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Lexical Retrieval Inhibition from Semantically Related Retrieval Primes

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by

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Abstract

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The phenomenological experience of lexical retrieval involves conscious and active attempts to retrieve semantically related information, but the direct influence of this retrieval process on subsequent 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., FOLIAGE) from their low-frequency definitions or descriptions (e.g., the leafy parts of a plant or tree, collectively). Across five experiments, target retrieval was preceded by the brief presentation of a prime word (Experiment 1), progressive demasking of the prime (Experiment 2), the retrieval of a prime word from its description (in Experiments 3 and 4), or retrieval of a prime word from episodic memory (Experiment 5). Primes were either "both" semantically and phonologically related (e.g., FOREST), only phonologically related (e.g., FOLDING), only semantically related (e.g., VEGETATION), or unrelated (e.g., PRODIGY) to the target word. In Experiment 1, phonological facilitation in target retrieval accuracy was observed when primes were passively viewed. In contrast, when participants attempted to identify primes via demasking (Experiment 2) or retrieve primes from their definitions (Experiments 3 and 4), no phonological facilitation was observed. Further, successful retrieval of

semantic and “both” primes in Experiments 3 and 4 facilitated target retrieval, and failure to retrieve semantic and “both” primes resulted in decreased target accuracy. This inhibitory influence of prime retrieval did not extend to retrieval of unrelated primes from episodic memory (Experiment 5). These studies suggest that unsuccessful retrieval of information from the same semantic space as the target word produces inhibition for subsequent target retrieval processes

Chapter 1: Introduction

When an individual attempts to retrieve a word from an existing network of knowledge, numerous 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 Bronte, Jane Austen, etc.). In the ideal situation, such semantically related associates and alternatives are slowly eliminated, and this process converges onto 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). 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 (for a review, see Roediger & Neely, 1982), 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.

One 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., under review; Meyer & Bock, 1992; White, Abrams & Frame, 2013). For example, Kumar et al.

(under review) 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 the phonological primes in target retrieval, and also reported reduced facilitation from "both" primes due to semantic overlap between the prime and the target, suggesting that phonology and semantics may exert competing influences on lexical retrieval. Importantly, they did not find any evidence of a difference in retrieval accuracy between semantic and unrelated primes, suggesting that the influence of presenting "pure" semantic primes on subsequent target retrieval was neither facilitatory nor inhibitory. Other lexical retrieval studies have also reported reduced facilitation from combined phonological and semantic ("both") primes (White, Abrams, & Frame, 2013), compared to pure phonological primes, and increased tip-of-the-tongue (TOT) reports following semantic primes compared to phonological primes (Meyer & Bock, 1992). However, an important feature of these experiments is that the primes in these studies were passively viewed before attempted target retrieval. Indeed, there is some evidence to suggest that *active* production of primes may differentially influence target retrieval, compared to conditions when primes are passively presented before attempted target retrieval.

To our knowledge, two studies have examined the effect of overtly retrieving semantically related primes on subsequent target retrieval from low-frequency word definitions. Cross and Burke (2004) examined the effect of producing semantically related or unrelated words on the occurrence of TOTs in younger and older adults. Participants first produced the name of a famous fictional character in response to a trivia question (e.g., The flower girl from

the musical *My Fair Lady* whom Prof. Higgins transforms into a fashionable lady presentable to society). The fictional character was either semantically related (e.g., Eliza Doolittle) or unrelated (e.g., Sundance Kid) to the subsequent target word (e.g., Audrey Hepburn). After two filler trials, participants named the picture of the celebrity who played that famous character. They found that producing the name of a related character did not influence the occurrence of TOTs in younger or older adults, although it resulted in higher accuracy, compared to producing an unrelated prime. They interpreted these results as evidence that semantically related alternate words do not produce TOTs or block access to the target word, but may actually facilitate retrieval via a spreading activation mechanism. However, it is important to note that Cross and Burke (2004) used related primes that were likely first associates, i.e., the primes were names of famous characters played by the *same* target actor. Thus, it is possible that activating this prime information may have in fact led to activating the target word itself, thus eliminating the possibility of greater TOT occurrence. Indeed, this would also explain the higher accuracy rates after producing a related prime, compared to an unrelated prime. It is possible that primes that are semantically related but not directly associated to the target may indeed interfere with or facilitate subsequent retrieval. Moreover, Cross and Burke (2004) excluded trials on which participants did not produce the correct prime, so it is unclear whether the prior retrieval "attempt" in and of itself facilitated or inhibited subsequent target retrieval in this study.

In a similar, more relevant study, Oberle and James (2013) examined the effect of producing "both" semantically and phonologically related primes and unrelated primes, on subsequent target retrieval. Participants first viewed a word description (e.g., The actor famous for his roles in movies such as *Risky Business, Top Gun,* etc.) and named a celebrity that was "both" semantically and phonologically related and shared the full first name with the target

(e.g., *Tom* Cruise) or unrelated (e.g., Nicholas Cage) to the target word (e.g., *Tom* Hanks). After two filler trials, participants named a picture of the target celebrity. Participants also stated whether they knew, did not know, or were in a TOT state for the celebrity's name after each description or photo. Importantly, to ensure that all participants knew the correct prime, prime descriptions remained on the screen for 12 seconds, followed by the presentation of the correct prime answer for 6 seconds. They found that "both" primes produced more correct responses to the target photo, and also led to fewer reported TOTs in both young and older adults, compared to an unrelated prime. They interpreted this pattern within the framework of the transmission-deficit hypothesis, according to which related primes strengthen connections between words, and thus facilitate production.

However, the results from the Oberle and James study raise two important questions. First, the primes in this study were "both" semantically and phonologically related to the target, so it is unclear whether the facilitation observed was due to the semantic or phonological relationship between the prime and target. Further, the "both" primes shared the full first name with the target, and it is possible that primes that share only partial phonology may not produce similar results (see White, Abrams & Frame, 2013). Indeed, other studies have shown that compared to pure phonological primes, "both" primes in fact produce less facilitation in target retrieval, specifically when the prime shares the first syllable with the target word (Kumar et al., under review; White, Abrams & Frame, 2013). Second, although participants in this study produced responses to prime descriptions, the *effect of producing* the correct or incorrect prime on subsequent target retrieval was not reported. The influence of retrieving incorrect, but related words prior to target retrieval thus remains unknown. On one hand, successful production of semantically related words may strengthen inter-node connections via spreading activation

(Cross & Burke, 2004; Oberle & James, 2013), and facilitate subsequent target retrieval. On the other hand, failure to produce such words may in fact inhibit semantically related representations (Barnhardt et al., 1996) and thus disrupt target retrieval, consequently leading to the phenomenological experience of "blocking" (Schacter, 1999). There is not much supporting evidence for the blocking hypothesis in the TOT literature (Cross & Burke, 2004; Burke et al., 1991; Meyer & Bock, 1992), and studies that do show evidence of inhibition from semantically related primes (as discussed in Roediger & Neely, 1982) either included correct target words as one of the presented primes (Brown, 1979), had participants knowingly retrieve multiple items from the same semantic category or used a picture naming paradigm (Brown, 1981). However, the specific effect of a *single* prime retrieval event in and of itself has not been investigated in these studies. Thus, it is theoretically important to investigate whether there is any evidence of disruption or blocking due to successful and unsuccessful prime retrieval on immediate target retrieval.

There is some additional evidence from word generation and list reading paradigms that active processing of related information can inhibit subsequent retrieval processes. Blaxton and Neely (1983) examined the influence of actively producing primes and targets in a word generation task. Participants either actively generated targets (e.g., BASS) within 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) which were also either actively generated or simply read after a category name (e.g., FISH). They found that when primes were simply read, related primes facilitated target generation and reading. However, when primes were *actively* generated, no such facilitation was observed in target generation in the four-prime condition, but facilitation was observed in the one-prime condition.

Further, they also reported greater response omissions in target generation following *generation* of semantic primes overall, compared to unrelated primes, suggesting that overt production of semantically related primes can potentially interfere with subsequent target generation processes. Importantly, again, the influence of unsuccessful prime generation processes on target generation was not examined in this study. Other research has also suggested that active selection or processing of semantically related words prior to target retrieval disrupts subsequent retrieval (Barnhardt et al., 1996; Tipper & Cranston, 1985). However, given that the subsequent tasks in these studies were list reading, word generation and lexical decision, we cannot conclude whether the same influences of prime retrieval failure and success would also extend to subsequent lexical retrieval from definitions.

Chapter 2: Overview of the Present Experiments

The present set of experiments were designed to investigate younger adults' ability to retrieve targets from low-frequency word definitions, following active retrieval of primes that were "both" semantically and phonologically, phonologically, semantically or unrelated to the target word. To anticipate, in Experiment 1, we examined the influence of simply presenting each type of prime before retrieving the target from a low-frequency word definition. We were mainly interested in replicating the previously reported pattern of passive phonological prime facilitation prior to target lexical retrieval (e.g., Kumar et al. under review; Meyer & Bock, 1992) with a different stimulus set.

The present study differed from previous studies in the following manner. Specifically, as shown in Figure 1, we investigated the influence of the primes not only in target retrieval, but also in response latency in a progressive demasking procedure (Ferrand et al., 2011) immediately following target retrieval (see Figure 1). We also assessed the phenomenological experience of participants during lexical retrieval across prime types. As shown in Figure 1, after attempting to retrieve the target from its definition, participants also specified their retrieval state. If exposure to semantically related information introduces lexical competitors in the system, it is possible that presenting semantically related information (i.e., in the semantic and "both" primes) may produce greater TOT and blocking experiences (Jones & Langford, 1987; Meyer & Bock, 1992), compared to phonological and unrelated primes.

