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How to drastically reduce priming in word stem completion—and still present the words

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This paper describes a series of experiments in which we demonstrated that "dysphonemic" word stems, which are likely not pronounced in isolation as they are within a word (e.g., MUS in MUSHROOM or LEG in LEGEND), showed less priming than did "phonemic stems" (e.g., MUS in MUSTARD or LEG in LEGACY). Furthermore, words with either dysphonemic or phonemic three-letter stems gave rise to equivalent levels of priming when test cues were four-letter stems (LEGE) or word fragments (L_G_ND). Moreover, the difference between phonemic and dysphonemic stems persisted when nonpresented completion rates were matched. A final cued-recall experiment revealed that performance was greater for phonemic stems than for dysphonemic stems and that this difference was greater for older participants than for younger ones. These results are not readily accounted for by extant theoretical approaches and point to important methodological issues regarding stem completion.

The distinction between recollective memory, in which performance involves conscious recollection, and nonrecollective memory, in which performance does not involve conscious recollection, has been the focus of many studies. Performance on nonrecollective memory tasks is typically measured in terms of priming, which, broadly speaking, may be defined as the change in performance with presented items relative to nonpresented items. Priming is manifest on a variety of nonrecollective tasks, ranging from completion of word puzzles to identification of visually degraded words to anagram solutions.

The word stem completion task has been used widely in studies of nonrecollective memory (e.g., Graf & Ryan, 1990; Rajaram & Roediger, 1993; Roediger & McDermott, 1993; Roediger, Weldon, Stadler, & Riegler, 1992). In the word stem completion task, participants are presented with a list of words and later asked to complete three-letter stems (e.g., GAL____ for GALLANT) with the first word that comes to mind. The probability of a given word being used as a completion to a stem increases if the word appeared in a preceding presentation task (a comprehensive review that includes findings with stem completion may be found in Roediger & McDermott, 1993). In general, the choice of presentation task does not significantly affect priming of stem completion: Presentation tasks that emphasize the meanings of words, or tasks that emphasize words' constituent letters, seem not to lead to different levels of priming of stem completion (e.g., Graf & Mandler, 1984; Rajaram & Roediger, 1993; Roediger & Srinivas, 1993; Roediger et al., 1992; but see Brown & Mitchell, 1994, and McClelland & Pring, 1991). For example, asking participants to use a word in a sentence, as opposed to asking them to judge whether a word contains a particular letter, does not affect the level of priming on stem completion. But, other experimental manipulations can bring out the effects of presentation tasks (e.g., Gibson, Brooks, Friedman, & Yesavage, 1993; Thapar & Greene, 1994).

Conceivably, word-specific characteristics, such as frequency of occurrence in the English language, word length, and phonemic properties, could affect priming. Nelson and colleagues (e.g., Nelson, Canas, Bajo, & Keelean, 1987) have provided evidence that the number of lexical and semantic associates affects stem completion. Nelson et al. found that lexical set size, defined in terms of the number of words that share the same test cue, affected per-

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formance on both fragment completion and cued recall tests, whereas semantic set size, defined in terms of the number of semantic associates a word has, affected only cued recall performance. Graf and Williams (1987) reported evidence that was suggestive of a relation between length and nonpresented completion rates, but their analyses are difficult to interpret because of multicollinearity among the measures they used to predict completion rate.

A peculiar word-specific characteristic that affects priming of word stem completion is the focus of this paper. In the course of our word stem completion experiments, we noticed that participants tended to use some words as completions to a given stem more than others. Although such an observation is not a startling one, we wondered what characteristics of words or stems would make such a situation more likely. We noticed that some three-letter stems have a likely pronunciation in isolation that matches their pronunciation in the target words (e.g., LEG for LEGACY), whereas other stems do not (e.g., LEG for LEGEND). We will refer to the former type of stems as *phonemic* stems and the latter type as *dysphonemic* stems. (Note that the terms phonemic and dysphonemic refer to the relation between a stem and a specific word, and not to the stem in isolation.)

Would the presence of dysphonemic or phonemic stems affect priming on word stem completion? On the one hand, most theoretical approaches and existing data would seem to predict that there would be little difference, since some degree of priming seems almost inevitable. Common thinking is reflected by statements such as "so long as the word is seen, priming will result; even radical changes in the surface features of the word create modest differences in priming" (Roediger & McDermott, 1993, p. 88) and that "lexical processing [at presentation] is critical for priming in the word fragment completion and perceptual identification implicit memory tests" (Roediger, Srinivas, & Weldon, 1989, p. 82). Indeed, priming has been observed after substantial transformations of a stimulus between presentation and test (Graf & Masson, 1993, passim). Though neither of the above statements implies that priming should be expected for all presented words, such statements embody the common, logical assumption that visually presenting a set of words and then giving a "typical" three-letter stem completion test reasonably soon afterwards should result in "normal" priming (albeit to slightly different degrees) of approximately 15%–20%. This statement would appear to be accurate if entire, unadulterated words are provided in the presentation phase and unadulterated cues (e.g., stems) are provided in the test phase. The occurrence of priming on stem completion following a typical presentation task would be predicted by theoretical explanations that have been offered as accounts of nonrecollective memory.

To foreshadow our results, we provide an illustration in which the common assumption of near-ubiquitous priming does not hold. In the present experiments, we used both words with phonemic stems and words with dysphonemic stems in word stem completion tests. Because a variety of letter combinations yield dysphonemic stems, there were variations among the stems we used: Words with dysphonemic stems ranged from LEGEND to MUSHROOM to COLONEL. Words with phonemic stems were rather unremarkable and ranged from LEGACY to MUSTARD to COLONY. Because of our interest in the possibility of age-associated changes in nonrecollective memory, we included both older and younger adults in two of our experiments. We did not find any evidence of age-associated differences, so, we will not emphasize this manipulation further.

EXPERIMENT 1

Graf and Ryan (1990) suggested that format-specific changes between presentation and test (e.g., typeface manipulations) may be more likely to change priming if the presentation task emphasizes the manipulation of interest. In keeping with this logic, we used a syllable judgment task in Experiment 1 (cf. Gibson et al., 1993) that required participants to count the number of syllables in a word. We suspected that highlighting the pronunciation of words during presentation might increase the likelihood of differences in priming between phonemic and dysphonemic stems.

