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Similar Attentional, Frequency, and Associative Effects for Pseudohomophones and Words

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Between the presentation and recall of 1 or 5 digits, Ss performed a secondary task of naming a visually presented letter string—a pseudohomophone (e.g., FOLE, HOAP) or its real-word counterpart (FOAL, HOPE). Memory load interacted with frequency (HOPE vs. FOAL, HOAP vs. FOLE) but not with lexicality (HOPE vs. HOAP, FOAL vs. FOLE). This outcome counters models in which nonwords are named by a slow (resource-expensive) process that assembles phonology and words are named by a fast (resource-inexpensive) process that accesses lexical phonology. When the associative priming-of-naming task was secondary to the memory task, pseudohomophone associative priming (HOAP–DESPAIR, FOLE–HORSE) equaled associative priming (HOPE–DESPAIR, FOAL–HORSE) and was affected in the same way by memory load. Assembled phonology seems to underlie the naming of both words and nonwords.

Does the procedure for naming nonwords differ from that for naming words? Many models of oral reading propose that words are named by finding an entry in an orthographic lexicon. The process by which the entry is found is called *direct visual or orthographic access*, and the phonology obtained in this direct manner is called *addressed phonology*. In the case of new words and nonwords, however, there are no lexical entries, and the phonology supporting naming must be computed or "assembled" (e.g., Patterson & V. Coltheart, 1987). The assembling of nonword phonology is usually envisaged as occurring by rule (e.g., M. Coltheart, 1978), by analogy (e.g., Glushko, 1979), or by a mixture of both (e.g., Rosson, 1985). Assembling a phonological code for a printed letter string is assumed to be a slow and arduous process relative to addressing an already assembled phonology in the lexicon. In ordinary word naming, both processes occur simultaneously, but the inherent swiftness of addressed phonology renders it the more dominant source of constraint on naming latencies with the consequence that the effects of assembled phonology (for example, a difference between regular and exception words) will be manifest rarely, only when naming is slow (Patterson & V. Coltheart, 1987). Arguments for viewing the two modes of deriving phonology as being engaged in a race, with the slower mode often cast in the role of a spoiler interfering with the faster mode, are familiar. Arguments can also be found, however, for a more conciliatory view in which the slower mode reinforces the results of the faster mode (e.g., Carr & Pollatsek, 1985).

Recently, Lukatela and Turvey (1991) examined a particular class of nonwords, namely, pseudohomophones, in the role of associative primes. They found that (a) the priming due to associated pseudohomophones (for example, TAYBLE–CHAIR) was equal in magnitude to that due to associated words (TABLE–CHAIR), (b) visual controls for the pseudohomophones (e.g., TARBLE) failed to prime, and (c) the pseudoassociative priming was the same for long (500-ms) and short (280-ms) stimulus onset asynchronies. They argued that such outcomes would be expected if the lexicon was phonological rather than orthographic and if lexical access occurred routinely through assembled phonology. The lexical representations for the words *table* and *chair* are /table/ and /chair/, respectively; the assembled phonologies of the primes TABLE, TAYBLE, and TARBLE are /table/, /table/, and /tarble/, respectively. Given the primes TAYBLE and TABLE, /table/ is assembled and /chair/ is activated by the lexical entry /table/ through the associative network. Given the prime TARBLE, /tarble/ is assembled, the lexical entry /table/ is not activated, and the lexical entry /chair/ remains at its pre-TARBLE level of excitation.

With respect to the traditional concerns about how letter strings are named, Lukatela and Turvey's (1991) results suggest that there may be no qualitative difference between naming nonwords and naming words. To pursue this suggestion, we focus on a particular aspect of the hypothesized difference between assembling phonology and accessing phonology, namely, that assembling phonology engages more processing resources than accessing phonology. If naming TAYBLE proceeds by way of a complicated computational process, and naming TABLE proceeds by way of an uncomplicated lexical look-up, then the availability of processing capacity should affect the naming of TAYBLE more than the naming of TABLE. In a recent study, Paap and Noel (1991) showed that naming low-frequency (LF) exception words was affected systematically by the size of a concurrent memory load. Subjects were presented a

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memory set of one or five digits prior to the presentation of a target word. They were required to name the word as quickly as possible and then to recognize whether a subsequently presented digit was in the original memory set. Paap and Noel (1991) hypothesized that for LF exception words, the "horse race" between the direct and mediated routes typically ends in a "photo finish" with the result that the verification process prefacing the naming response is hindered. By imposing a demand on processing capacity, assembling phonology is slowed more than the process of accessing phonology, such that the horse race ends unequivocally with the direct route the victor. This means that naming LF exception words should benefit from high, concurrent memory loads. The data revealed faster naming under the five-digit memory set than the one-digit memory set.

According to models that draw the distinction between assembled phonology and accessed phonology, TAYBLE should be affected by concurrent demands on processing capacity more so than TABLE. A phonological code for TAYBLE cannot be found by the direct route and must be assembled; in contrast, a phonological code for TABLE can be found directly, rendering the assembled phonology unnecessary. If assembling phonology demands more processing capacity—or, consonant with Navon's (1984) admonitions, suffers from more outcome conflicts with concurrent activities—then the more demanding the concurrent activity, the larger the difference in naming times between TAYBLE and TABLE. In contrast, if TAYBLE and TABLE are named in the same way (e.g., both rely on assembled phonology), as suggested by the experiments of Lukatela and Turvey (1991), then increasing the difficulty of concurrent activity should affect the naming latencies of each in equal degrees.

Experiment 1

Although the process of accessing a word's phonology in the lexicon is viewed in Paap and Noel's (1991) formulation as being more automatic than the process of assembling a word's phonology, it nonetheless requires attentional resources. Experiments show that processing LF words demands more capacity than processing high-frequency (HF) words (Becker, 1976; Herdman & Dobbs, 1989; Paap & Noel, 1991). Experiments also show, however, that LF (regular) words are typically named as fast as HF (regular) words (Seidenberg, Waters, Barnes, & Tanenhaus, 1984; Taraban & McClelland, 1987). One interpretation is that the process of assembling the phonology of LF words must often occur at a pace that is faster than direct lexical access and commensurate with the pace of direct lexical access for HF words. Consequently, reducing available capacity should enhance the naming latency difference between LF and HF regular words; with less capacity, naming LF words should be more dependent on the direct route, which is slower than the direct route for HF words (Paap & Noel, 1991).

Consider the LF word FOAL and the HF word HOPE and their pseudohomophones FOLE and HOAP, respectively. Consider the task of naming these letter strings in the context of concurrently holding in memory either five digits (high load) or one digit (low load). According to the dual process theory, we should see the following outcomes: (a) FOLE and HOAP should be named more slowly under the high load than under the low load, (b) the difference in naming times between FOAL and HOPE should be greater under the high load than under the low load, and therefore (c) the dependency of FOLE and HOAP on load should be different from the dependency of FOAL and HOPE on load. The implications of Lukatela and Turvey's (1991) experiments do not lead to such detailed predictions, but they do point to a very different major expectation: Words and nonwords homophonic to them should be affected similarly by load variation.

Method

Subjects. The participants in the experiment were 36 students from the Department of Psychology at the University of Connecticut. A subject was assigned to one of four groups, giving 9 subjects per group.

Materials. A set of 40 LF words with a mean frequency of occurrence 7.55 and a set of 40 HF words with a mean frequency of occurrence 270.73 were selected, on the basis of the Kučera and Francis (1967) count, from word lists used in the research of Lukatela and Turvey (1991). (The word set is given in the Appendix; as can be seen, LF and HF words are mostly regular with a few exception words in both subsets.) Each word was replaced by its pseudohomophone to produce a set of 40 LF pseudohomophones and a set of 40 HF pseudohomophones (see Appendix). In addition, a foil set of 30 regular words, of which 20 were LF words and 10 were HF words, was selected from a word list reported in Paap and Noel (1991).