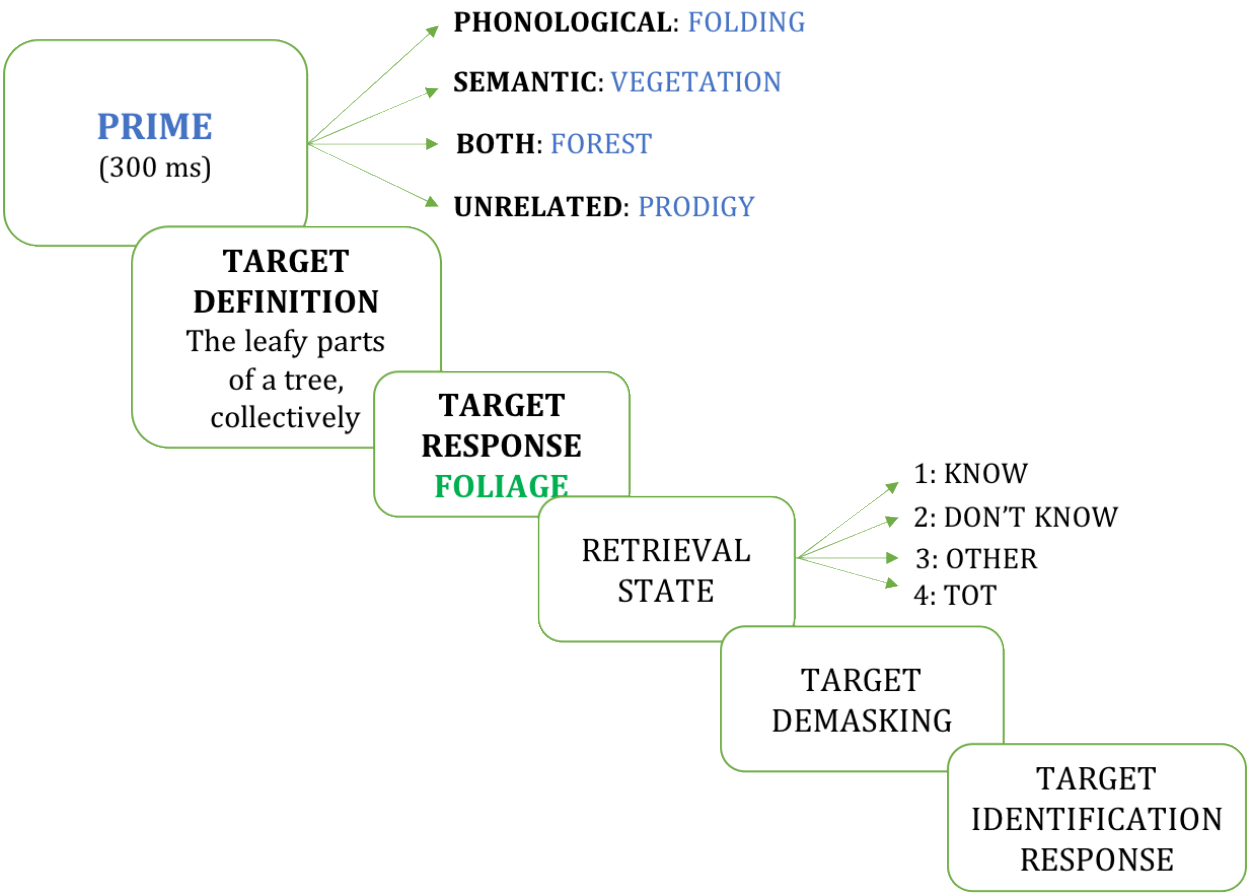

Figure 1. Experiment 1 paradigm

In Experiment 2, we investigated the influence of progressively demasking the prime on subsequent retrieval of a target word from its definition (see Figure 2). Here, we were interested in understanding the impact of gradual and prolonged retrieval processes for the prime on subsequent target retrieval processes, compared to the relatively brief and passive presentation of the prime in Experiment 1. Previously, Grainger et al. (2005) reported null effects of phonological neighborhood density in a progressive demasking task, where participants identified words with high/low orthographic and phonological neighborhoods. Thus, in contrast to Experiment 1, we might expect that progressive demasking of phonological primes may not produce any facilitation in subsequent target retrieval from its definition in Experiment 2.

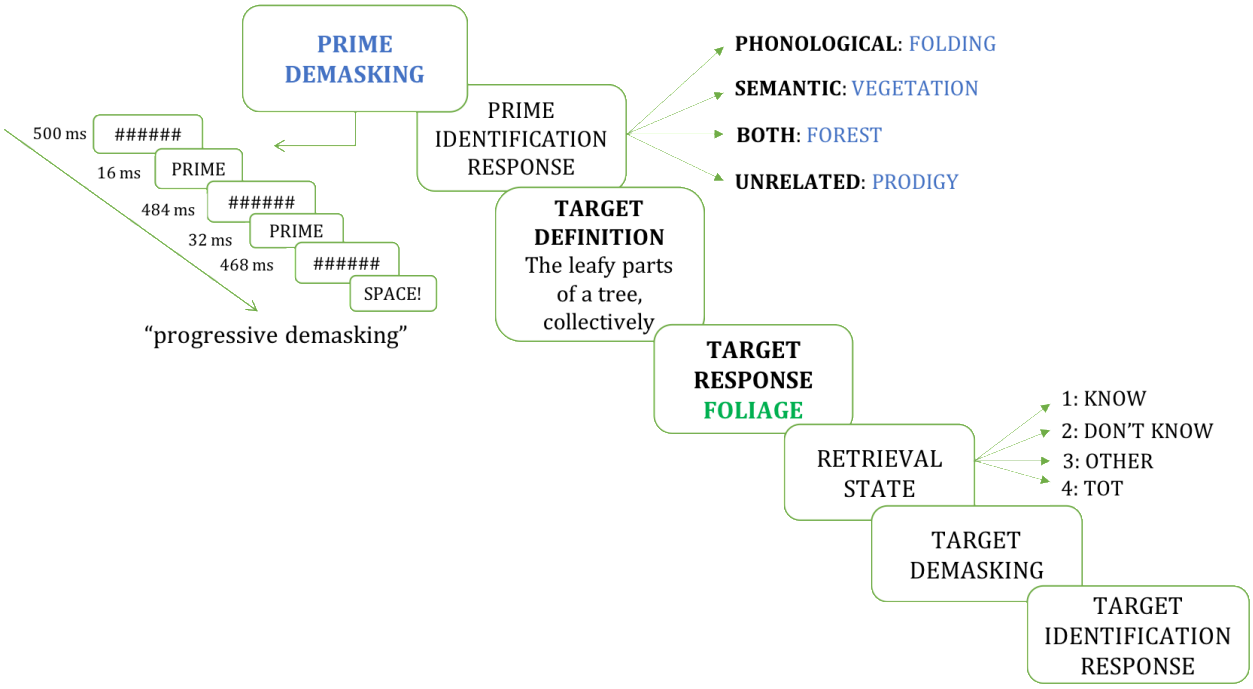

Figure 2. Experiment 2 paradigm.

In Experiment 3, we examined the effect of *actively* retrieving primes from short definitions or descriptions before participants viewed a low-frequency word definition and attempted to retrieve the target (see Figure 3). We were specifically interested in investigating the impact of these prior prime retrieval processes on subsequent target retrieval. Consistent with studies discussed earlier where the prime was actively produced, we predicted that successfully retrieving semantic and "both" primes would facilitate target retrieval compared to phonological and unrelated primes, but failure to retrieve semantic and "both" primes may produce interference in subsequent target retrieval (Barnhardt, Glisky, Polster & Elam, 1996; Blaxton & Neely,1983; Tipper & Cranston, 1985). In Experiment 4, we tested the influence of retrieving *only* semantic primes compared to retrieving *only* unrelated primes, to further clarify the specific inhibitory influence of retrieving semantic information on subsequent target retrieval.

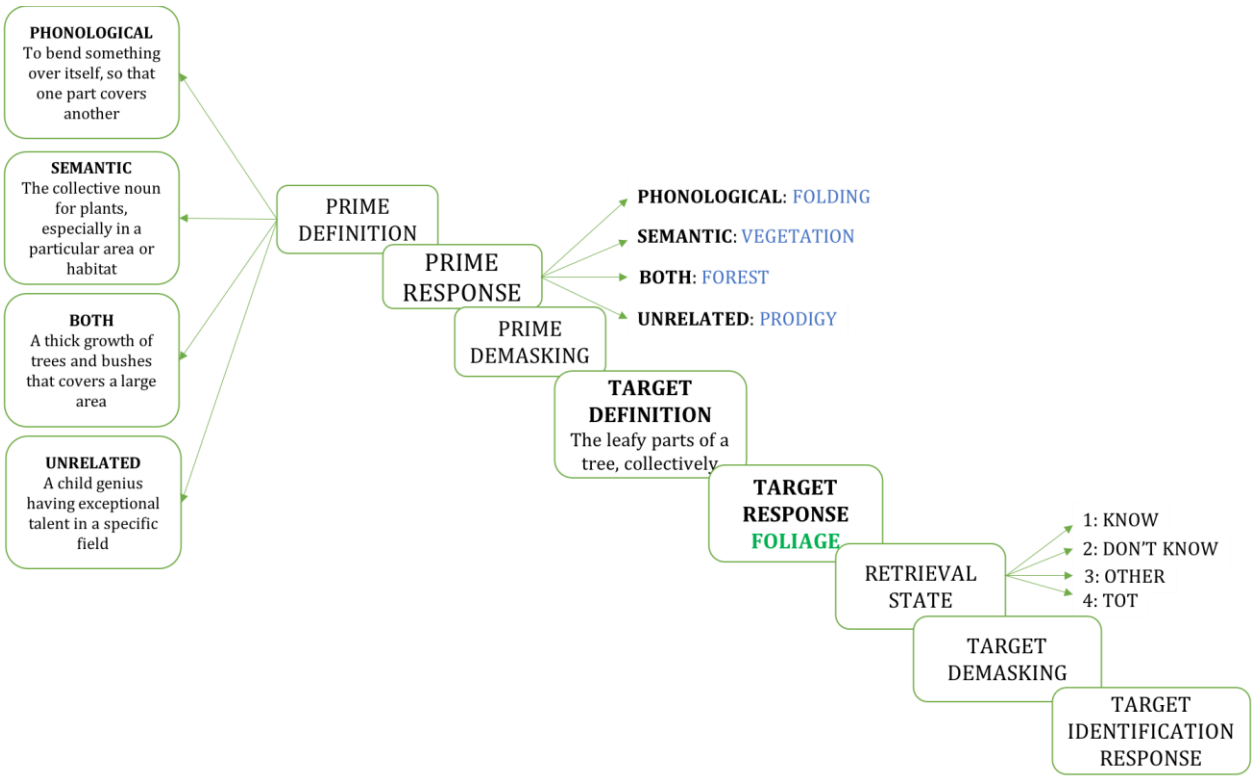

Figure 3. Experiment 3 & 4 paradigm.

Finally, in Experiment 5, we were interested in understanding whether the inhibitory effect of active production of primes extends to other types of retrieval situations. Specifically, we explored whether active retrieval from episodic memory influences subsequent retrieval of the target word from a low-frequency word definition. As shown in Figure 4, participants first studied a list of word pairs (e.g., BEAR-ALIVE), and then attempted to recall the item (e.g., ALIVE) when presented with a cue (e.g., BEAR-??????). Immediately after attempting to recall an item, participants attempted to retrieve a target word (e.g., foliage) from its definition as before. The item and the target were both progressively demasked after the first retrieval attempt. If the inhibitory influence of primes only occurs for retrieval from semantic memory, then we would expect no effect of item retrieval on subsequent target retrieval. Alternatively, if the effect

of retrieval also extends to episodic memory retrieval situations, we should see an effect of item retrieval success or failure on subsequent target retrieval.

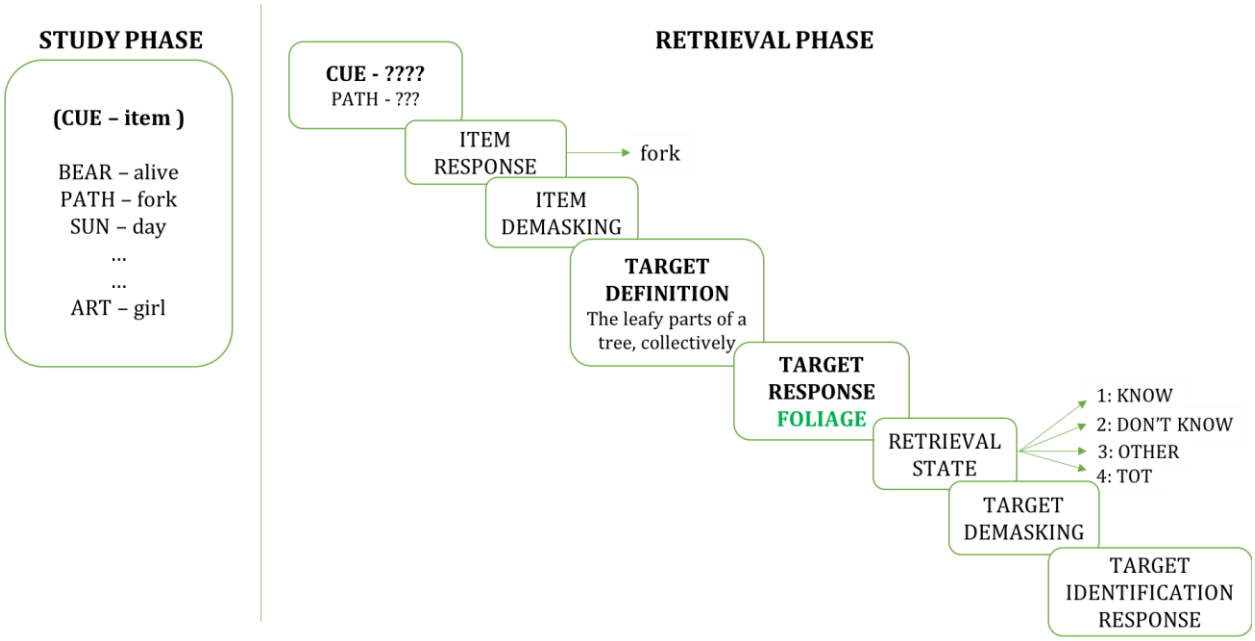

Figure 4. Experiment 5 paradigm.

