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Conscious and Unconscious Lexical Retrieval Blocking in Younger and Older Adults

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The effects of orthographically overlapping prime words in a word fragment completion task (modified from S. M. Smith & D. R. Tindell, 1997) were studied in younger and older adults. Participants studied words and then completed word fragments corresponding to those words. Fragments were preceded by a blocking, unrelated, or neutral prime. In Experiment 1, all participants were slower and less likely to complete the word fragments correctly in the blocking prime condition. Older adults also were more likely to use the blocking prime to incorrectly complete the word fragment compared with younger adults, even when warned against doing so (Experiment 2). Experiment 3 used a masked priming paradigm in younger adults to examine whether conscious processing of the prime word was necessary to produce blocking effects. Reliable blocking effects were obtained, including an intrusion rate similar to that observed in older adults in the first two experiments. These results suggest that certain aspects of word-finding failures in normal aging may be related to the reduced ability to control the activation of a lexical competitor when attempting to retrieve a target word.

Accurately retrieving words from memory is a constant activity in conversation. Speakers use syntactic, phonological, and semantic cues from the context of a discourse to produce appropriate and fluent responses. Although lexical retrieval is normally effortless, it sometimes fails. Such lexical retrieval failures are often accompanied by an unsettling feeling of knowing, as well as access to partial cues about the target word, such as its initial sound, syllable structure, or related words, as if one is aware of the target word yet cannot produce it (e.g., A. S. Brown, 1991; R. Brown & McNeill, 1966). Although lexical retrieval difficulties appear to be universal, the experience grows increasingly common in older adults (Bowles & Poon, 1985; A. S. Brown, 1991; Burke, MacKay, Worthley, & Wade, 1991; Rastle & Burke, 1996), such that one of the most common memory complaints of older adults involves such word-finding failures (Sunderland, Watts, Baddeley, & Harris, 1986).

Although it seems clear that an individual often has partial information about a target word during lexical retrieval failure (e.g., A. S. Brown, 1991; R. Brown & McNeill, 1966), there is an ongoing debate about how the activation of such partial information modulates retrieval of a target item in younger and older adults. For example, attempts to study lexical retrieval difficulties in the laboratory by presenting partial cues, such as a semantically related word or another word from the same word list as the target, have shown that partial cuing can both facilitate and impair target word retrieval. This difference in results has led to different accounts of the role of partial cues in lexical retrieval. Unfortunately, each of these accounts relies on different experimental methods, designs, and task demands. Ultimately, differences across these methods may lie in the varying need to control activation of irrelevant but partially activated information in a given task context. The need to control such irrelevant activation and retrieve the target word may depend on how much interference it generates (based on factors discussed in more detail below). Given recent evidence suggesting that aging may be accompanied by impairments in the ability to control activation of irrelevant information (e.g., Balota, Dolan, & Duchek, 2000; Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999; Zacks & Hasher, 1994; but see Burke, 1997; Hay & Jacoby, 1999; McDowd, 1997), lexical retrieval conditions in which the activation of similar words interferes with the ability to retrieve a target word (sometimes referred to as *lexical retrieval blocking*) may have particular significance in helping to understand age-related impairments in lexical retrieval. The current study was designed to investigate healthy older and younger adults' ability to control orthographically related prime words in a word fragment completion task.

Effects of Partial Cuing in Lexical Retrieval Difficulties

As mentioned, partial cuing of a target word has been demonstrated to facilitate lexical retrieval under some conditions and impair lexical retrieval under others. Evidence for both cases is briefly reviewed and potential factors in producing the differing results are discussed in more detail below.