Method

Participants. The participants were 40 adults with an average age of 70.02 years ($SD = 8.19$); their ages ranged from 57 to 90 years. The participants had an average of 15.05 ($SD = 3.00$) years of education. They were recruited through advertisements at community senior centers for a memory improvement course that was not related to the present experiments.

Materials. Our word pool consisted of 64 nouns (provided in Appendix A) selected from Kučera and Francis's (1967) word frequency corpus. All words were selected within the constraint that the first three letters (the stems) could be completed with at least 10 words. The words contained five to eight letters. Thirty-two of the words had dysphonemic three-letter stems, and the other 32 had phonemic stems. The median frequency of occurrence for words with phonemic stems was 12 per million and for those with dysphonemic stems was 8 per million (Kučera & Francis, 1967).

All words and stems were printed in uppercase 14-point Adobe Garamond font. For the presentation phase, the words were printed on the left side of a piece of paper with the presentation questions alongside them. The test comprised two sheets of paper with the three-letter stems followed by a blank line. The presentation and test pages were assembled in a booklet for the memory training course (the participants were not allowed to turn pages at any time during testing).

Design. Each group (phonemic and dysphonemic) of 32 words was divided into two sets of 16 words, A and B. Each set was further divided into two subsets of eight words each (A1 and A2, B1 and B2). For half of the participants, words in the A sets served as presented words and those in the B sets as nonpresented words; for the other half of the participants, the presentation statuses were reversed. The subsets (1 and 2) allowed for counterbalancing of the response to the presentation question: The questions were altered so that, for Subsets A1 and B1, the correct answer to the presentation question was "yes" for half of the participants and "no" for the other half; the same was true for Subsets A2 and B2.

Procedure. The participants were tested in groups of up to 16 at a time in a classroom-type setting. The experiment comprised two phases: a presentation phase during which the target words were presented and a test phase during which the word stem completion test was given.

The presentation phase was incorporated into the study phase of the memory improvement course. For the memory improvement course, the participants received a list of words to study (unrelated to our materials) and were told that they would be asked to recall them later. After studying the words for the course, the participants were told that they would be given another task for 6 min that required them to answer questions about words. This task was the presentation phase for the present experiment.

In the presentation phase, each word was accompanied by a statement that a word contained a specified number of syllables (e.g., "The word contains 2 syllables"). The participants were told to write a Y in a column on the right side of the page if a word contained the specified number of syllables or an N if it did not. The experimenter explained that the answers to the questions were needed for establishing "baseline information" and that it was important to answer the questions correctly. The participants were not told that they would later receive a test pertaining to the words.

After the presentation phase, the participants were allowed approximately 7 min to recall the words that they had studied for the memory improvement course. The participants were next given the word stem completion test. As in the presentation phase, the participants were told that the purpose of the task was to establish baseline information. The participants were asked to complete the word stems with the first word that came to mind and told that they should not use proper nouns. The experimenter provided the stem TAB as an example that could be completed with TABLE, TABLET, TABOO, and so on.

Results and Discussion

The overall correct completion rates are provided in Table 1 for both presented and nonpresented words. In this experiment, and several that follow, the nonpresented completion rates for phonemic and dysphonemic stems were rather different. We accounted for the different baselines in our computation of priming scores by following Snodgrass's (1989) formula for computing "relative" priming. This formula defines priming as the result of $[P(\text{presented}) - P(\text{nonpresented})]/[1 - P(\text{nonpresented})]$, where $P(\text{presented})$ is the proportion of completions for presented items and $P(\text{nonpresented})$ is the proportion correct for nonpresented items. Relative priming is in contrast to "absolute" priming, which is defined as $[P(\text{presented}) - P(\text{nonpresented})]$. The average absolute and relative priming scores are provided in Table 2. For all statistics, $\alpha = .05$.

The relative priming scores in Table 2 suggest that priming for words with phonemic stems was almost triple that of words with dysphonemic stems and the level of priming for dysphonemic stems was low. Statistically significant priming was observed for phonemic stems [$t(39) = 3.37$, $d = 1.08$],[1] as well as for dysphonemic stems [$t(39) = 2.76$, $d = 0.88$]. Also, priming for phonemic stems was significantly greater than that for dysphonemic stems [$t(39) = 2.63$, $d = 0.84$]. Thus, we were successful in reducing priming for stem completion.

The nonpresented completion rate for the dysphonemic stems was lower than that for the phonemic stems. Our use of a relative priming index accounts for this, yet one could question whether the difference in priming was an artifact of nonpresented completion rates because the level of priming was also lower for dysphonemic stems than for phonemic stems. Alternatively, it could be that we obtained this pattern of performance despite the difference in nonpresented completion rates rather than because of it. That is, because the nonpresented completion rate was lower for dysphonemic stems, there was presumably a greater potential for increase due to presentation than there was for phonemic stems (i.e., regression to the mean). If this were the case, then the nonpresented

Table 1
Average Presented and Nonpresented Completion Rates and Standard Deviations for Experiments 1–7

	Presented Stem Type				Nonpresented Stem Type			
	Phonemic		Dysphonemic		Phonemic		Dysphonemic	
	Avg.	*SD*	Avg.	*SD*	Avg.	*SD*	Avg.	*SD*
Experiment 1								
Three-letter	.33	.12	.09	.09	.19	.13	.04	.05
Experiment 2								
Three-letter (older)	.40	.13	.11	.07	.21	.12	.06	.06
Three-letter (younger)	.33	.11	.15	.13	.18	.09	.06	.06
Experiment 3								
Three-letter stems	.21	.09	.11	.09	.11	.08	.06	.07
Experiment 4								
Four-letter stems	.46	.14	.52	.14	.19	.07	.22	.07
Experiment 5								
Fragments (older)	.40	.17	.41	.21	.32	.15	.33	.19
Fragments (younger)	.41	.11	.43	.21	.32	.15	.36	.19
Experiment 6								
Letter (younger)	.27	.12	.22	.10	.10	.06	.10	.07
Experiment 7								
Older	.40	.13	.11	.07	.20	.13	.04	.05
Younger	.33	.13	.15	.13	.17	.09	.06	.08

Note—Under each experiment's heading is the type of test that was given, followed by the age group of the participants in parentheses.

