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Attempted Prime Retrieval Is a Double-Edged Sword: Facilitation and Disruption in Repeated Lexical Retrieval

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The phenomenological experience of lexical retrieval often involves repeated, active attempts to retrieve phonologically and/or semantically related information. However, the influence of these multiple retrieval attempts on subsequent lexical retrieval is presently unknown. We investigated the influence of passively viewing or actively retrieving different types of information at the critical moment preceding lexical retrieval through a novel priming paradigm. Participants attempted to retrieve target words (e.g., abdicate) from low-frequency descriptions (e.g., to formally renounce a throne). Target retrieval was preceded by passive viewing (Experiment 1), or active retrieval of the prime word (Experiments 2–6). Primes were either "both" semantically and phonologically related (e.g., abandon), only phonologically related (e.g., abdomen), only semantically related (e.g., resign), or unrelated (e.g., obvious) to the target word. When primes were passively viewed, phonological facilitation in target retrieval accuracy was observed. In contrast, when participants actively attempted to retrieve primes from their definitions, no phonological facilitation was observed. Successful retrieval of semantic and both primes facilitated subsequent target retrieval, whereas, failure to retrieve semantic and both primes inhibited subsequent target retrieval. These facilitatory and inhibitory influences of prime retrieval for semantic and both primes were independent of feedback on retrieval performance (Experiment 4) and participants' overall knowledge of the primes and targets (Experiment 5), and also did not extend to retrieval from episodic memory (Experiment 6). The findings are consistent with ongoing retrospective processes during target retrieval, which reengage prime retrieval success or failure and consequently produce benefits and costs during repeated retrieval from semantic memory.

Keywords: lexical retrieval, semantic inhibition, lexical access, semantic memory

When an individual attempts to retrieve a word from an existing network of knowledge, multiple interdependent processes are engaged. First, as the individual searches the network for the intended word, concepts that overlap in semantic features with the intended word are activated, some of which are explicitly retrieved. For example, in the attempt to retrieve the name of the author of the novel, *Little Women*, names of other female authors in the same literary genre may come to mind (e.g., Charlotte Brontë, Jane Austen, etc.). In the ideal situation, such semantically related associates and alternatives are slowly eliminated, and this process converges on the correct answer (e.g., Louisa May Alcott). Semantic access to the word then activates orthographic and/or phonological nodes, leading to successful production of the target word (Levelt, 2001, see Dell, 1986, for a more interactive model). However, in situations where the semantic representation of the intended word is not sufficiently activated to override other semantically related alternatives, it is possible that viewing or retrieving semantically related words or concepts may in fact interfere with access to the intended word, leading to unsuccessful retrieval. The phenomenological experience of lexical retrieval often involves actively producing related information (Brown & McNeill, 1966), but the extent to which *active* production of semantically related information during lexical retrieval to definitions influences subsequent retrieval has not been thoroughly investigated.

Studies investigating the influence of semantically related information on target retrieval processes have led to some mixed findings. On the one hand, there is ample evidence for facilitation from semantic primes in lexical decision tasks (Schvaneveldt & Meyer, 1973, see Neely, 1991, for a review) and category exemplar production (Freedman & Loftus, 1971). On the other hand, several studies have reported inhibitory effects of semantically related primes (see Roediger & Neely, 1982, for a review) when more active retrieval is engaged, for example in free recall of semantically related concepts (Brown, 1968; Karchmer & Winograd, 1971), picture naming (Brown, 1981) and repeated production of exemplars from a category (see Blaxton & Neely, 1983; Brown, 1981). While facilitation from semantic primes is consistent with a spreading activation account of lexical retrieval processes, inhibitory semantic priming effects are not easily accommodated within this framework (Dagenbach, Carr, & Barnhardt,

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All data and analysis scripts used in this project and have been made available at https://github.com/abhilasha-kumar/Repeated-Lexical-Retrieval. Portions of this work were presented at the Cognitive Aging Conference, 2018 and were also part of Abhilasha A. Kumar's M.A. thesis. We sincerely thank James H. Neely and Nate Kornell for their helpful feedback and comments on earlier versions of this article.

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1990; Roediger & Neely, 1982) without appealing to alternative mechanisms like automatic spreading inhibition (Brown, 1979; Martindale, 1981) or introducing retrieval assumptions that could explain the loss of facilitation typically expected from spreading activation (Raaijmakers & Shiffrin, 1981).

Several researchers have attempted to clarify the locus of semantic inhibitory effects. As noted, one important finding that has emerged from this work is that there appear to be differences in the effect of semantic primes when primes are passively presented (e.g., in lexical decision), compared with when they are actively retrieved (e.g., answers to word definitions, category exemplar production, etc.). For example, Blaxton and Neely (1983) had participants actively retrieve targets (e.g., BASS) from a semantic category (e.g., FISH) from a letter cue (e.g., B___?) or simply read the target, following one or four semantically related (e.g., COD) or unrelated primes (e.g., BASEBALL). The primes themselves were also either actively retrieved or simply read after a category label (e.g., FISH). They found that when primes were simply read, related primes facilitated both target generation and reading. However, when primes were *actively* retrieved, no such facilitation was observed in target retrieval in the four-prime condition, but facilitation was observed in the one-prime condition. Further, they also reported greater response omissions in target retrieval following retrieval of semantic primes overall, compared with unrelated primes. These findings are also consistent with other research suggesting that overt retrieval of semantically related primes can potentially interfere with subsequent target retrieval processes (Brown, 1979, 1981). Critically, this literature seems to suggest that the effects of multiple semantically related primes on subsequent target retrieval depend on the types of operations involved during prime processing, that is, passive priming or active retrieval.

Despite the ubiquity of retrieval failures and the phenomenological experience of retrieval blocking (Roediger & Neely, 1982), there is relatively little work examining the explicit consequences of successful or unsuccessful retrieval of semantically related information on target retrieval. Most studies on lexical retrieval have either used passively presented primes (Kumar, Balota, Habbert, Scaltritti, & Maddox, 2019; Meyer & Bock, 1992; White, Abrams, & Frame, 2013) or have not explicitly examined the consequences of prime retrieval success on subsequent target performance (Cross & Burke, 2004; Oberle & James, 2013). However, there is some evidence that while successful semantic retrieval produces facilitatory effects, *failed* semantic retrieval can indeed produce inhibition. For example, Dagenbach et al. (1990) reported inhibition for semantically related targets in a lexical-decision task when semantic retrieval for the primes was unsuccessful. In their study, participants first attempted to learn the definitions of rare words and then participated in a standard lexical-decision task in which the rare words served as primes. While semantic facilitation was observed when definitions of the prime words were successfully recalled, semantic inhibition in lexical decision was observed when definitions of the related primes could not be recalled (also see Barnhardt, Glisky, Polster, & Elam, 1996). Dagenbach et al. interpreted these results within a "center-surround" attentional retrieval framework, according to which when retrieval of the definition for the prime fails, the "center" (i.e., the prime) and its "surround" (i.e., related words and target) are inhibited, but when retrieval of the definition of the prime is successful, the prime is activated and facilitation for related words is observed (for a detailed account, see Dagenbach & Carr, 1994). Alternatively, Dagenbach et al. and Kahan (2000) also proposed other retrospective mechanisms that could account for these inhibitory effects, one of which was the idea of "backward checking" or "prime clarification" (Balota & Lorch, 1986; Kahan, 2000; Neely, 1977; Neely & Keefe, 1989) that is particularly relevant to the current research questions.

Neely (1977) proposed a retrospective mechanism that could potentially contribute to semantic priming effects in lexical decision tasks. The central argument was that individuals perform a retrospective check for prime-target relatedness that helps them decide whether the target is a word or nonword. Specifically, participants presumably reason that if there is a relationship between the prime and target, the target must be a word, and if there is no relationship, the target could be a nonword or an unrelated word, which slows down response latencies. Of course, the processes involved in lexical decision are different from those involved in lexical retrieval tasks. However, it is also possible that this retrospective process may be a reflection of more general lexical integration processes as subsequent words are processed in language, that is, integrating each word with the previous linguistic context (see Balota & Lorch, 1986; Forster, 1979). Within this context, it is likely that retrieval success at Time 2 is likely to be influenced by retrieval success at Time 1 in a recurrent manner, that is, each retrieval event is not a unique process but critically depends on the recent events that have occurred.

There is accumulating evidence that reminding plays an important role in a number of experimental paradigms. For example, work by Wahlheim and Jacoby (2013) suggests that when the reminding of a previous event produces an unsuccessful recollective event, it decreases the likelihood of successful current retrieval. The important observation here is that the extent to which the current retrieval state reminds an individual of a previous retrieval state can markedly influence performance, and such effects have indeed been found in both episodic memory tasks (see Hintzman, 2010; McKinley, Ross, & Benjamin, 2019) and in problem solving (see Ross, 1984, 1987). For example, Ross (1984) showed that performance for solving elementary probability theory problems was facilitated when the content during test was similar to previously learned content, compared with an unrelated baseline. One might also expect that the degree of similarity or overlap (e.g., semantic relationship) between the current event and the past event might modulate the degree to which reminding occurs in a retrieval-specific situation. Specifically, the more similar the current retrieval state is to a previous retrieval state, the more likely it may be that reminding occurs and influences current performance, although the effect of this reminding process on lexical retrieval has not been thoroughly investigated.

As discussed earlier, a common approach to studying lexical retrieval involves presenting a prime word before an attempt to retrieve the intended target word from a low-frequency word definition (Kumar et al., 2019; Meyer & Bock, 1992; White et al., 2013). For example, Kumar et al. (2019) presented participants with low-frequency word definitions (e.g., "The leafy parts of a plant or tree, collectively"), followed by briefly presented primes (300 ms) that were phonologically related (e.g., folding), semantically related (e.g., vegetation), "both" phonologically and semantically related (e.g., forest), or unrelated (e.g., prodigy) to the target word (e.g., foliage). Across three experiments, they found robust facilitation from phonological primes on target retrieval, and also reported reduced facilitation from both primes because of semantic overlap between the prime and the target, suggesting that phonology and semantics may exert competing influences on lexical retrieval (although facilitatory and superadditive effects for "both" primes have been found in other work, see Pastizzo, Neely, & Tse, 2008; Watson, Balota, & Sergent-Marshall, 2001). The effect of semantic primes on target retrieval did not differ from unrelated primes. However, the primes in these experiments were *passively* viewed before target retrieval. Of course, in more natural retrieval contexts, there may be *active* attempts to retrieve the correct word and these attempts may lead to the production of several semantically related words.

In contrast to the previous studies that have investigated passive prime processing, Cross and Burke (2004) reported that *retrieving* semantically related alternate words facilitated target retrieval in both younger and older adults. However, trials in which the prime word was not successfully produced were excluded from their analyses. Similarly, Oberle and James (2013) showed that actively retrieving primes that were both semantically and phonologically related to the target facilitated target retrieval and produced fewer TOTs in both younger and older adults, compared with unrelated primes. However, the specific effect of retrieval *success* for the primes was not directly examined in this study. In light of previous findings that suggest differential effects of prime retrieval success on target processing in lexical decision (Dagenbach et al., 1990) and category exemplar production (Blaxton & Neely, 1983), it is important to extend these previous investigations to examine the influence of the success of the prime retrieval event on subsequent target retrieval from low-frequency word definitions.

The present experiments were designed to investigate participants' ability to retrieve target words from low-frequency word definitions, following passive viewing or active retrieval of prime words that were both semantically and phonologically, phonologically, or semantically related or unrelated to the target word. To anticipate, in Experiment 1, we replicated previous patterns of phonological facilitation during passive presentation and also introduced demasking as another way of measuring retrieval processes. In Experiments 2–5, we investigated the influence of active retrieval of prime information from semantically related and unrelated definitions on subsequent target retrieval. Finally, in Experiment 6, we explored the influence of actively retrieving prime information from episodic contexts on subsequent lexical retrieval.

Experiment 1

Our first experiment examined the influence of passive presentation of prime information before the active retrieval of a target word to a low-frequency word definition. Our goal was to replicate the previously reported pattern of passive phonological prime facilitation before target lexical retrieval (e.g., Kumar et al., 2019; Meyer & Bock, 1992) and also investigate the influence of the primes not only on target retrieval, but also in response latencies to identify the target in a progressive demasking procedure (Ferrand et al., 2011). The progressive demasking task is a perceptual identification task through which word processing latencies can be reliably measured as a masked word is slowly revealed on the screen. The demasking task is assumed to slow down word recognition processes, making it sensitive to factors affecting the early stages of visual word recognition (Carreiras, Perea, & Grainger, 1997). We chose the progressive demasking procedure to reveal the correct target word so that participants were still engaged in an *active* identification task and were not passively reporting the target word. Therefore, if they had successfully retrieved the target or were close to retrieving it during the target retrieval phase, they should be relatively faster to identify the target word in demasking, and this effect may vary across the different prime conditions. Alternatively, if participants were unsuccessful in target retrieval or were thinking of an entirely different word, they would be relatively slower to identify the correct target word during demasking.

Method

Participants. Thirty-six young adults (M_{age} = 20.36 years, SD = 3.3) were recruited from undergraduate courses at Washington University and received course credit for participation. Mean score on the Shipley Vocabulary Test was 33.92 (SD = 3.20), and mean years of education was 13.5 (SD = 1.6). All participants were native English speakers. This and the following experiments were approved by the Institutional Review Board at Washington University in St. Louis.

Materials. The stimuli consisted of 72 target words. For each target, there were three prime words that served as "both" primes, semantically related primes and phonologically related primes, with the unrelated primes simply being the same words repaired with an unrelated target definition. Primes and targets included 60 targets and 132 primes (semantic, phonological, and "both" primes from Kumar et al., 2019), to which we added 12 additional target words and 36 new primes and modified some of the original primes so that they shared the same semantic category or greater phonological overlap with the targets, to achieve the desired 72 prime-target pairs and corresponding definitions.

Norming study. To ensure that the stimuli were constrained appropriately, we conducted a semantic-phonological rating task on Amazon Mechanical Turk (MTurk). Specifically, we were interested in evaluating if the stimuli in the "both" condition were similar to the phonological condition in phonology, and similar to the semantic condition in semantics. Similar to Kumar et al. (2019), on each trial, participants were presented the target word and one of the three related primes (i.e., both, phonological, or semantic). Eighty participants (M_{age} = 36.1 years, SD = 8.9) rated the 216 target-prime word pairs on a 7-point Likert scale with ratings that ranged from 1 (*not related at all*) to 7 (*highly related*) for relatedness in sound or meaning. The type of rating task was manipulated between-subjects, with 40 participants randomly assigned to the phonology or sound condition, and 40 participants randomly assigned to the semantic or meaning condition. Our analyses indicated that the primes overall achieved this goal. Specifically, the "both" primes were similar to the phonological primes when rated on sound (mean rating for "both" primes = 3.36, mean rating for phonological primes = 4.33), whereas the "both" primes were similar to the semantic primes when rated on meaning (mean rating for "both" primes = 4.54, mean rating for semantic primes = 5.13). Having said this, there were reliable differences in the "both" primes from the semantic and phonological conditions in the meaning-based rating and sound-based rating ($p < .05$). Given that the ratings were different, we used these estimates as covariates in the analyses reported in Footnotes 1 and 3.