Chapter 3: Experiment 1

3.1 Method

3.1.1 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.

3.1.2 Materials

The stimuli consisted of seventy-two target words, and each target word was matched with four other words which served as "both", phonological, semantic or unrelated primes. Thirty-three of the target words were proper nouns (names of people or places) and the remaining were common nouns, adjectives, and verbs. Fifty-nine target words and target definitions were taken from our previous study on lexical retrieval (Kumar et al., under review.), forty-three of which were taken or adapted from other studies (Burke et al., 1991; James & Burke, 2000; Meyer & Bock, 1992). We also retained forty-nine phonological primes, forty-seven semantic primes and forty-one "both" primes from our previous work. The remaining target words, primes, target definitions were specifically developed for this experiment. The unrelated primes for target words were chosen from among the phonological, "both" and semantic primes and counterbalanced across twelve separate lists. Typically, phonological and "both" primes overlapped in the first letter with the target word, but sometimes also in the overall syllabic structure and the first onset cluster and vowel. We also ensured that the semantic

and “both” primes were from the same semantic category. The full set of stimuli is available in the Appendix.

3.1.3 Pilot Study

In order to ensure that the stimuli were constrained appropriately, we conducted a semantic-phonological rating task on Amazon Mechanical Turk. Specifically, we were interested in evaluating if the stimuli in the “both” condition are similar to the phonological condition in phonology, and similar to the semantic condition in semantics. 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/sound condition, and 40 participants randomly assigned to the semantic/meaning condition. As shown in Figure 5, the primes mostly achieved the 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 very 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 ($p < .05$). The ratings afford a direct measure of the strength of the relationship and so we used these estimates as covariates in additional analyses (see Footnotes 2 and 3).

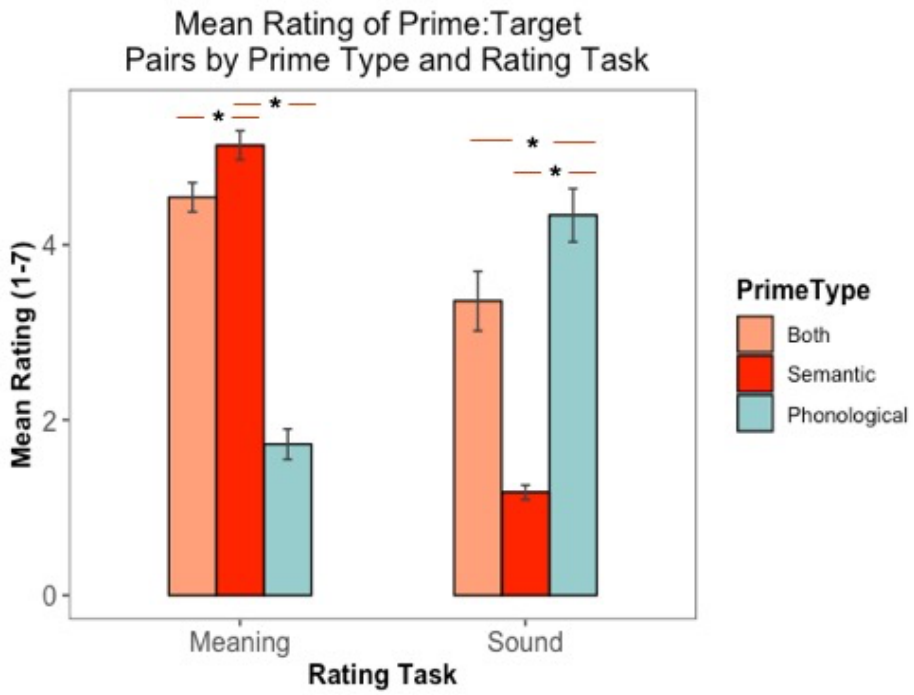

Figure 5. Ratings for PRIME-TARGET pairs for each prime type and rating task. Error bars represent standard errors of the mean. Asterisks indicate significant comparisons ($p < .05$).

3.1.4 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 every participant received one of the four prime types for each target, and neither primes nor targets were repeated within a given participant. Each experimental trial consisted of six components: prime, target definition, target response, state declaration, target demasking and target identification response (see Figure 1). Each prime was presented at the center of the screen for 300 ms. Immediately following the prime, the target definition was presented for 10 seconds at the center of the screen and participants attempted to retrieve the target. Participants were specifically instructed that the prime word was not the answer to the

definition. After typing a response and/or pressing the spacebar, participants indicated their retrieval state, by choosing between (1) You knew the answer, (2) Did not know the answer, (3) You have a related, but incorrect word in mind, and (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 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., foliage) and a mask (a row of pound signs matching the length of the word, e.g., ######). The total duration of target-mask pair 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. 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 correct answer and pressing spacebar. Participants were given 3 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.

3.2 Results

After attempting to retrieve the target, participants 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; (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 below (see Footnote 1 for details of state declaration analyses).

3.2.1 Target Retrieval Accuracy

Figure 6 displays the mean accuracy for target retrieval for each prime condition. We conducted a repeated-measures, one-way Analysis of Variance (ANOVA) on participants (F_1) and items(F_2), which yielded a main effect of prime condition, $F_1(3, 105) = 3.88$, $p = .01$, $\eta_p^2 = .09$; $F_2(3, 213) = 6.06$, $p < .001$, $\eta_p^2 = .08$. Follow-up comparisons revealed that target accuracy was greater when participants saw a phonological prime, compared to a semantic ($p = .03$), "both", ($p = .01$) and unrelated prime ($p = .01$). There were no other differences between other prime conditions[2].

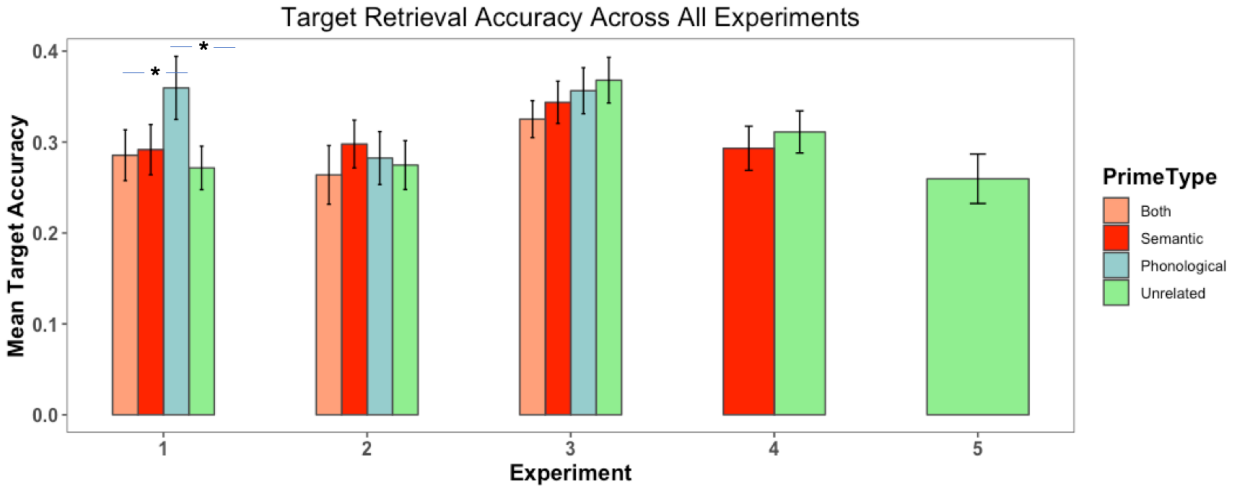

Figure 6. Mean target retrieval accuracy across prime conditions and experiments. Error bars represent standard errors of the mean. Asterisks indicate significant comparisons ($p < .05$).

3.2.2 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. 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 7000 ms were removed. Second, a mean and standard deviation were calculated from the remaining trials for each participant and any RTs that exceeded 3 standard deviations (SDs) 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 eliminate any effects of general slowing and individual differences across participants. A one-way ANOVA yielded no effect of prime condition, $F_1<1; F_2<1$.

3.3 Discussion

Results from Experiment 1 provide 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. (under review) previously 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 to a "both", semantic and unrelated prime. Experiment 1 further extends these results by demonstrating that presenting

a phonological prime *before* the definition also produces facilitation, similar to presenting the prime *after* the definition.

Interestingly, we do not find any evidence of prime influence on subsequent response times to identify the target through progressive demasking. Kumar et al. (under review) showed that processing a briefly presented prime before target retrieval interfered with participants' ability to select the correct answer in a subsequent multiple-choice task, especially for semantic and "both" primes. Further, this interference effect persisted even when participants were instructed that the prime was not the answer to the definition, although it was remarkably reduced in younger adults, compared to older adults. Similar to Kumar et al. (Experiment 2), participants in the present experiment were also instructed that the prime was *not* the answer to the definition, but importantly, the subsequent progressive demasking task was more implicit in nature, in contrast to an explicit multiple-choice task. We did not observe *any* influence of primes on subsequent target identification via demasking, suggesting that the effect of passively presenting phonological primes for brief durations does not extend to implicit processes for identifying the target word.

However, as previously discussed, it is possible that when participants are *actively* engaged in identifying the prime through progressive demasking, compared to passively viewing it as in Experiment 1, lexical inhibition of competing phonological nodes may lead to the loss of phonological facilitation in subsequent target retrieval (Grainger et al., 2005) and also impact subsequent implicit processes. Thus, in Experiment 2, we investigated whether gradual and prolonged exposure to the prime differentially influences immediate target retrieval as well as subsequent implicit processes of identifying the target word, compared to passively viewing the prime, as in Experiment 1.

Chapter 4: Experiment 2

4.1 Method

4.1.1 Participants

Thirty-nine young adults (M_{age} = 23.2 years, *SD* = 6.4) were recruited from undergraduate courses at Washington University and received course credit for participation. Thirty-six participants were native English speakers and the remaining three participants were excluded from further analysis due to extremely low (<5%) accuracy in the task. Mean score on the Shipley Vocabulary Test for younger adults was 33.92 (*SD* = 3.20), and mean years of education was 13.83 (*SD* = 2.8).

4.1.2 Materials

Materials were identical to those in Experiment 1.

4.1.3 Procedure

The experimental procedures were identical to those in Experiment 1 with one exception. Instead of passively viewing the prime for 300 ms, participants identified the prime through the progressive demasking procedure described earlier. 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 correct prime and pressing spacebar, the target definition appeared on the screen, and participants attempted to retrieve the target, specified their retrieval state and then identified the target through progressive demasking (see Figure 2).