Table 2
Average Absolute and Relative Priming Scores and Standard Deviations for Experiments 1–6

	Absolute Score				Relative Score			
	Phonemic		Dysphonemic		Phonemic		Dysphonemic	
	Avg.	*SD*	Avg.	*SD*	Avg.	*SD*	Avg.	*SD*
Experiment 1								
Three-letter	.14	.26	.05	.10	.14	.26	.05	.04
Experiment 2								
Three-letter (older)	.09	.28	.02	.08	.21	.26	.07	.06
Three-letter (younger)	.15	.20	.07	.10	.18	.09	.09	.14
Experiment 3								
Three-letter stems	.09	.13	.04	.11	.21	.09	.11	.10
Experiment 4								
Four-letter stems	.28	.14	.30	.13	.34	.18	.39	.17
Experiment 5								
Fragments (older)	.08	.14	.08	.24	.12	.22	.04	.45
Fragments (younger)	.09	.17	.07	.23	.09	.32	.05	.44
Experiment 6								
Letter (younger)	.17	.12	.12	.11	.19	.13	.13	.12

Note—Absolute priming scores were computed by subtracting nonpresented completion rates from presented completion rates. Relative priming scores were computed by [*P*(presented) − *P*(nonpresented)]/[1 − *P*(nonpresented)]. All scores were computed separately for each subject. Under each experiment's heading is the type of test that was given, followed by the age group of the participants in parentheses.

completion rates actually worked against the pattern of results we obtained.

We performed item analyses for the words in this experiment to evaluate the relation between nonpresented completion rates and degree of priming. In this analysis, we first calculated the proportion of participants who correctly completed each stem for presented and nonpresented conditions. Next, we computed absolute priming scores by subtracting the proportion of participants who completed the stem as a presented stem from those who completed it as a nonpresented stem (i.e., presented − nonpresented). To evaluate the relation between priming and the nonpresented completion rate, we computed the correlation between the priming score and the nonpresented completion rate for each type of stem. A positive correlation coefficient indicates that priming increased with the nonpresented completion rate. The correlation for phonemic stems was small and positive (+.22), and the correlation for dysphonemic stems was moderate and positive (+.64). Thus, there is some evidence that priming for dysphonemic stems was associated with nonpresented completion rates. Because the correlations were positive for both types of stem, we cannot exclude the possibility that differences in nonpresented completion rate may have contributed to the observed differences, though this possibility is tempered by the fact that priming for one type of stem was only weakly related to the nonpresented completion rate.

EXPERIMENT 2

Experiment 1 indicated that, following a syllable judgment task, priming of word stem completion was lower for words with dysphonemic stems than for those with phonemic stems. Perhaps the observed difference in priming between words with phonemic and dysphonemic stems occurred because of the syllable judgment task, which emphasized the phonemic qualities of the word (analogous to Graf & Ryan's, 1990, notion we discussed previously).

In Experiment 2, we checked this possibility by using a task that involved judging whether a word contained a specified letter. This presentation task is a common one (cf. Roediger & McDermott, 1993) and is ostensibly neutral with respect to the pronunciation of a word or its stem. We tested both older and younger adults in this experiment.

Method

Participants. The older participants were 52 community-dwelling adults whose average age was 69.64 years ($SD = 7.89$) and ranged from 55 to 87 years of age. The participants had an average of 14.96 ($SD = 2.47$) years of education.

The 52 younger participants were undergraduates at Grinnell College who participated for pay or course credit.

Materials and Design. The materials and counterbalancing were the same as in Experiment 1. The design was a 2 × 2 mixed factorial in which age (younger or older) was a between-participants variable and stem type (phonemic or dysphonemic) was a within-participants variable.

Procedure. The procedure was the same as in Experiment 1, except that, in the presentation phase, each word was accompanied by a question asking whether the word contained a particular letter (e.g., "Does the word contain the letter G?"). The participants were told to write a Y in a column on the right side of the page if the word contained the specified letter or an N if it did not.

Results and Discussion

The responses were scored as in Experiment 1 using the relative priming index, and the average priming scores are provided in Table 2; overall proportions correct are provided in Table 1. An analysis of variance (ANOVA) revealed a significant main effect of stem type [$F(1,102) = 11.12$, $MS_e = 0.28$, $d = 0.66$][2] but no significant main effect of age [$F(1,102) = 3.80$, $MS_e = 0.16$, $d = 0.39$]. The stem type × age interaction was not statistically significant ($F < 1$). There was statistically significant priming for both phonemic stems [$t(103) = 4.96$, $d = 0.98$] and for dysphonemic stems [$t(103) = 4.70$, $d = 0.93$].

Because the nonpresented completion rates for the two types of stem were again different, we performed an item analysis as described in Experiment 1 using absolute priming scores (separately for older and younger adults). For the older adults, the relation for the phonemic stems was +.24; for dysphonemic stems, it was −.54. For the younger adults, the relation for phonemic stems was +.04; for dysphonemic stems, it was +.31. Thus, the relation between the amount of priming and nonpresented completion rate was weaker than that observed in Experiment 1 and, for older adults, in the opposite direction. It seems less likely that differences in nonpresented completion rates were responsible for differences in priming, given the varying strength and direction of the relations.

Experiment 2 demonstrated that the adverse effect of dysphonemic stems on priming was not unique to the syllable judgment task. The fact that we used a letter judgment task leads to implications for other studies, because the letter task and variants of it are often used in studies of stem completion.

EXPERIMENT 3

Although words with phonemic and dysphonemic stems were selected according to the same criteria, it may be that a different pattern of results would obtain if the same stems were to serve as both phonemic and dysphonemic stems. We addressed this issue in Experiment 3. We acknowledge in advance that this experiment was not conclusive, because words whose initial three letters may serve as either a phonemic or dysphonemic stem may represent a unique stimulus population. Even with these limitations, we thought it prudent to explore different factors that may establish boundaries for our finding.