Four counterbalanced lists of stimuli were prepared. In each group, each subject saw 20 instances of each experimental stimulus set. For example, in one group the subject would see 20 FOAL (LF word) stimuli, 20 FOLE (LF pseudohomophone derived from FOAL) stimuli, 20 HOPE (HF word) stimuli, and 20 HOAP (HF pseudohomophone derived from HOPE) stimuli. Additionally, each subject saw 20 COIL (LF regular word) stimuli and 10 CAME (HF regular word) stimuli. Half of the stimuli were presented under conditions of high memory load and the remaining half under low memory load.

Design. A major constraint on the design was that a given subject never encountered a given word (in either its lexical or nonlexical pseudohomophonic form) more than once. There were eight (2 × 2 × 2) stimulus types (Memory Load × Lexicality × Frequency). Memory load (high vs. low) was both a within-subjects factor and a within-items factor, as was lexicality (pseudohomophone vs. word). Word frequency (LF vs. HF) was a within-subjects factor and a between-items factor.

Each subject was presented with 10 experimental stimuli from each of the eight types and with 30 foils, giving 110 stimuli. The experimental sequence was divided into five subsequences, with a brief rest in between. Stimulus types were ordered pseudorandomly within each subsequence. Experimental sequence was preceded by a practice sequence of 18 stimuli.

Procedure. Subjects, run one at a time, sat in front of the cathode-ray tube of an Apple IIe computer in a dimly lit room. A fixation point was centered on the screen. On each trial, there was a brief auditory warning signal after which a single-digit number (low memory load) or a five-digit number (high memory load) appeared for 2,000 ms. The subject was to keep the number in memory for several seconds until another single digit number (a *target digit*) would be presented.

After an interstimulus interval of either 1,000 ms or 2,000 ms (varied randomly), a letter string appeared for 500 ms. The subject was told that he or she would be viewing words and nonwords, and that the nonwords, when pronounced, could sound like English words. Subjects were required to pronounce each letter string as quickly and as distinctly as possible. In all conditions, latencies from the onset of the letter string to the onset of the response were measured by a voice-operated key. Naming was considered erroneous when the pronunciation included a phoneme not specified by allowable grapheme-to-phoneme correspondences in English, the pronunciation was not smooth (i.e., the subject hesitated after beginning to name), or the response was not loud enough to trigger the voice key.

Finally, after a 2,000-ms interstimulus interval, a target digit appeared for 1,000 ms. Subjects were required to decide as accurately and as fast as possible whether the target digit was a member of the memory set. Decisions were indicated by depressing a telegraph key with both thumbs for a "no" decision or by depressing a key slightly further away with both forefingers for a "yes" decision. If the decision was wrong, the message "Your decision was wrong" appeared on the screen. If the decision was wrong and if the naming latency exceeded 1,200 ms, another type of message, "You were wrong and you read slowly," appeared on the screen. If a correct decision had been made but with considerable hesitation (in excess of 1,200 ms), or following a long naming latency, the corresponding message was either "Your decision was correct but slow" or "Your decision was correct but you read slowly." All naming latencies, including those longer than 1,200 ms, were stored in the computer memory.

Subjects were instructed to treat the memory task as the primary task and the naming task as a less important secondary task. Subjects were also told that the secondary task was an interference intended to impair accurate decisions on the primary task. Subjects were invited to do their best to override the interference.

Table 1
Mean Naming Latencies (in Milliseconds) and Error Rates (in %) as a Function of Load and Frequency: Experiment 1

	Memory load			
	One digit		Five digits	
Target	Latency	Error rate	Latency	Error rate
	Low frequency			
FOAL				
M	555	0.83	544	1.67
SD by subject	60	2.80	45	3.78
SD by item	29	3.69	31	6.47
FOLE				
M	561	3.33	554	2.22
SD by subject	57	4.78	60	4.85
SD by item	38	7.55	41	4.39
	High frequency			
HOPE				
M	537	1.39	551	2.78
SD by subject	60	4.24	61	5.66
SD by item	39	3.61	37	7.53
HOAP				
M	573	4.17	579	2.78
SD by subject	54	6.04	59	6.15
SD by item	36	9.33	37	7.51

Results and Discussion

Table 1 presents the mean naming latencies, mean errors, and standard deviations for the four types of letter strings: FOAL, FOLE, HOPE, and HOAP. Figure 1 shows the mean latencies for the four stimulus types as a function of load. An analysis of variance (ANOVA) on subjects' latencies revealed significant main effects of lexicality (FOAL, HOPE = 547 ms vs. FOLE, HOAP = 567 ms), $F(1, 35) = 27.67, p < .001$, and frequency (HOPE, HOAP = 560 ms vs. FOAL, FOLE = 553 ms). The main effect of load was insignificant (one digit = 556 ms vs. five digits = 557 ms; $F < 1$). Load by frequency, $F(1, 35) = 16.78, p < .001$, and lexicality by frequency, $F(1, 35) = 15.14, p < .001$, were significant: LF stimuli (FOAL, FOLE) were named 16 ms faster than HF stimuli (HOPE, HOAP) under the five-digit load and 3 ms slower under the one-digit load; FOLE was named 8 ms slower than FOAL, and HOAP was named 32 ms slower than HOPE. The interaction of load and lexicality was not significant, and neither was the three-way interaction ($F < 1$). The ANOVA on items' means confirmed all of the preceding significant effects with the exception of frequency ($F < 1$): lexicality, $F(1, 78) = 31.11, p < .001$, Load × Frequency interaction, $F(1, 78) = 9.53, p < .01$, and Lexicality × Frequency interaction, $F(1, 78) = 11.24, p < .001$. In the error analysis the only significant effect was lexicality (FOAL, HOPE = 1.67 vs. FOLE, HOAP = 3.13), with subjects as the error term, $F(1, 35) = 7.06, p < .01$.

To test whether there was a typical frequency effect, the LF and HF words in the one-digit load condition were compared. The planned comparison found the difference (LF = 555 ms vs. HF = 537 ms) to be significant for subjects, $F(1, 35) = 10.82, p < .01$, and for stimuli, $F(1, 78) = 5.63, p < .05$. A further planned comparison was directed at the LF and HF pseudohomophones in the one-digit load

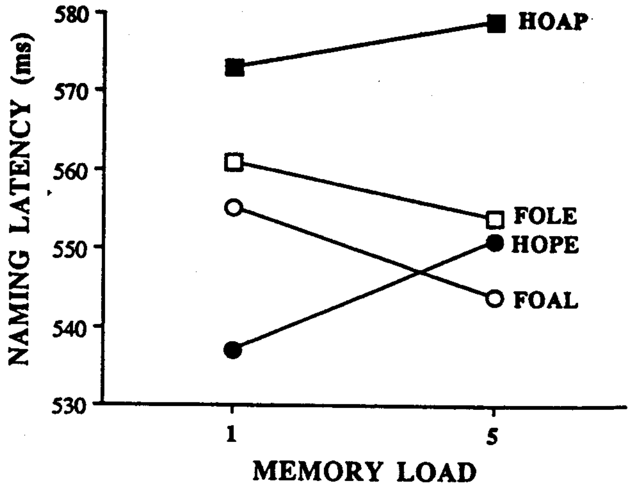

Figure 1. Mean latencies (in milliseconds, ms) for the four stimulus types as a function of load in Experiment 1.

condition. The difference (LF = 561 ms vs. HF = 573 ms) was significant for subjects, $F(1, 35) = 5.65, p < .05$, but not for stimuli, $F(1, 78) = 2.33, p > .05$.

Turning to the primary (memory) task, ANOVAs for subjects and items failed to reveal any significant effects. The one-digit and five-digit tasks were performed equally well (one digit = 20% errors vs. five digits = 21% errors) and indifferently to the manipulations of the secondary naming task (all $F\text{s} < 1$).

The main feature of the experiment is that FOAL and FOLE were affected in one way, and HOPE and HOAP were affected in another way, by the load manipulation. Relative to the one-digit load, the five-digit load speeded up the naming of FOAL and FOLE and slowed down the naming of HOPE and HOAP. This feature is unexpected from a model of oral reading in which nonwords are named by a slow process that assembles the letter string's phonology and words are named by a fast process that accesses a phonology already assembled in the lexicon. Pseudohomophones should be uniformly slowed by increased concurrent demands on attention, as should LF words, given that they rely heavily on the more attention-consuming process of assembled phonology. In sum, FOLE and HOAP should have been affected similarly by load, with poorer performance under the higher load, and FOAL and HOPE should have been affected dissimilarly by load, with the higher load more detrimental to FOAL than to HOPE. Clearly, these predictions of dual process theory were not confirmed. The main feature of the data is consistent, however, with the results of Lukatela and Turvey (1991): A nonword homophonic with a word is processed like that word. The implication is that assembling phonology is routine, an implication that is elaborated below.