4.2 Results

4.2.1 Effect of Prime Condition on Target Retrieval Accuracy

Figure 6 displays the mean accuracy for target retrieval for each prime condition. A one-way Analysis of Variance (ANOVA) revealed no effect of prime condition, $F_1<1$; $F_2<1$.

4.2.2 Effect of Prime Demasking on Target Retrieval Accuracy

Although there was no influence of prime condition on target retrieval accuracy, it is possible that response latencies to identify the prime implicitly influence retrieval processes for the target. Thus, we examined the influence of response latencies to identify the prime on subsequent target retrieval accuracy. In our analyses, we first excluded all trials for which the participant did not identify the correct prime. Then, we screened outliers using the same procedure as in Experiment 1, which excluded 4.6% of the total trials. After screening, we standardized the remaining trials and conducted all primary analyses using trial-level standardized RTs, to account for general slowing and individual differences. We used generalized linear mixed models (with a logit link) from the lme4 package (Bates & Sarkar, 2006) in the RStudio environment (R version 3.4.2 (2017-09-28), R Development Core Team, 2006) to examine the relationship between response latencies to identify the target and retrieval accuracy. We sequentially added random intercepts for participants and items and random slopes for prime condition and standardized RTs, 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 & Sarkar, 2006). Model fit increased significantly for the random intercepts, but not for the random slopes and thus only random intercepts were included in the final model. After this initial set of analyses, we included

standardized RTs to demask the prime, prime condition, as well as the two-way interaction between prime condition and standardized RTs in the final model as predictor variables. Following Aschenbrenner and Balota (2013), we relied on the procedure of a *t* and *z* value greater than 2.0 to indicate statistical significance.

Table 1 displays the fixed effects estimates from the final model. We observed a main effect of RT to identify the prime on target retrieval accuracy (F = 4.84 , p =.03). Importantly, however, there was no effect of prime condition (p = .17), and the two-way interaction was not significant (p = .70), suggesting that response latencies to identify the prime did not differentially influence target retrieval accuracy across the prime conditions.

Table 1

Fixed and random effect estimates from the best-fitting model predicting target retrieval accuracy from standardized RTs (z-RT) to identify the prime via progressive demasking.

Fixed Effects	**Experiment**	**Predictor(s)**	***F***	**p-value**
	2	Prime Condition	1.67	.174
		z-RT to identify prime	4.84	.029
		z-RT x Prime Condition	0.472	.703
	3	Prime Condition	1.57	.195
		z-RT to identify prime	7.34	.006
		z-RT x Prime Condition	3.27	.021
	4	Prime Condition	0.306	.546

		z-RT to identify prime	7.74	.005
		z-RT x Prime Condition	6.40	.012
	5	z-RT to identify prime	1.63	.202

Random Effects	**Experiment**	**Estimate**	**Std. Error**
Subject	2	.042	.178
	3	.011	.104
	4	.015	.109
	5	.043	.178
Item	2	.034	.161
	3	.027	.084
	4	.037	.173
	5	.051	.194

4.2.3 Effect of Prime Condition on Target Demasking

We also examined the influence of prime condition on response latencies to identify the target via demasking, as in Experiment 1. Again, a one-way Analysis of Variance (ANOVA) revealed no overall effect of prime condition on target identification times, $F_1<1$; $F_2<1$.

4.3 Discussion

Results from Experiment 2 indicate that when prime information is gradually identified through progressive demasking, no facilitation from phonological primes is observed in target retrieval accuracy, in contrast to the results obtained in Experiment 1. Indeed, a 2 (Experiment:

1, 2) x 4 (Prime Condition: Phonological, Semantic, “Both”, Unrelated) ANOVA revealed a marginally significant interaction by-participants, $F_1(3,210) = 2.31$, $p = .08$, which was significant by-items, $F_2(3,213) = 3.04$, $p = .03$, further reflecting a between-experiment difference in retrieval accuracy in the phonological condition. These results suggest that prolonged exposure to the prime before attempted target retrieval eliminates any overt benefit from the phonological prime. As noted, Grainger et al. (2005) reported null effects of phonological density in a progressive demasking task, where participants identified words with high and low orthographic and phonological neighborhoods. They suggested that this null effect occurs because the progressive demasking task requires unique word identification, which produces lexical inhibition of competing phonological codes, and overcomes any facilitative effect of phonological neighborhood, resulting in a null effect. This could clearly explain the lack of facilitation from phonological primes in Experiment 2. Specifically, participants were engaged in a word identification task for the prime, which may have led to the inhibition of competing phonological nodes, resulting in a null effect of phonology in subsequent target retrieval.

The current pattern of results suggests that a more sensitive measure of prime processing eliminates any overall phonological facilitation in subsequent performance on the target word. However, it is important to note that even though the progressive demasking task slows down prime processing, it does not simulate the phenomenological experience of retrieving words from the same semantic space, as is common in situations when an individual is trying to retrieve an intended word. Thus, in Experiment 3, we investigate whether explicit 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.

Chapter 5: Experiment 3

5.1 Method

5.1.1 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 for younger adults was 33.92 (*SD* = 3.20), and mean years of education was 13.83 (*SD* = 2.8). All participants were native English speakers.

5.1.2 Materials

Materials were identical to those in Experiment 2, with one exception. Each prime word also had a definition associated with it, that was specifically created for this experiment, using the Oxford English dictionary. Definitions that included the target word were modified; the complete list of stimuli is available in the Appendix.

5.1.3 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 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 spacebar, the target definition was presented for 10 seconds 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.

5.2 Results

5.2.1 Effect of Prime Condition on Target Retrieval Accuracy

Figure 6 displays the mean accuracy for target retrieval for each prime condition. A one-way Analysis of Variance (ANOVA) yielded no overall effect of prime condition, $F_1(3, 141) = 1.06$, $p = .37$, $\eta_p^2 = .02$; $F_2(3, 213) = 1.88$, $p = .13$, $\eta_p^2 = .03$.

5.2.2 Effect of Prime Retrieval on Target Accuracy

Figure 7 (Panel 1) displays the mean target retrieval accuracy for each prime condition, as a function of whether the prime was retrieved or not retrieved. We performed linear mixed effects analyses to examine the influence of prime type and prime retrieval on subsequent target retrieval accuracy, and included overall prime accuracy as a covariate in these analyses, to account for any differences in retrieval accuracy for the primes. Table 2 displays the fixed effects estimates from the final model. Importantly, we observed a reliable two-way interaction between prime type and prime retrieval ($F = 2.92$, $p = .03$). The two-way interaction indicated that the likelihood of retrieving the prime or failing to retrieve the prime significantly predicted the likelihood of retrieving the subsequent target. Importantly, follow-up comparisons revealed that this effect was mainly driven by the semantic and "both" primes, such that the difference between correct and incorrect target retrievals was marginally greater when semantic primes were retrieved or not retrieved, compared to phonological ($\beta = -0.24$, $t = -1.86$, $p = .06$), and unrelated primes ($\beta = -0.24$, $t = -1.93$, $p = .05$). The difference between correct and incorrect target retrievals was also significantly greater when "both" primes were retrieved or not

retrieved, compared to phonological (β = -0.28, t =2.22, p = .03), and unrelated primes (β = -0.28, z =-2.27, p = .02). Indeed, when prime conditions were collapsed across the meaning dimension, this effect indicated that when semantic and "both" primes were retrieved, they produced facilitation, compared to phonological and unrelated primes, p = .002. However, when semantic and "both" primes were *not* retrieved, they produced inhibition, compared to phonological and unrelated primes, p < .001. There were no differences between the phonological condition and unrelated condition in the proportion of correct and incorrect target retrievals (p = .99). There were also no differences between the semantic and "both" primes (p = .73)[3].

Table 2

Fixed and random effect estimates for target retrieval accuracy as a function of prime condition and prime retrieval accuracy

Fixed Effects	**Experiment**	**Predictor(s)**	***F***	**p-value**
	3	Prime Condition	1.49	.195
		Prime Retrieval	12.92	.003
		Prime Retrieval x Prime Condition	2.92	.033
		Overall Prime Accuracy	30.26	<.001
	4	Prime Condition	0.59	.088
		Prime Retrieval	17.52	.003
		Prime Retrieval x Prime Condition	8.71	.003
		Overall Prime Accuracy	85.79	<.001
	5	Item Retrieval	.099	.829
		Overall Item Accuracy	2.96	.086

Random Effects	**Experiment**	**Estimate**	**Std. Error**
Subject	3	.006	.073
	4	.004	.055
	5	.037	.159
Item	3	.028	.158
	4	.040	.049
	5	.055	.194

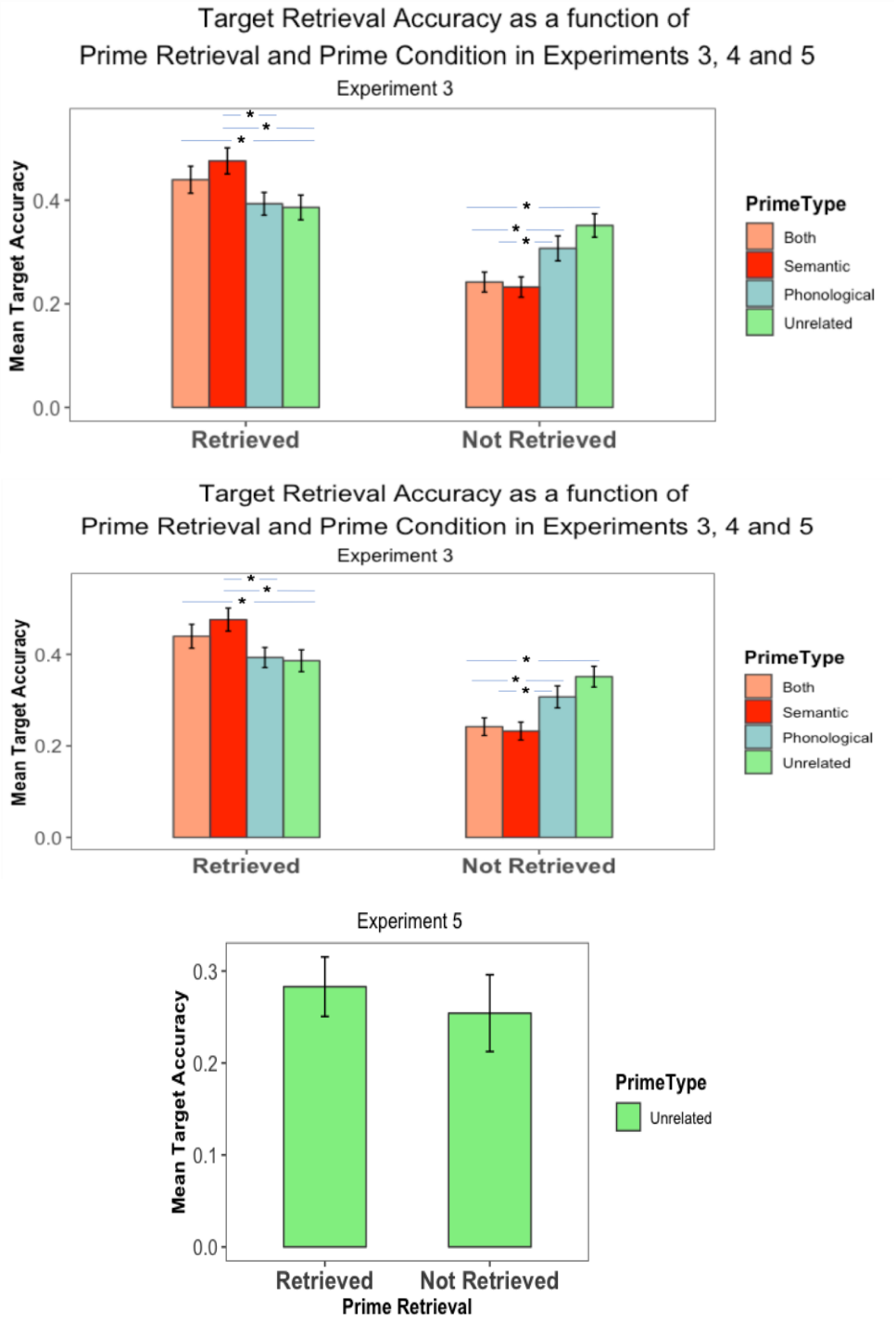

Figure 7. Target retrieval accuracy as a function of prime retrieval accuracy and prime condition, in Experiments 3, 4 and 5. Error bars represent standard errors of the mean. Asterisks indicate significant comparisons ($p < .05$).