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Partial Cuing Facilitates Lexical Retrieval

One paradigm in which partial cuing appears to facilitate lexical retrieval of a target word is commonly used in studies of tip-of-the-tongue (TOT) states. Researchers attempt to induce TOT states by asking participants to respond to general semantic knowledge questions or definitions of rare (low-frequency) words, which are often paired with related or unrelated lexical cues (e.g., Burke et al., 1991; Meyer & Bock, 1992; Perfect & Hanley, 1992). Researchers then measure how the cues affect the participant's ability to correctly retrieve the target word. Findings from early experiments and self-reports have suggested that the presence of related words (called *persistent alternates* or *interlopers*) can delay or block resolution of a TOT state (A. S. Brown, 1979; Burke et al., 1991; Jones, 1989; Jones & Langford, 1987). However, results of TOT studies purporting to show evidence of lexical retrieval blocking have often been qualified by methodological and design problems (e.g., for discussion of problems, see Meyer & Bock, 1992; Perfect & Hanley, 1992; Roediger, Neely, & Blaxton, 1983). The bulk of evidence from TOT research supports the notion that presenting related information ameliorates the occurrence and length of TOT states (e.g., James & Burke, 2000; Meyer & Bock, 1992; Perfect & Hanley, 1992; Rastle & Burke, 1996). For instance, Meyer and Bock (1992) found facilitation for semantically related cues presented during a TOT state. In addition, Burke and colleagues (e.g., James & Burke, 2000; Rastle & Burke 1996) have shown that prior processing of related information, such as syllables embedded in a target word, can decrease the likelihood of entering a TOT state in both younger and older adults during later retrieval of the target word.

Partial Cuing Impairs Lexical Retrieval

There is also evidence that supports the notion that activation of related information impairs retrieval of a target word within a lexical network, producing lexical retrieval blocking (e.g., Blaxton & Neely, 1983; A. S. Brown, 1981; Jones, 1989; Smith & Tindell, 1997). For example, Blaxton and Neely (1983) provided evidence of category-specific semantic inhibition when participants had to generate a target (e.g., *bass*) after retrieving multiple exemplars that were semantically related to the target (e.g., other types of fish). Additional evidence of impaired lexical retrieval from activation of related information stems from studies of part-list cuing. In part-list cuing, participants study a list of items and then are cued during retrieval with some items from the list. In this situation, participants' memory performance for noncued items is impaired, compared with when they are given no list items as cues (e.g., Nickerson, 1984; Roediger, 1974; Slamecka, 1968). Finally, Smith and Tindell (1997) have recently demonstrated robust lexical retrieval blocking within the orthographic domain using a word fragment completion task (e.g., given A _ L _ _ _ G Y for ALLERGY) in which highly related words (e.g., ANALOGY) had been previously activated during an incidental encoding task. Even when warned to ignore the incidentally encoded words, participants were less likely to complete the word fragments for which competitor words had been previously encountered.

Potential Contributing Factors to Lexical Retrieval Difficulties in Younger and Older Adults

It is clear that lexical retrieval can sometimes benefit from partial cuing of a target word, whereas at other times it can be disrupted. We believe there are three important factors relevant to the discrepancy between these experimental findings. First, the effect of related words on retrieval of a target word may be modulated by how relevant the overlap in code between competitor and target words is to task performance. If task performance relies heavily on information from a particular domain (e.g., phonological or orthographic), it could be that related nontarget information from that domain is more likely to interfere with retrieval of the target word. For example, when task performance (e.g., category exemplar generation) relies heavily on semantic characteristics, nontargets related to the targets on the basis of meaning can block target retrieval (as in Blaxton & Neely, 1983). Likewise, for tasks that rely heavily on structural information (e.g., word fragment completion), blocking may be caused by nontargets that share surface similarities with the target (as in Smith & Tindell, 1997).

Second, and on a related note, the discrepancy in the literature may be due to the differences in materials, specifically in the amount of overlap between related words and target words. For example, in a typical TOT study by Meyer and Bock (1992), subjects were primed with the phonological cue *depression* for the target word *decanter* (overlapping in the initial sound and syllable structure), and results showed that such primes facilitated retrieval of the target. In another study, James and Burke (2000) studied phonological priming and TOT states in younger and older adults. In the study, participants were asked to rate the pronunciation difficulty of 10 words, 5 of which were phonologically related to the answer to a general-knowledge question that followed the ratings. For the target word *abdicate*, for example, the phonological primes were *indigent*, *abstract*, *truncate*, *tradition*, and *locate*. James and Burke found similar phonological priming effects in younger and older adults, such that TOT states were reduced with prior processing of the phonologically related primes, though older adults still showed a higher rate of TOT states than younger adults.

