonology, and these authors did report this effect for nonword targets. However, the absence of facilitation in this experiment replicates Lupker and Colombo's (1994) results since Lupker and Colombo found facilitation only for low frequency irregular primes *and* targets.

The fact that interference from low frequency irregular primes was quite weak in Condition A (only showing up in the error data) could be explained if phonological codes for low frequency irregular primes are derived more slowly than those for high frequency primes (Seidenberg et al., 1984). It may be that a certain level of activation is needed in order to obtain these interference effects and an SOA of 129 ms might be too brief for the phonological code for a low frequency irregular word to be highly activated.

It is also possible that the short SOA might explain the absence of facilitation from rhyming regular primes. That is, facilitative effects from friends might arise more slowly than competition from enemies. If so, then the longer SOA used in Condition B would be more likely to produce facilitation from rhyming primes.

Condition B

Naming latencies. Trials were excluded from these analyses if the naming latency was outside the cutoff times (1.9% of all trials) or if the target was mispronounced (3.9% of all trials).

Mean naming latencies are presented in Table 1. There was a significant main effect of Prime Regularity ($F_1(1,22) = 22.11$, $p < .001$, *MSe* = 1968.5; $F_2(1,56) = 10.71$, $p < .005$, *MSe* = 2764.0) and a Prime Regularity by Relatedness interaction ($F_1(1,22) = 10.80$, $p < .05$, *MSe* = 898.6; $F_2(1,56) = 3.54$, $p = .06$, *MSe* = 1162.3). No other effects were significant.

Planned comparisons showed that, in the subjects analyses, target naming was significantly delayed by the high frequency irregular (t_1 (23) = 1.90, $p < .05$, one-tailed; t_2 (15) = 1.07, $p > .05$, one-tailed) and low frequency irregular (t_1 (23) = 1.90, $p < .05$, one-tailed; t_2 (15) = .85, $p > .05$, one-tailed) primes, although these effects were not significant in the items analyses. Target naming was not significantly facilitated by the high frequency regular or low frequency regular primes ($t_1 < 1$; $t_2 < 1$ in both cases).

Naming errors. Mean percentages of errors for each condition are presented in Table 1. The analysis of naming errors showed significant main effects of Relatedness ($F_1(1,22) = 4.32$, $p < .05$, *MSe* = 19.2; F_2 (1, 56) = 4.35, $p <$

.05, *MSe* = 17.9) and Prime Regularity ($F_1(1,22) = 42.37$, $p < .001$, *MSe* = 24.8; $F_2(1,56) = 7.63$, $p < .01$, *MSe* = 113.8) and a significant interaction of Relatedness and Prime Regularity ($F_1(1,22) = 4.49$, $p < .05$, *MSe* = 23.2; $F_2(1,56) = 12.07$, $p < .001$, *MSe* = 17.9). The Prime Frequency by Prime Regularity interaction was significant in the subjects analysis ($F_1(1,22) = 9.29$, $p < .001$, *MSe* = 40.8; $F_2 < 1$). These effects are attributable to a high number of errors in the related condition for high frequency irregular primes. No other effects were significant.

Using planned comparisons we examined the differences between naming errors in the related and unrelated conditions for each type of prime-target pair. There were significantly more errors in the related condition for high frequency irregular primes (t_1 (23) = 4.13, $p < .001$, one-tailed; t_2 (15) = 2.44, $p < .05$, one-tailed) and for low frequency irregular primes (t_1 (23) = 2.46, $p < .05$, one-tailed; t_2 (15) = 2.42, $p < .05$, one-tailed). The effects for high frequency regular and low frequency regular primes were not significant ($t_1 < 1$; $t_2 < 1$ in both cases).

The results of Condition B showed equivalent interference effects from both high and low frequency irregular primes. These results are slightly different than those of Condition A where the interference effect was much stronger for high frequency irregular primes. This difference, however, is reasonably well explained by the longer SOA in Condition B. When the SOA was increased from 129 to 314 ms the phonological codes for low frequency irregular words became more fully activated and produced more interference for naming regular neighbors.

As in Condition A, there was again no evidence of facilitation of target naming from rhyming primes. This finding is somewhat problematic for the conspiracy model (Taraban & McClelland, 1987) and its hypothesis that neighbors interact with each other and with the target and contribute to the synthesis of a pronunciation.

In Condition C we continued our examination of the time course of phonological interference and facilitation using an SOA of 814 ms. It can be assumed that by 814 ms the automatic activation generated by prime processing has, to some extent, dissipated and that whatever activation remains is being maintained by strategic control (Neely, 1977). That is, the activation available at 814 ms SOA is likely to involve strategic anticipation of target phonology, rather than being due to automatic activation within neighborhoods.

As noted, Burt and Humphreys (1993) did report interference effects after a substantial delay between prime and target. They concluded that phonological priming is a learning effect rather than an activation effect as postulated by Taraban and McClelland's (1987) model. However, Burt and Humphreys's participants pronounced both the prime and target. The output code generated when naming the prime aloud could, at least in theory, provide an additional source of interference. In the present study participants did not name the prime aloud. Thus, if interference effects are observed in Condition C, our results would extend Burt and Humphreys's results by demonstrating that interference effects for target naming occur at longer intervals even without overt naming of the prime.

Condition C

Naming latencies. Trials were excluded from these analyses if naming latencies were outside the cutoff times (1.7% of all trials), or if the target was mispronounced (2.0% of all trials).

As illustrated in Table 1, three main effects were significant: Relatedness ($F_1(1,28) = 13.31$, $p < .05$, *MSe* = 1628.9; $F_2(1,56) = 11.27$, $p < .001$, *MSe* = 1319.7), Prime Regularity ($F_1(1,28) = 91.28$, $p < .001$, *MSe* = 1029.7; $F_2(1,56) = 13.67$, $p < .001$, *MSe* = 3528.6) and Prime Frequency ($F_1(1,28) = 8.12$, $p < .05$, *MSe* = 854.5; $F_2(1,56) = 2.43$, $p = .12$, *MSe* = 3528.6), although the main effect of Prime Frequency was not significant by items. These effects were qualified by a significant Relatedness by Prime Regularity interaction ($F_1(1,28) = 39.33$, $p < .001$, *MSe* = 728.6; $F_2(1,56) = 14.08$, $p < .001$, *MSe* = 1319.7). No other effects were significant.

Planned comparisons showed significant interference for high frequency irregular primes

(t_1 (29) = 3.94, $p < .001$, one-tailed; t_2 (15) = 2.34, $p < .05$, one-tailed), and for low frequency irregular primes (t_1 (29) = 4.65, $p < .001$, one-tailed; t_2 (15) = 2.98, $p < .01$, one-tailed). There was no facilitation from either high frequency regular primes or low frequency regular primes ($t_1 < 1$; $t_2 < 1$ in both cases).

Naming errors. Mean percentages of errors for each condition are presented in Table 1. The analysis of naming errors showed significant main effects of Relatedness ($F_1(1,28) = 8.61$, $p < .01$, $MSe = 38.3$; $F_2(1,56) = 15.69$, $p < .001$, $MSe = 9.2$) and Prime Regularity ($F_1(1,28) = 34.59$, $p < .001$, $MSe = 39.7$; $F_2(1,56) = 14.32$, $p < .001$, $MSe = 38.1$). The Relatedness by Prime Regularity interaction was also significant ($F_1(1,28) = 9.62$, $p < .01$, $MSe = 39.7$; $F_2(1,56) = 15.69$, $p < .001$, $MSe = 9.2$). No other effects were significant.

Planned comparisons showed significant differences between error rates in the related and unrelated conditions for high frequency irregular primes (t_1 (29) = 3.16, $p < .005$, one-tailed; t_2 (15) = 2.82, $p < .01$, one-tailed), and for low frequency irregular primes (t_1 (29) = 1.94, $p < .05$, one-tailed; t_2 (15) = 2.78, $p < .01$, one-tailed). There were no differences in naming errors between related and unrelated conditions for either high frequency regular primes or low frequency regular primes ($t_1 < 1$; $t_2 < 1$ in both cases).

Priming with either a high or low frequency irregular word at 814 ms SOA delayed naming of regular targets. Further, the interference effects observed in Condition C do not appear to be due to a strategic expectancy process. If interference with target naming had arisen because participants were expecting a rhyming word (even after processing an irregular prime) and, hence, were keeping the relevant processing structures active, this would explain why there was interference in the irregular prime condition. However, such a strategy should also have led to facilitation when regular rhyming primes preceded target words. This was not the case as the results of Condition C showed little evidence of facilitation from regular rhyming primes.