Procedure. Each participant received all 72 target words, presented in a random order, in four blocks of 18 trials. For each participant, each prime type ("both", phonological, semantic, and unrelated) occurred for 18 words, and prime types for each target word were counterbalanced across participants, such that each target appeared equally often in each of the four priming conditions across participants and no prime or target was seen more than once by each participant. Each experimental trial consisted of six components: prime, target definition, target response, metacognitive retrieval state declaration, target demasking, and target identification response (see Figure 1). Each prime was presented at the center of the screen for 300 ms. Participants were specifically instructed that the prime word was not the answer to the definition and were given no additional instructions about the purpose of the prime. Specifically, participants were instructed as follows: "A word will flash on the screen before the definition. This word is not the answer to the definition." Immediately following the prime, the target definition was presented for 10 s at the center of the screen and participants attempted to retrieve the target. After typing a response to the target definition and/or pressing the spacebar, participants indicated their retrieval state, by choosing among (1) You know the answer, (2) Did not know the answer, (3) You have a related, but incorrect word in mind, or (4) The word is at the tip of your tongue. Based on Brown and McNeill (1966), in the instructions before the experimental trials, participants were told that a TOT state was a situation in which they know the answer but cannot come up with it right away, though they feel it is on the verge of coming to them. After declaring their metacognitive retrieval state, participants also identified the target through the progressive demasking procedure (Ferrand et al., 2011).

During progressive demasking, the display alternated between the target (e.g., abdicate) and a mask (a row of pound signs matching the length of the word, e.g., ########). The total duration of each target-mask pair cycle was held constant at 500 ms but the ratio of target display time to mask display time progressively increased. In the first cycle, the mask was presented for 500 ms, without the target. In the second cycle, the target was displayed for 16 ms followed by the mask for 484 ms. The duration of the target increased at each cycle (0, 16, 32, . . . 500 ms) and the duration of the mask decreased (500, 484, 468, . . . 0 ms). The demasking procedure continued until the target was fully revealed for 500 ms, or until the target was identified by the participants by pressing the spacebar. Participants then typed in the correct answer on the next screen. The next trial began immediately after typing in the target and pressing spacebar. Participants were given three practice trials, followed by 72 experimental trials. After every 18 trials, participants received a short break and continued with the experiment when they were ready.

Results

Across all experiments, we used generalized or simple linear mixed effect models (LME) from the lme4 package (Bates et al., 2019) in the RStudio environment (R Version 3.4.2 (2017–09-28), R Development Core Team, 2013) to examine the relationship between predictor variables and target retrieval accuracy and response latencies. We sequentially added random intercepts for participants and items and random slopes for predictor variables and assessed the increment in model fit after the inclusion of each additional random effect. Model fit was assessed using chi-square tests on the log-likelihood values to compare incremental models (Bates et al., 2019). Model fit increased significantly for the random intercepts, but not for the random slopes and only crossed random intercepts for subject and item were included in the final models (Baayen, Davidson, & Bates, 2008; Quené & van den Bergh, 2008). Following Kliegl, Masson, and Richter (2010), we relied on the procedure of t and z values greater than 2.0 to indicate statistical significance, as well as profile-likelihood confidence intervals (see Bates, Mächler, Bolker, & Walker, 2014), both of which are reported for each estimate in the model.

Target retrieval accuracy. Figure 2 displays the mean accuracy for target retrieval for each prime condition. As shown in Table 1, the best fitting model estimates indicated that target accuracy was greatest when participants saw a phonological prime, compared to a semantic ($p = .005$), "both" ($p = .004$), and unrelated prime ($p < .001$). There were no reliable differences between other prime conditions (ps $> .05$).[1]

Effect of prime condition on target demasking. After attempting to retrieve the target and reporting their retrieval state, participants also identified the correct answer through progressive demasking. Thus, we examined the influence of the primes on subsequent response latencies to identify the target through demasking. To avoid the undue influence of outliers in analyses of response latencies, each individual's response times (RTs) were screened in the following manner. First, RTs faster than 250 ms and slower than 7,000 ms were removed. Second, a mean and standard deviation were calculated from the remaining trials for each participant and any RTs that exceeded 3 *SD*s from the participant mean were also removed; 1.9% of the total trials were excluded in this process. After this trimming procedure, we standardized the remaining trials and conducted all primary analyses using trial-level standardized RTs, to minimize any differences across individuals in variability of overall response latencies (see Faust, Balota, Spieler, & Ferraro, 1999). As shown in Table 2, the results were quite clear in indicating no effect of prime condition on response latencies to identify the target via demasking. This null effect was also supported by a Bayes Factor (BF_{10}) analyses with default priors from the BayesFactor package in R (see Wagenmakers, Morey, & Lee, 2016 for a discussion of Bayesian statistics), where lower BF_{10} values indicate greater evidence for the null hypothesis. For example, a BF_{10} of 0.50 may be interpreted as twice as much evidence for the null, compared with the alternative hypothesis. Our analyses indicated greater evidence for the null (i.e., no effect of prime condition), compared with the alternative hypothesis, $BF_{10} = .10$. Additionally, we also tested for any effect of prime condition on incorrect and correct target trials separately, and those analyses also revealed no effect of the primes (ps $> .10$).

[1] We analyzed the extent to which the differences in phonological ratings for the phonological and "both" primes (see Materials section) influenced target retrieval performance in Experiment 1. After accounting for ratings on the phonological dimension, the effect of prime condition persisted, that is, there were reliable differences between the phonological and "both" primes ($p = .03$). This suggests that the facilitation observed from phonological primes cannot be entirely explained by the higher ratings of phonological strength for the phonological primes, compared with the "both" primes. Instead, it appears that the meaning information in "both" primes may contribute towards the loss of facilitation observed in Experiment 1 (see Kumar et al., 2019, for a detailed discussion).

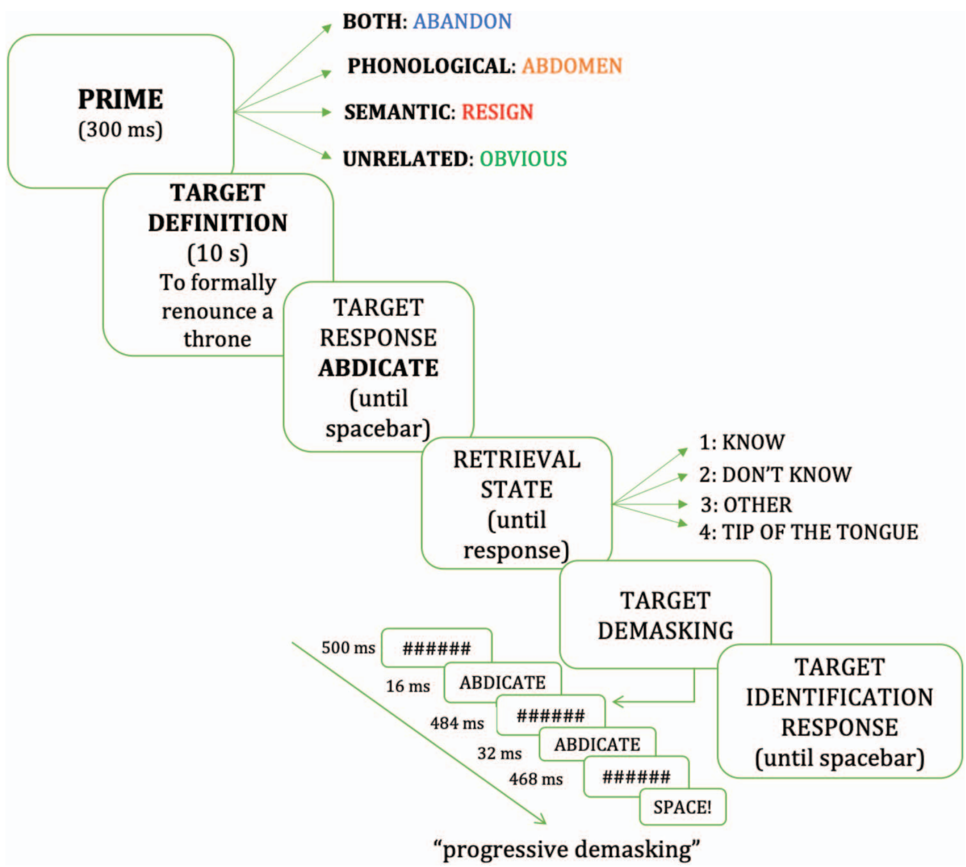

Figure 1. Paradigm for Experiment 1. See the online article for the color version of this figure.

After attempting to retrieve the target, participants also reported their retrieval state on each trial by choosing among: (1) They knew the correct answer to the definition; (2) They did not know the correct answer to the definition; (3) They have another incorrect word in mind; and (4) The word is at the tip of their tongue. Although we examined the impact of prime condition on retrieval states in our initial analyses, there were no consistent effects in state declaration across any of the experiments. Hence, we primarily focus on accuracy and response latencies for prime and target retrieval in the analyses reported in the present study (but see Footnote 2 for details of state declaration analyses).[2]

Discussion

Results from Experiment 1 provided clear evidence for phonological facilitation in target retrieval accuracy. These results replicate and extend our previous work on the influence of presenting phonological primes on lexical retrieval. Kumar et al. (2019) showed that when participants are presented with a phonological prime *after* a low-frequency word definition, they are more likely to retrieve the target word, compared with a "both", semantic, and unrelated prime. Experiment 1 further extended these results by demonstrating that presenting a phonological prime *before* the definition also produces facilitation. It is important to note here that the "both" prime did not produce any facilitation in this task, despite sharing phonology with the target word. As discussed in Footnote 1, this may be

[2] In Experiment 1, there was no effect of prime condition on the percentage of "know" responses, $F_1(3, 105) = 1.97$, $p = .12$, "other" responses, $F_1(3, 105) = 0.091$, $p = .97$, and "TOT" responses, $F_1(3, 105) = 0.19$, $p = .90$. There was a marginal effect of prime condition on the percentage of "don't know" responses, $F_1(3, 105) = 2.59$, $p = .06$, which indicated lower don't know responses in the semantic condition, compared with the unrelated ($p = .001$) and "both" ($p = .09$) prime conditions. In Experiment 2, there was no effect of prime condition on know, $F_1(3, 141) = 0.99$, $p = .39$, don't know, $F_1(3, 141) = 1.75$, $p = .16$, other, $F_1(3, 141) = 0.37$, $p = .77$, and "TOT" responses, $F_1(3, 141) = 1.24$, $p = .29$. In Experiment 3, again, there was no effect of prime condition on know, $F_1(1, 56) = 0.06$, $p = .81$, don't know, $F_1(1, 56) = .17$, $p = .68$, other, $F_1(1, 56) = 0.002$, $p = .96$, and TOT responses, $F_1(1, 56) = 1.14$, $p = .29$. Consistent with these patterns, in Experiment 4, there was no effect of prime condition on know, $F_1(1, 39) = 0.83$, $p = .37$, don't know, $F_1(1, 39) = 0.93$, $p = .34$, other, $F_1(1, 39) = 0.87$, $p = .36$, and TOT responses, $F_1(1, 39) = 0.53$, $p = .47$. Finally, in Experiment 6, we again found no effect of prime condition on know, $F_1(1, 29) = 0.01$, $p = .91$, don't know, $F_1(1, 29) = .06$, $p = .81$, other, $F_1(1, 29) = 0.04$, $p = .84$, and TOT responses, $F_1(1, 29) = 0.33$, $p = .57$. These results differ from the results reported in Kumar et al. (2019), and we believe these differences are attributable to the differences in experimental designs between the studies. Specifically, retrieval state judgments were recorded after attempted target retrieval in the current experiments, whereas Kumar et al. (2019) asked participants to specify their retrieval state immediately after seeing the definition, that is, before attempted retrieval. Thus, it is possible that having already attempted retrieval for the target word in the current experiments may have eliminated any overall effect of primes on these retrieval states. Additionally, Kumar at al. (2019) included a multiple-choice test after target retrieval, which may have also contributed to the differences in retrieval states across the prime conditions in their experiments.

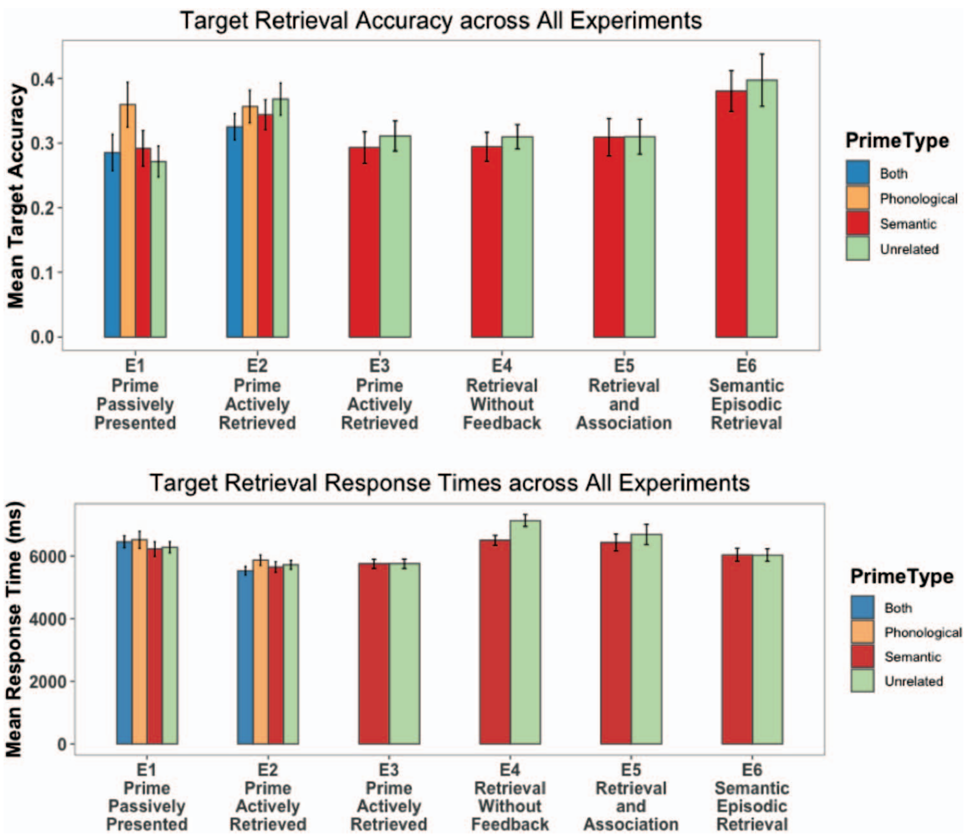

Figure 2. Mean target retrieval accuracy and response times (only for correct target trials) across prime conditions and Experiments 1–6. Error bars represent standard errors of the mean. See the online article for the color version of this figure.

because of the fact that the “both” prime is also semantically related to the target word, and semantics and phonology sometimes exert competing influences during lexical retrieval (for a detailed discussion, see Kumar et al., 2019).