5.2.3 Effect of Prime Demasking on Target Accuracy

Just as prime retrieval had an influence on subsequent 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 using generalized mixed effect models (with a logit link). The same screening procedures as in Experiment 2 were followed, which eliminated 3% of the total trials. Table 1 displays the fixed effects estimates from the final model. Importantly, we observed a significant two-way interaction between standardized RTs and prime condition (F = 3.27, p =.02). As shown in Figure 8 (Panel 1), the relationship between response time to identify the prime and target retrieval accuracy was magnified in the "both" (β = -0.33, z =-2.53, p = .01) and marginally in the semantic (β = -0.21, z =-1.67, p = .09) prime condition, compared to 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, compared to the unrelated primes. There were no differences between the phonological and unrelated prime conditions (p = .92).

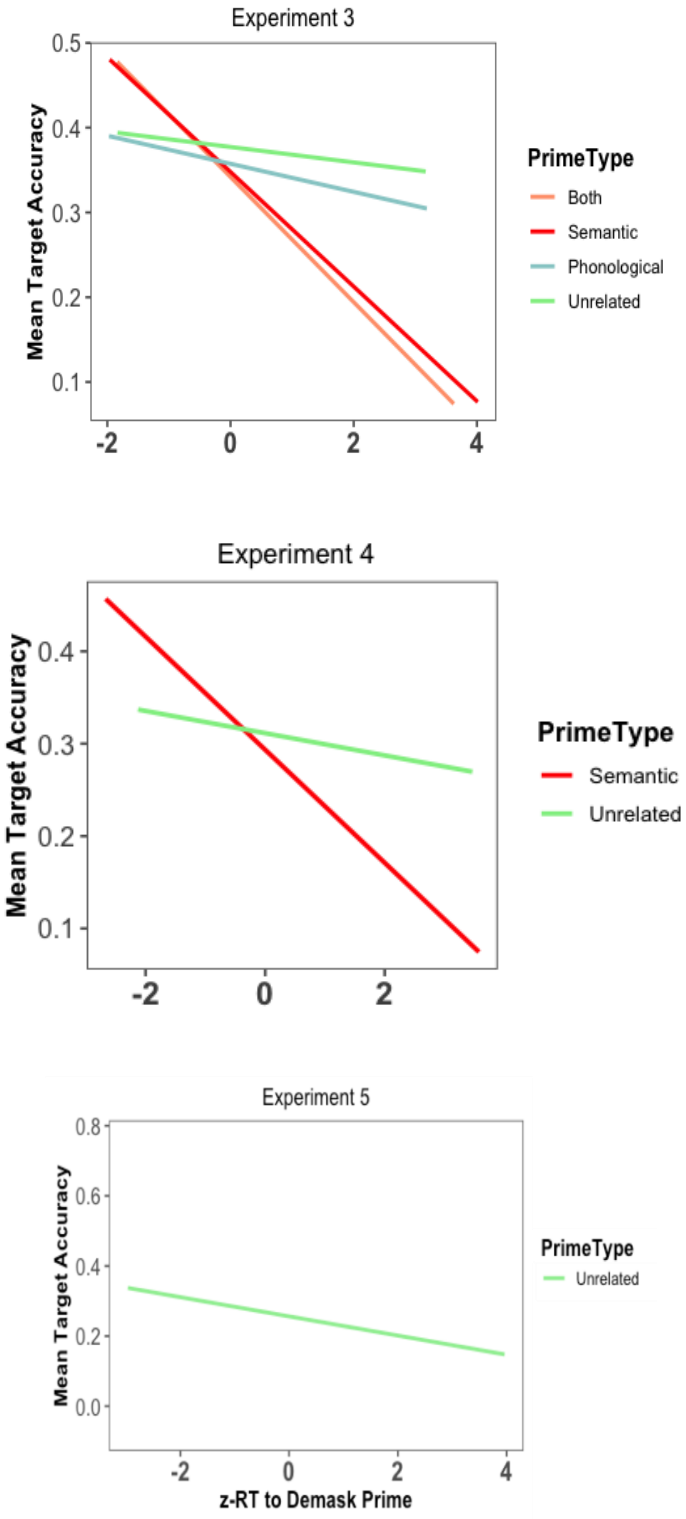

Figure 8. Mean target retrieval accuracy as a function of standardized response times to identify the prime, across prime conditions and experiments.

5.2.4 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 the demasking procedure on RTs to identify the target through demasking, using linear mixed effect models. Table 3 displays the fixed effects estimates from the final model. We observed a marginally significant two-way interaction between RT to identify the prime and prime condition ($F = 2.27$, $p = .08$). As shown in Figure 9 (Panel 1), the interaction mainly indicated that the slope for the semantic condition was marginally steeper than the unrelated condition ($\beta = 0.08$, $t = 1.84$, $p = .07$), but not the "both" ($p = .52$), and phonological condition ($p = .49$). The slope for the "both" condition was also steeper from the unrelated ($\beta = 0.10$, $t = 2.49$, $p = .01$), but not the phonological ($p = .18$) condition. The phonological condition did not differ from the unrelated condition ($p = .27$).

Table 3

Fixed and random effect estimates from the best-fitting model predicting standardized RTs (z-RT) to identify the target from standardized RTs to identify the prime via progressive demasking.

Fixed Effects	**Experiment**	**Predictor(s)**	***F***	**p-value**
	3	Prime Condition	1.14	.332
		z-RT to identify prime	69.11	<.001
		z-RT x Prime Condition	2.27	.078
	4	Prime Condition	0.06	.801
		z-RT to identify prime	35.26	<.001
		z-RT x Prime Condition	6.29	.012
	5	z-RT to identify prime	6.21	.013

Random Effects	**Experiment**	**Estimate**	**Std. Error**
Subject	3	0.00	0.00
	4	0.00	0.00
	5	0.00	0.00
Item	3	0.00	.064
	4	0.00	.067
	5	0.00	.078
Residual var.	3	.679	
	4	.667	
	5	.695	

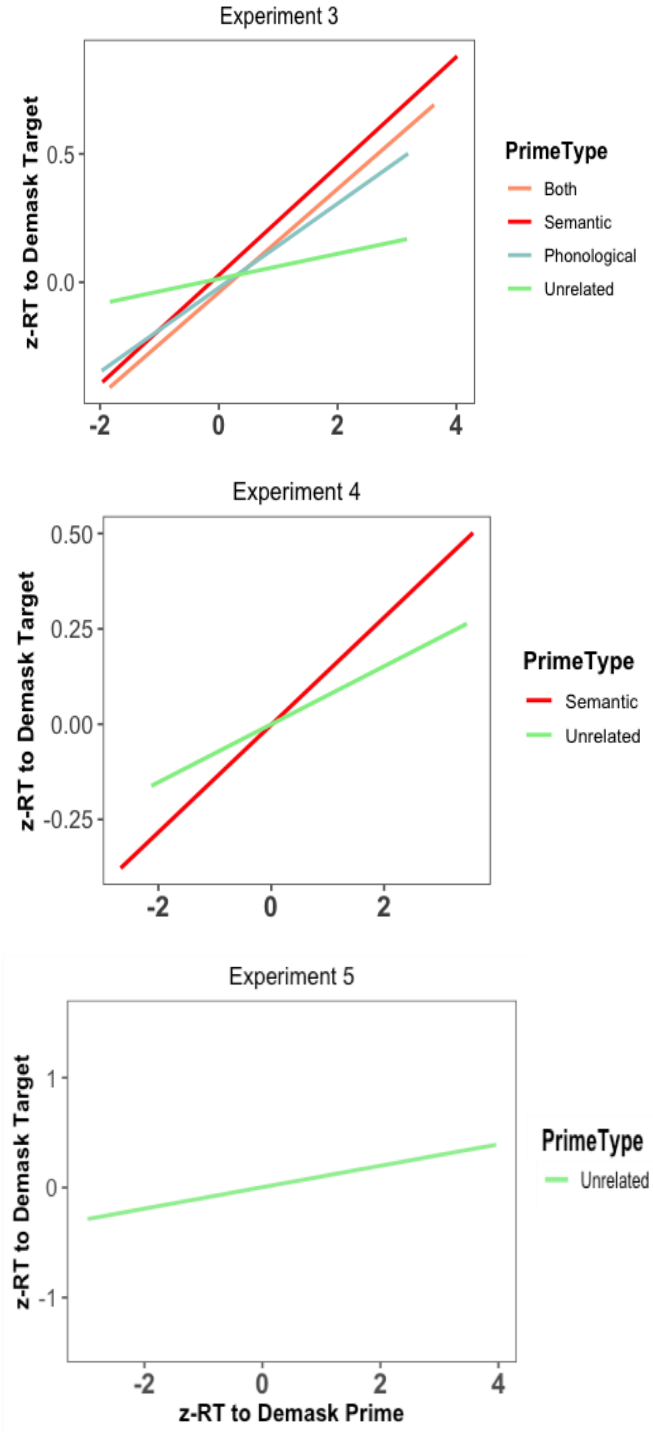

Figure 9. Standardized response times to identify the target through progressive demasking as a function of standardized response times to identify the prime, across prime conditions and Experiments 3, 4 and 5.

5.3 Discussion

The results of Experiment 3 provide clear evidence that prime retrieval processes significantly influence subsequent target retrieval. Specifically, failure to retrieve "both" and semantic primes predicted failure to retrieve the target word, and successful retrieval of "both" and semantic primes facilitated target retrieval. Further, response latencies to identify the semantic and "both" primes also predicted accuracy in target retrieval, and marginally predicted response latencies to identify the target through demasking. These findings suggest that when participants view the target definition, which is semantically related to the preceding prime retrieval event, they are possibly *reminded* of the failed retrieval attempt (Wahlheim & Jacoby, 2013), which inhibits their current retrieval process. On the other hand, when prime retrieval is successful, activation from the prime spreads to the semantically related target, thus producing facilitation. Although Experiment 3 provided evidence for the differential modulation of target retrieval performance after attempting to retrieve semantic and "both" primes, some of the effects in the analysis of response latencies were marginal and need further replication. Thus, in Experiment 4, we attempted to replicate this pattern through a stronger priming manipulation, by directly comparing *only* semantic and unrelated primes.

Chapter 6: Experiment 4

6.1 Method

6.1.1 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 for younger adults was 33.92 (*SD* = 3.20), and mean years of education was 13.83 (*SD* = 2.8). All participants were native English speakers.