The results from Experiment 1 indicate that conspiracy effects of body enemies do arise automatically and persist even after a prime's automatically generated activation should have substantially dissipated. Facilitation, on the other hand, does not arise either automatically or, at least under the present circumstances, strategically.

Taraban and McClelland's (1987) conspiracy model has some difficulty accounting for these data. According to the model, conspiracy effects result from the persistence of the activation generated by the prime. Thus, the interference effects in Condition C can only be explained if we assume that automatic prime activation has a rather long duration. Furthermore, the finding that at all three SOAs priming from body friends did not facilitate the subsequent naming of regular neighbors also poses at least a bit of a problem for the model.

Taraban and McClelland (1987) reported facilitation in nonword naming when nonword targets were preceded by regular words. Thus, it is a puzzle why facilitation was not found in the present study (or by Lupker & Colombo, 1994) using word targets. Other than the difference in the nature of the targets, possibly an important difference between the two studies is that in Taraban and McClelland's study primes were read aloud. Thus, the facilitation they reported may have been the result of facilitation derived from an output code. For example, the use of sufficiently similar articulatory-motor commands for primes and targets at the output stage of naming may have produced faster target naming.

Hypothesizing that phonological priming effects are due to output codes is not without precedent. As noted, Bradshaw and Nettleton's (1974) results seemed to show that overt articulation of both prime and target is necessary in order to get interference effects. They argued that interference occurs only when different articulatory output sets are used in succession. While the results of Experiment 1 indicate that this conclusion is too strong, it could be the case that naming the prime increases output interference for irregular primes and regular targets, and/or that naming the prime produces facilitation when primes and targets rhyme. If these types of interference and facilitative processes exist, they may be different from the ones proposed by the conspiracy model which localizes the effects at the phonological code generation stage of naming. These issues were investigated in Experiment 2.

EXPERIMENT 2

In Experiment 2 a between-subjects design was used to compare target naming latencies for participants who read the primes aloud to target naming latencies for participants who read the primes silently. In order to provide the best comparison between these two groups of participants, prime presentation duration was matched as closely as possible: The mean naming times for each of the primes in the "read primes aloud" (Aloud) condition were used to determine how long each of the primes should be presented in the "read primes silently" (Silent) condition.

Method

Participants. The participants in Experiment 2 were 56 undergraduate students at the University of Western Ontario. The first 28 individuals to participate in the experiment were assigned to the Aloud condition and the next 28 individuals were assigned to the Silent condition. In addition, in order to counterbalance assignment of targets to related and unrelated conditions, two groups of participants were created in both the Aloud and Silent conditions. As in Experiment 1, participants were assigned to these groups by their order of participation in the experiment.

Apparatus and stimuli. The apparatus and stimuli for Experiment 2 were the same as those used in Experiment 1.

Procedure. The procedure used in Experiment 2 was similar to the one used in Experiment 1. Participants were told that they would be presented with a series of word pairs. The participants in the Aloud condition were instructed to read aloud both the primes and targets as quickly and as accurately as possible. In this condition, each trial began with a 1000 ms fixation cross, immediately followed by the prime which remained on the screen until the participant named it aloud. Once the participant had initiated a naming response, the screen was blank for 500 ms. A 500 ms interstimulus interval was used so that the target would not appear while the prime was still being named. Following this interval the target appeared and remained on the screen until the participant named it aloud. Once the participant had initiated the naming response for the target, the screen was blank for an intertrial interval of 2000 ms.

The participants in the Silent condition were instructed to read the primes silently and pronounce the targets aloud, as quickly and as accurately as possible. The mean naming latency for each prime in the Aloud condition was calculated and used as the presentation duration for that prime in the Silent condition. Thus, for participants in the Silent condition the prime presentation duration varied from prime to prime. The trial procedure for the Silent condition was the same as that used in the Aloud condition, except that the primes were presented for predetermined intervals and the participants responded only to the targets. Since the average naming latency for primes in the Aloud condition was 560 ms, and a 500 ms blank screen was presented between presentation of the primes and targets, the average SOA for trials in the Silent condition was 1060 ms.

To ensure that participants in the Aloud condition were not adopting any unusual strategies in order to name the primes and targets in succession, we conducted a pilot study in which 20 participants were asked to name the stimuli used in Experiments 1 and 2. For this pilot study, stimuli were presented individually rather than as prime-target pairs. Presentation order was randomized for each participant. The correlation between mean naming latencies for the prime stimuli in the pilot study ($M = 528$ ms, $SD = 56$) and for the primes in the Aloud condition ($M = 560$, $SD = 59$) was $r = .88$. Therefore, the naming process for primes in the Aloud condition appeared to be quite similar to the process used in a standard naming task.

Results and Discussion

Naming latencies. In the Aloud condition, trials were excluded if the naming latency was

TABLE 2

Mean Naming Latencies (ms) and Naming Error Percentages (in Parentheses) for Targets in Experiment 2 as a Function of Prime Frequency, Prime Regularity, Relatedness, and Instruction Condition

Prime type	Related	Unrelated	RT effect	Error effect
Read primes aloud condition (mean SOA = 1060 ms)				
High frequency				
Regular	516 (0.4)	534 (1.8)	+18*	+1.4
Irregular	602 (15.2)	575 (6.7)	−27*,**	−8.5*,**
Low frequency				
Regular	522 (1.8)	541 (3.6)	+19*,**	+1.8
Irregular	612 (17.4)	574 (13.5)	−38*,**	−3.9*
Read primes silently condition (mean SOA = 1060 ms)				
High frequency				
Regular	545 (0.9)	548 (2.5)	+3	+1.6
Irregular	581 (13.3)	569 (6.5)	−12*	−6.8*,**
Low frequency				
Regular	545 (1.3)	549 (2.6)	+4	+1.3
Irregular	588 (13.8)	570 (10.3)	−18*,**	−3.5*,**

*$p < .05$ by subjects.
**$p < .05$ by items.

outside the cutoff times (1.5% of all trials), or if the prime or target was mispronounced (the prime was mispronounced on 2.5% of trials and the target was mispronounced on 7.6% of trials). Similarly, in the Silent condition, trials were excluded if the naming latency was outside the cutoff times (1.9% of all trials), or if the target was mispronounced (6.4% of all trials). Mean naming latencies are presented in Table 2. The correct naming latencies were submitted to a two (Relatedness) by two (Prime Regularity) by two (Prime Frequency) by two (Participant Group) by two (Instruction Condition) ANOVA, with Relatedness, Prime Regularity, and Prime Frequency as within-subject factors and Participant Group and Instruction Condition as between-subject factors.

As illustrated in Table 2, the main effects of Prime Regularity ($F_1(1,52) = 161.38$, $p < .001$, $MSe = 1478.7$; $F_2(1,112) = 39.82$, $p < .001$, $MSe = 3772.6$) and Relatedness ($F_1(1,52) = 4.89$, $p < .05$, $MSe = 941.2$; $F_2(1,112) = 4.25$, $p < .05$, $MSe = 655.6$) were significant. These main effects were qualified by a significant Prime Regularity by Relatedness interaction ($F_1(1,52) = 29.48$, $p < .001$, $MSe = 1150.9$; $F_2(1,112) = 33.19$, $p < .001$, $MSe = 655.6$).

Also significant was the Instruction Condition by Prime Regularity interaction ($F_1(1,52) = 19.37$, $p < .001$, $MSe = 1478.7$; $F_2(1,112) = 3.57$, $p = .06$, $MSe = 3772.6$). The difference between naming latencies for trials with regular primes ($M = 528$ ms) and trials with irregular primes ($M = 591$ ms) was bigger in the Aloud condition than in the Silent condition ($M = 547$ ms for trials with regular primes and $M = 577$ ms for trials with irregular primes). However, this interaction was qualified by the significant Instruction Condition by Relatedness by Prime Regularity interaction ($F_1(1,52) = 6.10$, $p < .05$, $MSe = 1150.9$; $F_2(1,112) = 5.32$, $p < .05$, $MSe = 655.6$). No other effects were significant.