We did not find any evidence of prime influence on subsequent response latencies to identify the target through progressive demasking. It is possible that the progressive demasking component focuses attention on the lexical/visual representation, instead of the semantic or phonological representation (Carreiras et al., 1997; Ferrand et al., 2011). However, even though we observed no influence of passively presented primes on target demasking, passive presentation clearly does not simulate the phenomenological experience of multiple retrieval attempts from the same semantic space, which is common in situations when an individual is trying to retrieve an intended relatively uncommon word. Thus, in Experiment 2, we investigated whether *explicit* attempted retrieval of a prime from a definition influences subsequent target retrieval processes, when prime retrieval is intended to direct participants to a phonologically and/or semantically similar space as the target word.

Experiment 2

Method

Participants. Forty-eight young adults (M_{age} = 19.2 years, SD = 1.2) were recruited from undergraduate courses at Washington University and received course credit for participation. Mean score on the Shipley Vocabulary Test was 33.92 (SD = 3.20), and mean years of education was 13.83 (SD = 2.8). All participants were native English speakers.

Materials. Materials were identical to those in Experiment 1, with one exception. Each prime word also had a definition associated with it, which was specifically created for this experiment, using the Oxford English dictionary. Prime definitions that included the target word were modified.

Procedure. Each experimental trial consisted of seven components: prime definition, prime response, prime demasking, target definition, target response, state declaration, and target demasking (see Figure 3). Each prime definition was presented at the center of the screen until participants typed a response and/or pressed the spacebar. Immediately after pressing the spacebar, the correct prime was slowly revealed on the screen through the progressive demasking procedure. We included this demasking procedure to ensure that any effects in target retrieval were not confounded by the presence or absence of the prime word itself, that is, all participants had access to the correct prime before attempting target retrieval, and hence any lingering effects of the prime were because of retrieval processes. The demasking procedure continued until the prime was fully revealed for 500 ms, or until participants indicated they had identified the prime by pressing the spacebar. Participants

Table 1
Model Estimates for Target Retrieval Accuracy as a Function of Prime Condition in Experiment 1

Term	Estimate	95% CI	*SE*	*z* value	*p* value
Fixed					
(Intercept)	−1.443	[−1.934, −0.968]	0.243	−5.934	<.001
Both	0.123	[−0.164, 0.41]	0.144	0.850	.395
Phonological	0.588	[0.307, 0.873]	0.142	4.132	<.001
Semantic	0.139	[−0.148, 0.427]	0.145	0.961	.337
Random					
Item	1.297	[1.069, 1.593]			
Subject	0.927	[0.71, 1.237]			

Note. All estimates are in reference to the unrelated prime condition.

then typed in the prime they had identified on the next screen. Whether or not the participant correctly reported the prime demasked at this point, they moved on to the target retrieval stage as soon as they typed in the word they identified and pressed the spacebar. Immediately after typing in the prime and pressing spacebar, the target definition was presented for 10 s and participants attempted to retrieve the target. After typing a response and/or pressing the spacebar, participants indicated their retrieval state and subsequently identified the target through the progressive demasking procedure.

Results

Effect of prime condition on target retrieval accuracy. Figure 2 displays the mean accuracy for target retrieval for each prime condition and Table 3 indicates the prime retrieval accuracy as a function of the different prime conditions along with item characteristics of the prime items. The best-fitting model estimates (as shown in Table 4) indicated that target accuracy following the "both" prime was slightly lower compared with the unrelated condition ($p = .032$), although there were no reliable differences between the other prime conditions (ps $>$ .1). Further, a cross-experiment LME analysis between Experiment 1 and 2 revealed a significant interaction between prime condition and experiment ($p = .004$). Specific contrast analyses indicated that the difference between the phonological and unrelated conditions was significantly different across Experiments 1 and 2 ($p < .001$), indicating that while *passive* presentation of primes resulted in phonological facilitation (Experiment 1), no such facilitation was observed when primes were *actively* retrieved (Experiment 2).

Effect of prime retrieval accuracy on target accuracy. Figure 4 (Top-left Panel) displays the mean target retrieval accuracy for each prime condition, as a function of whether the prime was retrieved or not retrieved. We examined the influence of prime type and prime retrieval on subsequent target retrieval accuracy and included overall accuracy for the prime item as a covariate in these analyses, to account for any differences in overall retrieval accuracy for the primes. Table 5 displays the best-fitting model estimates. We observed a reliable two-way interaction between prime type and prime retrieval ($p = .029$), which was mainly driven by differences in target retrieval accuracy when semantic and "both" primes were retrieved/not retrieved, compared with unrelated (ps $< .05$) and phonological (ps $< .06$) primes. This effect indicated that successful retrieval of semantic and "both" primes facilitated target retrieval, whereas unsuccessful retrieval of semantic and "both" primes inhibited target retrieval. There were no differences between the phonological and unrelated conditions in the proportion of correct and incorrect target retrievals ($p =$ .884). There were also no differences between the semantic and

Table 2
Model Estimates for Standardized RTs to Identify the Target via Demasking as a Function of Prime Condition in Experiment 1

Term	Estimate	95% CI	*SE*	*t* value	*p* value
Fixed					
(Intercept)	0.036	[−0.103, 0.176]	0.071	0.513	.609
Both	−0.001	[−0.094, 0.093]	0.048	−0.020	.984
Phonological	−0.015	[−0.108, 0.078]	0.048	−0.317	.751
Semantic	−0.066	[−0.16, 0.027]	0.048	−1.392	.164
Random					
Item	0.531	[0.445, 0.633]			
Subject	0	[0, 0.035]			
Residual	0.850	[0.826, 0.873]			

Note. RT = response time. All estimates are in reference to the unrelated prime condition.

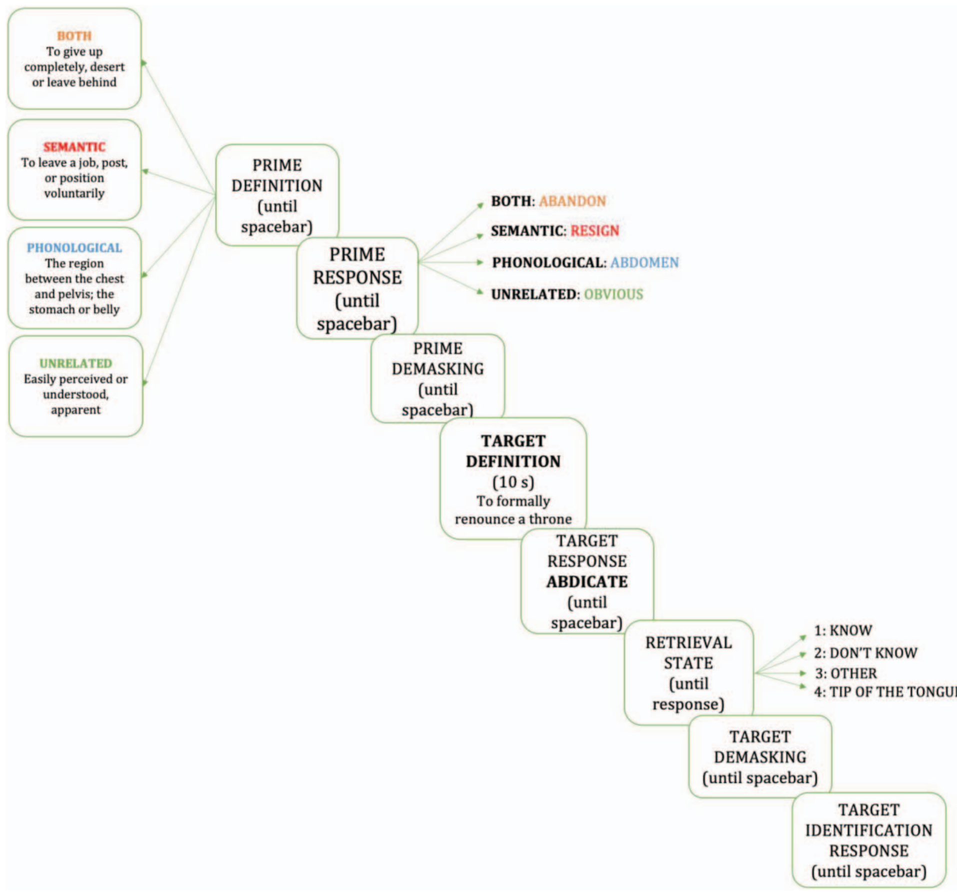

Figure 3. Paradigm for Experiment 2. See the online article for the color version of this figure.

"both" primes (p = .701).[3] We also separately tested the effect of prime retrieval success for each prime condition. While there was a significant increase in target accuracy when prime retrieval was successful for semantic (p = .001) and "both" (p = .001) primes, compared with when prime retrieval was unsuccessful, no such effect of prime retrieval success was observed for phonological (p = .135) or unrelated conditions (p = .518).

Effect of prime demasking on target accuracy. Just as prime retrieval success had an influence on subsequent target retrieval accuracy, it is possible that response latencies in prime demasking also systematically predict target accuracy. Thus, we examined the influence of response latencies to identify the prime through the demasking procedure on subsequent target retrieval accuracy. In our analyses of response latencies, we screened outliers using the same procedure as in Experiment 1, which excluded 3% of the total trials. After screening, we standardized the remaining trials and conducted all analyses using trial-level standardized RTs, to account for general slowing and individual differences. Table 6 displays the fixed effects estimates from the final model. We again observed a significant two-way interaction between standardized RTs and prime condition. As shown in Figure 5 (Top Panel), the relationship between RTs to identify the prime and target retrieval accuracy was magnified in the "both" (p = .011) and marginally in the semantic (p = .096) prime condition, compared with the unrelated prime condition. This suggests that faster (slower) identification of the semantic and "both" primes in demasking led to higher (lower) retrieval accuracy for the target word. There were no differences between the phonological and unrelated prime conditions (p = .924).

Effect of prime demasking on target demasking. In addition to examining the effect of prime demasking latencies on target accuracy, we also examined the influence of RTs to identify the prime through demasking on RTs to identify the target through demasking. Table 7 displays the fixed effects estimates from the final model. We again observed a reliable two-way interaction on target demasking times between RT to identify the prime and prime condition. As shown in Figure 6 (Top Panel), the interaction mainly indicated that the slope for the semantic condition was

[3] In Experiment 2, we also examined whether the effect of prime retrieval for the semantic and "both" primes differed after accounting for differences in the ratings on the semantic dimension (see Materials section). There were no differences between the effect of retrieval of semantic and "both" primes on target retrieval performance (p = .69) after accounting for differences in their ratings on the semantic dimension. In contrast, the effect of retrieving semantic primes was still reliably different from phonological primes (p = .03), and the effect of retrieving "both" primes was reliably different from phonological primes (p = .02), after accounting for ratings on the meaning dimension.

Table 3
Prime Retrieval Accuracy Across Different Prime Conditions and Experiments

Experiment	Prime type	*N*	Mean prime retrieval accuracy	*SE*	Mean log SUBTLEX freq.	Mean ortho. neighborhood size	Mean phono. neighborhood size	Mean sem. neighborhood density
2	Both*,**	48	0.42	0.02	2.14	1.08	2.76	0.54
	Phonological*	48	0.57	0.02	2.22	1.53	3.91	0.52
	Semantic**	48	0.46	0.02	2.23	0.88	2.31	0.54
	Unrelated**	48	0.48	0.02	—	—	—	—
3	Semantic	28	0.43	0.02	2.23	0.88	2.31	0.54
	Unrelated*	30	0.49	0.02	2.19	1.08	3.03	0.52
4	Semantic	40	0.47	0.02	2.23	0.88	2.31	0.54
	Unrelated*	40	0.55	0.02	2.22	1.53	3.91	0.52
5	Semantic	40	0.41	0.02	2.24	1.02	2.67	0.54
	Unrelated*	40	0.55	0.02	2.21	1.20	3.63	0.53
6	Semantic	42	0.45	0.04	2.27	1.13	3.13	0.55
	Unrelated	42	0.42	0.04	2.21	0.77	2.60	0.52

Note. Freq. = frequency; ortho. = orthographic; phono. = phonological; sem. = semantic; SUBTLEX freq. = subtitle frequency. All lexical characteristics were obtained from the English Lexicon Project (ELP; Balota et al., 2007).
* Indicates statistically significant difference ($p < .05$) from prime retrieval accuracy in unrelated prime condition. ** Indicates statistically significant difference ($p < .05$) from prime retrieval accuracy in the phonological condition.

marginally steeper than the unrelated condition ($p = .066$). The slope for the "both" condition was also steeper than the unrelated ($p = .013$) condition. The phonological condition did not differ from the unrelated condition ($p = .268$). This effect did not interact with target retrieval accuracy, although overall, participants were faster to identify the target on correct trials, compared with incorrect target trials.

Discussion

The results of Experiment 2 provided clear evidence that the success of prime retrieval processes significantly influence subsequent target retrieval. Specifically, failure to retrieve "both" and semantic primes predicted failure to retrieve the target word (compared with the phonological and unrelated primes), and successful retrieval of "both" and semantic primes facilitated target retrieval compared with the phonological and unrelated primes). In the current experiment, the phonological condition did not differ from the unrelated condition in predicting overall target accuracy. This is especially interesting as phonological primes have previously been shown to facilitate target retrieval (e.g., Kumar et al., 2019; Meyer & Bock, 1992). However, in the current experiment, participants were specifically focusing on the semantic dimension for both the primes and targets, and also actively retrieving the primes, in contrast to studies that have shown facilitation from passively viewing phonological primes. In addition, we observed that patterns for the "both" condition were quite similar to the semantic condition, presumably because the semantic dimension was emphasized in the definition task. It is important to note here semantics and phonology can sometimes exert competing influences during lexical retrieval (for a detailed discussion, see Kumar et al., 2019), although the semantic nature of the current task may have led participants to treat the both prime as more semantic than phonological. Specifically, in typical word retrieval studies, the target is retrieved through a definition but the prime is usually just presented passively, and in those cases, the phonological facilitation from the phonologically related words (i.e., the phonological and "both" primes) may be more automatic. This is indeed what we found in Kumar et al. (2019). Even so, the presence of a semantic relationship still dampened the automatic facilitation observed from "both" primes in Kumar et al. (2019). However, in the present experiment, the critical difference is that attention is being directed to the semantic aspect of the prime word because the participant accesses the prime through its definition, and is not simply passively reading the prime. Therefore, prime retrieval here is more attentionally demanding, and it is possible that attending to the semantic dimension of the "both" prime makes this dimension more salient compared with any phonological benefit that the "both" prime may have produced if it was passively viewed.

Table 4
Model Estimates for Target Retrieval Accuracy as a Function of Prime Condition in Experiment 2

Term	Estimate	95% CI	*SE*	*z* value	*p* value
Fixed					
(Intercept)	−0.774	[−1.192, −0.361]	0.210	−3.684	<.001
Both	−0.256	[−0.495, −0.019]	0.120	−2.143	.032
Phonological	−0.073	[−0.309, 0.162]	0.119	−0.619	.536
Semantic	−0.160	[−0.397, 0.077]	0.120	−1.335	.182
Random					
Item	1.368	[1.142, 1.662]			
Subject	0.716	[0.564, 0.921]			

Note. All estimates are in reference to the unrelated prime condition.