The present experiment has shown that under variation in cognitive load, nonwords homophonic with HF words behaved like HF words, and nonwords homophonic with LF words behaved like LF words. Why should this be so? In processing terms, what makes FOAL more like FOLE than like HOPE, and what makes HOPE more like HOAP than like FOAL? The likeness of FOAL and FOLE, on the one hand, and the likeness of HOPE and HOAP, on the other hand, are consistent with the hypothesis that the lexical representations of English words are phonological (Lukatela & Turvey, 1991). The assembled phonologies of FOAL and FOLE would both access the word unit for FOAL, and the assembled phonologies of HOPE and HOAP would both access the word unit for HOPE. Given the preceding as reason for the sameness in processing HOPE and HOAP (or FOAL and FOLE), what is the basis for the difference in processing HOPE and HOAP? To capture this difference, a notion such as pattern covariance seems to be required. The orthographic structures of HOPE and HOAP will both specify the same pattern of phonologic subsymbols. If we denote orthographic subsymbols by *o* and phonologic subsymbols by *p*, the two functional relations between *o* and *p* involving HOPE and HOAP are alike in *p* and in aspects of *o* but different in other aspects of *o* and in the connection weights between *o* and *p*. If connections are weaker for the mapping HOAP → /HOPE/ than for the mapping HOPE → /HOPE/, then naming HOAP will be slower than naming HOPE. Behind the preceding analyses is the theme that assembled phonology is not based on explicit rules, as traditionally argued in dual process theory (e.g., M. Coltheart, 1978), but on processes constrained implicitly by the continuous statistical regularity of orthographic–phonologic pairings (Van Orden, Pennington, & Stone, 1990).

Armed with the foregoing perspective on the commonalities and differences between a word and its homophonic nonword partner, we can turn to the more perplexing question of why the five-digit load should enhance FOAL and FOLE and impede HOPE and HOAP. A number of accounts of word identification assume a verification stage in which the results of stimulus encoding—candidate representations of the input—are compared with the representation of the input in the sensory store (e.g., Paap, Newsome, McDonald, & Schvaneveldt, 1982). Verification results in a match or a mismatch. If the degree of fit between the visual sensory evidence and a candidate representation exceeds a decision criterion, then the item is recognized and the appropriate articulatory units are activated. We can entertain the possibility that one site for the effects of load is the postlexical verification step. Clearly, a key idea with respect to verification is "criterion level." Is criterion level affected by load? A lowering of criterion commensurate with the demands of concurrent activity would explain the faster naming of FOAL and FOLE when five digits were being remembered, but it would not explain the slower naming of HOPE and HOAP under the same conditions. That the effects of variations in cognitive load and of other task features such as context (e.g., proportion of exception foils, proportion of nonwords, and so on) can be traced to adjustments in a single parameter, such as criterion level, is an attractive idea (see Stone & Van Orden, in press). What is needed to make it work in the present context is an understanding of how a single direction of change in criterion level can interact with frequency to produce an increase in naming time when frequency is high and a decrease in naming time when frequency is low. A consideration of processes below the verification stage is required. Consider the following two hypotheses. First, a word processing unit is characterized by a rate R of activation A that reflects its respective frequency of occurrence f. This first hypothesis is consistent with a working assumption of a number of network models of word recognition (e.g., Lukatela, Turvey, & Todorović, 1991). Second, a given load L reduces a word unit's R in proportion to a nonlinear function λ of L and f. Then, for word unit i with frequency f_i,

$$R_i(L) = R_i/\lambda(L, f_i),$$

where

$$\lambda(L, f_i) = 1, \qquad \text{for } L = 0,$$

$$1 < \lambda(L, f_i) < \lambda\text{max}, \qquad \text{for } L > 0.$$

Given the first hypothesis, the activation time to threshold τ_{HOPE} is less than the activation time to threshold τ_{FOAL}. Given the second hypothesis, both τ_{HOPE} and τ_{FOAL} are increased by a given L, with the size of the increase, $\Delta\tau$, larger for τ_{HOPE} than for τ_{FOAL}. This difference in the magnitudes of the $\Delta\tau$s would come about as follows. At time τ_i, a word unit's activity level A_i will exceed threshold. When $L = 0$,

$$\tau_i = A_{\mathrm{threshold}\,i}/R_i.$$

When $L > 0$,

$$\tau_{iL} = \tau_i[\lambda(L, f_i)].$$

Therefore,

$$\Delta\tau = \tau_{iL} - \tau_i.$$

If $\lambda(L, f_i)$ grows with f_i, as assumed, then $\Delta\tau$ will always be larger for HF words than for LF words. More specifically, $\Delta\tau$ will be larger for HOPE than for FOAL.

Collecting arguments, we can suppose that (a) processing time in the matrix of letter–phoneme connections is faster for a word than for its pseudohomophone, and more so for HF words than LF words; (b) concurrent cognitive activity induces a reduction in the verification criterion level proportional to load (the higher the load, the lower the criterion) that will have the same time-reduction effect ∂ on HF words and LF words; and (c) concurrent cognitive activity adds an amount $\Delta\tau$ to activation times to threshold for lexical representations that is proportionately greater for HF words than LF words. If $\Delta\tau_{\mathrm{LF}} < \partial < \Delta\tau_{\mathrm{HF}}$, then the advantage of (a) outweighs the disadvantage of (b) for LF words such as FOAL but does not outweigh the disadvantage of (b) for HF words such as HOPE. The consequence would be the observed interaction of load and frequency. Consider now the comparison between a word and its pseudohomophone. As noted above, HOAP and FOLE will be processed in the matrix of letter–phoneme connections more slowly than HOPE and FOAL, respectively. Within the lexicon, the activation of a word unit occurs at the same rate for stimulation by the word and by the word's pseudohomophone (Lukatela & Turvey, 1991); at verification, the processing times of a word and its pseudohomophone are reduced by the same amount in proportion to the load. The consequence would be the observed additive relation to load and lexicality.

Experiment 2

Consonant with the experiments of Lukatela and Turvey (1991), Experiment 1 suggests that pseudohomophones are processed similarly to words. The significant interaction between load and frequency and the insignificant interaction between load and lexicality provided the basis for inferring the similarity; however, the Load × Frequency interaction observed in Experiment 1 was both novel and unintuitive. Coupling these features of the interaction to the fact that it runs counter to predictions of the dual process theory reinforces the impression that further proof of the interaction is required. The second experiment replicates the first with a small but potentially significant modification.

From the perspective of dual process theory, Experiment 1 was designed to encourage the use of assembled phonology. More than one third of the stimuli were pseudohomophones, and many of the remainder were LF regular words. The bias toward rule-based assembled phonology can be diluted by including exception words. In the second experiment (practice and experiment proper) the number of exception words and HF regular words was approximately equal to the number of pseudohomophones and LF regular words. If a processing disassociation between words and pseudohomophones exists, then this equating of items favoring accessed phonology with items favoring assembled phonology should enhance its manifestation. In brief, the second experiment was designed to foster dissimilarity between the processing of FOLE and HOAP on the one hand and the processing of FOAL and HOPE on the other hand.

Note, however, that the category *exception word* is sensible only in the perspective of the dual process theory and its core thesis of rule-based assembled phonology. Given grapheme–phoneme correspondence rules, words are deemed regular if they obey the explicit rules and irregular or exceptional if they do not. Supplemental processes, such as direct activation of phonological codes in lexical memory, are required under dual process theory to accommodate irregular special cases. From a perspective that assumes a continuous statistical form of regularity and that explains rulelike word identification as the natural consequence of covariant learning, the dichotomy of "regular words" versus "exception words" is a theoretical fiction (Van Orden et al., 1990). Abiding this second perspective, we would expect to find the same outcome in the second experiment as was found in the first, namely, a dissimilarity between the processing of FOLE and FOAL on the one hand and the processing of HOAP and HOPE on the other hand. By hypothesis, this dissimilarity arises from the differences between the matrices of connection weights coding the phonologically identical FOLE and FOAL and the matrices of connection weights coding the phonologically identical HOAP and HOPE. Changing the composition of the background items may be expected to modulate overall response and error rates and even to affect the absolute time differences between words and nonwords, but we should not expect it to alter the partitioning according to phonological identity.