Planned comparisons were used to examine the difference between latencies in the related and unrelated conditions for each type of prime-target pair. In the Aloud condition, target naming was significantly delayed for high frequency irregular primes (t_1 (27) = 2.74, $p < .05$, one-tailed; t_2 (15) = 2.52, $p < .05$, one-tailed) and for low frequency irregular primes (t_1 (27) =

3.85, $p < .01$, one-tailed; t_2 (15) = 2.77, $p < .01$, one-tailed). Also, in that condition, facilitation of target naming was significant for high frequency regular primes (t_1 (27) = 1.82, $p < .05$, one-tailed; t_2 (15) = 1.50, $p = .07$, one-tailed) and for low frequency regular primes (t_1 (27) = 1.93, $p < .05$, one-tailed; t_2 (15) = 2.66, $p < .01$, one-tailed). In the Silent condition, target naming was significantly delayed for high frequency irregular primes, although the effect was not significant by items (t_1 (27) = 2.10, $p < .05$, one-tailed; t_2 (15) = .96, $p > .05$, one-tailed). There was also a significant effect for low frequency irregular primes (t_1 (27) = 3.15, $p < .01$, one-tailed; t_2 (15) = 3.11, $p < .005$, one-tailed). Finally, in the Silent condition, facilitation of target naming was not significant for either high frequency regular primes or low frequency regular primes ($t_1 < 1$; $t_2 < 1$ in both cases).

We also compared the size of interference and facilitation effects, across frequency, in the Aloud and Silent conditions. The magnitude of the interference effects from irregular primes in the Aloud and Silent conditions differed only marginally (t_1 (54) = 1.39, $p = .09$, one-tailed; t_2 (62) = 1.35, $p = .09$, one-tailed). The magnitude of the facilitation effects from regular primes in the Aloud and Silent did differ significantly (t_1 (54) = 2.48, $p < .05$, one-tailed; t_2 (62) = 1.59, $p = .06$, one-tailed), as would be expected since significant facilitation was observed only in the Aloud condition.

Naming errors. Mean percentages of errors for each condition are presented in Table 2. The analysis of naming errors showed significant effects of Relatedness ($F_1(1,52) = 9.99$, $p < .01$, $MSe = 44.0$; $F_2(1,112) = 3.81$, $p < .05$, $MSe = 64.1$), Prime Regularity ($F_1(1,52) = 183.89$, $p < .001$, $MSe = 52.3$; $F_2(1,112) = 33.21$, $p < .001$, $MSe = 196.6$) and their interaction ($F_1(1,52) = 24.79$, $p < .001$, $MSe = 45.2$; $F_2(1,112) = 11.56$, $p < .001$, $MSe = 64.1$). There was also an effect of Prime Frequency which was significant only in the subjects analysis ($F_1(1,52) = 17.62$, $p < .001$, $MSe = 29.8$; $F_2(1,112) = 1.54$, $p = .22$, $MSe = 196.6$) and an interaction of Prime Frequency and Prime Regularity that was significant only in the subjects analysis ($F_1(1,52) = 4.50$, $p < .05$, $MSe = 43.5$; $F_2 < 1$). No other effects were significant.

Planned comparisons showed that in the Aloud condition, the difference between errors in the related and unrelated conditions was significant for high frequency irregular primes (t_1 (27) = 5.16, $p < .001$, one-tailed; t_2 (15) = 2.18, $p < .05$, one-tailed) and for low frequency irregular primes in the subjects analysis (t_1 (27) = 2.37, $p < .05$, one-tailed; $t_2 < 1$). There were no effects for either high frequency regular primes or low frequency regular primes ($t_1 < 1$; $t_2 < 1$ in both cases).

In the Silent condition, there were significant effects in the errors for high frequency irregular primes (t_1 (27) = 4.13, $p < .001$, one-tailed; t_2 (15) = 2.41, $p < .05$, one-tailed) and for low frequency irregular primes (t_1 (27) = 2.12, $p < .05$, one-tailed; t_2 (15) = 1.50, $p = .07$, one-tailed). There were no effects for either high frequency regular primes or low frequency regular primes ($t_1 < 1$; $t_2 < 1$ in both cases).

The results of Experiment 2 suggest that, although interference from body enemies occurs even when primes are not read aloud, the effects may be larger when the prime is read aloud. Bradshaw and Nettleton (1974) argued that overt articulation of both prime and target is necessary to produce interference effects. They suggested that an articulatory output set may be established briefly when the prime is named, and that the application of this set may inhibit subsequent naming of a target that shares the prime's orthography but not its phonology. The results from Experiment 2 are partly consistent with this view. The fact that the interference effect was numerically larger when primes were read aloud suggests that processes of this sort may in fact be involved.

The results from Experiment 2 also support the conclusion that facilitation from regular rhyming primes does occur when the primes are read aloud. A possible explanation, in line with the Bradshaw and Nettleton (1974) argument, is that facilitation occurs when a similar articulatory set is established for naming the prime and the target. Taken together, the results from Experiment 2 suggest that there may be some validity to Bradshaw and Nettleton's (1974) claim that output codes are a source of both interference and facilitation effects.

EXPERIMENT 3

The main generalization to be drawn from the results of Experiments 1 and 2 is that phonological facilitation requires output coding of the prime while phonological interference is produced by both output and phonological coding of the prime. In Experiment 3 we attempted to determine which component of target processing is affected by these prime codes. That is, target processing also must involve both phonological and output coding. Although Bradshaw and Nettleton (1974) suggested that target output is the process affected by the prime's output code, it is equally possible that the prime's output code is actually affecting the phonological coding of the target.

We addressed these issues by using a set of prime-target pairs like EIGHT-HATE that have the same relation between output codes as those in the previous experiments (e.g., MATE-HATE), but that have a different relation between orthography and phonology. If, in previous experiments, what is being affected by the primes is the output coding process of the target, these EIGHT-HATE pairs should produce similar effects to those observed previously (i.e., facilitation only when the prime is named). However, because the phonological coding process of the target is different from that of the prime, if that process is the process being affected, no facilitation effects would be expected.

There is some literature on the issue of EIGHT-MATE priming. In a lexical decision task, Hillinger (1980) reported facilitation for EIGHT-MATE word pairs. Martin and Jensen (1988), however, were unable to replicate Hillinger's effect. Using a naming task, Peter, Lukatela, and Turvey (1990) also reported a failure to find facilitation for MATE primed with EIGHT. In the Peter et al. experiments, however, participants read the prime silently before naming the target. Based on the results of the present Experiment 2, it is possible that the naming of MATE would have been facilitated if the prime EIGHT had been named aloud.

One question to be addressed in Experiment 3, then, is whether there is facilitation for EIGHT-HATE as well as MATE-HATE when both primes and targets are named. A similar question can be asked about the interference effects. That is, since TOMB as a prime leads to interference in naming the target BOMB, will ROOM as a prime lead to interference in naming the target BOMB (either when the prime is named or when it is not)? If so, it would implicate the target output process as a locus of the interference effect. If not, it would suggest that the locus of the interference effect was solely the process of generating the target's phonological code.

Method

Participants. The participants in Experiment 3 were 88 undergraduate students at the University of Western Ontario. The first 44 individuals to participate in the experiment were assigned to the Aloud condition and the next 44 individuals were assigned to the Silent condition.

Apparatus. The apparatus was the same as that described for Experiment 1.

Stimuli. As in Experiments 1 and 2, the stimuli for Experiment 3 included both regular and irregular primes. Although each participant was presented with pairs of stimuli (one prime and one target in each pair), the stimuli for this experiment consisted of triples of two primes and one target. The triples were constructed so that formal similarity of prime and target could be manipulated within items. For instance, in the regular prime condition, one prime-prime-target triple was EIGHT-MATE-HATE. Using this triple, participants would either be presented with a phonologically and formally similar prime-target pair (MATE-HATE), a phonologically similar and formally dissimilar prime-target pair (EIGHT-HATE), or an unrelated pair (AXE-HATE or WINE-HATE). Similarly, a prime-prime-target triple in the irregular prime condition was ROOM-TOMB-BOMB, and participants would either be presented with a phonologically dissimilar and formally similar prime-target pair (TOMB-BOMB), a phonologically “pseudodissimilar” and formally dissimilar prime-target pair (ROOM-BOMB), or an unrelated pair (SEW-BOMB or CHEF-BOMB).

As in Experiments 1 and 2, the unrelated pairs (e.g., SEW-BOMB) were created such that there was minimal overlap in orthography between the prime and target. The mean overlap between primes and targets in the unrelated condition was 0.35 letters.

Thirty-two rhyming prime-prime-target triples were selected such that target frequency was less than 55 per million ($M = 14.9$, Median = 18) and the primes shared the regular phonology of the target (“regular” prime condition). Another 28 prime-prime-target triples were selected such that target frequency was less than 55 per million ($M = 14.4$, Median = 10) and one prime was irregular and formally similar to the target and the other prime rhymed with the first prime but was formally dissimilar to the target (“irregular” prime condition).