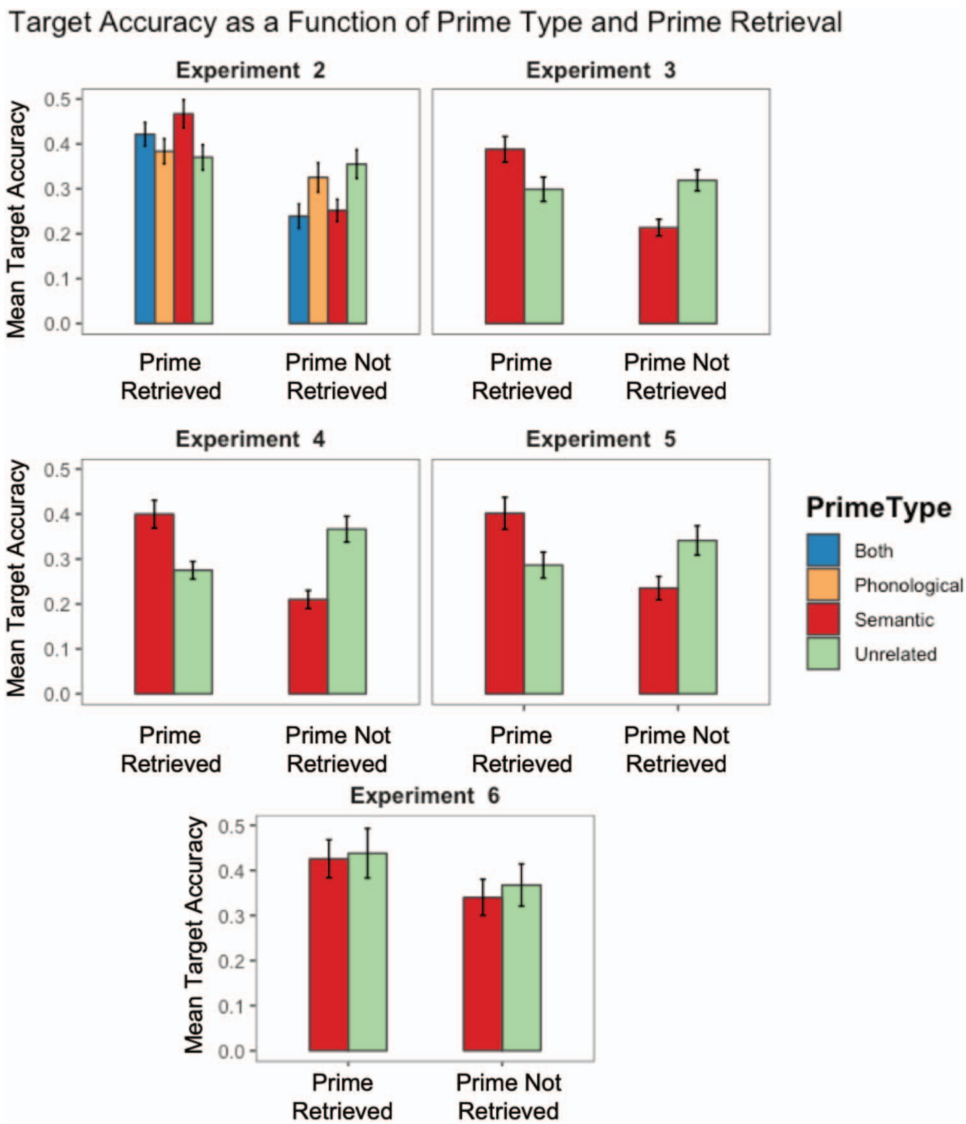

Figure 4. Target retrieval accuracy as a function of prime retrieval accuracy and prime condition, in Experiments 2–6. Error bars represent standard errors of the mean. See the online article for the color version of this figure.

Another important aspect of the current experiment is the finding that response latencies to identify the semantic and "both" primes also predicted accuracy in target retrieval. This is especially interesting because participants either eventually identified the correct prime themselves, or the prime was fully displayed on the screen before they moved on to target retrieval. This suggests that access to the prime word itself is not critical to the likelihood of retrieving the target word, but instead, the fluency of retrieving the prime is important. If prime retrieval was successful or the participant was close to retrieving the correct prime, then participants were faster to identify the prime word as it was demasked on the screen. However, if participants failed to initially retrieve the prime or were thinking of a completely different word, then they were slower to identify the demasked prime. When target definitions and target words were semantically related to the primes retrieved, this likely served as a cue or reminder of the preceding prime retrieval event and led to facilitation or inhibition in target retrieval. In this way, latencies to identify the semantic and "both" primes during demasking predicted target accuracy. It is important to note here that the results of Experiment 2 may also point to the possibility of a subject-by-item artifact Specifically, it is possible that the effects of facilitation and inhibition being observed here are attributable to idiosyncratic influences of knowledge that a participant might have about the prime or target, and how that knowledge may be correlated. We directly address this issue in Experiment 5, and also return to it in the General Discussion.

Although Experiment 2 provided evidence for the differential modulation of target retrieval performance after success or failure of retrieving semantically related prime information, this intriguing pattern needs to be further explored to better understand the mechanisms producing this pattern. For example, because of the

Table 5
Model Estimates for Target Retrieval Accuracy as a Function of Prime Retrieval and Prime Condition in Experiment 2

Term	Estimate	95% CI	*SE*	*z* value	*p* value
Fixed					
(Intercept)	−0.714	[−1.165, −0.267]	0.227	−3.142	.002
Prime retrieval	−0.030	[−0.202, 0.142]	0.087	−0.345	.730
Both	−0.242	[−0.48, −0.004]	0.120	−2.013	.044
Phonological	−0.070	[−0.309, 0.167]	0.120	−0.587	.557
Semantic	−0.159	[−0.398, 0.078]	0.120	−1.327	.185
Prime accuracy	−0.103	[−0.513, 0.312]	0.206	−0.500	.617
Prime Retrieval × Both	−0.302	[−0.557, −0.049]	0.128	−2.360	.018
Prime Retrieval × Phonological	−0.019	[−0.271, 0.234]	0.127	−0.146	.884
Prime Retrieval × Semantic	−0.253	[−0.504, −0.002]	0.127	−1.995	.046
Random					
Item	1.343	[1.119, 1.634]			
Subject	0.688	[0.539, 0.888]			

Note. All estimates are in reference to the unrelated prime condition and prime retrieval being unsuccessful.

within-participant design of the experiment, it is possible that participants directed attention to the semantic relationship on 50% of the trials which included such a relationship, compared with the unrelated trials, that is, the semantic relationship became more salient in the background of unrelated trials. This link between prime and target relatedness on half of the trials may have produced relative disruption compared with unrelated trials (i.e., the relatedness manipulation became salient to the participants); thus, contributing to the observed pattern. Specifically, over the course of the task, participants may have anticipated a relationship on some of the trials (i.e., semantic trials) because the semantic relationship appeared to be salient on previous trials in a retrospective manner (i.e., the target was related to the previous prime). One way to investigate this possibility would be to have participants view only related or only unrelated prime-target pairs, via a between-participants manipulation, which would make the relative salience of "relatedness" on certain trials constant. This was the goal of Experiment 3. The logic here is that in Experiment 3, when all trials are semantically related, while participants might notice an overall relationship, no particular trials will stand out relative to other trials in both the related and unrelated conditions. Further, it is also possible that the intermixing of phonological trials may have contributed to the effects in Experiment 2. Therefore, to simplify our analyses and specifically focus on semantic relatedness, we only presented semantically related and unrelated primes in further experiments and eliminated the phonological and "both" conditions from all the following experiments.

Experiment 3

Method

Participants. Fifty-eight young adults (M_{age} = 19.2 years, *SD* = 1.2) were recruited from undergraduate courses at Washington University and received course credit for participation. Mean score on the Shipley Vocabulary Test was 33.92 (*SD* = 3.20), and mean years of education was 13.83 (*SD* = 2.8). All participants were native English speakers.

Materials. Materials were identical to those in Experiment 2 with one exception. The stimuli consisted of 72 target words, and each target word was paired with only *two* other words which served as semantic or unrelated primes. The semantic primes were

Table 6
Model Estimates for Target Retrieval Accuracy as a Function of Prime Condition and RT to Identify the Prime via Demasking in Experiment 2

Term	Estimate	95% CI	*SE*	*z* value	*p* value
Fixed					
(Intercept)	−0.767	[−1.183, −0.355]	0.210	−3.656	<.001
z-RT	−0.001	[−0.175, 0.173]	0.088	−0.006	.995
Both	−0.252	[−0.493, −0.013]	0.121	−2.084	.037
Phonological	−0.083	[−0.321, 0.155]	0.120	−0.693	.488
Semantic	−0.179	[−0.419, 0.06]	0.121	−1.485	.137
z-RT × Both	−0.331	[−0.592, −0.074]	0.131	−2.534	.011
z-RT × Phonological	0.012	[−0.243, 0.266]	0.128	0.095	.924
z-RT × Semantic	−0.213	[−0.468, 0.04]	0.128	−1.665	.096
Random					
Item	1.361	[1.135, 1.656]			
Subject	0.718	[0.565, 0.923]			

Note. RT = response time. All estimates are in reference to the unrelated prime condition.

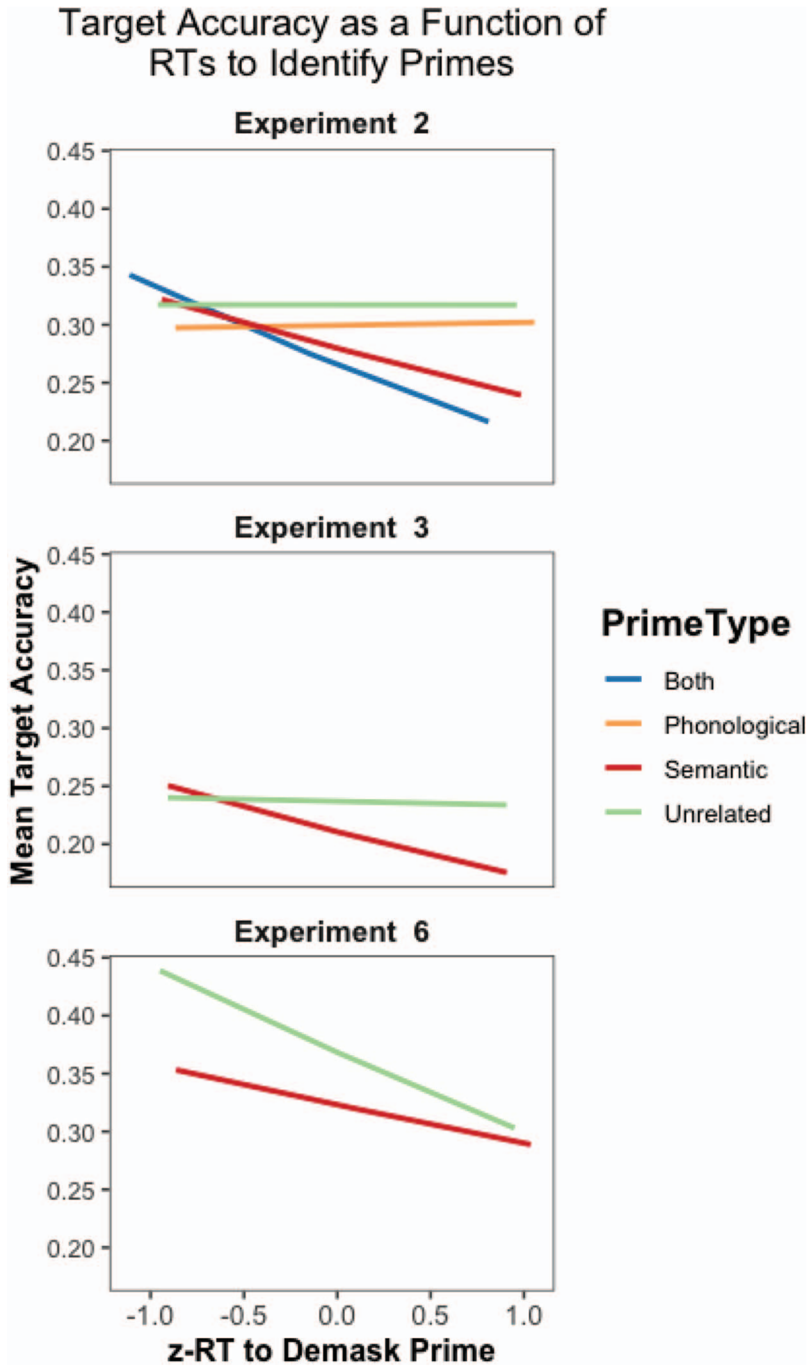

Figure 5. Mean target retrieval accuracy as a function of standardized response times to identify the prime, across prime conditions and Experiments 2, 3, and 6. See the online article for the color version of this figure.

the same as those used in previous experiments, and unrelated primes were randomly reordered primes from the other conditions.

Design and procedure. A between-subjects design was used, where 28 participants were randomly assigned to the semantic prime condition, and 30 participants were randomly assigned to the unrelated prime condition. Participants in the semantic prime condition only received definitions for semantic primes preceding target retrieval, and participants in the unrelated prime condition only received definitions for unrelated primes preceding target retrieval. All other aspects of the experimental procedure were identical to Experiment 2.

Results

Effect of prime condition on target retrieval accuracy. Figure 2 displays the mean accuracy for target retrieval for each prime

Table 7
Model Estimates for Standardized RT to Identify the Target as a Function of Prime Condition and RT to Identify the Prime via Demasking in Experiment 2

Term	Estimate	95% CI	*SE*	*t* value	*p* value
Fixed					
(Intercept)	0.030	[−0.108, 0.168]	0.070	0.423	.673
z-RT	0.067	[0.008, 0.126]	0.030	2.228	.026
Both	−0.050	[−0.129, 0.03]	0.041	−1.227	.220
Phonological	−0.035	[−0.114, 0.044]	0.040	−0.869	.385
Semantic	0.016	[−0.063, 0.095]	0.040	0.401	.689
z-RT × Both	0.105	[0.023, 0.188]	0.042	2.492	.013
z-RT × Phonological	0.048	[−0.037, 0.134]	0.044	1.108	.268
z-RT × Semantic	0.078	[−0.005, 0.161]	0.042	1.840	.066
Random					
Item	0.543	[0.457, 0.646]			
Subject	0.000	[0, 0.029]			
Residual	0.824	[0.803, 0.843]			

Note. RT = response time. All estimates are in reference to the unrelated prime condition.

condition. As shown in Table 8, model estimates indicated no overall effect of prime condition ($p = .534$).