Method

Subjects. The participants in the experiment were 32 students from the University of Connecticut. Each subject was assigned, by order of appearance at the laboratory, to one of four groups, giving 8 subjects per group. The subjects did not participate in Experiment 1. Two subjects in two different groups could not perform the task and were dropped from the analysis. To equate subject number per condition, 1 subject was randomly deleted from each of the other two groups.

Materials. These were the same as in Experiment 1, except that the regular word foils were replaced by exception word foils in each experimental sequence. A set of 20 COMB (LF exception word) stimuli and a set of 10 COME (HF exception word) stimuli were borrowed from Paap and Noel (1991). In each practice sequence, all regular words were also replaced by exception words.

Design and procedure. These were the same as in Experiment 1.

Results and Discussion

Table 2 presents the mean naming latencies, mean errors, and standard deviations for the four types of letter strings: FOAL, FOLE, HOPE, and HOAP. Figure 2 shows the mean latencies for the four stimulus types as a function of load. An ANOVA on subjects' latencies revealed a significant main effect of lexicality (FOAL, HOPE = 569 ms vs. FOLE, HOAP = 601 ms), $F(1, 27) = 20.93$, $p < .001$. Neither frequency (HOPE, HOAP = 586 ms vs. FOAL, FOLE = 584 ms) nor load (one digit = 587 ms vs. five digits = 583 ms) was significant ($F < 1$). The important interaction of load and frequency was significant, $F(1, 27) = 14.00$, $p < .001$; LF stimuli (FOAL, FOLE) were named 17 ms faster than HF stimuli (HOPE, HOAP) under the five-digit load and 14 ms slower under the one-digit load. No other interactions were significant ($F \approx 1$). The ANOVA on items' means confirmed the preceding significant effects: lexicality, $F(1, 78) = 31.22$, $p < .001$; Load × Frequency interaction, $F(1, 78) = 4.38$, $p < .05$. In the error analysis, the only significant effect was the Load × Lexicality interaction with subjects as the error term, $F(1, 27) = 4.5$, $p < .05$.

To test whether there was a typical frequency effect, the LF and HF words in the one-digit load condition were compared. The planned comparison found the difference (LF = 580 ms vs. HF = 563 ms) to be significant for subjects, $F(1, 27) = 10.82$, $p < .01$, but not for stimuli $F(1, 78) = 2.78$, $p > .05$. A further planned comparison was directed at the LF and HF pseudohomophones in the one-digit load condition. The difference (LF = 607 ms vs. HF = 597 ms) was not significant either for subjects, $F(1, 27) = 1.54$, $p > .05$, or for stimuli ($F < 1$).

Table 2
Mean Naming Latencies (in Milliseconds) and Error Rates (in %) as a Function of Load and Frequency: Experiment 2

	Memory load			
	One digit		Five digits	
Target	Latency	Error rate	Latency	Error rate
	Low frequency			
FOAL				
M	580	3.21	561	1.07
SD by subject	75	4.76	67	3.15
SD by item	43	7.88	43	3.33
FOLE				
M	607	1.43	588	3.21
SD by subject	88	3.56	74	6.12
SD by item	58	3.80	50	6.79
	High frequency			
HOPE				
M	563	1.07	573	1.43
SD by subject	62	3.15	56	3.56
SD by item	43	3.33	52	5.05
HOAP				
M	597	2.14	610	2.86
SD by subject	77	4.18	90	6.00
SD by item	46	6.26	50	6.63

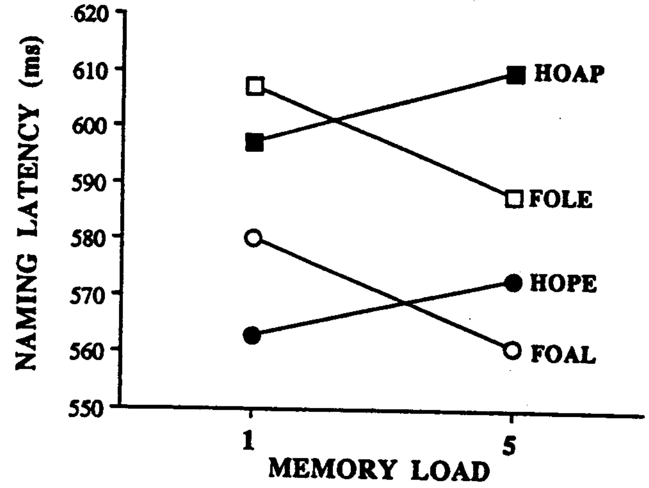

Figure 2. Mean latencies (in milliseconds, ms) for the four stimulus types as a function of load in Experiment 2.

Turning to the primary (memory) task, ANOVAs for subjects and items failed to reveal any significant effects. The one-digit and five-digit tasks were performed equally well (one digit = 17% errors vs. five digits = 15% errors) and indifferent to the manipulations of the secondary naming task (all *F*s < 1).

In sum, the second experiment corroborates the major outcome of the first experiment: The load manipulation affected FOAL and FOLE in one way and HOPE and HOAP in another way. Relative to the one-digit load, the five-digit load speeded up the naming of FOAL and FOLE and slowed down the naming of HOPE and HOAP. As underlined above, this outcome is unexpected from a model in which nonwords are named by a slow (resource-expensive) process that assembles the letter string's phonology and words are named by a fast (resource-inexpensive) process that accesses a phonology already assembled in the lexicon. The absence of the Lexicality × Frequency interaction of the first experiment may be attributed to the inclusion of exception words. A comparison of the two experiments suggests that the presence of multiple exceptional spellings slowed naming. In Experiment 1 the average naming latency was 557 ms; in Experiment 2 it was 585 ms. The overall slowing in naming seems to have been more pronounced in the case of FOLE than in the cases of the other stimulus types. Thus, the average latency increase from Experiment 1 to Experiment 2 was 21 ms for FOAL, 24 ms for HOPE, 28 ms for HOAP, and 41 ms for FOLE. If the inclusion of exception words raised the criterion at the verification stage, then it seems that this rise in criterion level was more detrimental to LF pseudohomophones than HF pseudohomophones. Importantly, this elevation in verification criterion did not eliminate the theoretically significant interaction between load and frequency.

As Figure 2 makes clear for both words and pseudohomophones, the effect of load depended on frequency. Ignoring pseudohomophones and considering only words, it is apparent that there are two ways of speaking about a frequency effect. The conventional way emphasizes absolute temporal differences—LF words are responded to more slowly than HF words. The unconventional way, expressed in the data pattern of Figure 2, emphasizes relative temporal differences—LF words are responded to more quickly under high load than low load, and HF words are responded to more quickly under low load than high load. With respect to the conventional frequency effect in naming, the effect is often small (e.g., Scarborough, Gerard, & Cortese, 1979; Waters & Seidenberg, 1985) or even nonsignificant (e.g., Richardson, 1976). In Experiment 2, the conventional frequency effect was statistically weak (significant only for subjects analysis). Given the outcome represented in Figure 2, frequency as a main effect may be less reliable and less theoretically significant than frequency as a variable interacting with other variables. Or, relatedly, pursuit of quantitative predictions involving frequency may be less revealing than pursuit of qualitative predictions involving frequency. The Frequency × Consistency interaction, in which consistency effects are more in evidence for LF words than for HF words (Seidenberg et al., 1984), is a qualitative feature that is potentially informative about general design characteristics of the word identification system, for example, the asymptotic performance consequences of covariant learning (Van Orden, 1987; Van Orden et al., 1990). We may consider the Frequency × Load interaction in a similar light.