In this experiment, prime frequency was not manipulated. Because there was a limited number of stimulus triples from which to choose we were unable to match the frequency of the two types of primes (formally similar and dissimilar) in the regular and irregular conditions. The mean frequencies of the primes in the regular condition were 130.0 (Median = 21.0) and 37.0 (Median = 11.0) for the formally similar and dissimilar primes, respectively. The mean frequencies of the primes in the irregular condition were 300.1 (Median = 50.0) and 150.5 (Median = 21.5) for the formally similar and dissimilar primes, respectively. In Experiment 2, where prime frequency was manipulated and the SOA was similar to that used in this experiment, prime frequency did not interact with relatedness in either the latency or error data. Therefore, although the mean frequencies for the prime conditions in Experiment 3 were somewhat different, there was no reason to believe that any effects involving relatedness would be affected by those differences.

There were four different versions of the stimulus list in the experiment as each target was paired with each of the two types of related primes and the two types of unrelated primes. In order that each participant see only one version of the stimulus list, four groups of participants were used in both the Aloud and Silent conditions. Participants were assigned to these groups by the order in which they appeared for the experiment.

Following eight practice trials, each participant was presented with 60 experimental trials. The stimuli were presented in a different random order for each participant. A complete list of the primes and targets is presented in the Appendix.

Procedure. The procedure was similar to that used in Experiment 2. The mean naming latency for each prime in the Aloud condition was calculated and was used as the presentation duration for that prime in the Silent condition. Since the average naming latency for primes in the Aloud condition was 612 ms, and a 500 ms blank screen was presented between the prime and target, the average SOA for trials in the Silent condition was 1112 ms.

Results and Discussion

Naming latencies. Trials were excluded from these analyses if the naming latency was outside the cutoff times (2.4% of trials in the Silent and Aloud conditions combined), or, in the Aloud condition, if the prime or target was mispronounced (the prime was mispronounced on 2.1% of trials and the target was mispronounced on 5.2% of all trials). In the Silent condition, trials were also excluded if the target was mispronounced (3.0% of trials). Mean naming latencies are presented in Table 3. The correct naming latencies were submitted to a two (Relatedness) by two (Prime Regularity) by two (Formal Similarity) by two (Participant Group) by two (Instruction Condition) ANOVA, with Relatedness, Prime Regularity, and Formal Similarity as within-subject factors and Participant Group and Instruction Condition as between-subject factors.

As illustrated in Table 3, the main effect of Prime Regularity was significant ($F_1(1,80) = 39.78$, $p < .001$, $MSe = 1211.9$; $F_2(1,52) = 2.19$, $p = .09$, $MSe = 12800.6$). The interactions of Prime Regularity and Relatedness ($F_1(1,80) = 6.46$, $p < .05$, $MSe = 1134.8$;

TABLE 3

Mean Naming Latencies (ms) and Naming Error Percentages (in Parentheses) for Targets in Experiment 3 as a Function of Orthographic Similarity, Prime Regularity, Relatedness, and Instruction Condition

Prime type	Related	Unrelated	RT effect	Error effect
Read primes aloud condition (mean SOA = 1112 ms)				
Formally similar				
Regular	562 (3.5)	579 (3.8)	+17*	+0.3
Irregular	614 (10.7)	578 (4.7)	−36*,**	−6.0*,**
Formally dissimilar				
Regular	586 (4.2)	575 (5.5)	−11	+1.3
Irregular	583 (4.8)	586 (4.5)	+3	−0.3
Read primes silently condition (mean SOA = 1112 ms)				
Formally similar				
Regular	555 (3.4)	561 (3.2)	+6	−0.2
Irregular	587 (3.9)	570 (2.7)	−17*	−1.2
Formally dissimilar				
Regular	564 (2.0)	570 (3.2)	+6	+1.2
Irregular	574 (3.2)	582 (2.3)	+8	−0.9

*$p < .05$ by subjects.
**$p < .05$ by items.

$F_2(1,52) = 3.34$, $p = .07$, $MSe = 2712.6$) and Prime Regularity and Formal Similarity ($F_1(1,80) = 10.20$, $p < .005$, $MSe = 1292.6$; $F_2(1,52) = 3.61$, $p = .06$, $MSe = 2100.7$), were also significant.

Further, the three-way interaction of Prime Regularity, Relatedness, and Formal Similarity was significant ($F_1(1,80) = 22.24$, $p < .001$, $MSe = 1127.4$; $F_2(1,52) = 4.00$, $p < .05$, $MSe = 4447.9$), as was the four-way interaction of Instruction Condition, Prime Regularity, Relatedness, and Formal Similarity ($F_1(1,80) = 4.83$, $p < .05$, $MSe = 1127.4$; $F_2(1,52) = 2.07$, $p = .14$, $MSe = 2149.9$), although this effect was not significant in the items analysis. The interaction of Prime Regularity, Relatedness, and Formal Similarity was much larger in the Aloud condition.

Planned comparisons showed that, in the Aloud condition, there was significant interference for formally similar, irregular primes (TOMB-BOMB) (t_1 (43) = 3.36, $p < .001$, one-tailed; t_2 (27) = 3.13, $p < .005$, one-tailed). Also, in that condition, facilitation of target naming was significant for formally similar, regular primes (MATE-HATE) (t_1 (43) = 2.39, $p < .05$, one-tailed; t_2 (31) = 1.36, $p = .09$, one-tailed), although the effect was only marginally significant in the items analysis. The effect for formally dissimilar, regular (EIGHT-HATE) primes went in the opposite direction to what had been expected (t_1 (43) = 1.79, $p = .08$, two-tailed; t_2 (31) = 1.74, $p = .09$, two-tailed), and was not significant. Target naming was not significantly affected by the formally dissimilar irregular (ROOM-BOMB) primes ($t_1 < 1$; $t_2 < 1$). In the Silent condition, there was significant interference for target naming for formally similar irregular primes (TOMB-BOMB) (t_1 (43) = 2.48, $p < .01$, one-tailed; t_2 (27) = 1.06, $p = .15$, one-tailed), although the effect was not significant in the items analysis. There was no significant effect for formally similar regular primes (MATE-HATE) ($t_1 < 1$; $t_2 < 1$), or for formally dissimilar irregular (ROOM-BOMB) (t_1 (43) = 1.14, $p = .13$, one-tailed; t_2 (27) < 1) or regular (EIGHT-HATE) ($t_1 < 1$; $t_2 < 1$) primes.

We also compared the size of interference and facilitation effects in the Aloud and Silent conditions. The difference in the interference effects from formally similar irregular primes in the Aloud and Silent conditions was significant by subjects and marginally significant by items (t_1 (86) = 1.69, $p < .05$, one-tailed; $t_2(27)$ = 1.48, $p = .09$, one-tailed). The difference in the facilitation effects from formally similar regular primes in the Aloud and Silent was marginally significant by subjects (t_1 (86) = 1.53, $p = .06$, one-tailed; t_2 (31) = .96, $p = .14$, one-tailed), due to the fact that facilitation was observed only in the Aloud condition. The effects of formally dissimilar irregular primes were not significantly different in the Aloud and Silent conditions ($t_1 < 1$; $t_2 < 1$). The difference in the effects of formally dissimilar regular primes in the two conditions was not significant (t_1 (86) = 1.60, $p = .15$, two-tailed; t_2 (31) < 1), and the small difference that did arise went in the wrong direction.

Naming errors. Mean percentages of errors for each condition are presented in Table 3. The analysis of naming errors showed a significant main effect of Instruction Condition ($F_1(1,80) = 11.24$, $p < .001$, $MSe = 47.0$; $F_2(1,52) = 5.78$, $p < .05$, $MSe = 26.9$). The interaction of Instruction Condition and Prime Regularity was also significant ($F_1(1,80) = 4.27$, $p < .05$, $MSe = 24.1$; $F_2(1,52) = 2.84$, $p = .09$, $MSe = 26.9$), although the effect was only marginally significant in the items analysis.

This analysis also showed a significant interaction of Prime Regularity and Relatedness ($F_1(1,80) = 4.76$, $p < .05$, $MSe = 32.6$; $F_2(1,52) = 5.01$, $p < .05$, $MSe = 28.6$). The other significant effect was the three-way interaction of Instruction Condition, Prime Regularity, and Formal Similarity ($F_1(1,80) = 6.11$, $p < .05$, $MSe = 24.1$; $F_2(1,52) = 2.27$, $p = .13$, $MSe = 35.7$), although the effect was not significant in the items analysis.