Effect of prime retrieval accuracy on target accuracy. Figure 4 (Top-right Panel) displays the mean target retrieval accuracy for semantic and unrelated primes, as a function of whether the prime was retrieved or not retrieved. As before, we included overall mean accuracy of the prime as a covariate in these analyses. Table 9 displays the fixed effects estimates from the final model. We observed a significant two-way interaction between prime type and prime retrieval, which indicated that target retrieval accuracy was predicted by successful or unsuccessful retrieval of semantic primes, compared with unrelated primes ($p = .002$). We also separately tested the effect of prime retrieval success in the semantic and unrelated conditions. While there as a significant increase in target accuracy when prime retrieval was successful in the semantic condition ($p < .001$), no significant effect was observed for the unrelated condition ($p = .087$). Replicating the pattern observed in Experiment 2, this effect indicated that when semantic primes were retrieved, they produced facilitation compared with unrelated primes, and when semantic primes were *not* retrieved; they produced inhibition compared with unrelated primes.

Effect of prime demasking on target accuracy. Next, we examined the influence of response latencies to identify the prime through the demasking procedure on subsequent target retrieval accuracy. The same screening procedures as in Experiment 2 were followed, which excluded 4.6% of the total trials. Table 10 displays the fixed effects estimates from the final model. We observed a significant two-way interaction between standardized RTs and prime condition on target retrieval accuracy. As shown in Figure 5 (Middle Panel), the relationship between RTs to identify the prime and target retrieval accuracy was magnified and monotonically decreased for the participants in the semantic prime condition ($p = .012$), compared with those in the unrelated prime condition. This effect indicated that faster (slower) identification of the semantic primes led to higher (lower) target retrieval accuracy, compared with unrelated primes, replicating the patterns observed in Experiment 2.

Effect of prime demasking on target demasking. We also examined the influence of RTs to identify the prime through the demasking procedure on RTs to identify the target through demasking. Table 11 displays the fixed effects estimates from the final model. We observed a significant two-way interaction between RT to identify the prime and prime condition. As shown in Figure 6 (Middle Panel), the interaction mainly indicated that the slope for the semantic condition was steeper and linearly increased, compared with the unrelated condition ($p = .012$), suggesting that faster (slower) identification of the semantic primes predicted faster (slower) identification of the target, compared with unrelated primes, replicating the patterns observed in Experiment 2. This effect did not interact with target retrieval accuracy, although overall, participants were faster to identify the target on correct trials, compared with incorrect target trials.

Discussion

Experiment 3 replicated the results from Experiment 2, and further clarified the specific facilitatory and inhibitory influence of semantic prime retrieval on subsequent target retrieval processes. These results provide clear evidence for the hypothesis that a preceding unsuccessful retrieval event from the same semantic space as the target for participants randomly assigned to only retrieve semantic primes inhibits current target retrieval, compared with those participants randomly assigned to only retrieve unrelated primes. However, when retrieval from the same semantic space is successful, it can actually facilitate subsequent retrieval for the related target word.

One possible reason for the observed patterns of semantic facilitation and inhibition could be the component of prime demasking that is common to Experiments 2 and 3. Specifically, it is possible that demasking the prime and hence providing feedback to participants about their attempted prime retrieval is producing the patterns described above, that is, knowing that they retrieved the correct or incorrect semantically related prime leads participants to successfully or unsuccessfully retrieve the upcoming target. In Experiment 4, we explicitly tested for this possibility by eliminating the demasking part of the procedure. Thus, if demasking the prime was critical to the observed patterns, the effects of semantic facilitation and inhibition would be eliminated in the following experiment. However, if the mechanisms involved in repeated lexical retrieval are not critically dependent on knowing the correct answer, then we should observe the same pattern observed in Experiments 2 and 3.

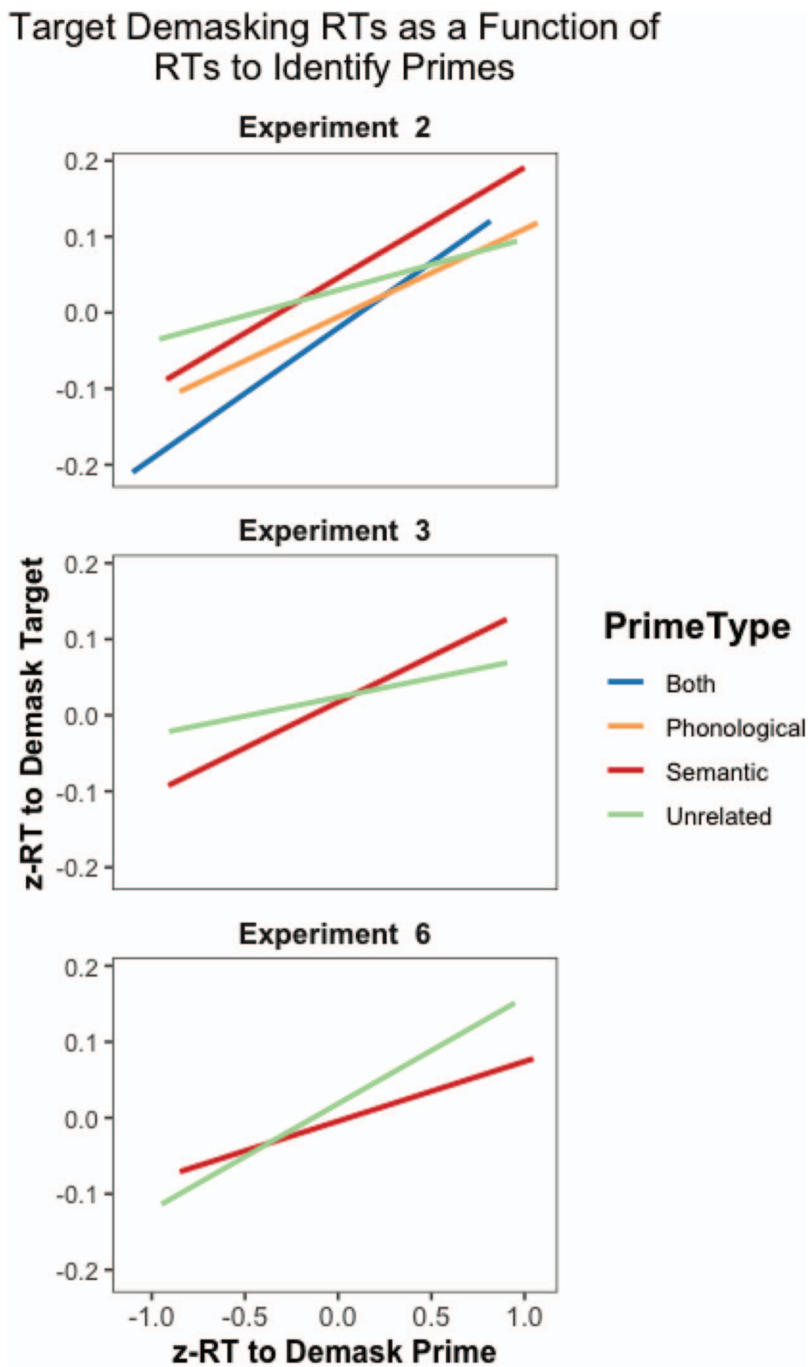

Figure 6. Standardized response times to identify the target through progressive demasking as a function of standardized response times to identify the prime, across prime conditions and Experiments 2, 3, and 6. See the online article for the color version of this figure.

Experiment 4

Method

Participants. Forty young adults (M_{age} = 19.7 years, *SD* = 1.4) were recruited from undergraduate courses at Washington University and received course credit for participation. Mean score on the Shipley Vocabulary Test was 31.28 (*SD* = 2.7), and mean years of education was 13.53 (*SD* = 1.4). All except three participants were native English speakers, who performed at the same level as the group average and hence the final data are reported for all participants.

Materials. Target words and semantic primes were identical to those in Experiment 3 with one exception. All unrelated primes were again randomly chosen from among the previously used unrelated primes.

Table 8
Model Estimates for Target Retrieval Accuracy as a Function of Prime Condition in Experiment 3

Term	Estimate	95% CI	*SE*	*z* value	*p* value
Fixed					
(Intercept)	−1.165	[−1.637, −0.699]	0.237	−4.912	<.001
Semantic	−0.143	[−0.601, 0.314]	0.229	−0.622	.534
Random					
Item	1.476	[1.233, 1.795]			
Subject	0.814	[0.659, 1.019]			

Note. All estimates are in reference to the unrelated prime condition.

Design and procedure. The experimental procedure was identical to Experiment 3 with the exception of prime and target demasking, and the use of a within-subjects design. Immediately after attempting to retrieve the prime word, participants saw a low-frequency word definition for the target word and proceeded to retrieve the target. Participants then specified their retrieval state for the target and moved on to the next trial. Thus, participants were not given any feedback about whether they correctly retrieved the prime or target.

Results

Effect of prime condition on target retrieval accuracy. Figure 2 displays the mean accuracy for target retrieval for each prime condition. As shown in Table 12, model estimates indicated no overall effect of prime condition ($p = .18$).

Effect of prime retrieval accuracy on target accuracy. Figure 4 (Middle-left Panel) displays the mean target retrieval accuracy for semantic and unrelated primes, as a function of whether the prime was retrieved or not retrieved. Table 13 displays the fixed effects estimates from the final model. We again observed a significant two-way interaction between prime type and prime retrieval, which indicated that target retrieval accuracy was predicted by successful or unsuccessful retrieval of semantic primes, compared with unrelated primes ($p = .004$). Replicating the pattern observed in Experiment 2 (and 3), this effect indicated that when semantic primes were retrieved, they produced facilitation compared with unrelated primes, and when semantic primes were *not* retrieved, they produced inhibition compared with unrelated primes. Indeed, a cross-experiment LME analysis between the semantic and unrelated conditions of Experiments 2 and 4 (both within-subject designs) yielded no interaction between prime condition, prime retrieval accuracy, and experiment ($p = .705$). Furthermore, we separately tested the effect of prime retrieval success on target retrieval accuracy in the semantic and unrelated conditions. While successful prime retrieval led to higher target accuracy in the semantic condition, compared with failed prime retrieval ($p = .031$), there was no such effect of prime retrieval success in the unrelated condition ($p = .193$).

Discussion

Experiment 4 replicated the results from Experiment 2 (and 3) and provided clear evidence that prime or target demasking was not critical to the semantic facilitation and inhibition effects observed during repeated lexical retrieval from the same semantic space. These results are particularly interesting because they suggest that even when participants had no knowledge about whether they correctly retrieved the prime, they experienced facilitation when the semantic prime was correct and inhibition when the semantic prime was incorrect. Thus, the effects of prime retrieval success reflect lingering influences of the retrieval processes, as opposed to processes involved in matching the word that is demasked with the related definition on the target trial. It appears that prior retrieval success or failure from a particular semantic space before target retrieval was attempted critically influenced the likelihood of retrieving the correct target word.

A potential concern regarding the facilitation and inhibition effects observed in Experiments 2–4 may be that knowledge about the prime is correlated with knowledge about the target, and retrieval itself is not producing the above patterns. For example, participants who know the word "resign" also tend to know the

Table 9
Model Estimates for Target Retrieval Accuracy as a Function of Prime Retrieval Success and Prime Condition in Experiment 3

Term	Estimate	95% CI	*SE*	*z* value	*p* value
Fixed					
(Intercept)	−0.628	[−1.139, −0.12]	0.258	−2.436	.015
Prime retrieval	−0.139	[−0.275, −0.005]	0.068	−2.056	.040
Semantic	−0.155	[−0.59, 0.278]	0.218	−0.713	.476
Prime accuracy	−1.103	[−1.567, −0.646]	0.231	−4.769	<.001
Prime Retrieval × Semantic	−0.273	[−0.452, −0.094]	0.090	−3.026	.002
Random					
Item	1.501	[1.252, 1.826]			
Subject	0.765	[0.615, 0.962]			

Note. All estimates are in reference to the unrelated prime condition and prime retrieval being unsuccessful.

Table 10
Model Estimates for Target Retrieval Accuracy as a Function of Prime Condition and RT to Identify the Prime via Demasking in Experiment 3

Term	Estimate	95% CI	*SE*	*z* value	*p* value
Fixed					
(Intercept)	−1.170	[−1.648, −0.698]	0.240	−4.871	.000
z-RT	−0.152	[−0.621, 0.316]	0.235	−0.647	.518
Semantic	−0.019	[−0.146, 0.106]	0.063	−0.303	.762
z-RT × Semantic	−0.229	[−0.41, −0.049]	0.091	−2.526	.012
Random					
Item	1.479	[1.227, 1.788]			
Subject	0.827	[0.668, 1.037]			

Note. RT = response time. All estimates are in reference to the unrelated prime condition.

word "abdicate," and when participants do not know the word "resign", they also do not know the word "abdicate". To address this possibility, we conducted Experiment 5, in which we attempted to estimate the knowledge participants have about the primes and targets through a word association task. Specifically, after attempting to retrieve primes and targets from their definitions during the first phase of the experiment, we asked participants to generate three associates to each of the primes and targets during the second phase. We hypothesized that participants who knew the primes and target words would produce greater and more relevant associates, and this knowledge would predict greater target accuracy. In this way, we could use these estimates to examine whether correlated word knowledge about the prime and target modulated the facilitation and inhibition effects observed from the retrieval of semantically related primes. If the effects observed were simply because of highly correlated knowledge of primes and targets, then we should not observe any facilitation and inhibition from semantic prime retrieval in Experiment 5 after accounting for this knowledge. On the other hand, if the effects were specific to the act of retrieving the prime, we should continue to observe facilitation and inhibition from semantic prime retrieval in this experiment after accounting for the measure of prime and target knowledge.

Experiment 5

Method

Participants. Forty young adults were recruited from undergraduate courses at Washington University ($N = 20$, $M_{age} = 18.69$ years, $SD = 0.95$) and MTurk ($N = 20$, $M_{age} = 27.67$ years, $SD = 3.3$) and received course credit or up to $10 for participation. Mean years of education was 13.43 ($SD = 1.97$) in the Washington University sample and 13.94 ($SD = 1.39$) in the MTurk sample. All participants were native English speakers.

Materials. To reduce the total time taken to complete the experiment, we selected 60 items from the materials used in Experiment 4. The 12 eliminated items consisted of target words with extremely high (>80%) or low accuracy (<10%), which were likely at ceiling or floor and hence not contributing to the interactive effects of prime retrieval success with target retrieval success.

Design and procedure. The experimental procedure was identical to Experiment 4, with two exceptions. First, because of overall null effects of retrieval state declarations in Experiments 1–4, we eliminated this component from the present experiment. Immediately after attempting to retrieve the prime word, participants saw a low-frequency word definition for the target word and proceeded to retrieve the target. Participants were not given any feedback about whether they correctly retrieved the prime or target (as in Experiment 4), and additionally, were also not asked to specify their retrieval state for the target word. Second, after completing the lexical retrieval task, participants also performed a word association task. Participants were presented with all prime words, one at a time, and asked to produce three one-word associates to the prime word presented. Participants had 15 s to generate each associate and were instructed to simply press enter if they were unable to produce any associates to advance to the next word. After producing associates for all the primes, partici-

Table 11
Model Estimates for Standardized RT to Identify the Target as a Function of Prime Condition and RT to Identify the Prime via Demasking in Experiment 3

Term	Estimate	95% CI	*SE*	*t* value	*p* value
Fixed					
(Intercept)	0.024	[−0.115, 0.163]	0.070	0.339	.735
z-RT	−0.007	[−0.057, 0.044]	0.026	−0.252	.801
Semantic	0.050	[0.011, 0.089]	0.020	2.492	.013
z-RT × Semantic	0.071	[0.016, 0.126]	0.028	2.510	.012
Random					
Item	0.577	[0.487, 0.684]			
Subject	0.000	[0, 0.027]			
Residual	0.817	[0.799, 0.835]			

Note. RT = response time. All estimates are in reference to the unrelated prime condition.