Figure 2 depicts the important fact that the Frequency × Load interaction holds equally for pseudohomophones. That is, the behavior of a pseudohomophone (e.g., FOLE, HOAP) under load variation is predictable from the frequency of its base word (FOAL, HOPE). The latter conclusion contradicts that drawn by McCann and Besner (1987). They found that base word frequency, though having a significant effect on word pronunciation, had no significant influence on pseudohomophone pronunciation. They also found that pseudohomophones were named reliably faster than nonhomophonic ("ordinary") nonwords. In conjunction, these observations led them to conclude that there is a phonological lexicon in which whole-word entries reside and that the phonology assembled for a pseudohomophone makes contact with information in this lexicon. The latter feature gives pseudohomophones their advantage over ordinary nonwords that have no (validating) representation in the phonological lexicon. The discrepancy between the conclusion drawn in the present article and that drawn by McCann and Besner may be reflective of the point made above concerning the theoretical roles of main effects and interactions involving frequency. In the present experiment, there was no significant difference between naming times for FOLE (LF) and HOAP (HF), that is, no evidence of a conventional frequency effect. There was, however, very reliable evidence that the differential responses of LF and HF words to load were duplicated by their respective pseudohomophones. The observation of Lukatela and Turvey (1991) that priming by associated pseudohomophones (e.g., TAYBLE–CHAIR) is equal in magnitude to that by associated words (TABLE–CHAIR) suggests that pseudohomophones and words contact the same lexicon and do so in the same way. The results of the present experiment reinforce this suggestion. Collectively, the two sets of results encourage an account of the differential speed advantages of words over pseudowords and pseudowords over ordinary nonwords in terms of a single lexicon and a single mode of access.

It remains for us to comment on the facts that neither Experiment 1 nor 2 revealed a main effect of cognitive load, contrary to Paap and Noel (1991), and that the error rate on the primary task was approximately twice as high (about 20%) as that in Paap and Noel (1991). These outcomes raise the possibility that the subjects in the present experiments, in contrast to the subjects of Paap and Noel, neglected the primary task. A third experiment was conducted with the intent of enforcing the memory task as primary.

Experiment 3

To reiterate, Experiments 1 and 2 did not show a main effect of load either on naming latencies or on memory errors, and in both experiments the average memory error rate was of the order of 20%, independent of load. The outcomes of Experiments 1 and 2 are suggestive of a theoretically important conclusion, namely, that pseudohomophones and their word counterparts are processed in the same way. In significant part, this conclusion rests on the observations of an interaction of load and frequency and a noninteraction of load and lexicality. The conclusion would be strengthened, therefore, by repeating both observations under conditions in which (a) the memory task was performed proficiently (errors less than 10%), (b) decision latency on the memory task was affected by the memory load (longer decision latency for a five-item load than for a one-item load), (c) the size of the memory load affected naming latencies (longer naming latency for a five-item load than for a one-item load), and (d) the naming task did not affect the memory task. The third experiment was conducted with certain provisions intended to improve performance on the memory task and to guarantee its implementation as the primary task of the subject. Requirements (a)–(d) define the criteria for the dual task of Paap and Noel to be used as a tool for studying dual process theory. It was determined beforehand, therefore, that analyses would be restricted to the data of those subjects who satisfied all four criteria.

Method

Subjects. The participants in the experiment were 60 students from the University of Connecticut. Each subject was assigned, by order of appearance at the laboratory, to one of four groups, giving 15 subjects per group. The subjects did not participate in Experiments 1 and 2. Three of the subjects could not read the pseudohomophones in any sensible manner (e.g., TAIP was pronounced as /tap/ or /tip/). Five subjects exceeded the preestablished 10% error criterion, and 24 subjects did not meet the other criteria identified above (most of the latter subjects failed to name words slower under high memory load than under low memory load). Therefore, only 28 subjects met all preset criteria.

Design. The materials and conditions were the same as in Experiment 1.

Procedure. The procedure was as described in Experiment 1 with several important modifications introduced to enhance subjects' accuracy on the memory task. The subject was instructed that the priorities of the experiment were as follows. First, he or she was to perform as accurately as possible on the memory task. The subject was informed that his or her errors were to be recorded and would be reported to the subject at regular intervals. Second, the subject was to make the decisions about the target digit in the memory task as fast as possible. The subject was informed that his or her speed on the memory task was to be measured in fractions of a second, so small improvements in speed of response would be noted. Third, the subject was to name the letter string, which could make sense or not, as fast and as accurately as possible, and to pronounce it distinctly. The subject was informed that the naming speed was to be measured and reported to the subject at regular intervals. Following the instructions, the subject was given practice trials. At the end of the practice trials, the subject was presented three scores as promised on the computer screen, namely, number of memory errors, average speed of decision in milliseconds, and average speed of naming in milliseconds. The subject was also given a general judgment from the computer about the quality of his or her performance. This judgment was tied to the number of errors on the memory task.

With respect to the experiment proper, changes from the procedure of Experiment 1 included a reduction of the intertrial interval to 1,500 ms, an increase of the decision time for which a warning signal was given that the decision was slow from 1,200 to 1,400 ms, and a deletion of the dual warning that the decision was wrong and that the naming was slow. The latter deletion was for the purpose of reducing the subject's tendency to regard the two tasks as correlated. As promised, at the end of each of five blocks of 22 trials the subject was given a computer message (of the same type presented at the end of the practice session) informing him or her of memory errors, speed of recall, and speed of naming, with a general comment on the overall performance tied to the number of errors on the memory task.

Results and Discussion

One given pseudohomophone was persistently misread (FYER was read as FLYER by almost all of the 28 selected subjects) and discarded. To counterbalance the number of stimuli, one stimulus was deleted from each situation. Table 3 presents the mean naming latencies, mean errors, and standard deviations for the four types of letter strings: FOAL, FOLE, HOPE, and HOAP. Figure 3 shows the mean latencies for the four stimulus types as a function of load. An ANOVA on subjects' latencies revealed a significant main effect of load (one digit = 537 ms vs. five digits = 552 ms), $F(1, 27) = 28.05$, $p < .001$, and a significant main effect of lexicality (FOAL, HOPE = 534 ms vs. FOLE, HOAP = 555 ms), $F(1, 27) = 29.88$, $p < .001$. The main effect of frequency (HOPE, HOAP = 542 ms vs. FOAL, FOLE = 548 ms) was not significant, $F(1, 27) = 3.83$, $p > .05$. The important interaction of load and frequency was significant, $F(1, 27) = 9.42$, $p < .01$, as was the Lexicality × Frequency interaction, $F(1, 27) = 12.91$, $p < .001$. LF stimuli (FOAL, FOLE) were named 16 ms faster than HF stimuli (HOPE, HOAP) under the five-digit load and 3 ms slower under the one-digit load; FOLE was named 13 ms slower than FOAL, and HOAP was named 28 ms slower than HOPE. The Load × Lexicality interaction was not significant, and neither was the three-way interaction ($F < 1$). The ANOVA on items' means confirmed most of the preceding significant effects: load, $F(1, 70) = 10.19$, $p < .01$; lexicality, $F(1, 70) = 26.60$, $p < .001$; Load × Frequency interaction, $F(1, 78) = 4.37$, $p < .05$. The main effect of frequency, $F(1, 70) = 0.31$, $p < 1$, and the Lexicality × Frequency interaction, $F(1, 70) = 2.76$, $p > .05$, were not significant. In the error analysis, the only significant effect was lexicality (FOAL, HOPE = 1.39% errors vs. FOLE, HOAP = 5.26% errors) with subjects as the error term, $F(1, 27) = 24.17$, $p < .001$.