6.1.2 Materials

Materials were identical to those in Experiment 3 with one exception. The stimuli consisted of 72 target words, and each target word was matched with only *two* other words which served as semantic or unrelated primes. The semantic primes were the same as those used in previous experiments, and unrelated primes were chosen from among the previously used unrelated primes in previous experiments.

6.1.3 Design and Procedure

A between-subjects design was used, where twenty-eight participants were randomly assigned to the semantic prime condition, and thirty 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. The experimental procedure was identical to Experiment 3.

6.2 Results

6.2.1 Effect of Prime Condition on Target Retrieval Accuracy

Figure 6 displays the mean accuracy for target retrieval for each prime condition. A one-way Analysis of Variance (ANOVA) yielded no overall effect of prime condition, $F_1<1$; $F_2=2.18$.

6.2.2 Effect of Prime Retrieval on Target Accuracy

Figure 7 (Panel 2) displays the mean target retrieval accuracy for semantic and unrelated primes, as a function of whether the prime was retrieved or not retrieved. We performed linear mixed effects analyses to examine the influence of prime type and prime retrieval on subsequent target retrieval accuracy, and included overall prime accuracy as a covariate in these analyses, to account for differences in retrieval accuracy for the primes. Table 2 displays the fixed effects estimates from the final model. Importantly, we observed a significant two-way interaction between prime type and prime retrieval ($F = 8.71$, $p = .003$). Follow-up comparisons revealed that the difference between correct and incorrect target retrievals was greater when semantic primes were retrieved or not retrieved, compared to unrelated primes ($\beta = 0.26$, $z=2.94$, $p = .003$). Thus, when semantic primes were retrieved, they produced facilitation compared to unrelated primes, $p = .03$, and when semantic primes were *not* retrieved, they produced inhibition compared to unrelated primes, $p < .001$.

6.2.3 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 accuracy using generalized mixed effect models (with a logit link). The same screening procedures as in Experiment 3 were followed,

which excluded 4.6% of the total trials. Table 1 displays the fixed effects estimates from the final model. Importantly, we observed a significant two-way interaction between standardized RTs and prime condition. As shown in Figure 8 (Panel 2), the relationship between response time to identify the prime and target retrieval accuracy was magnified and monotonically decreasing in the semantic prime condition (β = -0.11, z =-2.53, p = .01), compared to the unrelated prime condition. This effect indicated that faster (slower) identification of the semantic prime led to higher (lower) target retrieval accuracy, compared to unrelated primes.

6.2.4 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, using linear mixed effect models. Table 3 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 (F = 6.29 , p = .01). As shown in Figure 9 (Panel 2), the interaction mainly indicated that the slope for the semantic condition was steeper and linearly increased, compared to the unrelated condition (β = 0.04, t =2.51, p = .01), suggesting that faster (slower) identification of the semantic primes predicted faster (slower) identification of the target, compared to unrelated primes.

6.3 Discussion

Experiment 4 replicated the results from Experiment 3, and further clarified the specific inhibitory influence of semantic prime retrieval on subsequent target retrieval processes. These results provide clear evidence for the hypothesis that the memory of a preceding unsuccessful retrieval event from the same semantic space as the target inhibits current target retrieval. However, when retrieval from the same semantic space is successful, it facilitates subsequent

retrieval for the related target word. This suggests that while on one hand, activation from the prime spreads to the target word when the prime is correctly retrieved, on the other hand, when this prime retrieval is unsuccessful, not only is the prime representation inhibited, but in fact the failure to access the prime's lexical representation from its semantic space has inhibitory consequences on subsequent target retrieval from the same semantic space.

An important question that still remains unanswered is whether this cost of retrieval failure is specific to retrieval attempts from the same space in semantic memory, or can one extend this phenomenon to other types of retrieval situations. In Experiment 5, we explored this question within an episodic memory retrieval task.

Chapter 7: Experiment 5

In Experiment 5, we employed an episodic cued-recall task to investigate the influence of an episodic retrieval event on subsequent retrieval from semantic memory. After studying a list of word pairs (e.g., BEAR-ALIVE), participants first attempted to retrieve the item (e.g., ALIVE) when presented with a cue (e.g., BEAR). Immediately following attempted retrieval of the item, they attempted to retrieve the target word from a low-frequency word definition. Preceding word pairs were unrelated to the target word. We predicted that if target inhibition only occurs for words that are semantically related to the subsequent target (as demonstrated in Experiments 3 and 4), then successful or unsuccessful retrieval of the item from its cue should not influence subsequent target retrieval.

7.1 Method

7.1.1 Participants

Twenty-six young adults (M_{age} = 19.7 years, *SD* = 1.3) were recruited from undergraduate courses at Washington University and received course credit for participation. Mean score on the Shipley Vocabulary Test for younger adults was 31.03 (*SD* = 3.38), and mean years of education was 13.92 (*SD* = 1.58). Twenty-five participants were native English speakers, and the performance of the only non-native English speaker did not differ from the average and hence their data was not excluded from the final sample.

7.1.2 Materials

The stimuli consisted of 48 target words, and each target word was matched with one definition, and one cue-item word pair. The target words and definitions were chosen from the

stimuli used in Experiment 4. The cue-item word pairs were selected from stimuli used by Maddox et al. (under review) for their episodic cued-recall task, and we ensured that the chosen word pairs were semantically and phonologically unrelated to the target pair they were matched with in the current experiment.

7.1.3 Design and Procedure

Participants first studied a list of forty-eight word pairs (e.g., BEAR-ALIVE), each presented at the center of the screen for 5 seconds. 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. In the retrieval phase, each experimental trial consisted of six components: cue presentation, item retrieval, item demasking, target definition, target response, state declaration and target demasking (see Figure 4). First, the cue and a series of question marks were presented at the center of the screen (e.g., BEAR - ???????), and participants attempted to recall the item (e.g., ALIVE) or pressed the spacebar when they could not recall the item. Immediately after pressing the spacebar, the item was slowly revealed on the screen through the progressive demasking procedure. The demasking procedure continued until the item was fully revealed for 500 ms, or until the item was identified by the participants by pressing the spacebar. Participants then typed in the correct item on the next screen. Immediately after typing in the item and pressing spacebar, the target definition was presented for 10 seconds 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.

7.2 Results

7.2.1 Effect of Item Retrieval on Target Accuracy

Participants first retrieved an item from its cue, and then attempted to retrieve the target from its definition. Figure 7 (Panel 3) displays the mean target retrieval accuracy as a function of whether the item was retrieved or not retrieved. We conducted linear mixed effects analyses to examine the influence of episodic item retrieval success on subsequent target retrieval accuracy, and included overall item accuracy as a covariate in these analyses, to account for differences in retrieval accuracy for the items. Table 2 displays the fixed effects estimates from the final model. Importantly, we observed no reliable effect of episodic item retrieval success on subsequent target retrieval performance ($F < 1$).

7.2.2 Effect of Item Demasking on Target Accuracy

We examined the influence of response latencies to identify the item through the demasking procedure on subsequent target retrieval accuracy using generalized mixed effect models (with a logit link). The same screening procedures as in Experiment 4 were followed, which excluded 1.1% of the total trials. Table 1 displays the fixed effects estimates from the final model. As shown in Figure 8 (Panel 3), we observed no effect of response time to identify the item on subsequent target retrieval accuracy ($F = 1.6$, $p = .20$) .

7.2.3 Effect of Item Demasking on Target Demasking

We also examined the influence of RTs to identify the item through the demasking procedure on RTs to identify the target through demasking, using linear mixed effect models. Table 3 displays the fixed effects estimates from the final model. We observed a main effect of RT to identify the prime on RT to identify the target ($F = 6.21$, $p = .01$). As shown in Figure 9

(Panel 3), this effect indicated that faster response latencies to identify the episodic target resulted in faster responses to identify the target.

7.3 Discussion

The results from Experiment 5 suggest that retrieval from episodic memory does not influence subsequent retrieval of a target word from a low-frequency word definition. Item retrieval performance in the cued recall task did not predict target accuracy, and response times to identify the item via demasking also showed no influence on subsequent retrieval accuracy. These results are in contrast with results from Experiments 3 and 4, where we observed an effect of prime retrieval on subsequent retrieval accuracy for the target, when primes were retrieved from the same semantic space as the target. These results indicate that prime retrieval success influences subsequent performance only when retrieval is from the same semantic space as the target, and does not extend to retrieval from episodic memory.

Chapter 8: General Discussion

The present set of experiments investigated the influence of active and passive production of related information on subsequent lexical retrieval of a target word from a low-frequency word definition. Our results provide clear evidence that attempts to retrieve words from semantic memory indeed influence subsequent retrieval of the target word. We now discuss specific findings from the current study and their theoretical implications.

8.1 Effect of Prime Presentation vs. Retrieval

The results from Experiment 1 indicate that passive presentation of a phonological prime facilitates subsequent retrieval of the target word, consistent with previous work (Kumar et al., under review; Meyer & Bock, 1992). Importantly, the present set of experiments also examined the influence of active processing and retrieval of prime information on lexical retrieval. Our results suggest that when the prime is actively processed, through progressive demasking (e.g., Experiment 2) or active retrieval (e.g., Experiments 3, 4 and 5), no facilitation from phonological primes is observed in subsequent target retrieval. Specifically, when participants identified the prime through progressive demasking in Experiment 2, no phonological facilitation in target retrieval was observed. In Experiment 3, we found that 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 to phonological and unrelated primes. These findings were further replicated in Experiment 4, where retrieval of semantic primes facilitated

target retrieval, and failure to retrieve semantic primes inhibited target retrieval, compared to unrelated primes. These results provide important data regarding the influence of active retrieval processes for the prime, on subsequent lexical retrieval. As discussed previously, to our knowledge, Cross and Burke (2004) and Oberle and James (2013) are the only two studies that have used a similar paradigm to examine the influence of actively producing the prime word on subsequent retrieval of the target word from a definition. We now discuss how the present results add to these studies.

Cross and Burke (2004) examined the influence of actively producing semantic and unrelated primes on TOT occurrence. They found that producing the name of a semantically related character (e.g., Eliza Doolittle) did not influence TOT occurrence for the name of the actor who played that character (e.g., Audrey Hepburn), compared to producing an unrelated character (e.g., Sundance Kid). Importantly, as discussed earlier, Cross and Burke (2004) excluded trials on which the prime word was not produced, so the effect of *retrieving* the prime was unclear in this study. Our results suggest that the attempt to produce the prime word indeed influences the subsequent retrieval process, such that successful production of semantically related words facilitates retrieval, whereas unsuccessful production hinders target retrieval. Facilitation from successful retrieval of semantic primes, as indicated by the present set of experiments, would also explain the higher accuracy rates for the target that Cross and Burke (2004) observed after producing semantic primes, compared to unrelated primes. In a similar study, Oberle and James (2013) also examined the effect of producing "both" and unrelated words that shared the first name with the target word, on subsequent retrieval. They reported greater target retrieval accuracy following successful production of "both" primes, compared to unrelated primes. However, again, Oberle and James (2013) did not report the specific effect of

producing or *failing to produce* the "both" and unrelated primes on target retrieval. Higher retrieval accuracy following production of semantically related words (i.e., the "both" primes) is again consistent with our findings of facilitation from successful production of semantically related words. Additionally, our results also provide predictions for situations in which retrieval is *not* successful and suggest that failure to produce semantically related words indeed inhibits subsequent target retrieval.