Planned comparisons showed that, in the Aloud condition, there were significantly more errors in the related condition for formally similar, irregular primes (TOMB-BOMB) (t_1 (43) = 2.73, $p < .005$, one-tailed; t_2 (27) = 2.35, $p < .05$, one-tailed). There were no other significant effects in the Aloud condition (all $t_1 < 1$; $t_2 < 1$). In the Silent condition, there were no significant effects ($t_1 < 1$, $t_2 < 1$).

The results of Experiment 3 for formally similar primes and targets (TOMB-BOMB and MATE-HATE) replicated the results of Experiment 2. For target naming, there was evidence that phonological interference from enemy primes occurred when primes were read silently, and this effect appeared to increase when primes were read aloud. Phonological facilitation from friend primes occurred only when primes and targets were both named aloud. These results in Experiment 2 led us to conclude that both phonological facilitation and, to some extent, phonological interference are due to output coding of the prime.

In Experiment 3 we attempted to determine what *target* process or processes (i.e., phonological code generation or output) is being affected in these tasks. This was done by determining whether the interference and facilitation effects were dependent on formal similarity between the primes and targets. If the effects due to generating output codes for the primes are purely the result of interactions between codes at the output level, then formally dissimilar rhyming primes and targets would produce the same facilitation when named aloud as formally similar rhyming primes and targets. Our results showed that formally dissimilar rhyming primes did not affect target naming, regardless of whether the primes were named aloud. In addition, target naming was not interfered with by our primes that rhymed with, but were spelled differently than, our enemy primes even when those primes were named aloud. Thus, there is little evidence that either the facilitation or interference effects observed in previous experiments were due simply to the interaction of output codes.

GENERAL DISCUSSION

In this paper, we have focused on the process underlying word naming. Clearly, this process involves translating orthographic codes into phonological codes, and articulation. Our specific issue of interest has been how this word naming process can be affected by phonologically similar and dissimilar primes. Our results suggest to us something very important about word naming and priming: The important components in these processes are not units and codes, but rather are the shared *connections* and weights linking orthographic and phonological units. Thus, in the account of the data that we will propose, the central issue is how those weights are affected by the presentation of formally similar primes.

In this research, we addressed two specific empirical issues. The first issue was the impact of naming the primes on both the interference from formally similar irregular primes and the facilitation from formally similar (i.e., rhyming) regular primes. As noted, according to Taraban and McClelland's (1987) conspiracy theory these effects are due entirely to the phonological coding process. However, in Taraban and McClelland's studies, as in most other studies in this literature, participants named the primes aloud, raising the possibility that output codes are somehow involved in the process. In fact, such a view had been expressed by Bradshaw and Nettleton (1974) who reported that these interference effects do not arise when primes are not named.

Our results show that irregular primes do *not* have to be named in order to cause interference in naming regular targets. However, as reported by Lupker and Colombo (1994), our results also show that there is little, if any, facilitation from regular, rhyming primes when those primes are not named. In Experiments 2 and 3 the interference and potential facilitation effects were examined further by contrasting a condition in which participants read the primes silently with a condition in which participants named the primes aloud. The results showed that the interference effects arising when primes are read silently tended to increase when the primes were named aloud. The results also indicated that naming the primes aloud does facilitate the naming of formally similar rhyming targets.

The second specific issue addressed in these experiments was the time course of interference from irregular primes and facilitation from regular, rhyming primes. Taraban and McClelland (1987) argued that interference and facilitation arise because the residual activation of the prime's representational structures influences target processing. Burt and Humphreys (1993), however, found that phonological interference survived a lengthy prime-target interval (10 intervening trials) and argued that this delayed interference was inconsistent with Taraban and McClelland's residual activation account (as well as with any other account that would try to explain these effects in terms of the concept of residual activation).

In our Experiment 1, interference was observed at SOAs ranging from 129 to 814 ms. In Experiments 2 and 3 interference (and facilitation when the primes were named) was observed at average SOAs of 1060 and 1112 ms. These findings suggest that although phonological interference effects arise rapidly, consistent with models attributing these effects to automatic activation, the effects also persist well beyond the time when automatic activation of a prime's representational structures should have decayed (unless maintained by control processes). The question is whether this time course of interference and facilitation can be explained by any model of word naming.

Before considering how these results might be interpreted by models of word naming, we should consider some empirical issues surrounding our lack of a facilitation effect when primes were not named. As noted, the targets used in the regular prime condition were generally consistent. From the perspective of the conspiracy theory one might ask whether it is legitimate to expect facilitation when naming regular-consistent words since these words are not exposed to competition from neighbors and, hence, are named very rapidly. Regular-inconsistent words, on the other hand, are exposed to some competition from irregular neighbors and, therefore, activating a friend of these words might be somewhat more likely to produce facilitation. More generally, the question is whether the lack of facilitation is simply a floor effect due to the speed with which regular-consistent words are named.

Certainly, this is a legitimate question. Although Lupker and Colombo (1994) produced little evidence of priming with (mainly) regular-consistent rhyming pairs, they did show that when rhyming *irregular* word pairs involving low frequency targets are used (e.g., WASH-SQUASH), facilitation is obtained, even when the primes are not named. Thus, the chance of observing facilitation may be higher for regular-inconsistent words than for regular-consistent words. As the results of the Aloud conditions of Experiments 2 and 3 indicate, however, facilitation effects *are* obtained for regular-consistent words when the prime is read aloud. Thus, it is clear that even regular-consistent words can be facilitated if the conditions are right.

Further, one cannot explain those facilitation effects by suggesting that target naming was generally slower, and thus above floor, when facilitation was observed. In Experiment 2, for example, in the Aloud condition we observed facilitation from regular rhyming primes (18 ms for high frequency primes and 19 ms for low frequency primes) even though response times on the unrelated trials were actually slightly *faster* than those for the same trials in the Silent condition (534 and 541 ms for high frequency and low frequency regular primes in the Aloud condition, and 548 and 549 ms for high and low frequency regular primes in the Silent condition, respectively). Thus, it seems unlikely that the lack of facilitation when primes were read silently was due to a methodological or empirical artifact.

Models of Word Naming

According to Taraban and McClelland's (1987) conspiracy model, when a reader processes a prime, the representational structures for that word are activated. This activation affects the time to generate a phonological code for a subsequent target word. The model predicts that the activation produced by a formally similar irregular prime will inhibit pronunciation of a regular target, because the prime and target have conflicting phonological features. The activation produced by a regular prime, however, should facilitate regular target pronunciation since the prime and target share most phonological features.

Our discovery of interference even at relatively brief SOAs supports the assumption of the conspiracy model that interference stems from activation of the prime. However, the fact that the interference lasted well beyond the time when automatic activation of the prime should have dissipated and further, that the effect does not appear to be due to expectancies are difficult to reconcile with the conspiracy model. Finally, as stated above, the conspiracy model suggests that facilitation and interference occur by the same mechanism—activation of neighbors. Thus, there is no reason to expect interference without parallel facilitation, as we found in all three experiments when the primes were read silently.

To this point, we have been discussing the conspiracy model in the specific terms in which it was presented by Taraban and McClelland (1987). The generic model is somewhat more flexible in that it involves a number of parameters. Could the parameters of the conspiracy model be set in such a way to make it predict interference but not facilitation? The important parameter here would seem to be the degree of inhibition between word-level units. When a prime word is presented, the lexical unit for the prime is activated. If one assumes that this activation has not decayed by the time the target word is presented, any formal similarity between prime and target will serve to further increase the activation in the word-level unit for the prime. The resulting activation in this unit may be so strong that it inhibits target processing at the word level. For a regular, rhyming prime and target, this inhibition may then eliminate any facilitation that might be provided by the fact that the prime and target share phonological features. For an irregular nonrhyming prime, this inhibition simply adds to the interference effect. Thus, with the correct selection of parameters the model could be made to predict interference without facilitation.

There are two problems with this account, however. The first is that it predicts inhibition effects even in a task like the lexical decision task, in which there are typically no phonological facilitation effects. Such a prediction is inconsistent with the previous literature (e.g., Colombo, 1986; Lupker & Colombo, 1994; Segui & Grainger, 1990). The second problem is that it would be unable to explain the facilitation in our Aloud condition. That is, in order to account for the increased interference from enemy primes in the Aloud condition, one must make the assumption that naming the prime more strongly activates the prime's representational structures (including its word-level unit), effectively increasing the prime's ability to inhibit its neighbors. The problem, of course, is that this increased inhibition would affect the word-level units for friend targets as well. Thus, the implication is that one would be less likely to observe facilitation from friend primes in the Aloud condition than in the Silent condition. Obviously, this is not what occurred.