In this experiment, we used the letter judgment task and created a pool of three-letter stems that served as both phonemic and dysphonemic stems. Because dysphonemic stems are distinguished by their sound with respect to a parent word, dysphonemic stems become phonemic by changing the target completion (e.g., LEGEND to LEGACY).

Method

Participants. The group of 48 participants was recruited as in Experiment 1. The average age of the participants was 68.81 years ($SD = 7.73$) and ranged from 55 to 86 years of age. The participants had an average of 15.34 ($SD = 2.24$) years of education.

Materials. We generated a pool of 56 yoked pairs of words for which each pair shared the same three-letter stem (provided in Appendix B). One stem in each pair was phonemic, and the other was dysphonemic. The yoked pairs were matched as closely as practicable with respect to frequency of occurrence and word length. The words with phonemic stems had a median frequency of occurrence of 4.5 per million, and those with dysphonemic stems had a median frequency of occurrence of 8 per million according to Kučera and Francis (1967). The words contained from 5 to 10 letters.

Design. The 56 word stems were divided into two groups of 28, A and B. These two groups allowed for each stem (phonemic and dysphonemic) to serve as the stem of a presented word equally often. Thus, half the participants received a presentation list composed of Group A words, and the other half received a presentation list composed of Group B words. The A and B groups were subdivided into two subgroups, thus yielding A1, A2, B1, and B2. The subgroups allowed each member of the yoked pair to be presented equally often. For example, Subgroup B1 contained the word LEGACY, and Subgroup B2 contained its yoked counterpart LEGEND. Half the participants who received an A presentation list received the A1 subgroup, and half received the A2 subgroup; the same was true for Subgroups B1 and B2. In this way, each stem served as a phonemic stem for half of the participants and as a dysphonemic stem for the other half of the participants.

The letter judgment questions were constructed such that the correct answer for half of the questions was "yes" and for the other half was "no." Within the constraint of stem type, words were paired randomly with question answers.

Procedure. The procedure followed that of Experiment 2.

Results and Discussion

We computed the average number of target words used as completions for stems "designated" as phonemic and dysphonemic for presented and nonpresented stems. Completions that used designated target completions to nonpresented stems were scored as correct. A designated completion was one that was assigned to a nonpresented condition according to our counterbalancing scheme (note that there are two target completions for each stem, only one of which was the designated completion). There were 14 designated completions for each class of stem (presented and nonpresented phonemic stems, presented and nonpresented dysphonemic stems).

The average relative priming scores are provided in Table 2; overall completions rates are provided in Table 1. Because each stem had both a phonemic and a dysphonemic completion, we computed completion rates based on designated target words for both presented and nonpresented stems. The level of priming was statistically significant for both phonemic stems [$t(47) = 4.77$, $d = 1.39$] and dysphonemic stems [$t(47) = 2.57$, $d = 0.37$]. As in Experiments 1 and 2, there was greater priming for phonemic stems than for dysphonemic stems [$t(47) = 2.12$, $d = 0.62$].

EXPERIMENT 4

In Experiment 4, we sought to investigate whether dysphonemic stems do not give rise to "normal" levels of priming on any test. Perhaps words with dysphonemic stems show less priming for reasons other than the dysphonemic property of their three-letter stems and, consequently, would exhibit less priming than words with phonemic stems even on tests in which the nature of the three-letter stem is not relevant. To check this possibility, we altered the three-letter stems so that they contained four, rather than three, letters. The addition of the fourth letter removed the dysphonemic quality, because the pronunciations of the stems would likely be similar to the pronunciation in the parent word.

Method

Participants. The participants were 96 adults whose average age was 69.26 years ($SD = 7.57$) and ranged from 56 to 90 years of age. The participants had an average of 15.07 ($SD = 2.56$) years of education. The participants were recruited as in Experiment 1.

Materials. We added a fourth letter to the phonemic and dysphonemic stems used in Experiment 3. The word FIST was changed to FISTS to allow the creation of a four-letter stem.

Design. The design was the same as that of Experiment 1.

Procedure. The procedure differed from that of Experiment 2 in that four-letter, rather than three-letter, stems were used.

Results and Discussion

Because the difference between the nonpresented completion rates was trivial, we computed absolute priming scores, which are presented in Table 2; overall completion rates are provided in Table 1. Although the four-letter stems themselves were neither phonemic nor dysphonemic, we classified words based on their three-letter stems for comparative purposes. As would be expected with longer stems, overall completion rates and priming increased. Priming was found for both phonemic stems [$t(95) = 18.76$, $d = 3.85$] and dysphonemic stems [$t(95) = 22.52$, $d = 4.62$]. In stark contrast to Experiments 1 and 2, and of direct interest here, is that there was no difference in priming between phonemic and dysphonemic stems [$t(95) = 1.64$, $d = 0.33$].

Experiment 4 demonstrated that when the dysphonemic quality of the stems is eliminated by including an additional letter, those words with either dysphonemic or phonemic stems exhibit similar degrees of priming. More importantly, this experiment provided evidence against the hypothesis that words with dysphonemic stems do not give rise to priming on a stem completion test because of some unmeasured word characteristics.

EXPERIMENT 5

The objective of Experiment 5 was to determine whether words with dysphonemic three-letter stems would exhibit less priming than words with phonemic three-letter stems on a word fragment completion test. Four-letter stems may be specific (as evidenced by overall higher completion rates compared with three-letter stems) and, thus, in some way uniquely lead to priming, whereas other nonrecollective tests may not. Though this possibility seems unlikely, it is prudent to check. In this experiment, we used words with phonemic stems and words with dysphonemic stems in a word fragment completion test. The word fragment completion test differs from a stem completion test in that letters are randomly replaced with blanks to form a fragment (e.g., L _ G _ ND).

Method

Participants. The group of older participants consisted of 56 adults whose average age of the participants was 68.89 years ($SD = 7.91$) and ranged from 55 to 95 years of age. The participants had an average of 14.96 ($SD = 2.47$) years of education. The participants were recruited in the manner described in Experiment 1.

The 48 younger participants were undergraduates at Grinnell College who participated for pay or course credit.