8.2 Facilitation from Semantic Retrieval Success

Results from Experiment 3 and 4 suggest that when semantically related primes are successfully retrieved, they produce facilitation in subsequent target retrieval. Semantic prime facilitation is a common finding in lexical decision tasks (Meyer, Schvaneveldt, & Ruddy, 1975; Neely, 1976), where processing a word (e.g., doctor) facilitates processing of a related word (e.g., nurse). Consistent with the spreading activation account, when a prime word is processed, other related words are automatically activated in the memory network, which leads to faster lexical decision times for the semantically related target word. This facilitation is observed when the prime is passively processed (Kirsner & Craik, 1971), actively attended to (Meyer et al., 1975) or actively ignored (Warren, 1977). However, none of these studies have examined the influence of actively *retrieving* semantically related information on subsequent *retrieval* processes for the target word. There is some evidence from picture naming studies that suggests that production of multiple items from the same semantic category in fact produces a cumulative semantic interference effect in response latencies for each successive item (Brown, 1981; Howard et al., 2006). In the current set of experiments, participants retrieved a single prime word from a definition and we observed *facilitation* in target retrieval if they successfully retrieved an immediately preceding semantically related prime. Importantly, we did not observe this

facilitation when the semantically related primes were *not* retrieved, suggesting that the act of successful *production* in and of itself activated related concepts within the same semantic space. When the semantically similar definition for the target word was presented subsequently, the retrieval process for the target word benefited from this activation. Importantly, we did not observe an effect when phonological and unrelated primes were successfully retrieved.

Dell (1986) posited a spreading activation account for retrieval in sentence production that can potentially account for the present findings, albeit in a post-hoc manner. Dell suggested that when a word is selected for production, it is "tagged" as such and it activates other semantically related neighbors. After being tagged, the activation for an already selected node gradually dissipates. In the current study, it is possible that when the prime word was successfully retrieved, the production process tagged the prime word, and activated its semantically related neighbors. Given that participants were instructed that the prime word was not the answer to the target definition, when the definition for the target was presented, the next most activated word in the network, which was possibly the target, was selected for production. Since this process of spreading activation is driven by semantics, this facilitation from prime retrieval was not observed for phonological and unrelated primes. Thus, consistent with Dell's account, when semantically related primes are successfully produced, they facilitated target retrieval, compared to semantically unrelated primes.

8.2 Inhibition from Semantic Retrieval Failure

In the present set of studies, we also observed inhibition in target retrieval when retrieval of semantically related words (i.e., semantic and "both" primes) was unsuccessful, compared to phonological and unrelated primes. Thus, it appears that failure to retrieve a word from a particular semantic space proactively interfered with the attempt to retrieve another word from

the same semantic space. In the paired-associate learning literature, proactive interference is said to occur when memory for an initial word pair (e.g., A-B) interferes with the memory for an upcoming word pair (e.g., A-D). Wahlheim and Jacoby (2013) proposed a memory-for-change account that is particularly relevant to the current set of results. In their study, participants studied two lists of word pairs, with word pairs that were either repeated across lists (e.g., A–B, A–B), were paired with same cue but a changed response (e.g., A–B, A–D) in the second list, or were completely different control pairs (e.g., A–B, C–D). They found that when participants could not detect or recollect the change, proactive interference was observed for the A-B, A-D pairs, but when change was detected and recollected, proactive facilitation was observed.

In the current set of experiments, the definitions for the prime word (e.g., A) and target word (e.g., A') intentionally used similar wording to enable access to the same semantic space. Thus, the semantic and "both" prime conditions (e.g., A-B, A'-D) appear to resemble the A-B, A-D condition in Wahlheim and Jacoby (2013), and the phonological and unrelated conditions resemble the A-B, C-D condition. Now consider the situation when the prime word was not retrieved. After the failure to retrieve the prime (e.g., B) from its definition (e.g., A - ???), participants viewed a semantically similar definition (e.g., A' - ???) for the target word, and were quite possibly *reminded* of the immediately preceding event (e.g., A-???) due to the similar cues (e.g., A and A'). However, when the prime was *not* retrieved, it is possible that this reminding process produced no concrete recollection of the prime word itself but instead reminded them of the *failure* to retrieve, which in turn interfered with the current retrieval process for the target word. This result is consistent with the Wahlheim and Jacoby (2013) findings when change was *not* recollected in the paired associate recall paradigm, i.e., participants experienced proactive interference when the prime word was not retrieved/recollected. In contrast, when the prime was

indeed retrieved, the presentation of the target definition possibly reminded participants of the preceding successful retrieval event. Given that the prime word had been "tagged" when it was retrieved (Dell, 1986), and participants knew that answers to definitions would not be repeated, the next most activated word (i.e., the target) in the semantic space was thus retrieved. Thus, the reminding process produced facilitation for the target when the prime was recollected, and interference when it was not recollected. Hence, to the extent that the prime word and target word are accessed from the same semantic space, failure to retrieve the prime produces inhibition in target retrieval. An important next step in this line of research would be to investigate the magnitude and duration of this inhibitory effect of producing semantically related words on subsequent target retrieval.

8.3 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 5, 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 the item from episodic memory did not influence subsequent target retrieval. This experiment provides important information about the nature of retrieval processes that impede subsequent retrieval. To the extent that episodic and semantic memory represent different memory systems, it appears that inhibition occurs only when words are retrieved from the same semantic space as the subsequent target word. It is important to note,

however, that all the studied word pairs in Experiment 5 were unrelated to the target word, and it may be the case that if semantically related words are retrieved from episodic memory, similar levels of inhibition would be observed due to semantic interference, as in Experiments 3 and 4. However, the memory-for-change account (Wahlheim & Jacoby, 2013) would predict that since the prime word (e.g., B) is retrieved from an *episodic* cue (e.g., A-???), and the subsequent target (e.g., D) is retrieved from a different *semantic* cue (e.g., C-???), no interference should be observed in target retrieval, as no "reminding" process is initiated for the episodic cue when the semantic cue appears. Further work is needed to examine whether retrieval of semantically related words from episodic memory impacts subsequent target retrieval from a definition.

8.4 Conclusion

The present set of experiments provide 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 show that the inhibitory effect is localized to retrieval of information from the same semantic space, and does not extend to episodic retrieval processes. These findings are consistent with a memory-for-change 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.

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Footnotes

[1] 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 to the unrelated ($p = .001$) and "both" ($p = .09$) prime conditions. In Experiment 2, there was no effect of prime condition for "know", $F_1(3, 105) = 1.94$, $p = .13$, "don't know", , $F_1(3, 105) = 1.03$, $p = .38$, "other", $F_1(3, 105) = 0.39$, $p = .76$, and "TOT" responses, $F_1(3, 105) = 0.49$, $p = .69$. In Experiment 3, again, 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 4, 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, $F_1(1, 56) = 1.14$, $p = .29$. Finally, in Experiment 5, since all primes were unrelated, we could not examine the percentage of retrieval states as a function of prime condition.

[2] 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, i.e., 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 to 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., under review, for a detailed discussion).

[3] In Experiment 3, 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.

Appendix

Complete list of Stimuli for Experiments 1, 2 and 3

Target	Target Definition	Phon. Prime	Phon. Definition	Semantic Prime	Semantic Definition	Both Prime	Both Definition
abdicate	To formally renounce a throne	abdomen	The region between the chest and pelvis; the stomach or belly	resign	To leave a job, post, or position voluntarily	abandon	to give up completely, desert or leave behind
aborigine	A dark-skinned member of a race living in Australia when Europeans arrived	abortion	A deliberate termination of a pregnancy	native	Belonging to something, by birth, for example to a country or language	abroad	Not within your own country, for example travelling or studying in an international place
abstain	To refrain deliberately and often with an effort	absolve	Grant remission of a sin to, let off the hook	refuse	Show unwillingness towards, not accept something	avoid	Stay clear from; keep out of the way of someone or something
advocate	To plead the cause of another; to support	adverb	A word or phrase that modifies an adjective	condone	To accept and allow wrong behavior to continue	advance	Move forward, increase or raise

	or promote						
Alcott	Last name of author of Little Women	alchemy	A pseudo-scientific discipline before chemistry in medieval times	Bronte	Last name of British author of Wuthering Heights	Austen	Last name of English author of Pride and Prejudice
anachronism	A thing belonging to a period other than that in which it exists, i.e. the past or future	anaerobic	Term for organisms that do not use oxygen	misplace	To lose something for a short time by forgetting where you put it	abnormality	something that deviates from what is usual or expected
anagram	Word made by changing the order of letters in another word; e.g. plum, lump	anaconda	large snake found in tropical South America	puzzle	an activity of putting pieces together to make a picture	acronym	a word formed from the first letters of each word in a phrase
Andes	South America's largest mountain range	android	A robot with a human appearance; also an operating system for smart phones	Himalayas	Mountains on the border between India and Tibet and in Kashmir, Nepal and	Alps	Highest most extensive mountain range in Europe

					Bhutan		
Aurora	Real name of princess nicknamed Sleeping Beauty	Australia	Both a country and continent nicknamed Land Down Under	Cinderella	Princess with evil stepmother, who loses her glass slipper at midnight	Ariel	Real name of princess nicknamed The Little Mermaid
Bangkok	Capital of Thailand known for its vibrant night life	banister	a structure like a fence with a bar on top that is built along side of stairs	Shanghai	China's biggest city on the central coast and global financial hub, famous for the Bund, a waterfront promenade	Beijing	The capital of China and the world's thirdmost populous city
barter	To trade by exchanging goods for other goods instead of money	bartender	A person who mixes and serves drinks	tariff	A tax on goods coming into or leaving a country	bargain	To negotiate the terms and conditions of a transaction
Beckham	Last name of British soccer player known for his left foot	Beckett	Last name of Irish absurdist playwright, known for Waiting for Godot	Messi	Last name of Argentine soccer player who plays for Barcelona	Buckingham	Name of palace in London visited by many tourists

binomial	A mathematical expression consisting of two terms	biannual	happening twice a year	equation	a mathematical statement in which two expressions are equal	bilateral	having or relating to two sides; affecting both sides
carcass	The complete remains of a dead animal	canvas	a strong, rough white cloth mounted on easels for painting	skeleton	the structure of bones that supports the body of a person or animal	corpse	the dead body of a human being
Carroll	Last name of author of Alice in Wonderland	caravan	Historically the name for a group of people, especially traders or pilgrims, traveling together across a desert	Rowling	Last name of author of Harry Potter series	Christie	Last name of Prolific English writer of detective stories
chameleon	A small lizard with skin that changes color to match its surroundings	camel	A desert animal with humps on its back	gecko	a small tropical lizard typically seen on walls	camouflage	a way of hiding something by painting it or covering it with leaves
Churchill	Last name of British	Charles	Last name of the Prince of	Thatcher	Last name of first female	Chamberlain	Last name of British Prime Minister who