Table 12
Model Estimates for Target Retrieval Accuracy as a Function of Prime Condition in Experiment 4

Term	Estimate	95% CI	*SE*	*z* value	*p* value
Fixed					
(Intercept)	−1.171	[−1.632, −0.724]	0.228	−5.129	<.001
Semantic	−0.131	[−0.327, 0.064]	0.098	−1.339	.18
Random					
Item	1.535	[1.274, 1.876]			
Subject	0.742	[0.571, 0.979]			

Note. All estimates are in reference to the unrelated prime condition.

pants also produced at most three associates for all the target words, using the same procedure.

Results

Effect of prime condition on target retrieval accuracy. Figure 2 displays the mean accuracy for target retrieval for each prime condition. As shown in Table 14, model estimates again indicated no overall effect of prime condition ($p = .18$).

Effect of prime retrieval accuracy on target accuracy. Figure 4 (Bottom-left Panel) displays the mean target retrieval accuracy for semantic and unrelated primes, as a function of whether the prime was retrieved or not retrieved. Table 15 displays the fixed effects estimates from the final model. We again observed a significant two-way interaction between prime type and prime retrieval, which indicated that target retrieval accuracy was predicted by successful or unsuccessful retrieval of semantic primes, compared with unrelated primes ($p = .004$). Furthermore, we separately tested the effect of prime retrieval success on semantic and unrelated conditions. While successful prime retrieval led to higher target accuracy in the semantic condition, compared with failed prime retrieval ($p = .003$), there was no such effect of prime retrieval success in the unrelated condition ($p = .849$). Replicating the pattern observed in Experiment 4, this effect indicated that when semantic primes were retrieved, they produced facilitation, and when semantic primes were *not* retrieved, they produced inhibition in target retrieval accuracy, compared with unrelated primes. Indeed, a cross-experiment LME analysis between Experiments 4 and 5 yielded no interaction between prime condition, prime retrieval accuracy, and experiments ($p = .638$).

Effect of prime and target knowledge on target accuracy. The primary goal of this experiment was to address the possibility that correlated prime and target knowledge within an individual may be producing the observed patterns of facilitation and inhibition. As a reminder, to estimate the knowledge participants had about each of the prime and target words, we asked each participant to generate at most three associates to each prime and target after the lexical retrieval task. Therefore, each participant received 60 primes and 60 targets, to which they produced at most three associates. To analyze the responses from this word generation task, we first excluded responses that were not directly related to the intended prime or target word. For example, for the target word, "Mercury," referring to the definition, "Last name of British singer-songwriter; lead singer of the band Queen," participants often produced associates like "planet," and "earth,", in the associate generation task to the word "Mercury", because the definition was not presented in the second associate production phase. We excluded such trials from our analyses as these responses (although technically correct) did not reflect the knowledge participants had about the intended primes and targets. This process excluded 9.04% of the total trials. We also excluded trials on which participants produced the target word as an associate to the prime, or the prime as an associate to the target word, because these responses may have been primed by the preceding retrieval task. This process excluded an additional 2.63% of the total trials.

For the remaining trials, we computed a measure of prime and target knowledge as follows. To simultaneously account for the total number and quality of associates produced for each prime or target, we computed the semantic relatedness between each prime

Table 13
Model Estimates for Target Retrieval Accuracy as a Function of Prime Retrieval Success and Prime Condition in Experiment 4

Term	Estimate	95% CI	*SE*	*z* value	*p* value
Fixed					
(Intercept)	−1.410	[−1.933, −0.903]	0.259	−5.446	<.001
Prime retrieval	−0.292	[−0.623, 0.039]	0.166	−1.753	.080
Semantic	−0.462	[−0.765, −0.161]	0.151	−3.048	.002
Prime accuracy	0.756	[0.27, 1.249]	0.245	3.082	.002
Prime Retrieval × Semantic	0.664	[0.227, 1.103]	0.220	3.020	.003
Random					
Item	1.503	[1.246, 1.84]			
Subject	0.744	[0.571, 0.983]			

Note. All estimates are in reference to the unrelated prime condition and prime retrieval being unsuccessful.

Table 14
Model Estimates for Target Retrieval Accuracy as a Function of Prime Condition in Experiment 5

Term	Estimate	95% CI	*SE*	*z* value	*p* value
Fixed					
(Intercept)	−1.160	[−1.65, −0.679]	0.245	−4.738	<.001
Semantic	−0.039	[−0.248, 0.168]	0.105	−0.379	.71
Random					
Item	1.225	[0.989, 1.537]			
Subject	1.069	[0.834, 1.399]			

Note. All estimates are in reference to the unrelated prime condition.

or target word and each associate produced, by using cosine similarity indices derived from a pretrained computational model of semantic memory, word2vec (Mikolov, Chen, Corrado, & Dean, 2013). Word2vec is a state-of-the-art neural network model of semantic memory that captures higher-order semantic relationships between words. In the word2vec model, high cosine similarity indicates that the words are closer in a multidimensional space and are, therefore, more similar to each other. In the context of the current experiment, higher cosines between the associates and the prime or target would indicate that the participant had greater knowledge about the specific words' meanings. To compute an index of total prime knowledge, the cosine similarity between each associate and each prime or target was added to produce a composite prime or target knowledge score per trial. When a participant did not produce a particular associate, a cosine of 0 was added to their total prime or target knowledge score. For example, for the prime "perjury," participant AC produced the associates "lie," "law," and "judge," so their Prime Knowledge Score for "perjury" was the sum of the cosines between "lie" and "perjury" (0.24), "law" and "perjury" (0.17), and "judge" and "perjury" (0.25) = 0.66. For the target "libel," participant AC produced the associates "law", "rule," and "court," so their Target Knowledge Score for "libel" was the sum of the cosines between "law" and "libel" (0.26), "rule" and "libel" (.11), and "court" and "libel" (.26) = 0.63. This process was repeated for each individual target and prime to obtain an individual's estimate of Prime Knowledge Score and Target Knowledge Score for each prime and each target presented to each individual participant.

Next, we examined the correlation between Prime Knowledge Score and Target Knowledge Score within a participant, at the item level. To calculate the correlations, the following procedure was used. First, the 60 prime-target pairs were divided into the 30 pairs that were in the semantic prime condition, and the 30 pairs that were in the unrelated prime condition. Next, these 30 trials within each prime condition were further divided into successful or unsuccessful prime retrieval trials. Finally, as mentioned earlier, we excluded trials on which the participant produced an invalid response or produced the prime or target in the association task were removed. For participant AC, this excluded nine trials. Therefore, after excluding these nine invalid trials, among the remaining 23 valid trials in the semantic prime condition, there were nine trials on which the semantic prime was successfully retrieved, and 14 trials on which the semantic prime was not successfully retrieved. Similarly, among the remaining 28 valid trials in the unrelated prime condition, there were 15 trials on which the unrelated prime was successfully retrieved, and 13 trials on which the unrelated prime was not retrieved. Correlations were then calculated between Prime Knowledge Score and Target Knowledge Score at the item level for these four different conditions (semantic-successful, semantic-unsuccessful, unrelated-successful, and unrelated-unsuccessful) for each participant, resulting in four cells per participant. For example, for the semantic-successful condition for participant AC, the correlation between the Prime Knowledge Score and Target Knowledge Score for the nine trials in this cell was $r = .405$. The correlations for the remaining three cells were also calculated in a similar manner for each participant. It is important to note here that these correlations represent the overall knowledge a participant may have about particular items. Therefore, one important question is whether the correlations calculated in this way are greater for the semantic condition, compared with the unrelated condition. Indeed, as predicted, the mean correlation between prime and target knowledge scores for each par-

Table 15
Model Estimates for Target Retrieval Accuracy as a Function of Prime Retrieval Success and Prime Condition in Experiment 5

Term	Estimate	95% CI	*SE*	*z* value	*p* value
Fixed					
(Intercept)	−1.174	[−1.728, −0.632]	0.276	−4.257	<.001
Prime retrieval	−0.089	[−0.437, 0.258]	0.175	−0.514	.607
Semantic	−0.365	[−0.680, −.052]	0.158	−2.312	.021
Prime accuracy	0.148	[−0.374, 0.672]	0.263	0.563	.573
Prime Retrieval × Semantic	0.732	[0.268, 1.198]	0.234	3.129	.002
Random					
Item	1.186	[0.956, 1.492]			
Subject	1.051	[0.819, 1.379]			

Note. All estimates are in reference to the unrelated prime condition and item retrieval being unsuccessful.

ticipant was significantly higher for semantically related primes and targets ($r_{\text{mean}} = 0.24$, $r_{\text{CI}} = [0.17, 0.31]$), compared with the semantically unrelated primes and targets ($r_{\text{mean}} = -0.16$, $r_{\text{CI}} = [-0.20, -0.11]$), and this difference was statistically significant, $t(39) = 8.65$, $p < .001$. This confirms the validity of our measure and indicates that a given participant's knowledge of the prime was correlated with their knowledge of the target in the semantically related condition.

The key question, of course, is whether the correlations for successful retrievals is greater than unsuccessful retrievals for the semantic condition, compared with the unrelated condition. This would imply that the effects we are observing are primarily because of a subject-by-item knowledge-based artifact, that is, when a participant knows the prime, they also tend to know the target and this idiosyncratic knowledge is in fact producing the relationship between prime and target retrieval success/failure. However, if the effects are indeed because of the facilitation from successful prime retrieval and inhibition from unsuccessful prime retrieval attempts, these effects should persist when these correlations are covaried out in the LME analyses. Thus, we included these correlations at the item level within each participant as a covariate in our LME model predicting target accuracy with prime condition and prime retrieval accuracy. Our analyses again produced a highly significant two-way interaction between prime retrieval success and prime condition ($p < .0001$), after covarying out correlated prime-target knowledge score (see Table 16). This indicates that even though correlated prime-target knowledge does in fact differ across semantic and unrelated prime conditions, there is an independent effect of prime retrieval success and failure for semantically related items driving the present facilitation and inhibition effects (see Figure 7).

Discussion

Experiment 5 replicated the results from Experiment 4 and provided evidence that the observed semantic retrieval facilitation and inhibition effects were in large part because of prime retrieval success and failure, given that the effect persisted after controlling for correlated knowledge about the prime and target words. We further discuss the implications of these findings in the General Discussion.

An important question that arises out of the combined results from Experiments 2–5 is whether this cost and benefit of semantic retrieval failure and success is specific to retrieval attempts from the same space in semantic memory, or can one find similar effects in other types of successful and unsuccessful retrieval situations. Specifically, it is not clear whether semantic retrieval success or failure modulates subsequent retrieval performance in all situations when primes and targets are semantically related, or is it localized to retrieval attempts that direct attention to the common semantic space shared by the prime and target. In Experiment 6, we explored this question within the context of an episodic memory retrieval task.

Experiment 6

In Experiment 6, we used an episodic cued-recall task to investigate the influence of retrieving semantically related and unrelated items from an episodic retrieval event on subsequent retrieval from semantic memory. Participants first studied a list of word pairs (e.g., LIGHT-resign or LIGHT-obvious). During a test trial, they first attempted to retrieve the episodically associated item (e.g., resign or obvious) when presented with a cue (e.g., LIGHT). Immediately following attempted retrieval of the item, they attempted to retrieve the target word (e.g., abdicate) from its low-frequency word definition. Items retrieved from an episodic context were either semantically related (e.g., resign) or unrelated (e.g., obvious) to the upcoming target word (e.g., abdicate). We predicted that if retrieval from a *semantic space* was critical in determining subsequent influence on target retrieval (as in Experiments 2, 3, 4, and 5), then retrieval of semantically related or unrelated items from *episodic cues* would not influence target retrieval accuracy. On the other hand, if simply the semantic relationship between the item previously retrieved and the target was critical and did not depend on the retrieval context per se, then we would see similar levels of facilitation and inhibition in target retrieval as before. Furthermore, if correlated prime and target knowledge was the sole contributor to the patterns of semantic facilitation and inhibition, then one might still expect some carryover effects of episodic prime retrieval on target retrieval. However, if these effects were driven more by semantic retrieval success or failure, then we should not expect to see any effect of retrieving semantically related primes in the current task.

Table 16
Model Estimates for Target Retrieval Accuracy as a Function of Prime Retrieval Success, Prime Condition, and the Correlation Between Prime and Target Knowledge Scores Based on the Word Association Task in Experiment 5

Term	Estimate	95% CI	*SE*	*t* value	*p* value
Fixed					
(Intercept)	0.350	[0.285, 0.415]	0.033	10.548	<.001
Semantic	−0.144	[−0.208, −0.08]	0.033	−4.359	.000
Prime retrieval	−0.066	[−0.12, −0.012]	0.028	−2.364	.020
Correlated knowledge	−0.008	[−0.086, 0.07]	0.040	−0.201	.841
Prime Retrieval × Semantic	0.255	[0.178, 0.331]	0.039	6.464	<.0001
Random					
Subject	0.161	[0.125, 0.207]			
Residual	0.123	[0.108, 0.139]			

Note. All estimates are in reference to the unrelated prime condition, and prime retrieval being unsuccessful.

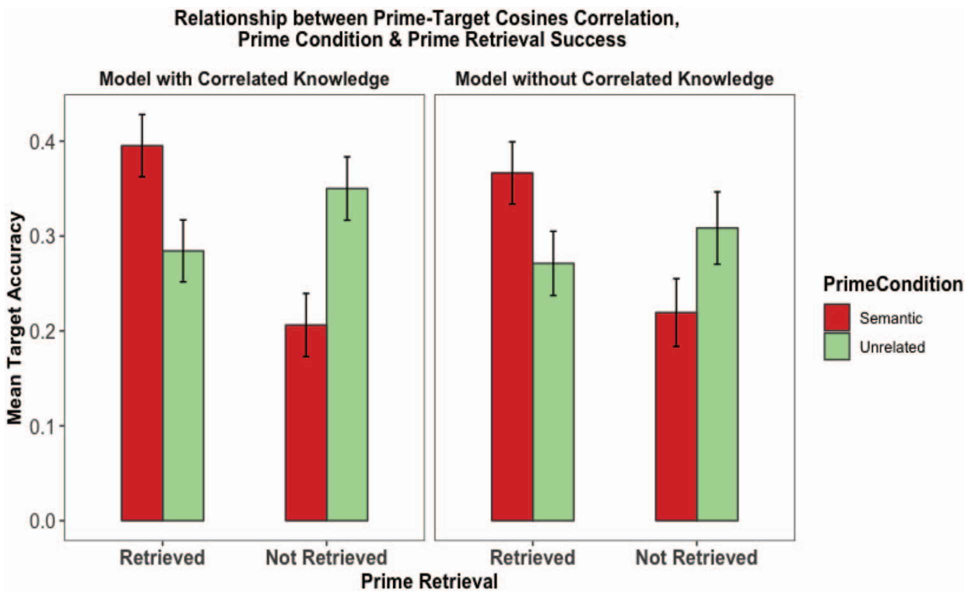

Figure 7. The predicted relationship between target accuracy, prime retrieval, and prime condition, when correlated prime-target knowledge was not included in the model versus when it was included as a covariate in Experiment 5. See the online article for the color version of this figure.