Materials. The word pool from Experiment 1 was used to construct word fragments by removing the second and fourth letters from words with six or fewer letters and the third, fifth, and seventh letters from words with seven or more letters. Though some fragments may have had more than one completion, none of the fragments could be completed by other words in the pool. For LITTER, the third and fourth letters were removed to allow for the creation of a nonoverlapping fragment. A typographical error resulted in identical fragments for HITTER and HITHER appearing on the test; both words were dropped from scoring.

Design and Procedure. The design was the same as in Experiment 2. The procedure differed from that of Experiment 2 only in that word fragments, rather than stems, were used.

Results and Discussion

Priming scores were computed as in Experiment 4, and the average absolute priming scores are presented in Table 2; average overall completion rates are in Table 1. The pattern of results of Experiment 5 was similar to that of Experiment 4.

An ANOVA (stem type × age) revealed no statistically significant interaction or main effects (all Fs < 1). We might note that, for the older adults, there was statistically significant priming for both phonemic stems [$t(55) = 4.41$, $d = 1.19$] and dysphonemic stems [$t(55) = 2.48$, $d = 0.67$]. Though the effect size for words with phonemic stems was greater than for those with dysphonemic stems, the mean priming levels for the two types of word was virtually identical, and the difference between priming for the two types of stem was not significantly different [$t(55) = 0.12$, $d = 0.03$]. For the younger participants, there was statistically significant priming for phonemic stems [$t(55) = 4.24$, $d = 1.14$] and for dysphonemic stems [$t(55) = 2.31$, $d = 0.62$]. The amount of priming for phonemic stems did not differ from that for dysphonemic stems [$t(55) = 0.63$, $d = 0.17$]. (We provide relative priming scores for these data in Table 2 for the sake of completeness. The similar nonpresented completion rates would not suggest computing them. There were no statistically significant differences between the means for the relative priming scores.)

Thus, the pattern of results with fragment completion in Experiment 5 was analogous to those of Experiment 4 with four-letter stems. These findings are consistent with the argument that the difference in priming between phonemic and dysphonemic stems is not peculiar to words with dysphonemic three-letter beginnings.

EXPERIMENT 6

Across the previous experiments, the nonpresented completion rates for dysphonemic stems were less than those for phonemic ones. Thus, as we discussed for Experiment 1, the nonpresented completion rate was confounded with degree of priming. Several findings suggest that the difference in priming between phonemic and dysphonemic stems is not an artifact of nonpresented completion rate differences. First, the item analyses suggest that priming was not strongly associated with nonpresented completion rates. Second, the effect size measure we reported, Cohen's d, indicates that effect size for priming of the two types of stem was not small. These points aside, the difference in nonpresented completion rates existed, and we cannot say that the same results would obtain if they were equal.

In Experiment 6, we addressed the issue of unequal nonpresented completion rates by deriving pools of words whose nonpresented completion rates were roughly equal. We created a pool of words with phonemic or dysphonemic stems whose nonpresented completion rates were roughly equal by gathering nonpresented completion rates from 36 undergraduates.

Method

Participants. Thirty-six undergraduates participated for either extra course credit or pay.

Materials, Design, and Procedure. From the pilot stems, we selected 32 words with dysphonemic stems and completion rates that ranged from 1 to 9, with a mean completion rate of 3.48 and a mode of 1. For the phonemic stems, we selected 32 words with similar completion rates. The completion rates ranged from 1 to 7, with a mean of 2.94 and a mode of 1. The words are provided in Appendix C.

For the experiment proper, the design and procedure were as in Experiment 2.

Results and Discussion

Priming was calculated according to the absolute priming index in light of the equivalent nonpresented completion rates (see Table 1), and the average scores are provided in Table 2. The nonpresented completion rates for phonemic and dysphonemic stems were equal [$t(35) = 0.00$]. There was statistically significant priming for phonemic stems [$t(35) = 8.67$, $d = 1.45$] and for dysphonemic stems [$t(35) = 6.41$, $d = 1.07$]. There was significantly greater priming for phonemic stems than for dysphonemic stems [$t(35) = 2.16$, $d = 0.36$].

To evaluate the generalizability across items, we performed an analysis in which words were treated as a random effect and participants as a fixed effect. This analysis revealed statistically significant priming for both phonemic stems [$t(31) = 5.74$, $d = 1.01$] and dysphonemic stems [$t(31) = 5.15$, $d = 0.91$], but the difference between the two did not attain statistical significance [$t(62) = 1.37$, $d = 0.17$]. This result does not contradict the argument that findings in the present experiment were a reflection of the behavior of the particular word pool. Though this argument could hold, it is also possible that a lack of power to detect a significant difference between the type of stem may have been responsible for the absence of the effect.

In this experiment, we demonstrated that the difference in priming between phonemic and dysphonemic stems is demonstrable when nonpresented completion rates are equal. This finding is consistent with the item analyses reported in the previous experiments and comparisons of effect sizes. The results of Experiment 6 are consistent with the argument that differences in priming between phonemic and dysphonemic stems are not an artifact of nonpresented completion rates.

EXPERIMENT 7

In Experiment 7, we wished to determine whether the difference in priming between words with phonemic and dysphonemic stems on word stem completion (a nonrecollective test) generalized to stem-cued recall (a recollective test). The quality of dysphonemic stems as cues may be a more or less generalized phenomenon in that dysphonemic stems may be poor cues in both recollective and nonrecollective tests. If so, the impact of our results would be greater. On the other hand, the difference between the two stem types might disappear if participants were asked to recollect a specific set of words. In this experiment, we changed our test from one of stem completion to stem-cued recall by asking participants to use words from the presentation task whenever possible. We tested both older and younger adults.

Method

Participants. The participants were 20 older adults who were recruited as in Experiment 1. The average age of the participants was 69.40 years ($SD = 7.34$) and ranged from 58 to 87 years. The participants had an average of 14.55 ($SD = 1.99$) years of education.

The 24 younger participants were undergraduates at Grinnell College who participated for pay or course credit.

Materials, Design, and Procedure. The materials and design were the same as in Experiment 2. Thus, we used a 2×2 mixed factorial design in which stem type (phonemic or dysphonemic) was a within-participants variable and age (younger or older) was a between-participants variable.