According to the tenets of the DRC model (Coltheart et al., 1993; Coltheart & Rastle, 1994) consistency effects are the result of processing on the lexical route. The workings of the lexical route are, in fact, quite similar to those embodied in the conspiracy model. Thus, the DRC model would make similar predictions to those of the conspiracy model. As discussed above, it might be possible to set parameters to predict no facilitation. Overall, however, this model will have no greater success than the conspiracy model because it will run into the same problems as the conspiracy model.

If one wishes to account for the present results, it appears that the most problematic issue to be dealt with is that when participants are called upon to name the primes, facilitation effects emerge and interference effects become more potent. In fact, as Burt and Humphreys (1993) demonstrated, naming the prime produces phonological interference effects at delays of up to 30 seconds between primes and targets. As they suggested, these types of results really are best described by PDP-type models (i.e., models based on learned correspondences between orthography and phonology) as long as those models also incorporate shorter-term, larger weight changes.

To extend Burt and Humphreys' (1993) explanation to the present data, their explanation must also account for: (a) the lack of facilitation from rhyming primes that are not named aloud, and (b) the effects of naming the prime aloud (facilitation for rhyming pairs and increased interference from formally similar, nonrhyming primes). This can be accomplished if one assumes that simply viewing the prime increases the short-term weights for the orthography-to-phonology correspondences but *only to a certain level,* while naming the prime increases those weights to a higher level.

More specifically, in English, the correspondence between orthography and phonology for most words is regular, by definition. For regular primes, the weights in the PDP model already represent, to a large degree, the appropriate orthography-to-phonology correspondences. Thus, increasing these strengths to a certain level, by exposing the system to a regular rhyming prime, may not represent much of an increase. Regular primes may thus have little effect on naming rhyming targets. However, when the prime is named, the increase in short-term weights would be more substantial. Those increased weights may represent a strong enough bias toward the regular pronunciation that regular targets would show facilitation.

With respect to the interference effect, the orthography-to-phonology correspondences of irregular words are not very well represented. Thus, for irregular words, any weight change would be expected to produce interference when naming a regular, nonrhyming target even when the prime is simply viewed. If those weights get an additional increase because the prime is named, the interference effect would, of course, increase. It also follows that the irregular primes should produce reliable facilitation effects when the target is a rhyming irregular word (e.g., WASH-SQUASH) as Lupker and Colombo (1994) reported.

The bottom line is that the increased interference and the appearance of facilitation can both be explained if one assumes that the effect of naming aloud is simply to create larger short-term weight changes (i.e., weight changes that are larger than those that occur from just viewing the prime). That is, the effect of naming the prime aloud versus reading it silently is merely a quantitative one. The result is to turn a small interference effect into a larger one and a virtually null facilitation effect into a significant one.

Weight changes of this sort are described by McClelland and Rumelhart (1985) in their distributed model of information processing and memory. They describe a model of memory in which memory traces decay at a much slower rate than do patterns of activation. Individual inputs to the system " . . . exert large short-term effects on the weights, but after they decay the residual effect is considerably smaller" (McClelland & Rumelhart, 1985, p. 166). If word primes have the same effect on the naming system as memory traces do on the memory system, then this type of short-term weight change mechanism could be used to model the effects observed in the present experiments. These assumptions about the existence and influence of short-term weights obviously need additional empirical evaluation.

Conclusions

The present results show, for word naming, a pattern of facilitation and interference from body neighbors that cannot be easily explained by any of the existing models. Those findings suggest that priming effects arise not from reactivation of phonological and output units or codes, but from learning effects on weighted connections between orthography and phonology.

This conclusion further points to the importance of considering links and processes, rather than units and codes, in explaining and predicting word naming. It appears that models of word naming in which effects are based on the influence of various codes (orthographic, phonological, output) fail to capture what is happening in our tasks. We suggest instead that the types of priming effects we observed are best captured by a model that attributes these effects to the links between such representations. We also suggest that the present findings are best accounted for by a PDP-type model modified to include immediate, short-term, larger weight changes on connections between orthography and phonology (Burt & Humphreys, 1993). However, we also see no compelling reason that a similar mechanism could not ultimately be incorporated into other models (e.g., Coltheart et al.'s (1993) DRC model) as well.

APPENDIX

Experiment 1: *Stimuli and Item Means for Naming Latencies and Error Percentages in Conditions A, B, and C*

	Condition A		Condition B		Condition C	
Prime type	Latency	Errors	Latency	Errors	Latency	Errors
High frequency irregular						
Related						
what-chat	574	11	635	8	548	7
want-rant	627	0	631	0	626	0
mind-wind	620	44	651	42	541	14
son-don	564	17	592	42	606	7
none-lone	614	11	599	0	566	0
gross-floss	599	0	648	0	606	0
lose-hose	654	0	660	17	697	7
word-cord	600	5	641	0	596	0
move-cove	736	5	639	0	712	0
blood-brood	726	22	704	25	659	14
most-frost	619	0	558	0	574	0
done-hone	693	33	600	17	728	28
give-dive	615	33	584	17	576	0
have-cave	631	11	549	0	569	28
some-dome	585	11	619	8	694	14
put-nut	554	0	546	0	532	0

APPENDIX—*Continued*

	Condition A		Condition B		Condition C	
Prime type	Latency	Errors	Latency	Errors	Latency	Errors
High frequency irregular						
Unrelated						
mind-chat	571	11	564	0	522	0
lose-rant	588	5	568	0	694	5
son-wind	554	17	532	25	514	7
gross-don	620	5	558	17	577	7
want-lone	600	0	577	0	559	0
none-floss	614	0	549	0	529	0
word-hose	673	5	671	17	696	0
what-cord	557	0	545	0	562	0
blood-cove	575	0	634	0	558	0
done-brood	623	22	737	8	591	7
move-frost	541	0	619	0	592	0
give-hone	761	28	742	17	673	7
most-dive	523	0	575	0	561	0
some-cave	531	5	577	0	552	7
put-dome	601	5	603	8	591	0
have-nut	508	0	522	0	530	0
High frequency regular						
Related						
need-weed	555	0	535	0	543	0
help-kelp	598	0	612	0	571	0
tell-bell	554	0	537	0	583	0
size-prize	553	5	594	0	576	0
mass-lass	502	0	603	0	523	0
thin-chin	542	0	623	0	503	0
base-chase	539	5	550	8	532	5
site-kite	514	0	569	0	514	0
boy-toy	512	0	491	0	539	0
feet-beet	618	0	557	0	583	0
man-tan	589	0	544	0	517	0
ship-chip	646	5	629	0	571	0
back-sack	587	5	544	0	535	0
gun-bun	612	0	573	0	584	0
park-bark	575	0	568	0	584	0
chair-stair	607	0	562	0	591	0
Unrelated						
help-weed	547	0	553	0	536	0
need-kelp	654	0	633	0	601	0
mass-bell	565	0	508	0	503	0
tell-prize	579	0	556	0	548	0
size-lass	556	0	529	0	562	0
base-chin	574	0	557	0	524	0
site-chase	567	5	529	0	554	5
thin-kite	605	0	572	0	540	0
feet-toy	503	0	557	0	501	0
gun-beet	570	0	604	0	623	0
boy-tan	502	0	572	0	562	0
back-chip	483	0	565	0	502	0

APPENDIX—*Continued*

Prime type	Condition A		Condition B		Condition C	
	Latency	Errors	Latency	Errors	Latency	Errors
High frequency regular						
Unrelated						
man-sack	590	5	633	17	590	0
ship-bun	550	0	626	8	611	0
chair-bark	548	0	607	0	580	0
park-stair	585	0	601	0	534	0
Low frequency irregular						
Related						
deaf-leaf	621	11	650	0	589	7
tomb-bomb	612	5	592	8	640	0
wart-mart	616	0	615	0	570	0
sew-dew	604	0	621	8	605	0
said-raid	563	0	637	8	551	7
soot-loot	547	5	575	8	540	0
wand-sand	555	0	566	8	531	7
quoth-broth	598	0	696	0	614	0
quart-chart	652	0	566	0	600	0
squash-thrash	717	0	612	0	715	7
wash-mash	620	11	553	0	577	7
wear-sear	640	33	666	0	738	7
caste-paste	623	0	632	8	644	0
worse-morse	646	5	688	0	733	0
doll-toll	640	11	603	17	672	7
vein-stein	626	39	595	42	791	28
Unrelated						
soot-leaf	563	0	541	0	528	0
deaf-bomb	683	5	597	0	625	0
said-mart	610	0	679	0	560	0
wart-dew	628	0	576	0	559	0
sew-raid	572	0	537	8	541	0
quoth-loot	623	0	545	8	550	0
tomb-sand	565	0	520	0	568	0
wand-broth	679	5	584	0	672	7
squash-chart	583	0	602	0	535	0
quart-thrash	661	0	755	0	670	0
wear-mash	539	11	584	0	548	0
vein-sear	684	5	699	0	604	0
worse-paste	587	0	632	0	599	0
wash-morse	636	0	618	0	618	0
caste-toll	523	5	671	17	587	0
doll-stein	672	22	591	25	613	21
Low frequency regular						
Related						
sled-fled	612	0	686	0	601	0
claw-flaw	576	0	613	0	592	0
bib-rib	544	0	556	0	529	0
noose-moose	581	0	692	17	581	0