Table 3
Mean Naming Latencies (in Milliseconds) and Error Rates (in %): Experiment 3

	Memory load			
	Low		High	
Target	Latency	Error rate	Latency	Error rate
	Low frequency			
FOAL				
M	531	1.19	540	1.19
SD by subject	60	3.50	59	3.50
SD by item	41	3.99	42	4.67
FOLE				
M	548	3.57	548	4.76
SD by subject	66	6.80	59	6.36
SD by item	54	8.09	51	8.35
	High frequency			
HOPE				
M	522	0.79	545	2.38
SD by subject	60	2.91	56	5.54
SD by item	44	3.61	48	5.21
HOAP				
M	549	6.75	575	5.95
SD by subject	62	8.19	76	9.31
SD by item	54	9.87	51	8.69

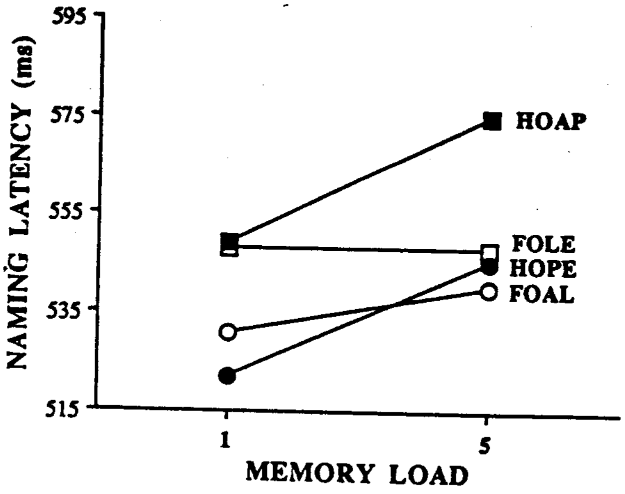

Figure 3. Mean latencies (in milliseconds, ms) for the four stimulus types as a function of load in Experiment 3.

Turning to the primary (memory) task, ANOVAs for subjects and items on decision latencies revealed that only the main effect of memory load (one digit = 506 ms vs. five digits = 660 ms), $F(1, 27) = 154.50, p < .001$, and $F(1, 70) = 484.19, p < .001$, was significant. Other main effects and interactions were absent ($F < 1$). A similar pattern of results was revealed by an ANOVA on decision errors in the memory task. The main effect of load (one digit = 2.18% errors vs. five digits = 5.36% errors) was significant for subjects, $F(1, 27) = 11.56, p < .01$, and for stimuli, $F(1, 70) = 9.51, p < .01$. Other effects did not reach significance. These results confirm that the group of 28 selected subjects performed the memory task as the main task: Latencies and errors in memory decisions were affected by the size of memory load but not by the naming task.

The results of Experiment 3 corroborate and reinforce the major conclusion of Experiments 1 and 2: A pseudohomophone is processed like its word counterpart. Specifically, the experiment repeats the important observations of the interaction of load and frequency and the noninteraction of load and lexicality under conditions in which (a) the memory task was performed proficiently (errors less than 10%), (b) decision latency on the memory task was affected by the memory load (longer decision latency for the five-item load than for the one-item load), (c) naming latencies were affected by the memory load (longer naming latency for the five-item load than for the one-item load), and (d) the naming task did not affect the memory task. Satisfaction of the aforementioned conditions means that the memory task was the subject's primary task and that the subsidiary naming task was affected by the availability of attention. According to dual process theory, nonwords and LF words are named by a slow process that assembles phonology prelexically, and HF words are named by a fast process that accesses lexical phonology. Furthermore the theory implies that assembling phonology is more demanding than visually accessing phonology. Consequently, FOLE and HOAP should have been affected similarly by load, with poorer performance under the higher load, and FOAL and HOPE should have been affected dissimilarly by load, with the higher load more detrimental to FOAL than to HOPE. As in the previous two experiments, these predictions of dual process theory were not confirmed.

Finally, comments should be made on the contrast between Experiment 3 and Experiments 1 and 2, respectively, as reflected in the contrast between Figure 3 and Figures 1 and 2, respectively, and between Experiments 1 and 2 and the experiments of Paap and Noel (1991). According to the account advanced in the discussion of Experiment 1, the flattening of LF latencies as a function of load from Figure 1 and 2 to Figure 3 may be attributable to a change in the inequality relation among $\Delta\tau_{LF}$, ∂, and $\Delta\tau_{HF}$. To reiterate, concurrent cognitive activity (a) induces a reduction in the verification criterion level proportional to load (the higher the load, the lower the criterion) that will have the same time-reduction effect ∂ on HF items and LF items and (b) adds an amount $\Delta\tau$ to activation times to threshold for lexical representations that is proportionately greater for HF items than for LF items. If $\Delta\tau_{LF} < \partial < \Delta\tau_{HF}$, as suggested for Experiment 1, then the advantage of (a) outweighs the disadvantage of (b) for LF words and pseudohomophones but does not outweigh the disadvantage of (b) for HF words and pseudohomophones. The implication is that in Experiment 3, the greater attentional demands affected ∂, such that $\partial < \Delta\tau_{LF} < \Delta\tau_{HF}$, with the advantage of (a) no longer outweighing the disadvantage of (b) for LF items.

Recall that Paap and Noel (1991) found that LF exception words benefitted from high loads, whereas LF regular words did not. In Experiments 1 and 2 of the present series, as just noted, LF regular words were named faster under high loads. (The LF set was almost entirely regular, as inspection of the Appendix reveals.) One potential reason for the different outcome of Experiments 1 and 2 from that of Paap and Noel is the difference in composition of the stimulus set. They balanced regular and exception words over low and high frequency. Another potential reason is suggested by the present experiment and its interpretation. Numerically, FOAL under high load was responded to slower than FOAL under low load, consonant with the observation of Paap and Noel. The argument of the preceding paragraph holds that the Load × Frequency relation is contingent on the attensity of the load, that is, its actual degree of attentional demand. In Experiment 3, the attensity of load was, presumably, more similar to the load attensity characterizing the Paap and Noel study than had been the case in Experiments 1 and 2.

Experiment 4

Lukatela and Turvey (1991) demonstrated that DESPAIR was primed equally by HOAP and HOPE but was not primed by DORN. This phenomenon of priming due to associated pseudohomophones suggests that lexical representations are coded and accessed phonologically. In the context of the present research, the equal priming of DESPAIR by HOAP and HOPE follows the observations made in Experiments 1–3 that a pseudohomophone is processed in a manner qualitatively similar to the processing of its word counterpart. In this experiment, we address the effect of load on associative priming by words and pseudohomophones. Arguments presented above ascribe the basic naming latency difference between a pseudohomophone such as HOAP and its word counterpart HOPE to the connective matrix mapping letter units to phoneme units. The difference does not arise at verification or in the lexicon. The lexical representation /HOPE/ is activated at the same pace by HOAP and HOPE, once their respective phonologies are assembled, because the pseudohomophone and its word counterpart are coded in the same way for access, namely, as /HOPE/. Consequently, the resultant priming of /DESPAIR/ occurs at the same rate and to the same degree for the primes HOPE and HOAP.

In Experiment 4, DESPAIR was named following HOPE and GONE and following HOAP and GAWN. It was expected that the latency difference in the HOAP versus GAWN contrast would be the same as in the HOPE versus GONE contrast, and it was expected that this identity of latency differences would be upheld over memory loads of one and five items. That is, there should be no interaction between prime lexicality and associativeness (in agreement with Lukatela & Turvey, 1991), between load and prime lexicality, and among load, prime lexicality, and association. Also in Experiment 4, HORSE was named following FOAL and MUTE and following FOLE and MEWT. The expectations identified in the preceding for the HF primes were expected to hold for the LF primes. HF words (and nonwords homophonous with them) and LF words (and nonwords homophonous with them) do not differ in lexical associative processes; that is, the processes by which FOAL and FOLE prime HORSE are not different from the processes by which HOPE and HOAP prime DESPAIR. An additional expectation, therefore, is that there should be no interactions with prime frequency.

Method

Subjects. The participants in the experiment were 50 students from the University of Connecticut. Each subject was assigned, by order of appearance at the laboratory, to one of eight groups, giving 7 subjects in Groups 1 and 2 and 6 subjects in the remaining six groups (3–8). The subjects did not participate in the earlier experiments.