Why is it that when Meyer and Bock (1992) and James and Burke (2000) prime subjects with information that overlaps with the target, they find facilitation in target retrieval, yet Smith and Tindell (1997) and others (Kinoshita & Towgood, 2001; Lustig & Hasher, 2001) find the exact opposite? The difference may lie partly in the amount of overlap between the prime and the target. Each of the phonological primes presented by James and Burke (2000) overlapped minimally with the target word, even though the words in sum overlapped with the target as a whole. The primes also did not activate one particular competitor in the lexical network; instead, their activation was distributed across several words that converged on the target. Thus, it may be that a study like James and Burke shows facilitation effects, as no single strong competitor was introduced to challenge the retrieval of the target word. On the contrary, Smith and Tindell activated only one prime, but the prime shared a high degree of orthographic overlap (an average of 50% of shared orthography) with the target. Participants performed a task in which the orthographic code was extremely relevant to successful performance and, outside the target, the blocking prime was a one of a very few viable competitors available for completing the fragment. In summary, it may be that there is a point at which overlap between a related word and a target could cease to serve as a helpful contribution toward retrieval of a target word and, instead, begin to produce interference between the related word and target word, producing blocking.

Finally, a third factor that might explain the incongruent findings is whether related information is actively retrieved and generated from the lexical network (as in Blaxton & Neely, 1983) or, as in most TOT studies, is passively presented or read by participants (e.g., Meyer & Bock, 1992; Rastle & Burke, 1996). Indeed, Blaxton and Neely (1983) found facilitation when subjects had to read multiple exemplars related to the target and, as noted, interference when multiple exemplars had to be generated from a category. A competitive retrieval event appears to be more disruptive when lexical retrieval must take place (i.e., generation), compared with passive reading.

Age-Related Changes In Lexical Retrieval

Although it is common for all individuals to experience word-finding difficulties, as noted earlier, this experience appears to grow increasingly common with age (Bowles & Poon, 1985; A. S. Brown, 1991; Burke et al., 1991; Rastle & Burke, 1996). For instance, Burke and colleagues (Burke et al., 1991; Rastle & Burke, 1996) have demonstrated through both self-report and laboratory data that older adults encounter a higher incidence of TOT states than younger adults. Increasing difficulty in retrieving words and names, however, is only a subset of a range of other age-related cognitive changes (such as impairments in long-term memory, e.g., Balota et al., 2000; Craik & Jennings, 1992; Light, 1991; Park & Schwartz, 2000). There are other cases in which older adults have increased difficulty performing tasks in which information that is incorrect but highly relevant to the target is activated (e.g., Braver et al., 2001; Marsh, Dolan, Balota, & Roediger, in press; Spieler, Balota, & Faust, 1996). If related information is activated within the lexical network, then the ability to ignore or dampen activation of irrelevant information may be key in reducing potential response competition between retrieval of related information and retrieval of the target. Such breakdowns in the ability to control irrelevant activation may be related to increasing lexical retrieval difficulties in older adults. If there are indeed conditions in which related information may actually compete with retrieval of a target word, as suggested by evidence supporting the notion of blocking in lexical retrieval (Blaxton & Neely, 1983; Smith & Tindell, 1997), then it might be expected that older adults would have particular difficulty controlling the influence of such related information (e.g., discriminating and selecting between relevant and irrelevant sources of activation for output), leading to increased lexical retrieval difficulties compared with younger adults.

Research Overview

We developed a novel priming paradigm with a word fragment completion task, based in part on stimuli used by Smith and Tindell (1997). Our task was designed to exploit factors influencing lexical retrieval in order to create "ideal" conditions for producing lexical retrieval difficulties. This was accomplished by (a) increasing the relevance of presented information related to the target by using a task (fragment completion) that required use of a specific domain or code for successful performance, namely the orthographic code; (b) exploiting potential interference in this code by incorporating a very high degree of orthographic overlap between competitor words and target words; (c) presenting orthographically overlapping lexical competitors for a duration (250 ms) that may be optimal for automatic lexical activation and nonoptimal for dampening activation of lexical competitors through attentional processes (Balota, Black, & Cheney, 1992; Neely, 1977); and (d) exploring this blocking effect in a population that has been shown to experience impairments in the ability to control activation of irrelevant information, including healthy older adults (Experiments 1 and 2) and younger adults under subthreshold priming conditions (Experiment 3).