APPENDIX—*Continued*

	Condition A		Condition B		Condition C	
Prime type	Latency	Errors	Latency	Errors	Latency	Errors
Related						
bug-tug	537	0	593	0	538	0
tent-dent	537	0	589	0	575	0
tail-nail	517	0	535	0	523	0
beer-deer	573	0	631	0	566	0
couch-pouch	691	11	565	8	609	0
sting-cling	603	5	544	0	571	0
log-hog	566	0	550	0	584	0
pig-dig	567	0	536	0	558	0
loom-doom	582	0	565	0	596	0
lamp-damp	590	5	527	0	549	0
nest-pest	622	0	560	0	562	0
cane-pane	597	5	553	5	545	0
Unrelated						
tail-fled	627	0	616	0	621	0
noose-flaw	599	0	565	0	584	0
bug-rib	570	0	548	0	558	0
claw-moose	603	0	549	8	585	0
sled-tug	601	0	558	0	541	0
beer-dent	581	0	560	0	564	0
tent-nail	546	0	541	8	540	0
bib-deer	612	0	576	0	547	0
sting-pouch	561	11	585	8	582	0
loom-cling	582	5	639	0	538	0
nest-hog	553	0	564	0	555	0
log-dig	553	0	550	0	559	0
pig-doom	558	5	651	0	584	0
couch-damp	539	0	573	0	547	0
cane-pest	536	0	602	0	604	0
lamp-pane	547	5	713	8	625	0

Experiment 2: *Stimuli and Item Means for Naming Latencies and Error Percentages*

	Aloud condition		Silent condition	
Prime type	Latency	Errors	Latency	Errors
High frequency irregular				
Related				
what-chat	579	7	591	0
want-rant	587	0	581	0
mind-wind	538	21	672	21
son-don	601	28	573	14
none-lone	559	14	535	7
gross-floss	598	0	596	0
lose-hose	625	7	630	21
word-cord	558	0	598	0

APPENDIX—*Continued*

Prime type	Aloud condition Latency	Aloud condition Errors	Silent condition Latency	Silent condition Errors
High frequency irregular				
Related				
move-cove	679	21	608	0
blood-brood	685	21	668	43
most-frost	570	14	541	0
done-hone	761	50	665	43
give-dive	619	21	536	0
have-cave	545	7	561	0
some-dome	641	14	566	43
put-nut	522	0	521	0
Unrelated				
mind-chat	549	0	587	0
lose-rant	580	0	595	0
son-wind	569	7	526	28
gross-don	564	0	574	7
want-lone	591	7	529	0
none-floss	596	0	595	0
word-hose	669	7	590	14
what-cord	548	7	537	0
blood-cove	617	0	695	0
done-brood	624	50	590	21
move-frost	520	0	592	0
give-hone	746	28	590	21
most-dive	493	0	519	0
some-cave	522	0	516	0
put-dome	579	0	610	7
have-nut	461	0	488	0
High frequency regular				
Related				
need-weed	494	0	528	0
help-kelp	547	0	612	0
tell-bell	473	0	496	0
size-prize	506	0	530	0
mass-lass	477	0	526	0
thin-chin	520	0	560	0
base-chase	519	7	519	0
site-kite	493	0	525	0
boy-toy	514	0	500	0
feet-beet	536	0	553	7
man-tan	500	0	527	7
ship-chip	557	0	620	0
back-sack	567	0	547	0
gun-bun	520	0	543	0
park-bark	500	0	543	0
chair-stair	562	0	577	0
Unrelated				
help-weed	510	0	523	21
need-kelp	639	0	671	0
mass-bell	632	14	524	0

APPENDIX—*Continued*

	Aloud condition		Silent condition	
Prime type	Latency	Errors	Latency	Errors
	High frequency regular			
Unrelated				
tell-prize	536	0	540	0
size-lass	546	0	539	0
base-chin	555	14	553	0
site-chase	529	0	569	0
thin-kite	537	0	530	0
feet-toy	492	0	498	0
gun-beet	544	0	579	0
boy-tan	536	0	523	7
back-chip	481	0	493	7
man-sack	542	0	578	7
ship-bun	479	0	531	0
chair-bark	505	0	537	0
park-stair	552	0	579	0
	Low frequency irregular			
Related				
deaf-leaf	521	0	519	0
tomb-bomb	575	7	567	7
wart-mart	524	0	605	0
sew-dew	635	7	575	0
said-raid	655	21	621	0
soot-loot	538	57	557	7
wand-sand	536	0	499	0
quoth-broth	635	0	611	7
quart-chart	586	7	577	0
squash-thrash	658	36	685	14
wash-mash	534	7	541	7
wear-sear	723	7	729	43
caste-paste	591	43	650	7
worse-morse	698	7	617	21
doll-toll	651	14	587	36
vein-stein	756	64	676	71
Unrelated				
soot-leaf	534	50	538	7
deaf-bomb	564	0	557	14
said-mart	557	0	540	0
wart-dew	552	7	571	0
dew-raid	578	14	553	0
quoth-loot	610	14	558	7
tomb-sand	533	28	536	14
wand-broth	623	0	599	7
squash-chart	546	7	541	0
quart-thrash	627	0	631	7
wear-mash	495	0	509	0
vein-sear	594	7	674	21
worse-paste	570	7	564	0
wash-morse	575	0	582	14
caste-toll	577	28	522	21
doll-stein	688	57	634	43

APPENDIX—*Continued*

Prime type	Aloud condition		Silent condition	
	Latency	Errors	Latency	Errors
Low frequency regular				
Related				
sled-fled	563	0	612	0
claw-flaw	563	0	553	0
bib-rib	519	0	539	0
noose-moose	516	7	519	0
bug-tug	517	0	519	0
tent-dent	488	0	538	0
tail-nail	496	0	511	0
beer-deer	485	0	557	0
couch-pouch	536	7	550	0
sting-cling	541	0	608	0
log-hog	492	0	482	0
pig-dig	507	0	554	7
loom-doom	529	0	550	0
lamp-damp	497	7	580	7
nest-pest	540	7	535	0
cane-pane	568	0	510	7
Unrelated				
tail-fled	627	0	574	7
noose-flaw	589	21	568	0
bug-rib	543	7	557	0
claw-moose	564	0	544	7
sled-tug	542	0	523	0
beer-dent	545	0	585	0
tent-nail	506	14	554	0
bib-deer	527	0	597	7
sting-pouch	537	0	565	0
loom-cling	564	0	565	7
nest-hog	482	0	507	0
log-dig	481	0	532	0
pig-doom	556	7	550	7
couch-damp	489	7	509	0
cane-pest	526	0	532	0
lamp-pane	562	0	536	0

APPENDIX—*Continued*

Experiment 3: *Stimuli and Item Means for Naming Latencies and Error Percentages*

	Aloud condition		Silent condition	
Prime type	Latency	Errors	Latency	Errors
"Regular" formally similar				
Related				
tile-bile	569	0	603	0
liar-briar	666	0	695	0
staff-chaff	619	9	678	27
perk-clerk	568	0	471	0
goal-coal	582	0	578	0
moon-coon	628	11	540	0
cope-dope	526	0	508	0
cream-dream	555	0	555	0
tame-fame	522	0	604	9
cries-flies	533	18	527	9
moat-gloat	582	0	598	0
thief-grief	587	0	554	0
mate-hate	510	0	544	0
fire-hire	523	0	515	0
cane-mane	507	0	507	0
beat-meat	551	0	565	0
hole-mole	503	0	516	0
boor-moor	560	0	509	18
goose-moose	509	22	481	0
noise-poise	676	0	490	9
nude-rude	512	0	499	0
tale-sale	516	0	583	0
stew-spew	517	20	747	45
lacks-tacks	570	0	570	0
wall-tall	490	9	513	0
bird-third	564	0	559	0
first-thirst	541	0	626	0
light-tight	539	0	587	0
rough-tough	542	0	479	0
wine-vine	567	0	623	0
made-wade	567	0	563	0
field-yield	525	0	488	0
Unrelated				
tame-bile	598	0	564	0
light-briar	739	0	599	27
tale-chaff	899	33	579	36
moon-clerk	592	0	588	0
mate-coal	539	0	555	0
perk-coon	535	11	559	0
fire-dope	540	0	596	0
moat-dream	544	0	544	0
bird-fame	543	0	530	9
goal-flies	541	18	545	0