Materials. The set of 40 LF words (e.g., FOAL, MUTE) with a mean frequency of occurrence 7.55 and the set of 40 HF words (e.g., HOPE, GONE) with a mean frequency of occurrence 270.73 were borrowed from Experiment 1. Substituting each word by its pseudohomophone produced corresponding sets of 40 LF pseudohomophones (e.g., FOLE, MEWT) and 40 HF pseudohomophones (e.g., HOAP, GAWN). These words and pseudohomophones were used as contexts in the associatively related context–target pairs. Appropriate target words were drawn from previous work (see Appendixes in Lukatela & Turvey, 1991). Four sets of associatively related context–target pairs were prepared: the LF word context set (FOAL–HORSE, MUTE–DEAF), the LF pseudohomophone context set (FOLE–HORSE, MEWT–DEAF), the HF word context set (HOPE–DESPAIR, GONE–AWAY), and the HF pseudohomophone context set (HOAP–DESPAIR, GAWN–AWAY). By re-pairing two appropriate pairs within a given set, four other sets of unrelated context target pairs were also prepared: the LF word context set (FOAL–DEAF, MUTE–HORSE), the LF pseudohomophone context set (FOLE–DEAF, MEWT–HORSE), the HF word context set (HOPE–AWAY, GONE–DESPAIR), and the HF pseudohomophone context set (HOAP–AWAY, GAWN–AWAY). In addition, a set of 30 unrelated word–pseudohomophone pairs (e.g., MINER–GURL) were made to serve as foils.

Eight counterbalanced lists of the context–target pairs were prepared. In each list, there were 10 instances of each experimental set. For example, in one list there were 10 FOAL–HORSE pairs, 10 FOLE–HORSE pairs, 10 HOPE–DESPAIR pairs, 10 HOAP–DESPAIR pairs, 10 FOAL–DEAF pairs, 10 FOLE–DEAF pairs, 10 HOPE–AWAY pairs, 10 HOAP–AWAY pairs, and 30 MINER–GURL foil pairs. Half of the stimuli were presented under conditions of high memory load and the remaining half under low memory load.

Design. A major constraint on the design was that a given subject never encountered a given context word (in either its lexical or nonlexical pseudohomophonic form) or a given target word more than once. There were 16 ($2 \times 2 \times 2 \times 2$) stimulus types (Memory Load × Associativeness × Lexicality of the Context × Frequency of the Context). Memory load (low vs. high) was both a within-subjects factor and a within-items factor, as was associativeness (pseudohomophone context vs. word context). Word frequency (LF vs. HF) was a within-subjects factor and a between-items factor.

Each subject was presented with 5 experimental stimuli from each of the eight types and with 30 foils, giving 110 stimuli. The experimental sequence was divided into five subsequences, with a brief rest in between each. Stimulus types were ordered pseudorandomly within each subsequence. The experimental sequence was preceded by a practice sequence of 16 stimuli.

Procedure. The procedure was as described in Experiment 3 with modifications to accommodate the associative priming paradigm. After an interstimulus interval of either 1,000 ms or 2,000 ms (varied randomly), a letter string written in upper case appeared for 200 ms, and after a brief interval (interstimulus interval = 100 ms) another letter string written in lower case appeared for the next 200 ms. The subject was told that he or she would be viewing words and nonwords and that the nonwords, when pronounced, could sound like English words. Subjects were required to pronounce, as quickly and as distinctly as possible, the lowercase letter string only. Subjects were recommended to read silently the preceding uppercase letter string because on some trials the silent reading might help in reading aloud, with greater accuracy, the target letter string. In all conditions, latencies from the onset of the target (i.e., lowercase) letter string to the onset of the response were measured by a voice-operated key.

Results and Discussion

Table 4 presents the mean naming latencies, mean errors, and standard deviations for the eight types of the context–target pairs: FOAL–HORSE, FOLE–HORSE, MUTE–HORSE, MEWT–HORSE, HOPE–DESPAIR, HOAP–DESPAIR, GONE–DESPAIR, and GAWN–DESPAIR, under one-digit load and under five-digit load. For brevity, in the following analysis the context–target pairs will be designated by their context letter strings (e.g., FOAL stands for FOAL–HORSE, etc.). An ANOVA on subjects' naming latencies revealed significant main effects of load (one digit = 502 ms vs. five digits = 493 ms), $F(1, 49) = 16.69$, $p < .001$; associativeness (associate = 491 ms vs. control = 504 ms), $F(1, 49) = 34.68$, $p < .001$; lexicality of the context letter strings (FOAL, HOPE = 496 ms vs. FOLE, HOAP = 499 ms), $F(1, 49) = 4.50$, $p < .05$; and frequency of the context letter strings (HOPE, HOAP = 494 ms vs. FOAL, FOLE = 501 ms). No interaction reached significance. The ANOVA on items' means confirmed two of the preceding significant main effects: main effect of load, $F(1, 78) = 8.74$, $p < .01$, and main effect of associativeness, $F(1, 78) = 11.54$, $p < .001$. Lexicality of the context letter string, $F(1, 78) = 2.04$, $p > .05$, did not reach significance. All other two-, three-, and four-way interactions were insignificant ($F < 1$). In the analysis on subjects' errors in the naming task, the only significant effect was the Load × Associativeness × Frequency interaction, $F(1, 49) = 5.39$, $p < .05$. In the analysis on items' means, this interaction did not reach significance, $F(1, 78) = 2.86$, $p > .05$.

Analyses of decision latencies on the memory task revealed a very significant effect of load (one digit = 532 ms vs. five digits = 734 ms) for subjects, $F(1, 49) = 400.58$, $p < .001$, and for stimuli, $F(1, 78) = 1027.79$, $p < .001$. The

Table 4
Mean Naming Latencies (in Milliseconds) and Error Rates (in %): Experiment 4

	Memory load			
	Low		High	
Target	Latency	Error rate	Latency	Error rate
Low-frequency word context				
FOAL–HORSE				
M	499	3.20	492	2.80
SD by subject	62	10.19	65	8.09
SD by item	39	7.64	42	7.23
MUTE–HORSE				
M	508	2.00	504	1.20
SD by subject	71	6.06	65	4.80
SD by item	53	5.43	43	4.45
Low-frequency pseudohomophone context				
FOLE–HORSE				
M	501	2.80	494	2.00
SD by subject	62	7.01	63	6.06
SD by item	49	9.81	52	7.59
MEWT–HORSE				
M	510	2.00	502	2.80
SD by subject	74	7.28	65	7.01
SD by item	57	5.43	44	9.07
High-frequency word context				
HOPE–DESPAIR				
M	488	1.20	477	2.80
SD by subject	68	4.80	69	7.01
SD by item	47	4.45	48	7.34
GONE–DESPAIR				
M	508	3.60	493	0.80
SD by subject	75	7.76	63	3.96
SD by item	50	9.54	50	3.68
High-frequency pseudohomophone context				
HOAP–DESPAIR				
M	498	3.20	483	2.80
SD by subject	72	7.41	68	7.01
SD by item	43	6.53	53	7.82
GAWN–DESPAIR				
M	505	5.20	499	2.00
SD by subject	66	8.86	67	6.06
SD by item	56	10.78	48	5.28

main effect of the context's frequency (HOPE, HOAP = 624 ms vs. FOAL, FOLE = 642 ms) was significant for the subject analysis, $F(1, 49) = 13.75$, $p < .001$, but not for the item analysis, $F(1, 78) = 1.78$, $p > .05$. Analyses of decision errors on the memory task did not reveal significant effects. The important effect of load (one digit = 4.90% errors vs. five digits = 6.50% errors) was in the right direction, and it was marginally significant both for subjects, $F(1, 49) = 3.37$, $p < .07$, and for stimuli, $F(1, 78) = 3.29$, $p < .07$.

The experiment confirms the observation of Lukatela and Turvey (1991) that a pseudohomophone can act as an associative prime with the same effectiveness as its word counterpart. Thus, HOAP primes DESPAIR as well as HOPE primes DESPAIR. The experiment extends this observation by showing that it is indifferent to concurrent processing demands. That is, differences between the one-digit load and five-digit load memory tasks engendered differences in overall speed of naming but did not engender differences in the associative primings by pseudohomophone and word. The direction of the effect of load on naming latency has bearing on the model presented in the *Results and Discussion* section of Experiment 1. The faster naming of DESPAIR and HORSE under high load is in agreement with the suggestion that load lowers verification criterion, with lower criteria for higher loads. Furthermore, the experiment shows that the magnitude of the priming by a pseudohomophone and its word counterpart is the same regardless of the word counterpart's frequency. Thus, LF stimuli FOAL and FOLE primed as well as HF stimuli HOPE and HOAP. Collectively, these outcomes of Experiment 4 amplify the understanding that associative priming in the lexicon takes place between phonological representations and that these lexical representations are accessed phonologically (Lukatela & Turvey, 1991).