The procedure differed from that in Experiment 2 only in that the stem completion test was changed to one of stem-cued recall. No mention was made of the ensuing test during the presentation phase.

At the time of the test, the participants were told that some of the three-letter beginnings were derived from words from the previous judgment task. They were told it was important to use words from the judgment task whenever possible but to use the first word that came to mind as a completion if they could not remember a word from the judgment task.

Results and Discussion

Because the nonpresented completions rates were unequal, we applied the formula for relative priming to compute the postpresentation gain; the average completion rates for presented and nonpresented words are provided in Table 1, and priming scores are provided in Table 2. An ANOVA revealed no significant main effect of age ($F < 1$) and a significant main effect of stem type [$F(1,42) = 10.60$, $MS_e = 0.30$, $d = 1.00$]. The stem type $\times$ age interaction was not statistically significant ($F < 1$).

It appears that dysphonemic stems are poor cues for both stem completion and stem-cued recall. Interestingly, a comparison between effect sizes of this experiment and those of Experiments 1 and 2 revealed that the effect of stem type was greater for stem-cued recall than for stem completion. To evaluate this difference further, we performed an ANOVA using relative priming scores from the participants of Experiments 2 and 7, which included stem type, age, and type of test (cued recall or stem completion). This analysis revealed statistically significant main effects of type of test [$F(1,144) = 5.12$, $MS_e = 0.20$, $d = 0.38$] and stem type [$F(1,144) = 21.69$, $MS_e = 0.56$, $d = 0.78$]. No other main effects or interactions were statistically significant (all Fs < 1.41).

As an aside, we did not find a statistically significant age effect, which would often be expected for cued recall tasks. Experiment 7 differed from most cued recall experiments in that the participants were told of the impending recall phase prior to receiving the presentation list. Inasmuch as spontaneous mnemonic strategies differ for younger and older adults (cf. Brooks, Friedman, Gibson, & Yesavage, 1993), it may be that older adults used a phonemic strategy to a greater degree than younger adults.

GENERAL DISCUSSION

In this paper we have found that words with dysphonemic stems showed significantly less priming on three-letter stem completion than did words with phonemic stems.

In the following sections, we will discuss two sets of issues that the present experiments raise. The first set is methodological in nature and is relevant to experimental design. The second set is theoretical, and our findings are discussed with respect to two currently popular theoretical models.

Methodological Issues

Our experiments raise methodological issues that should not be overlooked in studies of stem completion. Before discussing these issues, we would like to point out that our search for words with dysphonemic stems was far from exhaustive, and our criteria were relatively strict. For example, LEGEND was classified as having a dysphonemic stem, but a word such as ASSASSIN was not. However, ASSASSIN would be considered to have a dysphonemic stem because of the pronunciation of ASS within the word ASSASSIN is likely to differ from its pronunciation in isolation. Should "milder" dysphonemic stems also lead to less priming than phonemic stems, our findings would apply to an even greater number of words, though probably not to as great a degree.

Little attention has been paid to the nature of the stems, except for Nelson et al.'s (1987) work concerning lexical set size. Indeed, there has been little attention paid to the role of word characteristics in stem completion, except for their frequency of occurrence in the English language (Roediger et al., 1992) or their positions within a presentation list (Rybash & Osborne, 1991). We did not examine whether the presence or absence of dysphonemic stems interacted with any experimental manipulations that affect stem completion. At best, a random distribution of words with dysphonemic stems would result in low power to detect effects of experimental manipulations across all conditions. At worst, an imbalance of words with dysphonemic stems would bias a significant difference between conditions.

The differences in priming are not attributable to the choice of dysphonemic words per se; the results of Experiments 4 and 5 indicate that words with dysphonemic and phonemic stems show no detectable differences in priming in either four-letter stem completion or word fragment completion. We suspect that words with dysphonemic stems would lead to "normal" priming on tests other than fragment completion, such as picture identification (e.g., Weldon & Roediger, 1987), perceptual identification (e.g., Brooks, 1987; Jacoby & Dallas, 1981), or general knowledge questions (e.g., Blaxton, 1989). This likelihood is especially important in comparisons of stem completion with other nonrecollective tests (e.g., Rajaram & Roediger, 1993).

In cross-test comparisons, counterbalancing words across tests would still leave stem completion at a disadvantage if dysphonemic stems are present. Statistically, the existence of such a situation could lead to either Type I or Type II errors, depending on the nature of the comparison. To illustrate, suppose the level of priming is approximately .20 when only words with phonemic stems are used. If 25% of the words had dysphonemic stems, the magnitude of priming would decrease to .15. This situation could be even more troublesome if a particular experimental manipulation interacts with the dysphonemic nature of the stems. If the researcher is unaware of this interaction, the erroneous conclusion that stem completion behaves differently than another test might be reached.

Finally, we could conjecture that there are other, as yet undiscovered, word-specific characteristics that could affect priming and possibly interact with experimental manipulations. For these reasons, we would encourage researchers to include their stimulus materials in scientific reports so that, if other characteristics are uncovered, their findings may be interpreted accordingly.

Theoretical Issues

Before we offer an interpretation of our results, we would like to note that our findings are neither predicted by nor readily accounted for by existing theories.[3] Some of the theories that would not account for our findings focus on the concordance of demands placed on the participants at presentation and test (e.g., Graf & Ryan, 1990; Roediger & McDermott, 1993), the "activation" of a preexisting, or closely related, concept of a presented word (e.g., Graf & Mandler, 1984; Lewandowsky, Kirsner, & Bainbridge, 1989), and the operation of different memory "systems" (e.g., Schacter, Cooper, & Delaney, 1990; Tulving & Schacter, 1990). Rather than proceed through an account of the challenges our findings present for each theoretical account, we will describe the challenges presented by our findings for two currently popular approaches.