Method

Participants. Forty-four Washington University students (M_{age} = 18.6 years, *SD* = 0.76, 14 men and 18 women) received 1 hr of course credit for participation. All 44 participants were native English speakers. Data from two of the participants was not included in the analysis because of low accuracy (<10%) on either item or target retrieval. The mean Shipley Vocabulary Test score for the 42 remaining participants was 31.8 (*SD* = 3.0), and the mean years of education was 12.5 years (*SD* = 0.68).

Materials. The stimuli consisted of 48 target words, and each target word had a definition, and one cue-item word pair. Each cue word was paired with a semantically related and unrelated prime, and primes were counterbalanced across two separate lists. The target words, primes, and definitions were chosen from the stimuli used in Experiment 1. The cue words were selected from stimuli used by Maddox, Balota, Kumar, Millar, and Churchill (2019), and we ensured that the chosen cue was semantically and phonologically unrelated to the target that it was matched with in the current experiment.

Design and procedure. Participants first studied a list of 48 word pairs (e.g., LIGHT-resign), each presented at the center of the screen for 5 s. After the first study phase, participants studied the word list a second time. We included two study sessions to ensure the word pairs had been adequately encoded. The retrieval phase closely followed the procedures used in Experiment 2. Specifically, each experimental trial consisted of six components: cue presentation, prime retrieval, prime demasking, target definition, target response, state declaration, and target demasking (see Figure 8). First, the cue and a series of question marks were presented at the center of the screen (e.g., LIGHT - ???????), and participants attempted to recall the prime (e.g., resign) or pressed the spacebar when they could not recall the prime. Immediately after pressing the spacebar, the prime was slowly revealed on the screen through the progressive demasking procedure. The demasking procedure continued until the prime was fully revealed for 500 ms, or until the prime was identified by the participants by pressing the spacebar. Participants then typed in the correct prime on the next screen. Immediately after typing in the prime and pressing the spacebar, the target definition was presented for 10 s and participants attempted to retrieve the target. After typing a response and/or pressing the spacebar, participants indicated their retrieval state and subsequently identified the target through the progressive demasking procedure.

Results

Effect of prime condition on target retrieval accuracy. Figure 2 displays the mean accuracy for target retrieval for each prime condition. As indicated by model estimates in Table 17, there was no overall effect of prime condition (related vs. unrelated) on retrieval accuracy (p = .308).

Effect of prime retrieval accuracy on target accuracy. Figure 4 (Bottom-right Panel) displays the mean target retrieval accuracy as a function of whether the item was retrieved or not retrieved for each prime condition. Table 18 displays the best-fitting model estimates. We observed no interaction between prime condition and prime retrieval (p = .449), in contrast to the results of Experiment 5. Indeed, a cross-experiment LME analysis between Experiments 5 and 6 yielded a significant interaction between prime condition, prime retrieval accuracy, and experiment (p = .029), indicating that the semantic facilitation and inhibition effects observed in Experiment 5 were not replicated in Experiment 6.

Effect of prime demasking on target accuracy. We examined the influence of response latencies to identify the prime through the demasking procedure on subsequent target retrieval. The same screening procedures as in Experiment 5 were followed,

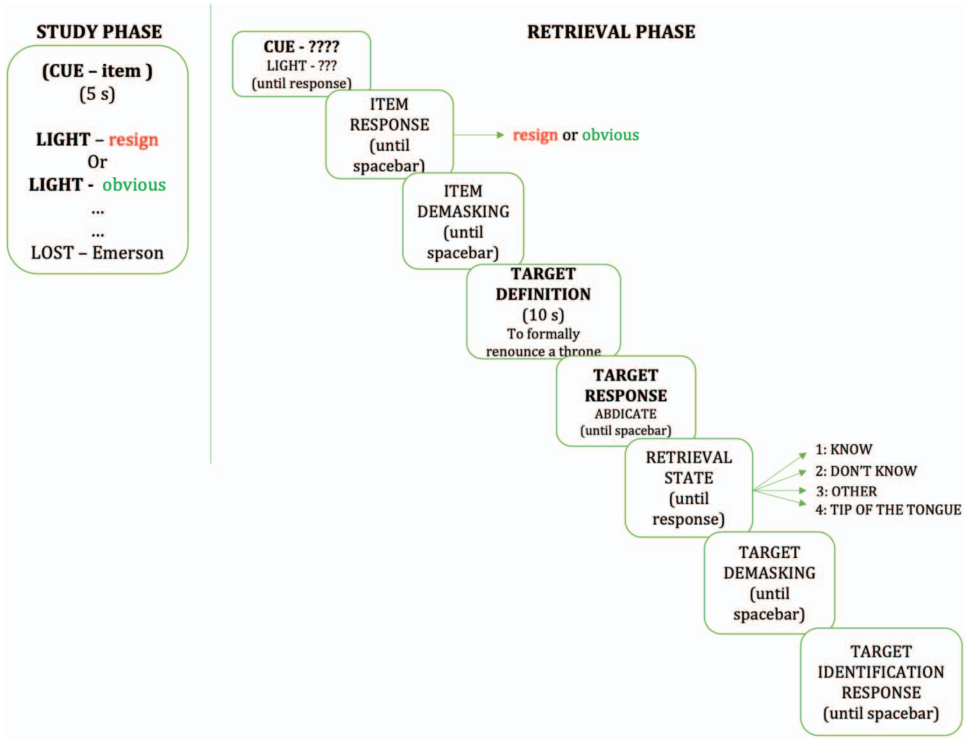

Figure 8. Paradigm for Experiment 6. See the online article for the color version of this figure.

which excluded 2.8% of the total trials. Table 19 displays the best-fitting model estimates. As shown in Figure 5 (Bottom Panel), we observed no interaction between prime condition and response time to identify the prime via demasking ($p = .685$).

Effect of prime demasking on target demasking. Next, we examined the influence of RTs to identify the prime through the demasking procedure on RTs to identify the target through demasking. Table 20 displays the best-fitting model estimates. As shown in Figure 6, there was no interaction between prime condition and response latencies to identify the prime via demasking ($p = .148$).

Discussion

The results from Experiment 6 indicated that retrieval from episodic memory does not influence subsequent retrieval of a target word from a low-frequency word definition, even when items are semantically related to the upcoming target. Item retrieval performance for the semantic primes in the cued recall task did not predict target accuracy, and response latencies to identify the semantically related prime via demasking also did not show a differential influence on subsequent retrieval accuracy, compared with unrelated primes. Furthermore, these results provide some evidence against the prime-by-participant confound that was addressed in Experiment 5. If correlated knowledge between the prime and target word was producing the effects of semantic facilitation and inhibition, we should have observed the same effects in this experiment, as individuals still retrieved semantically related and unrelated primes before target retrieval. Therefore, these results indicate that prime retrieval *success* or *failure* influences subsequent performance specifically when retrieval is from the same semantic space as the target and does not extend to retrieval from episodic memory.

Table 17
Model Estimates for Target Retrieval Accuracy as a Function of Prime Condition in Experiment 6

Term	Estimate	95% CI	*SE*	*z* value	*p* value
Fixed					
(Intercept)	−0.617	[−1.088, −0.153]	0.235	−2.624	.009
Semantic	−0.110	[−0.324, 0.104]	0.108	−1.019	.308
Random					
Item	1.191	[0.952, 1.520]			
Subject	0.898	[0.694, 1.182]			

Note. All estimates are in reference to the unrelated prime condition.

Table 18
Model Estimates for Target Retrieval Accuracy as a Function of Prime Retrieval and Prime Condition in Experiment 6

Term	Estimate	95% CI	*SE*	*z* value	*p* value
Fixed					
(Intercept)	−0.360	[−0.755, 0.027]	0.198	−1.817	.069
Prime retrieval	−0.183	[−0.321, −0.046]	0.070	−2.620	.009
Semantic	−0.185	[−0.374, 0.003]	0.096	−1.925	.054
Prime accuracy	−0.100	[−0.890, 0.697]	0.403	−0.248	.804
Prime Retrieval × Semantic	0.074	[−0.117, 0.264]	0.097	0.758	.449
Random					
Item	0.529	[0.388, 0.715]			
Subject	0.118	[0, 0.281]			

Note. All estimates are in reference to the unrelated prime condition and item retrieval being unsuccessful.

General Discussion

The present set of experiments focused on the influence of active retrieval of semantically and phonologically related and unrelated information on subsequent lexical retrieval of a target word from a low-frequency word definition. Our results provide clear evidence that repeated attempts to retrieve words for low-frequency definitions are consistently influenced by the degree of semantic relatedness between the prime and target, as well as the nature of processing (active vs. passive) of the prime word. We now discuss specific findings from the current experiments and their theoretical implications.

Phonological Facilitation in Lexical Retrieval

The results from Experiment 1 indicated that with the present set of materials, passive presentation of a phonological prime facilitated subsequent retrieval of the target word, further confirming the evidence for passive phonological facilitation in the extant literature (e.g., James & Burke, 2000; Kumar et al., 2019; Meyer & Bock, 1992; White et al., 2013). The present set of experiments also examined the influence of active retrieval of prime information on lexical retrieval. Our results suggest that when primes are actively retrieved (as in Experiment 2), no facilitatory effect of phonology is observed for the same materials that produced facilitation from passive prime presentation in Experiment 1. We believe this is likely because of the fact that an active prime retrieval event directs attention to semantic retrieval for the prime to the low-frequency word definitions, and this minimizes any automatic influence of phonology. As discussed, the evidence for pure phonological facilitation in lexical retrieval has only been found in situations when the prime is passively presented, and our results add to the extant literature and provide more information about the specific conditions under which such facilitation may or may not be observed. The processes involved in active retrieval of the prime word are likely mediated by different mechanisms compared with passive viewing of the prime, and theories of lexical retrieval suggest that semantics and phonology closely interact in such situations. For example, Levelt (2001) proposed that overt production of a word is first guided by semantic and lexical access to the target item, followed by the retrieval of morphological, phonological and syllabic codes, along with articulatory gestures. It is possible that once the prime word has been accessed and retrieved from a particular semantic space, the retrieval of a subsequent target word from a similar semantic space leads to a retrospective "reminding" that specifically directs attention to only the semantic dimension. In situations when the definitions are semantically similar (as in the case of semantic and both primes), this leads to semantic facilitation or inhibition, conditional upon prime retrieval success. However, when prime and target definitions are not semantically related (as in the case of phonological and unrelated primes), this emphasis on semantic retrieval to low-frequency word definitions likely leads participants to minimize the phonological dimension of the prime word and, therefore, no phonological facilitation is observed. Of course, this is a post hoc account of the present results, and clearly future research should attempt to disentangle the different conditions

Table 19
Model Estimates for Target Retrieval Accuracy as a Function of Prime Condition and RT to Identify the Prime via Demasking in Experiment 6

Term	Estimate	95% CI	*SE*	*z* value	*p* value
Fixed					
(Intercept)	−0.596	[−1.07, −0.129]	0.237	−2.512	.012
z-RT	−0.173	[−0.334, −0.009]	0.083	−2.082	.037
Semantic	−0.136	[−0.354, 0.082]	0.110	−1.235	.217
z-RT × Semantic	0.048	[−0.186, 0.283]	0.118	0.406	.685
Random					
Item	1.184	[0.943, 1.513]			
Subject	0.928	[0.715, 1.226]			

Note. RT = response time. All estimates are in reference to the unrelated prime condition.

Table 20

Model Estimates for Standardized RT to Identify Target as a Function of Prime Condition and RT to Identify the Prime via Demasking in Experiment 6

Term	Estimate	95% CI	*SE*	*t* value	*p* value
Fixed					
(Intercept)	0.019	[−0.114, 0.152]	0.067	0.278	.782
z-RT	0.140	[0.082, 0.198]	0.030	4.734	.000
Semantic	−0.023	[−0.102, 0.056]	0.040	−0.571	.568
z-RT × Semantic	−0.061	[−0.144, 0.0216]	0.042	−1.449	.148
Random					
Item	0.422	[0.337, 0.528]			
Subject	0.000	[0, 0.041]			
Residual	0.892	[0.864, 0.921]			

Note. RT = response time. All estimates are in reference to the unrelated prime condition.

under which phonological primes facilitate or do not facilitate lexical retrieval. However, collectively, these findings indicate that *attention* may play an important role in lexical retrieval tasks, and the extent to which an individual may be influenced by a particular dimension (i.e., semantics, phonology, and morphology) in a retrieval task may critically depend on where attention is focused during the task. Traditional models of word retrieval do not typically include attention as a factor that may influence these processes (e.g., Dell, 1986; Levelt, 2001). Therefore, it is important to recognize that attentional mechanisms may be critical in complex retrieval tasks, and how attention makes different dimensions of a word more or less salient is an important avenue for future research (see, for example, Balota & Yap, 2006).

Facilitation and Inhibition From Semantic Retrieval Success and Failure

In addition to examining the effect of actively producing phonologically related primes before lexical retrieval, we also examined the extent to which production of semantically related words influences lexical retrieval. In Experiments 2 and 3, although we found little overall influence of prime type on retrieval success, we did find that prime type strongly interacted with prime retrieval success in modulating target retrieval success. Specifically, successful retrieval of semantic and "both" primes facilitated target retrieval, and unsuccessful retrieval of the semantic and "both" primes hindered target retrieval. The analyses of demasking response latencies further confirmed these findings, such that faster identification of semantic and "both" primes resulted in greater target retrieval accuracy, whereas slower identification of the semantically related primes led to decreased target retrieval accuracy, compared with phonological and unrelated primes. These demasking analyses provide important converging evidence for the facilitatory and inhibitory effects of semantic prime retrieval, especially because they do not depend on conditional analyses. Instead, it appears that if individuals were close to retrieving the prime, or had successfully retrieved it, they were faster to recognize the prime word during demasking, which in turn facilitated target retrieval. On the other hand, when prime retrieval was unsuccessful or individuals were thinking of a different word, it was reflected in slower response latencies to identify the prime during demasking, and subsequent inhibition in target retrieval. It is also noteworthy that these facilitatory and inhibitory effects occurred independently of the prime word being available since all primes were demasked in these experiments, with the exception of Experiments 4 and 5. Hence, the retrieval effect was localized to the processes related to retrieval success or failure, not the specific prime word itself. In Experiments 4 and 5, we observed the same pattern even when the prime was not demasked, suggesting that feedback about retrieval performance was not critical to these effects.