Conclusion

The dual process theory has been attacked on the grounds that a rule-governed phonological process for accessing the lexicon is unwarranted (e.g., Humphreys & Evett, 1985). In the alternative view, lexical access is achieved for all word forms in a word-specific manner, by the direct visual route. Evidence from the present experiments and other recent studies with English language materials (e.g., Lukatela & Turvey, 1991; Perfetti, Bell, & Delaney, 1988; Van Orden, 1987; Van Orden, Johnston, & Hale, 1988) and evidence from studies with Serbo-Croatian language materials (reviewed by Lukatela & Turvey, 1990a, 1990b, 1991) suggest a different criticism of dual process theory: The primary constraint on lexical access is phonological, not visual, and this constraint is engendered not by a mechanism of effective procedures (explicit rules) and symbol manipulation but by a mechanism that instantiates the continuous statistical regularity relating orthographic and phonologic patterns (Van Orden et al., 1990).

References

Becker, C. A. (1976). Allocation of attention during visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 2,* 556–566.

Carr, T. H., & Pollatsek, A. (1985). Recognizing printed words: A look at current models. In D. Besner, T. G. Waller, & G. E. MacKinnon (Eds.), *Reading research: Advances in theory and practice* (Vol. 5, pp. 1–82). Orlando, FL: Academic Press.

Coltheart, M. (1978). Lexical access in simple reading tasks. In G. Underwood (Ed.), *Strategies of information processing* (pp. 151–216). London: Academic Press.

Glushko, R. (1979). The organization and activation of orthographic knowledge in reading aloud. *Journal of Experimental Psychology: Human Perception and Performance, 5,* 674–691.

Herdman, C. M., & Dobbs, A. R. (1989). Attentional demands of visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 15,* 124–132.

Humphreys, G. W., & Evett, L. J. (1985). Are there independent lexical and nonlexical routes in word processing? An evaluation of the dual-route theory of reading. *The Behavioral and Brain Sciences*, *8*, 689–740.

Kučera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English*. Providence, RI: Brown University Press.

Lukatela, G., & Turvey, M. T. (1990a). Automatic and prelexical computation of phonology in visual word identification. *European Journal of Cognitive Psychology*, *2*, 325–343.

Lukatela, G., & Turvey, M. T. (1990b). Phonemic similarity effects and prelexical phonology. *Memory & Cognition*, *18*, 128–152.

Lukatela, G., & Turvey, M. T. (1991). Phonological access of the lexicon: Evidence from associative priming with pseudohomophones. *Journal of Experimental Psychology: Human Perception and Performance*, *17*, 951–966.

Lukatela, G., Turvey, M. T., & Todorović, D. (1991). Is alphabet biasing in bialphabetical word perception automatic and prelexical? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *17*, 653–663.

McCann, R. S., & Besner, D. (1987). Reading pseudohomophones: Implication for models of pronunciation assembly and the locus of word–frequency effects in naming. *Journal of Experimental Psychology: Human Perception and Performance*, *13*, 14–24.

Navon, D. (1984). Resources—A theoretical soup stone? *Psychological Review*, *91*, 216–234.

Paap, K. R., Newsome, S. L., McDonald, J. E., & Schvaneveldt, R. W. (1982). An activation-verification model for letter and word recognition. *Psychological Review*, *89*, 573–594.

Paap, K. R., & Noel, R. W. (1991). Dual-route models of print to sound: Still a good horse race. *Psychological Research*, *53*, 13–24.

Patterson, K., & Coltheart, V. (1987). Phonological processes in reading: A tutorial review. In M. Coltheart (Ed.), *Attention and performance XII: The psychology of reading* (pp. 421–448). Hillsdale, NJ: Erlbaum.

Perfetti, C. A., Bell, L. C., & Delaney, S. (1988). Automatic (prelexical) phonetic activation in silent word reading: Evidence from backward masking. *Journal of Memory and Language*, *27*, 59–70.

Richardson, J. T. E. (1976). The effects of stimulus attributes upon latency of word recognition. *British Journal of Psychology*, *67*, 315–325.

Rosson, M. (1985). The interaction of pronunciation rules and lexical representations in reading aloud. *Memory & Cognition*, *13*, 90–99.

Scarborough, D. L., Gerard, L., & Cortese, C. (1979). Accessing lexical memory: The transfer of word repetition effects across task and modality. *Memory & Cognition*, *7*, 3–12.

Seidenberg, M. S., Waters, G. S., Barnes, M. A., & Tanenhaus, M. K. (1984). When does irregular spelling or pronunciation influence word recognition? *Journal of Verbal Learning and Verbal Behavior*, *23*, 383–404.

Stone, G., & Van Orden, G. C. (in press). Strategic control of processing in word recognition. *Journal of Experimental Psychology: Human Perception and Performance.*

Taraban, R., & McClelland, J. L. (1987). Conspiracy effects in word pronunciation. *Journal of Memory and Language*, *26*, 608–631.

Van Orden, G. C. (1987). A ROWS is a ROSE: Spelling, sound, and reading. *Memory & Cognition*, *15*, 181–198.

Van Orden, G. C., Johnston, J. C., & Hale, B. L. (1988). Word identification in reading proceeds from spelling to sound to meaning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *14*, 371–385.

Van Orden, G. C., Pennington, B. F., & Stone, G. O. (1990). Word identification in reading and the promise of subsymbolic psycholinguistics. *Psychological Review*, *97*, 488–522.

Waters, G. S., & Seidenberg, M. S. (1985). Spelling–sound effects in reading: Time course and decision criteria. *Memory & Cognition*, *13*, 557–572.

(*Appendix follows on next page*)

Appendix

Low- and High-Frequency Words and Their Corresponding Pseudohomophones as Used in Experiments 1–4

Low frequency		High frequency		Low frequency		High frequency	
Word	Pseudohomophone	Word	Pseudohomophone	Word	Pseudohomophone	Word	Pseudohomophone
ACHE	AICHE	BIBLE	BYBLE	MOAN	MONE	MAIN	MAYN
BAKE	BAIK	BREAK	BRAIK	MUTE	MEWT	MOST	MOAST
BLADE	BLAID	DATE	DAIT	NAIL	NALE	MONTH	MUNTH
CHEAT	CHEET	DEAL	DEEL	OATS	OTES	NEAR	NEER
CIDER	SIDER	DOOR	DORE	OBEY	OBAY	PIECE	PEECE
CRATE	CRAIT	DREAM	DREEM	PIE	PYE	RAIN	RANE
DOME	DOAM	EARLY	URLY	PLEA	PLEE	ROAD	ROED
FAKE	FAIK	EAST	EEST	RAID	RADE	SAFE	SAIF
FOAL	FOLE	FEAR	FEER	ROBE	ROAB	SAME	SAIM
GALE	GAIL	FIGHT	FITE	ROPE	ROAP	SHAPE	SHAIP
GLEAM	GLEEM	FIRE	FYRE	ROAR	RORE	SNOW	SNOE
GLOBE	GLOAB	FLOOR	FLORE	SHAVE	SHAIV	STONE	STOAN
GOAT	GOTE	GAIN	GANE	TAME	TAIM	TAKE	TAIK
GRAPE	GRAIP	GROUP	GRUPE	TEASE	TEEZE	TONE	TOAN
GRIEF	GREEF	HEAR	HEER	THIEF	THEEF	WAIT	WATE
LAME	LAIM	HOPE	HOAP	TOAD	TODE	WHILE	WHYLE
LEAF	LEEF	HOUSE	HOWSE	TRAIT	TRATE	WHITE	WHYTE
LEASH	LEESH	LADY	LAIDY	TROOP	TRUPE	WIFE	WYFE
LEAP	LEEP	LEAST	LEEST	WADE	WAID	WAR	WOAR
LEASE	LEESE	LIGHT	LITE	WHEAT	WHEET	READ	WREED

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