Transfer-appropriate processing. Roediger and colleagues' (e.g., Roediger & Blaxton, 1987; Roediger &

McDermott, 1993; Roediger & Srinivas, 1993; Weldon, 1993) version of transfer-appropriate processing assumes that test performance is largely determined by the degree to which the operations, or "processes," necessary to complete a test match those operations invoked during a previous presentation episode. Thus, maximal priming should be observed when processes match and minimal priming when they do not. There are at least two orthogonal dimensions on which tasks can be classified (Rajaram & Roediger, 1993; Roediger & McDermott, 1993; Roediger, Weldon, & Challis, 1989; Roediger et al., 1992): data-driven, which involves attention to structural aspects of the stimulus, and conceptually driven, which pertains to the meaning of a stimulus. Tasks are generally considered to be blends of various sorts of processing, and stem completion is typically described as being largely data-driven (e.g., Roediger & McDermott, 1993; Roediger, Weldon, & Challis, 1989).

From our interpretation, Roediger's version of transfer-appropriate processing does not predict our results, because a central tenet is that the degree of perceptual/conceptual overlap between presentation and test processes governs the degree of priming. There are, of course, many findings that support this tenet—so many that Weldon and Jackson-Barrett (1993) asked "why do primes that bear no physical similarity to the test stimulus produce any priming at all?" (p. 520). Regarding the present findings, why do test stimuli that are physically *identical* to portions of the presented words produce very little priming? If stem completion relies largely on matches between "perceptual features" (e.g., Roediger & McDermott, 1993), the match between a dysphonemic stem and its parent word would be the same as between a phonemic stem and its parent word. Thus, there should be no difference in priming between words with phonemic and dysphonemic stems.

Weldon's (1991; Weldon & Jackson-Barrett, 1993) "lexical access hypothesis" assumes priming in such tasks as stem completion requires that a presentation stimulus must "access the same lexical unit represented by the test word" (Welden & Jackson-Barrett, 1993, p. 520) and that a presentation task "must provide access to the target lexical unit to produce priming" (Weldon, 1991, p. 537). These conditions would appear to be readily met by presenting words and then providing their three-letter stems at test. In light of the present findings, the lexical access hypothesis may describe conditions that are sufficient to give rise to priming in stem completion, but not conditions that are necessary.

One could, of course, argue that the pronunciation of the stem is an aspect of the perceptual features that should match between presentation and test (an argument that we consider subsequently). This argument is consistent with the principle of transfer-appropriate processing, but it is not an assumption that has been included in prior conceptualizations of stem completion.

Graf and Ryan's (1990) version of transfer-appropriate processing differs from Roediger's version primarily in that Graf and Ryan propose integrative and elaborative processes rather than data-driven and conceptually driven ones. Integrative processes are thought to involve integration of the features of a target into a whole, whereas elaborative processes are thought to involve associations between the target and other concepts or meanings. Nonrecollective memory is attributed primarily to integration and recollective memory to elaboration. Like Roediger's version of transfer-appropriate processing, this version of transfer-appropriate processing does not appear to predict our results, nor does it seem to account readily for them. Conceivably, one could formulate a post hoc account that involved the assumption that dysphonemic stems somehow did not represent an "integrated" part of the word, but it is difficult to see how such an incorporation would mesh with previous stem completion research and provide conclusive predictions of our findings without allowing for their absence.

Apart from their retrospective nature, modifications of specific transfer-appropriate processing theories would be at the expense of parsimony and would not provide increased predictive or explanatory power. That is, the approaches would still be able to account equally well for either the presence or the absence of our findings.

The general *principle* of transfer-appropriate processing would account for our results—the principle that the degree of match between what a subject does at presentation and test determines performance. This principle allows for a more phenomenological approach in which participants "bring" a pronunciation of the cue. That is, LEG is more likely to be pronounced as in LEGACY than as in LEGEND. Thus, a match of activity would be more likely when the presented word was LEGACY.

PRS systems. Our findings could be considered further evidence of the specificity of implicit memory. Specificity of priming effects are found often when changes in surface features of words between presentation and test affect nonrecollective memory, as in changes of modality (Bassili, Smith, & McLeod, 1989), typography (Gibson et al., 1993) or voice of spoken stimuli (Schacter, Church, & Osowiecki, 1994). Schacter (1990) proposed a systems approach to account for the specificity of priming effects. He proposed that, of the multiple systems of memory, there is a subsystem that processes and represents the form and structure of words (and other stimuli). The activation of the representations in this subsystem, called the *perceptual representation system* (PRS) accounts for priming effects and their perceptual specific nature.

Schacter's PRS approach does not, however, predict that the visual presentation of a word would produce differential levels of priming according to the relation between the pronunciation of a stem in isolation and its pronunciation within a word. For example, according to Schacter (1990),

> it is hypothesized that visual processing of a word . . . creates a representation of its particular visual features in the word form system . . . it seems reasonable to argue further that the visual word form system is engaged during implicit test performance. (p. 552)

The PRS approach would predict that

> if a specific representation has been created in the word form system during study, and the test stimulus matches critical visual features of that representation, then participants will be better able to identify the word from a brief exposure or will be more likely to produce the word in response to a graphemic fragment. (Schacter, 1990, p. 552)

Thus, it is not readily apparent why an intact word's representation in PRS would produce greater priming for phonemic stems than for dysphonemic ones (in light of the fact that the visual word form characteristics are equivalent for both) and yet produce equivalent amounts of priming on four-letter stem completion and word fragment completion.

Conclusions

We are left with the issue of why dysphonemic stems lead to less priming than do phonemic stems. One explanation could be that participants may adopt a strategy in which they infer a possible pronunciation of the stem. For dysphonemic words, this pronunciation is probably not congruent with that of the previously presented target words, and so priming is decreased. Such an interpretation is ostensibly simplistic, but it raises serious issues regarding the nature of stem completion. For example, the acceptance of stem completion as a largely phonemic task is at odds with the finding that rhyme does not affect stem completion (Pitarque, Algarabel, & Meseguer, 1992). Indeed, many researchers (e.g., Roediger & McDermott, 1993; Weldon, 1991, 1993) assume that the presentation of the word itself is a (if not "the") critical aspect that the determines whether priming occurs.

Three issues temper the interpretation of our findings. First, on the basis of the present data, words with dysphonemic stems seem to have lower nonpresented completion rates than do words with phonemic stems. If nonpresented completion rates for words are not individually matched prior to the experiment, our findings present more potential difficulty. To the extent that nonpresented completion rates are equated, the impact of dysphonemic stems may be diminished, though the results of Experiment 6 argue against this idea.