A potential concern regarding our interpretation of these findings is the effects we observed are not attributable to the act of retrieval per se, but instead may be because of potential idiosyncratic influences of specific primes and/or prime-by-participant interactions. For example, it may be the case that prime items that are typically retrieved are better semantic cues for the target items than items that are often failures. To explicitly test for this possibility, we used the ratings of semantic relatedness that we collected in Experiment 1 to norm our stimuli via MTurk. Across Experiments 2–5, we found no difference between ratings for semantic primes that were successfully retrieved versus semantic primes that were not successfully retrieved, $t(70) = -0.944$, $p = .348$. For the both primes only used in Experiment 2, this difference was again not significant, $t(70) = 0.081$, $p = .936$. When the relative strength of the cues was included as a covariate in our analyses in Experiment 2 (see Footnote 3), the effects of prime retrieval success and failure continued to persist, providing further evidence against this hypothesis. Of course, given that we did not collect ratings for unrelated primes in our norming study, we could not do the same covariance analyses for the rest of the experiments. However, collectively, these analyses suggest that it is not the case that primes that were retrieved were in fact better semantic cues than those that were not retrieved.

A second possibility is that there is an idiosyncratic participant by item correlation between knowledge of the prime and knowledge of the target that may have produced the observed patterns. One aspect of the current design that is relevant here is that participants received the correct prime after attempted retrieval in Experiments 2 and 3, so it was not the case that participants did not "know" the prime before moving on to target retrieval. Of course, this does not entirely eliminate the possibility that the knowledge of the prime may indeed be correlated with knowledge of the target word within each individual and this may be influencing the current patterns. To specifically address this possibility, we conducted Experiment 5, where we attempted to obtain estimates of each participants knowledge of the primes and targets. Specifically, immediately after the lexical retrieval task, participants produced associates to each of the primes and target words. We estimated the knowledge participants had about the primes and targets through the relative semantic distance between the associate and the prime or target word in a state-of-the art computational semantic space (word2vec; also see Mandera, Keuleers, & Brysbaert, 2017; Mikolov et al., 2013). We then computed within-participant correlations between prime and target knowledge scores at the item level as a function of prime condition and prime retrieval success. These correlations were used as covariates in our LME analyses for target retrieval accuracy, with prime condition, and prime retrieval success as predictors. Although the idiosyncratic correlations between prime and target knowledge were indeed larger for semantic primes than unrelated primes (supporting the utility of this measure), we still found semantic facilitation and inhibition effects (see Figure 7), such that successful retrieval of semantic primes facilitated target retrieval and unsuccessful retrieval of semantic primes inhibited target retrieval, even after controlling for within-participant correlated knowledge of primes and targets. Although our measure of correlated prime-target knowledge has face validity (i.e., correlations were higher for the semantic prime condition, compared with the unrelated prime condition), we also recognize the possibility that idiosyncratic semantic knowledge at the participant level may have contributed to the observed results, and that more sensitive measures may be able to detect a larger influence. Specifically, our correlation-based analyses were limited to the three associates generated by participants in the word association task. Of course, the word association task is limited in the extent to which it can capture the vast knowledge participants may have about a particular concept or topic. Furthermore, our correlations were based on trials that were further split by prime condition and prime retrieval, which can lead to smaller sample sizes in particular cells. Therefore, future work should attempt to disentangle the effects of idiosyncratic participant knowledge on lexical retrieval using more sensitive measures and greater sample sizes. Despite these limitations, we believe that the current experiment provides a novel way of testing the participant-by-item artifact.

Finally, it is important to emphasize here that the semantic facilitation and inhibition effects were always compared with an unrelated or phonologically related baseline condition. That is, one simple account of the present findings could be that participants are simply poor during some points of the task at retrieving the primes and targets, and this is what is contributing to the relatively better performance following prime retrieval versus poor performance following failed prime retrieval. However, because we are measuring the facilitation and inhibition effects against baseline unrelated or phonologically related conditions (and prime items were counterbalanced across the related and unrelated conditions), we believe that these effects are specifically related to particular type of prime-target retrieval relationships (i.e., semantic overlap) producing the facilitatory and inhibitory effects.

While forward facilitation from semantic primes is a common finding in lexical decision tasks (see Neely, 1991, for a review), it is important to note that we did not see any overall forward influence of semantic primes on target retrieval in the current set of experiments, that is, the facilitatory and inhibitory effect of semantic primes was conditional upon successful or unsuccessful prime production. Thus, it is more likely that the observed effects reflect a retrospective influence from the prime retrieval success during target retrieval. If there was a prospective influence of the primes, we may have expected an effect of prime retrieval success or failure on target retrieval accuracy, independent of prime condition. However, it is only in relation to the target retrieval event that we observe any effects, and these effects are conditional on prime condition; therefore, suggesting that the retrospective reminding process that occurs when the target definition is presented may be contributing to these effects.

There is ample evidence for backward semantic priming (e.g., from the target BELL to the prime HOP) in lexical decision and pronunciation tasks (Kahan, Neely, & Forsythe, 1999; Koriat, 1981; Seidenberg, Waters, Sanders, & Langer, 1984), especially in situations when target processing is more difficult, that is, masked, compared with when target processing is relatively easier (Thomas, Neely, & O'Connor, 2012). However, these effects have not been previously investigated in a lexical retrieval paradigm, although the notion of effortful or difficult target processing directly applies to lexical retrieval to low-frequency word definitions. In the current design, after attempting to retrieve the prime, participants viewed a target definition that was semantically similar to the definitions for semantic and both primes. It is, therefore, possible that the target definition then acted as a retrieval cue for the preceding retrieval event (Jacoby, Wahlheim, & Kelley, 2015), that is, when prime retrieval was attempted. If prime retrieval was successful, this reminding produced facilitation in target retrieval, because of shared semantic features between the prime and target (Chwilla, Hagoort, & Brown, 1998; Masson, 1995; McRae, de Sa, & Seidenberg, 1997). However, if prime retrieval was unsuccessful, it is possible that the relationship between the target and the prime served as a *reminder* of the failed retrieval attempt (Hintzman, 2010; Ross, 1984). This may have produced a Zeigarnik-type effect because of the memory of an "incomplete" retrieval process being triggered (Zeigarnik, 1927) and, thus, inhibiting the current retrieval process for the target word, compared with the unrelated baseline. Specifically, being reminded of the incomplete prime retrieval event may have led participants to linger on that event, that is, leading to additional rumination or distraction, and subsequently causing disruption in the current target retrieval event. Our effects were not confounded by the availability of the prime word during target retrieval in the current set of experiments, because all primes were demasked before target retrieval was attempted (except in Experiments 4 and 5).

It is important to note here that the center-surround mechanism discussed earlier (Dagenbach & Carr, 1994) may also have contributed to the observed effects, although this hypothesis would require further investigation. Specifically, in the Dagenbach et al. study, the newly learned prime was presented to the participants and they were asked to retrieve its definition. Within this framework, the activated "center" is composed of the prime that is presented and any synonyms, whereas other words that are semantically related (i.e., associates) form the dampened "surround" (Barnhardt et al., 1996). Therefore, when the prime's definition is not successfully recalled, the surrounding associates of the prime suffer inhibition, whereas synonyms escape this inhibition because they are in the center of the field and, therefore, already activated. On the other hand, when the prime's definition is recalled, facilitation is observed for all semantically related targets. However, in the current design for Experiments 2–5, the prime word itself needed to be retrieved and the definition was presented to the participants that is, the reverse of the Barnhardt et al. design. Therefore, it is unclear which words would form the "center" and which words would form the "surround" in this case. For example, do the words contained in the definition all fall in the "center", and if so, do their synonyms also fall within the "center"? Clearly, the present design is significantly different from the Dagenbach et al. study and the ambiguity of which words may fall within the "center" and "surround" in the current studies makes it difficult to hypothesize that the center-surround mechanism may fully account for the present findings.

Although the center-surround mechanism may play a role in the present results, we content that it is primarily the success or failure of the prime retrieval attempt that appears to be reretrieved during target retrieval in a retrospective manner that is critical here. Indeed, there is evidence from paired-associate learning to suggest that when identical cues (e.g., A-B, A-D) are used at the time of retrieval, successful recollection of change produces proactive facilitation, but unsuccessful recollection of the change produces proactive interference (Wahlheim & Jacoby, 2013). Of course, the A-B, A-D paradigm clearly differs from the current set of experiments because the words B and D are typically unrelated in paired associate learning, whereas in the current experiments, B (i.e., the prime) and D (i.e., the target) are intentionally related in the semantic condition. There is also evidence for retrieval-induced facilitation and inhibition in the literature on retrieval practice (Anderson, Bjork, & Bjork, 2000; Chan, 2009; Chan, McDermott, & Roediger, 2006). In these studies, "inhibition" is hypothesized to occur because of either actual suppression or inhibition, or because of a retrieval block. Within the context of the current set of experiments, we believe our results are most consistent with an inhibition/suppression account, especially because participants were unable to come up with any response at all on approximately 80% of the unsuccessful target trials. If participants were experiencing a retrieval block, it would be more likely that they produce the blocking word itself. However, given that we have no evidence of such blocking words being produced, we believe this is unlikely. Collectively, the present results have implications for theories of lexical retrieval and suggest that there need to be explicit accounts for how successful and unsuccessful retrieval processes influence downstream lexical retrieval. We believe that the current findings are consistent with a retrospective reminding account, such that the extent to which characteristics of the target retrieval event overlap in meaning with the prime retrieval event predicts the facilitation and inhibition observed in target retrieval.

The notion that retrospective processes influence lexical retrieval also has broader implications for research that focuses on repeated retrieval-based processes operating on lexical retrieval (Kumar et al., 2019; Oberle & James, 2013), verbal fluency (Bousfield & Sedgewick, 1944; Hills, Jones, & Todd, 2012), free association (Nelson, McEvoy, & Schreiber, 2004), picture naming (Howard, Nickels, Coltheart, & Cole-Virtue, 2006), and exemplar production (Freedman & Loftus, 1971) among others. Previous research has examined how individuals search the semantic space to produce responses in the verbal fluency and free association tasks (Abbott, Austerweil, & Griffiths, 2015; Hills et al., 2012; Jones, Gruenfelder, & Recchia, 2011), and how semantic inhibition effects found in picture naming can inform theories of semantic representation (Alario & Martín, 2010; Oppenheim, Dell, & Schwartz, 2010). However, these computational accounts either consider each retrieval event in isolation or do not have explicit accounts for how the *success* or *failure* of a previous retrieval event may influence an upcoming retrieval event through retrospective mechanisms. The current findings suggest that the *success* of retrieving a particular item from a semantic space is dependent upon the success of retrieving other items from the same semantic space and, therefore, critically alters the semantic search process. Models that propose mechanisms for search and retrieval processes operating on semantic memory representations, therefore, need a process-based account for how retrieval success or failure might modulate later search processes. Newer computational models that keep track of prior events in the form of recurrent connections (Peters et al., 2018) or attention-based mechanisms (Vaswani et al., 2017) appear to be promising, although these models have not been directly applied to lexical retrieval tasks so far. In general, our findings identify local semantic dependencies between retrieval outcomes that may influence performance in retrieval-based tasks operating on semantic memory representations.

Prime Retrieval From Episodic Memory

In addition to examining the impact of retrieving information from semantic memory on subsequent target retrieval, we also examined whether episodic memory retrieval influences subsequent lexical retrieval from definitions. To our knowledge, this is the first study to examine the consequences of preceding episodic retrieval on lexical retrieval performance. Specifically, in Experiment 6, participants first attempted to recall items from their cues, based on a previously studied list of word pairs. Immediately after attempting to retrieve the item, they attempted to retrieve a target word from its low-frequency definition. We found that the likelihood of correctly recalling an item semantically related or unrelated to the target from episodic memory did not influence subsequent target retrieval. This experiment provided important information about the nature of retrieval processes that impede or facilitate subsequent retrieval. To the extent that episodic and semantic memory represent different memory systems (Tulving, 1972) or distinct types of retrieval operations, it appears that facilitation and inhibition occurs only when words are retrieved from the same semantic space as the subsequent target word, although it is important to note here that there are multiple aspects of the design of Experiment 6 that differed from Experiments 2–5, which may have contributed to the lack of priming effects.[4]

It should also be noted that Experiment 6 potentially provides more support against the prime-by-participant confound addressed in Experiment 5, because one might expect facilitation and inhibition in this task if only correlated prime-target knowledge was contributing to these effects. However, an alternative account may be that idiosyncratic knowledge does not contribute to any effects in Experiment 6 because domain knowledge is not relevant to performance in this task. Our current design does not differentiate between these two accounts.[5] Collectively, however, the results of Experiment 6, and the above discussion indicate that the change of context and task demands can significantly alter the observed priming effects, consistent with a transfer-appropriate processing account (Morris, Bransford, & Franks, 1977), that is, the processes engaged in lexical retrieval (as in Experiments 2, 3, 4, and 5) are distinct from those involved in episodic retrieval (as in Experiment 6), and thus, the lack of an effect may be attributable to the lack of structural overlap between the two types of tasks. In addition, within event-based models of cognition (e.g., Shipley & Zacks, 2008), one might consider retrieval from episodic memory a significantly distinct event compared with retrieval from semantic memory, as episodic retrieval events involve reconstructive processes, whereas semantic retrieval may involve accessing preexisting knowledge structures.

Conclusion

The present set of experiments provide converging evidence for a facilitatory influence of successful production and an inhibitory influence of unsuccessful production of semantically related information on subsequent lexical retrieval from a definition. We also showed that the facilitatory and inhibitory effect of semantic prime retrieval is localized to retrieval of information from the same semantic space, is independent of feedback on retrieval performance and correlated prime-target knowledge and does not extend to episodic retrieval processes. These findings are consistent with a retrospective reminding account, according to which recollecting the unsuccessful retrieval of semantically related words interferes with subsequent retrieval for the target word, whereas recollecting the successful retrieval of semantically related words activates the representation of the target word and facilitates subsequent retrieval.

[4] Specifically, in Experiments 2–5, the priming effects were observed in a situation in which (a) the prime and target were semantically related (e.g., *resign-abdicate*), (b) the definitional cues were semantically related to their respective primes and targets (e.g., the definition for *resign* was related to *resign*), (c) the definitional cues for the prime and its respective target were semantically related to each other (e.g., the definitions for *resign* and *abdicate* were related to each other), and (d) the retrieval orientation for primes and targets was semantically based (e.g., retrieval was from definitions). On the other hand, in Experiment 6, we observe the lack of priming effects in a situation in which (a) the prime and target are semantically related (e.g., as in Experiments 2–5, resign-abdicate), (b) the episodic cues for the primes were semantically unrelated to their respective primes (e.g., light-resign; unlike in Experiments 2–5), (c) the episodic word cues for the primes and the semantic definitions for the targets are not semantically related to each other (e.g., light is not related to the definition for abdicate; unlike in Experiments 2–5), and (d) the retrieval orientation was episodically based for prime retrieval (unlike in Experiments 2–5) and semantically based for targets (as in Experiments 2–5). Thus, while we can rule out possibility (a) that simply a semantic relationship between the prime and target produces the facilitatory and inhibitory effects, the current design of Experiment 6 does not allow a determination of whether the effects in Experiments 2–5 were because of (b) or (c) or (d) or some combination of these differences, and further work is needed to clarify which aspect of the semantic space is being accessed and is critical to performance in lexical retrieval tasks. We thank James Neely for this comment.

[5] We thank Nate Kornell for this comment and suggestion.

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