During the first phase of the experiment, participants studied a list of low-frequency words. Immediately following this phase, participants received a word fragment completion task, with the fragments having only one unique solution—a target word that was previously studied in the first phase of the experiment. The unique twist in the present paradigm is that, just prior to the fragment, one of three prime types was presented: a blocking prime, an unrelated prime, or a neutral prime (see Table 1 for examples of conditions). The critical blocking prime word was orthographically similar to the target word (i.e., it shared the same initial letter and had an average of over 50% shared orthography with the target word), though it could never correctly complete the fragment.

With some important differences, we expected our results to be somewhat similar to those of other studies that have used materials like those designed by Smith and Tindell (1997). Previous research with these materials has principally used an implicit memory procedure with younger adults (Kinoshita & Towgood, 2001; Lustig & Hasher, 2001; Smith & Tindell, 1997). The general procedure for these studies is as follows: Participants incidentally encode targets, orthographically similar nontargets, and unrelated words (by rating them for pleasantness, for instance). After encoding the words, they are asked to complete word fragments for which they were earlier implicitly primed during list presentation with the answer (the target), an orthographically related nontarget, or an unrelated word. As described above, when subjects are implicitly primed with an orthographically overlapping nontarget blocker, the typical finding is that younger adults are less likely to correctly complete fragments and are more likely to use this

Table 1
Examples of Stimuli Used in All Experiments

Condition	Prime	Word fragment
Blocking word	ANALOGY	A_L_ _GY
Unrelated word	MAXIMUM	A_L_ _GY
Neutral	&&&&&&&	A_L_ _GY

Note. Participants solved 36 word fragments, 12 in each prime condition (blocking, unrelated, and neutral). Duration of the prime differed across experiments. In Experiments 1 and 2, both younger and older adults received the prime for a duration of 250 ms, unmasked. In Experiment 3, younger adults received a masked prime for a 17-ms duration, with a backward pattern mask for 100 ms (e.g., #@#@#@#@), which minimized visual processing of the prime.

incorrect blocker word to complete the fragment (i.e., *intrusions*). These blocking effects in completion rates and intrusions have been quite robust and difficult to completely eliminate, although they can be modulated. Smith and Tindell (1997) were able to increase or decrease blocking effects slightly depending on the instructions given to subjects about how to treat the previously encoded words. Kinoshita and Towgood (2001) were able to decrease blocking effects by dividing attention during the incidental encoding phase.

It is useful to highlight how our procedure differed from earlier studies. First, our procedure was an explicit memory task in which participants intentionally studied words and, later, actively attempted to retrieve them to complete the word fragments. We did this in part to ensure that fragment completion rates were not at floor levels. We were also interested in how the influence of explicit processes might affect blocking effects typically observed in completion rates and intrusions. Making the task rely more on explicit memory may increase awareness of the interference caused by a competing word when one is attempting to retrieve the target (somewhat like the Stroop task). Such awareness can then activate controlled processes to aid in discriminating and selecting the appropriate output (e.g., help resolve response competition).

Second, participants in our study processed both the target and the interfering word within a trial, as opposed to previous studies in which participants studied one or the other. This was meant to introduce two fairly accessible sources of competing activation in the lexical network. Moreover, in Experiments 1 and 2, the interfering word (the blocking prime) was presented at a short duration (250 ms) with a minimal interstimulus interval that was meant to ensure that the activation of the competitor was essentially automatic (Neely, 1977). This is because we were more interested in how younger and older adults were able to resolve the sources of competing activation after a competitor had been activated, rather than in their ability to control whether a competitor was activated at all. When a competitor is strongly activated along with the target in the lexical network, one would expect participants to have difficulty completing the fragment, just as one observes in participants in the implicit version of the task. However, increased awareness of the ensuing competition may then allow subjects in an explicit version of the task to control their final output more than subjects in the implicit version; for example, they should be less likely to intrude the blocker as an answer, because it is clear that it never is correct.