Second, three-letter stems themselves sometimes form words, and this occurred twice as frequently for dysphonemic stems as for phonemic stems. This issue is discounted to some extent by the results of Experiment 3 in which the same three-letter cues served as both phonemic and dysphonemic stems. However, some stems were more likely to form whole words than others. It is not clear whether this confound would affect our findings, but it is conceivable that a "whole-word" three-letter stem could serve to inhibit the production of a presented word.

Finally, when completion rates for nonpresented words differed, we used a relative index of priming that accounted for the baseline. Several researchers (e.g., Snodgrass, 1989) have proposed that a relative index is more reflective of the findings than an absolute index when baselines differ. Many studies of priming of stem completion use an absolute priming index, and, even though overall nonpresented completion rates may be equal, completion rates are rarely matched word for word across word pools. For the sake of consistency with previous research, we can state that when our data were analyzed with an absolute index of priming, the pattern of results was exactly the same. This parallel further extends the generality of our findings.

Our research highlights the importance of exploring the influences of word-specific factors on nonrecollective memory. Future research along the same lines may suggest the need for reconsidering some conceptions of nonrecollective memory. That is, word-specific factors may be more powerful determinants of nonrecollective memory than are delay or presentation task manipulations. Such factors are not necessarily under the conscious control of the participant and make nonrecollective memory all the more fascinating.

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NOTES

1. For all pairwise comparisons, we report Cohen's d (Rosenthal, 1984), which is a standardized effect size measure, to facilitate comparisons of effect sizes.

2. The usual measure of effect size associated with F ratios is ω^2. Because the F ratios in this paper all have 1 degree of freedom for their numerators, we can convert them to t statistics and compute Cohen's d for ease of comparison with the other experiments.

3. We should note that some theories may be so flexible as to allow an account of our findings, but this alone is not sufficient (cf. Watkins, 1989) because they can account for an absence of our findings equally well.

APPENDIX A
Words Used in Experiments 1, 2, 5, and 7

Dysphonemic Stems	Phonemic Stems
ANCHOVY	ACTIVATE
ANTHEM	APOLOGY
ARCHERY	BALLOON
AUTHOR	BLURRY
BACHELOR	BUFFET
BATHING	BUTLER
BOTHER	CATALOG
BUSHEL	CAUGHT
CASHEW	CENTURY
CHORUS	CRAZY
COLONEL	DIVINITY
CUSHION	DRAMA
FASHION	DREAM
FATHER	ELEPHANT
FIGHT	EPISODE
HITHER	FLUSH
LASHING	GALLON
LATHER	GENTLE
LETHAL	GIRDLE
LITHE	HOSTAGE
MACHINE	LENGTH
MUSHROOM	PICTURE
NOTHING	PURIFY
PATHETIC	RENTAL
PIGEON	SAUCE
PITHY	SIMILAR
RATHER	SUMMER
RUSHED	SURPRISE
SECEDE	TERMINAL
TACIT	TIMBER
WASHING	VILLAGE
WITHOUT	WREATH

APPENDIX B
Words Used in Experiments 3 and 4

Dysphonemic Stems	Phonemic Stems
ALTHOUGH	ALTERNATIVE
ANCHOVY	ANCHOR
ANTHEM	ANTELOPE
ARCHERY	ARCTIC
ASTHMA	ASTOUND
AUTHOR	AUTISTIC
BACHELOR	BACKYARD
BATHING	BATON
BISHOP	BISCUIT
BOTHER	BOTANY
BUSHEL	BUSBOY
CACHE	CACKLE
CASHEW	CASTLE
CATHOLIC	CATEGORY
CHAOTIC	CHAPLAIN
CHORUS	CHOCK
COLONEL	COLONY
CUSHION	CUSTODIAN
EMPHASIS	EMPTY
FASHION	FASTER
FATHOM	FATIGUE
FIGHT	FIGMENT
FISHING	FIST(S)
GUSHER	GUSTY
HITHER	HITTER
INCHES	INCUR
LASHING	LASSO
LATHER	LATCH
LEGEND	LEGACY
LETHAL	LETTING
LIGHTNING	LIGAMENT
LITHE	LITTER
MACHINE	MACKEREL
MIGHTY	MIGRANT
MUSHROOM	MUSEUM
NEPHEW	NEPOTISM
NOTHING	NOTORIETY
ORCHARD	ORCHID
PATHETIC	PATIO
PIGEON	PIGMENT
PITHY	PITFALL
RATHER	RATTLE
RICHLY	RICKETY
RIGHT	RIGOR
RUSHED	RUSTY
RUTHLESS	RUTABAGA
SECEDE	SECURE
SIGHT	SIGNAL
SIPHON	SIPPED
SUBTLE	SUBMIT
TACIT	TACKLE
TETHER	TETANUS
TIGHT	TIGER
TITHE	TITANIC
WASHING	WASTEFUL
WITHHELD	WITNESS

APPENDIX C
Words Used in Experiment 6

Dysphonemic Stems	Phonemic Stems
ANCIENT	ACTIVITY
ARCHAIC	ANTONYM
AUTHOR	APOLOGY
BACHELOR	BALLOON
BISHOP	BLUNT
BOTHER	BUFFET
BUSINESS	BUTLER
CACHE	CAUSTIC
CATHARSIS	CLUTTER
CHARACTER	CRASH
CUSHION	DIVORCE
FATHER	DRAMA
FIGHT	DREAM
GOTHIC	ELEGANT
HITHER	EPILEPSY
LEGEND	FLUID
LETHAL	GALAXY
MACHINE	GENERAL
MIGHT	GIRTH
MUSHROOM	HOSPITAL
NEPHEW	LENTIL
NOTHING	PATENT
ORCHARD	PURSUE
PITHY	RENAL
RATHER	SAUNA
RIGHT	SIMILAR
RUTHLESS	SUMMON
SIGHT	SURGERY
SIPHON	TERMITE
SUBTLE	TIMBER
TIGHT	VILLAIN
WITHER	WREATH

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