	Prime Minister during World War II		Wales and Queen Elizabeth II's eldest son		British Prime Minister		signed the Munich Agreement during World War II
Clemens	Original last name of Mark Twain	commence	to begin or start something, typically a speech or address	Sawyer	last name of a character in Twain's books	Conrad	Last name of American author of Heart of Darkness
congruent	Identical in form; coinciding exactly when superimposed	Congress	U.S. body of government split into the House and the Senate	parallel	two lines that never intersect	compatible	Able to exist together without trouble or conflict, typically used for partners in a relationship
Connery	Last name of first actor to portray the character of James Bond	Cobain	Last name of American singer-songwriter; lead singer of rock band Nirvana	Brosnan	Last name of Irish actor who played James Bond in 4 films	Cruise	Last name of American actor in the movie Top Gun
covenant	A promise between God and humans	convenient	involving little trouble or effort, easy	protocol	a system of rules that explain procedures to be followed in formal situations	contract	a written or spoken agreement that is intended to be enforceable by law
Dante	First name of Italian poet	dawn	the first appearance of light in the sky	Homer	Greek epic poet known for the Iliad	Devil	Another name for Lucifer or Satan

	known for writing "The Inferno"		before sunrise		and the Odyssey		
default	failure to fulfill an obligation, especially to repay a loan	difficult	To be hard and not easy; requiring great effort	surrender	cease resistance to an enemy and submit to their authority	defect	a shortcoming, imperfection, or flaw
deplete	To use up or exhaust the supply or resources of something	depth	the third dimension after width and height	consume	to eat, drink or ingest food or drink	delete	to remove, cut or eliminate, especially in writing
diverge	To extend in separate directions from a common point	digest	to break down food in the stomach	split	Separate into parts or portions	differ	To not have the same traits or characteristics
eccentric	to be unconventional, slightly quirky and weird	ecstatic	Feeling great rapture or delight; euphoric	bizarre	Surprisingly and grossly unusual or weird	erratic	Liable to sudden unpredictable change
exorcism	The act or ridding an evil spirit from a	exercise	Physical activity to improve health and	possession	The controlling of a person by	exile	The state of being banished from one's native country

	person or place		fitness		the devil		
Faraday	Last name of English scientist most known for his work on electromagnetic induction; also a unit of charge	Fahrenheit	A temperature scale other than the Celsius	Newton	English physicist known for developing the three laws of motion	Feynman	American theoretical physicist known for his lectures, and work on quantum mechanics
foliage	The leafy parts of a plant or tree, collectively	folding	To bend something over itself, so that one part covers another	vegetation	The collective noun for plants, especially in a particular area or habitat	forest	A thick growth of trees and bushes that covers a large area
Garland	Last name of singer and actress who played Dorothy in Wizard of Oz	garnish	To put something on (food) as a decoration	Hepburn	Last name of iconic actress in Breakfast at Tiffany's	Garner	Last name of American actress recently divorced from Ben Affleck
gosling	The noun for a young goose	goblin	a mischievous, ugly dwarflike creature of	puppy	the noun for a young dog	gobble	The sound a turkey makes

			folklore				
Hancock	Last name of first man to sign Declaration of Independence	handle	a part of something designed to be held	Jefferson	American president and author of the Declaration of Independence	Hoover	last name of the US President during the Great Depression
Helsinki	Capital of Finland	handkerchief	A square piece of cloth used for wiping the nose, or as a costume accessory	Budapest	capital of Hungary, also a song by George Ezra	Holland	another name for The Netherlands
hoist	To raise something to a height, for example a flag	holly	A Christmas shrub having prickly green leaves and red berries	dredge	To dig or pull out something from a river or harbor	heave	To lift or pull something with effort
Hussein	Last name of Iraqi dictator responsible for the Gulf War, deposed after US-led invasion of Iraq in 2003	hymn	A religious song or prayer usually heard in Church	Stalin	Last name of Russian dictator who succeeded Lenin as head of Communist Party	Hitler	Last name of German dictator during World War II, responsible for the Holocaust

idiosyncrasy	A distinctive characteristic of an individual, place, or thing	idiot	someone extremely stupid who behaves foolishly	uniqueness	the quality of being very special, and different from everyone else	individualism	the belief that needs of each person are more important than the needs of the whole society
interject	To say something abruptly, especially as an aside or interruption	implement	To put a plan or agreement into effect	mention	to make a short reference to something or someone	interfere	to meddle with or get in the way of some activity
Jagger	Last name of English singer-songwriter; lead singer of The Rolling Stones	Jackman	Last name of Australian actor, known for playing Wolverine in X-Men	Tyler	Last name of American singer-songwriter; lead singer of Aerosmith	Jackson	Last name of American singer, called the "King of Pop", known for Thriller and Beat It
libel	The illegal act of writing untrue things about someone; slander	label	a word or phrase that describes or identifies something or someone	perjury	the crime of lying in a court of law	litigate	to make something the subject of a law suit; sue
loquacious	Tending to talk a great deal;	locket	a small case that is usually worn on a	verbose	using more words than are	laconic	a person who uses very few words

	chatty		chain around a person's neck		needed		
Mandela	Last name of South African imprisoned for 27 years before becoming president	Mandarin	the official language in China	Gandhi	Last name of preeminent leader of the independence movement in British-ruled India	Mendel	last name of an Austrian botanist known for his work in genetics
meager	Lacking in quantity or quality, as in richness or strength	medium	half way between high and low levels	sparse	thinly dispersed or scattered	minimum	the lowest value in a set of numbers
Mercury	Last name of British singer-songwriter; lead singer of the band Queen	murder	The act of premeditated killing of a person by another person	Bowie	Last name of British singer-songwriter, most known for the song Space Oddity	McCartney	Last name of British rock star, who with John Lennon, wrote songs for the Beatles
Miller	Last name of the author of The Death of a	military	The ground armed forces or army of a country	Shakespeare	Last name of British playwright who wrote Romeo and Juliet	Melville	Last name of the author of Moby Dick

	Salesman						
mince	To cut or chop food into very small pieces, especially meat	milk	a dairy product that cows produce	grate	to rub cheese against a sharp surface to reduce it to shreds	mash	to crush something to make it uniformly soft, for example a potato
monotony	Tedious sameness of life, or sound	monopoly	a board game of property and financial dealings using fake money	invariable	quality of not changing, being static and constant	monogamy	the practice of being married to only one person at a time
Monroe	Last name of American actress, famous for her picture in a flying white dress	Monarch	The name of an American butterfly with orange wings with black patterns	Houston	Last name of American singer most known for her song, I Will Always Love You	Madonna	First name of American pop singer, known for the song Like a Virgin
Nairobi	Capital of Kenya, often the starting location for safaris	narrate	to tell a story, to give a spoken or written account	Madagascar	An island in Africa known for wildlife, also an animated movie	Nile	North flowing river in Africa
nullify	Make legally void, or cancel out	numbness	unable to feel anything in a particular part of the	invalidate	to show or prove something to be false or	neutralize	to balance something with its opposite, for example in acid-base

			body due to cold or injury		incorrect		chemistry
Nuremberg	German city that was the site of trials of Nazi war criminals	neural	Of or relating to the nervous system	Berlin	Capital of Germany, known for its famous wall	Nazis	Collective name for German soldiers under Hitler's reign during the Holocaust
obscure	Not discovered or known about, hidden	obstruct	to block or hinder something so that things cannot cross through easily	secretive	someone who keeps feelings or information concealed from someone else	opaque	not transparent, or able to be seen through
omnipotent	Having unlimited power; able to do anything, typical of a God	omnivore	an animal or person that eats both plants and animals	unlimited	not restricted in terms of number, quantity or extent	omniscient	knowing everything, having complete knowledge
ostentatious	Characterized by vulgar or pretentious display, designed to impress	osteoporosis	A condition in which the bones become weak and break easily	flashy	bright, showy or fancy in a way that is meant to attract attention	obvious	easily perceived or understood, apparent
Oswald	Last name of John F. Kennedy'	osmosis	The process that causes a liquid	Booth	last name of the man who assassinat	Osama	First name of terrorist mastermind behind 9/11 assassinated in

	s assassin		(especially water) to pass through the wall of a living cell		ed Lincoln		2011
Ottawa	Capital of Canada	otter	Small playful brown fury animal that swims in fresh water streams	Toronto	Capital of Ontario in Canada, home to the iconic CN tower	Ontario	The most populated territory in Canada, bordering the Great Lakes
panacea	A medicine which can cure any illness	panda	large black-and-white animal that lives in China and eats bamboo	remedy	a medicine or treatment for a disease, usually herbal	placebo	a pill given to a patient that does not have any effect
paragon	A person or thing characterized as a perfect example of a particular quality	parachute	equipment allowing people to fall safely after jumping from an aircraft	ideal	perfect, exactly right for a particular purpose, situation, or person	paradigm	a typical example of something, an approach for investigating a topic
polygamy	The practice of having more than one spouse at the same	polygon	a flat shape having at least three straight sides and angles, typically	marriage	the legally recognized union of two partners in a relationship, for	promiscuous	having many sexual partners at the same time

	time		more than 5		example a man and woman		
precocious	a quality of developing advanced abilities, typically at a young age	precarious	dangerously likely to fall or collapse	advanced	being ahead of others in progress or ideas	prodigy	a child genius having exceptional talent in a specific field
prophecy	A prediction of what will happen in the future, often in Greek mythology	professor	a teacher especially of the highest rank at a college or university	forecast	prediction of the future events, for example the weather	prognosis	a prediction about the likely course of a disease
Seoul	Capital of South Korea, known for advanced technology and Buddhist temples	sofa	another name for a plush couch, typically in the living room	Tokyo	Capital of Japan, also its most populous city	Saigon	other name of Ho Chi Minh city in Vietnam and famous Broadway musical
Shaw	Last name of Irish author well known for	ship	a large boat used for traveling long distances over the	Wilde	Last name of an Irish author of The Picture of Dorian	Shelley	Last name of British author of Frankenstein

	Pygmalion		sea		Gray		
Sicily	Italian island known for its mafia families, also the setting for The Godfather	sizzle	to make a hissing sound like the sound water makes when it hits hot metal	Corsica	Island to the south of France in the Mediterranean Sea	Switzerland	country in Europe known for its cheese and knives
Skywalker	Last name of Darth Vader's son in Star Wars	skyscraper	A very tall building in a city, for example in New York City	Leia	First name of Star Wars princess with a distinctive hairstyle	Solo	Last name of Chewbacca's copilot in Star Wars
surrogate	A woman who bears a child on behalf of another woman	survivor	A reality TV show where strangers are marooned in an isolated location	midwife	A woman skilled in aiding the delivery of babies	substitute	Someone who takes the place of another person, for example in a sport
Thoreau	Last name of American philosopher known for writing Walden	thorny	having a lot of sharp impeding spikes, for example in a rose	Emerson	Last name of American essayist and poet, who led the transcendentalist movement; also called	Tolstoy	Last name of Russian author of War and Peace

					Waldo		
tic	A habitual spastic motion of particular muscles, a symptom of Tourette syndrome	tip	the usually pointed end of something, for example an iceberg	jerk	a sudden fast movement in the body	twitch	to make a slight movement that is not deliberate, especially in the face
tsunami	The name for a tidal wave, also a natural calamity that struck Japan	turmeric	A common Indian yellow spice from the ginger family	hurricane	A destructive storm with very strong winds typically in North America	typhoon	A destructive storm with very strong winds typically around China or Japan
Turing	Last name of British mathematician who broke German codes during World War II	Turner	Last name of American singer most known for the song, What's Love Got to Do with It	Hawking	Last name of British theoretical physicist, author of A Brief History of Time	Tesla	Last name of engineer-inventor who discovered the principle of alternating current
Watson	Last name of Sherlock Holmes' assistant and friend	Watt	the unit of electrical power that something uses, for example a microwave	Doyle	Last name of British author of Sherlock Holmes	Weasley	Last name of Harry Potter's male ginger best friend

Wayne	Last name of Batman's secret identity	wake	the wave that spreads behind a boat as it moves forward	Kent	last name of Superman's secret identity	Walker	last name of Hellcat's secret identity
Yellowstone	National park in Wyoming atop a volcanic hot spot	Yesterday	24-hour period before the current 24 hours, also the name of a Beatle's song	Glacier	National park in Montana's Rocky Mountains	Yosemite	National park in California's Sierra Nevada mountains