Finally, in addition to completion rates and intrusions, a broader range of dependent measures was used in the present study, compared with previous studies, in order to better characterize the nature of the blocking effects. In particular, we also measured response latencies and errors of omission. One might expect response latencies to show a blocking effect such that comparison of the blocker and the target—and subsequent selection of a response—would increase the time taken to complete a given fragment, compared with conditions in which an unrelated or neutral prime was presented. In older adults, one might even expect a trade-off between increased response latencies and intrusions, on the basis of evidence from age-related differences in the Stroop task. For example, Spieler et al. (1996) found that individuals with dementia of the Alzheimer's type (DAT) did not show the expected increase in Stroop interference in response latencies but did show a large effect in word intrusion rate. They suggested that the control systems of the individuals with DAT were often overtaxed in the incongruent condition, such that they were relying more on the "word" pathway and were unable to withhold the intruding word (which would have produced extra-long response latencies). Instead, these individuals simply output the interfering word as an intrusion (see Balota & Ferraro, 1996, for a similar pattern in word naming).

Omission rates, in which participants do not give an answer before the trial ends, may also be involved in a trade-off with response latencies in much the same way intrusions are. An increase in the omission rate in the blocking condition compared with the unrelated and neutral prime conditions may imply that participants are sometimes able to withhold the blocking word long enough not to use it as a fragment completion, but are still not able to retrieve the correct answer before the trial ends.

Experiment 1

The goal of the first experiment was to explore how retrieval of a target word in a word fragment completion task was affected by the activation of another lexical item immediately prior to retrieval in this novel blocking paradigm. Both younger and older adults were included so that the role of age-related changes in the ability to control the activation of a competing word in producing lexical retrieval difficulties could be investigated.

Method

Participants. Thirty-six younger adults ($M = 19.4$ years, $SD = 1.4$) were recruited from undergraduate courses at Washington University and received course credit for participating. Thirty older adults ($M = 72.2$ years, $SD = 5.8$) were recruited from the Washington University Aging and Development Subject Pool and received monetary compensation for participating. All participants were given the Shipley Vocabulary Test (Shipley, 1940). Older adults showed significantly higher vocabulary scores ($M = 19.3$, $SD = 1.1$) than younger adults ($M = 18.3$, $SD = 0.9$), $t(64) = 3.98$, $p < .01$. Older adults also had significantly more years of education ($M = 14.3$, $SD = 2.7$) than younger adults ($M = 13.3$, $SD = 1.1$), $t(64) = 2.06$, $p < .05$.

Apparatus. The stimuli were presented on a P133v computer monitor which allowed for millisecond resolution. A Gerbrands G1314T electronic voice key (Gerbrands Corp., Arlington, VA) was interfaced to the computer to detect the onset of the pronunciation. The stimuli were presented on a screen with 640 × 480-pixel resolution.

Materials. The stimuli consisted of 36 triplets, each triplet containing a target word, prime word, and word fragment (see Appendix). Twelve triplets were based on the Smith and Tindell (1997) stimuli, and 24 were constructed anew. The target word, prime word, and word fragment in each triplet were all of the same length (either 7 or 8 letters). A prime word was one of three types: blocking, unrelated, or neutral (i.e., a row of ampersands; see Table 1 for examples of conditions). A blocking prime word was defined as a word that was orthographically similar to the target word; that is, it shared the same initial letter and had several (average 4; range = 4–6) overlapping letters with the target word, though it could never correctly complete the fragment. An unrelated prime word was a word that was not orthographically similar to the target word. A neutral prime consisted of a row of ampersands equal in length to the target word. Each word fragment had a unique solution, which was the target word, and none of the primes were ever the correct answers.

All participants received the same 36 target words and the corresponding word fragments in randomized order in one testing session. The prime word presented for any given fragment in a testing session was counterbalanced across subjects, such that a participant would receive either the blocking, unrelated, or neutral prime for a given fragment. Participants received 12 trials in each of the three prime conditions.

Procedure. Participants were seated comfortably in front of a computer monitor at an approximate distance of 45–60 cm. There were two phases to the experiment: a study phase, and a word fragment completion phase. Before the experiment began, participants received practice trials for both phases of the experiment with a list of 12 triplets not used during the rest of the experiment.