APPENDIX—*Continued*

Prime type	Aloud condition Latency	Aloud condition Errors	Silent condition Latency	Silent condition Errors
“Regular” formally similar				
Unrelated				
noise-gloat	658	0	601	0
tile-grief	591	0	504	0
wine-hate	543	9	511	0
cope-hire	531	0	603	9
wall-mane	553	9	553	9
first-meat	501	0	474	0
cries-mole	513	0	533	0
rough-moor	548	0	629	0
nude-moose	641	0	589	0
goose-poise	556	0	655	0
cream-rude	569	0	608	0
vein-sale	553	0	537	0
thief-spew	600	30	629	18
made-tacks	604	0	533	0
lacks-tall	569	0	455	0
hole-third	543	0	573	0
stew-thirst	563	0	521	0
liar-tight	576	0	526	0
field-tough	642	10	624	0
beat-vine	585	0	546	0
staff-wade	546	0	512	0
boor-yield	601	0	547	0
“Irregular” formally similar				
Related				
warn-barn	598	0	502	0
dead-bead	731	36	746	9
heard-beard	684	9	596	10
tomb-bomb	608	11	612	0
blood-brood	746	45	776	27
quart-chart	550	0	510	0
what-chat	545	10	558	0
word-cord	569	0	634	0
wear-dear	601	0	651	0
sew-dew	623	0	645	0
some-dome	626	27	609	9
break-freak	623	9	582	0
most-frost	563	0	577	0
sown-frown	668	22	558	0
lose-hose	625	0	569	0
deaf-leaf	620	27	585	0
none-lone	560	0	692	0
soot-loot	758	0	589	0
worse-morse	758	0	617	10
worm-norm	546	0	521	0
caste-paste	629	0	596	0
low-plow	588	18	572	0
said-raid	596	9	603	0

APPENDIX—*Continued*

	Aloud condition		Silent condition	
Prime type	Latency	Errors	Latency	Errors
“Irregular” formally similar				
Related				
wand-sand	540	10	525	0
four-sour	570	0	529	0
squash-thrash	705	0	589	9
shoe-toe	574	0	465	0
wool-tool	555	0	518	0
Unrelated				
worm-barn	565	0	629	0
four-bead	698	0	638	18
worse-beard	553	9	584	0
sew-bomb	574	0	515	0
most-brood	548	30	600	36
wear-chart	548	9	527	9
blood-chat	585	0	549	0
deaf-cord	586	0	512	0
break-dear	552	0	545	9
said-dew	568	0	561	0
heard-dome	541	9	545	0
wand-freak	574	0	613	0
what-frost	544	0	532	0
warn-frown	651	0	643	0
squash-hose	570	10	662	0
tomb-leaf	562	0	470	0
word-lone	568	9	525	0
none-loot	515	0	468	0
caste-morse	597	0	574	0
lose-norm	574	0	603	0
some-paste	582	0	530	0
quart-plow	586	10	635	0
soot-raid	675	0	530	0
dead-sand	521	0	615	9
low-sour	522	10	572	0
wool-thrash	680	0	652	0
sown-toe	577	0	617	0
shoe-tool	578	0	559	0
“Regular” formally dissimilar				
Related				
aisle-bile	584	0	628	0
buyer-briar	655	9	581	9
graph-chaff	758	0	756	20
quirk-clerk	596	10	546	0
bowl-coal	624	0	537	0
tune-coon	605	0	562	0
soap-dope	544	0	488	9
maim-fame	594	0	550	0
guys-flies	635	9	604	0
note-gloat	578	0	533	18
beef-grief	561	0	606	0

APPENDIX—*Continued*

	Aloud condition		Silent condition	
Prime type	Latency	Errors	Latency	Errors
“Regular” formally dissimilar				
Related				
eight-hate	562	0	540	0
choir-hire	573	0	612	0
vein-mane	577	0	568	0
suite-meat	569	0	506	0
soul-mole	484	0	487	0
lure-moor	620	33	556	0
juice-moose	518	0	551	0
toys-poise	607	0	595	0
lewd-rude	495	0	554	0
veil-sale	595	0	628	0
flu-spew	685	18	575	9
axe-tacks	642	10	647	9
maul-tall	604	0	600	0
nerd-third	624	9	561	0
worst-thirst	513	0	518	0
quite-tight	570	0	480	0
cuff-tough	621	0	541	0
sign-vine	563	0	529	0
suede-wade	520	0	554	0
sealed-yield	558	0	590	0
Unrelated				
sign-bile	512	0	541	0
quite-briar	660	0	709	9
veil-chaff	717	13	557	18
guys-clerk	607	9	526	0
nerd-coal	681	18	685	0
soap-coon	621	10	594	0
soul-dope	558	0	646	9
note-dream	504	0	474	0
eight-fame	550	0	564	0
bowl-flies	598	11	696	27
toys-gloat	580	0	501	0
buyer-grief	566	0	586	0
axe-hate	537	0	481	0
quirk-hire	543	0	594	0
graph-mane	558	9	511	0
worst-meat	533	0	522	0
tune-mole	530	0	553	0
sealed-moor	504	0	559	0
lewd-moose	504	0	517	0
cane-poise	609	9	543	9
juice-rude	536	0	514	0
cuff-sale	566	0	508	0
beef-spew	711	30	797	11
suede-tacks	602	20	534	9
maim-tall	558	9	533	18
choir-third	614	0	703	0
flu-thirst	570	0	586	0

APPENDIX—*Continued*

	Aloud condition		Silent condition	
Prime type	Latency	Errors	Latency	Errors
"Regular" formally dissimilar				
Unrelated				
aisle-tight	581	0	551	0
seem-tough	584	0	584	0
suite-vine	581	0	591	0
maul-wade	543	0	486	0
lure-yield	542	0	497	0
"Irregular" formally dissimilar				
Related				
horn-barn	507	0	581	0
fled-bead	710	10	558	20
curd-beard	708	9	690	0
room-bomb	525	18	607	0
mud-brood	697	18	724	18
port-chart	553	0	523	0
nut-chat	598	0	602	0
nerd-cord	532	0	500	0
care-dear	560	0	543	0
so-dew	564	0	521	0
sum-dome	597	0	636	9
make-freak	634	0	564	0
toast-frost	595	0	617	0
moan-frown	610	0	564	0
cruise-hose	581	0	606	9
chef-leaf	545	0	483	0
sun-lone	542	0	504	0
put-loot	506	0	506	0
curse-morse	657	0	624	18
germ-norm	548	0	557	0
mast-paste	646	0	625	0
dough-plow	563	9	590	0
bled-raid	571	0	555	9
bond-sand	521	0	520	0
bore-sour	552	18	530	0
posh-thrash	643	20	666	0
glue-toe	541	0	563	0
bull-tool	553	0	557	0
Unrelated				
germ-barn	494	0	523	0
port-bead	671	22	650	0
curse-beard	702	9	619	9
chef-bomb	548	0	586	0
toast-brood	686	18	657	27
bond-chart	619	9	636	0
mast-chat	582	0	548	0
so-cord	601	9	539	0
make-dear	556	0	608	0
bled-dew	570	0	646	0
curd-dome	542	9	511	0

APPENDIX—*Continued*

	Aloud condition		Silent condition	
Prime type	Latency	Errors	Latency	Errors
	“Irregular” formally dissimilar			
Unrelated				
care-freak	593	0	650	0
mud-frost	583	0	542	0
horn-frown	585	0	578	0
moan-hose	629	10	560	0
room-leaf	508	0	574	0
nerd-lone	551	0	558	0
sun-loot	519	0	563	0
nut-morse	626	0	512	0
cruise-norm	536	0	543	0
sum-paste	550	0	506	0
bore-plow	636	0	729	27
put-raid	542	0	605	0
fled-sand	594	0	645	0
dough-sour	697	0	619	0
bull-thrash	646	0	630	0
posh-toe	540	0	498	0
glue-tool	525	0	542	0

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