In the study phase of the experiment, 36 target words were presented in uppercase letters one at a time on a computer screen. Participants were asked to read each of the words aloud and were told that the words would be used later to complete word fragments in a fragment completion task. Each trial consisted of the following sequence of events: (a) The word *READY?* was presented on the screen until the experimenter pressed a key; (b) a target word was presented on the screen; (c) the participant read the word aloud, and the computer recorded the response latency by detecting the voice onset; (d) the word remained on the screen for a total of 5 s, after which it was cleared from the screen; (e) the experimenter coded the accuracy of the participant's response (as correct, incorrect, no answer, or a voice-key error) by means of a keypress; and (f) there was an interval of 3 s before the start of the next trial.

After all 36 words were presented in the study phase of the experiment, the word fragment completion phase began. Participants were explicitly instructed to speak into the microphone in order to complete the fragment with the item presented during the study phase. Before each trial began in the word fragment completion task, the word *READY?* was presented on the screen until the experimenter pressed a key, which cleared the screen. After the screen was cleared, a prime was presented for 250 ms, unmasked, in uppercase letters, with one space between each letter. The screen was cleared for 250 ms after the prime appeared, followed by a word fragment that corresponded to one of the 36 words previously studied. The word fragment letters were presented in uppercase letters, and missing letters were replaced by an underscore, with one space between each letter or underscore (see Table 1). The participant had 5 s to respond vocally. After 5 s, the word fragment was cleared from the screen, the experimenter coded the participant's response accuracy on the keyboard, and there was a 3-s interval before the next trial began.

The accuracy of the response was coded by the experimenter in the following manner: (a) a *correct* response if the participant used the target word to complete the fragment; (b) an *intrusion* error if the participant completed the fragment with the blocking prime word; (c) an incorrect *other* response if the participant completed the fragment with an incorrect response other than the blocking prime; (d) an incorrect *omission* if the participant failed to make a response in 5 s; and (e) a *voice key* error if the voice key did not correctly register the voice onset, for example, was triggered by an extraneous sound such as a cough.

Results

For all experiments reported, response latencies less than 150 ms or 2.5 standard deviations above or below each participant's mean in each prime type condition were treated as outliers. All effects were evaluated at the $p < .05$ level unless otherwise noted. For Experiments 1 and 2, age (younger, older) was entered as a between-subjects variable and prime type (blocking, unrelated, and neutral) was entered as a within-subjects variable in a two-way analysis of variance (ANOVA).

Evidence for lexical retrieval blocking was defined by four dependent measures: (a) an increase in response latency to produce the correct solution to the fragment in the blocking prime condition relative to the unrelated and neutral prime conditions, (b) an overall lower level of accuracy in the blocking prime condition relative to the unrelated and neutral prime conditions, (c) an increased intrusion rate (i.e., usage of the blocking prime as a solution to word fragments) in the blocking prime condition relative to the unrelated and neutral prime conditions, and (d) an increase in the omission rate in the blocking prime condition relative to the unrelated and neutral prime conditions. (It should be noted that there was not a one-to-one correspondence between intrusion and omission errors, as there were a variety of other types of errors that could be made by participants.) Separate analyses were conducted on each dependent variable.

Response latencies. Figure 1a displays the mean response latencies for correct solutions to the word fragments as a function of prime type and age group. First, there was a main effect of age, and as expected, younger adults were significantly faster than older adults, $F(1, 64) = 18.24$, $MSE = 362{,}906.00$. Second, there was a main effect of prime type, $F(2, 128) = 23.47$, $MSE = 137{,}358.70$, such that mean response latencies for correct answers in the blocking prime condition were significantly slower than in either the unrelated, $t(65) = 5.84$, or neutral, $t(65) = 5.57$, prime conditions. There was no difference between the unrelated and neutral conditions, $t(65) = 0.47$. More important, both groups produced the same level of blocking, which was confirmed by the lack of an Age × Prime Type interaction ($F < 1$).

Percent correct. Figure 1b displays the percent correct word fragment completions by condition for each age group. Again,

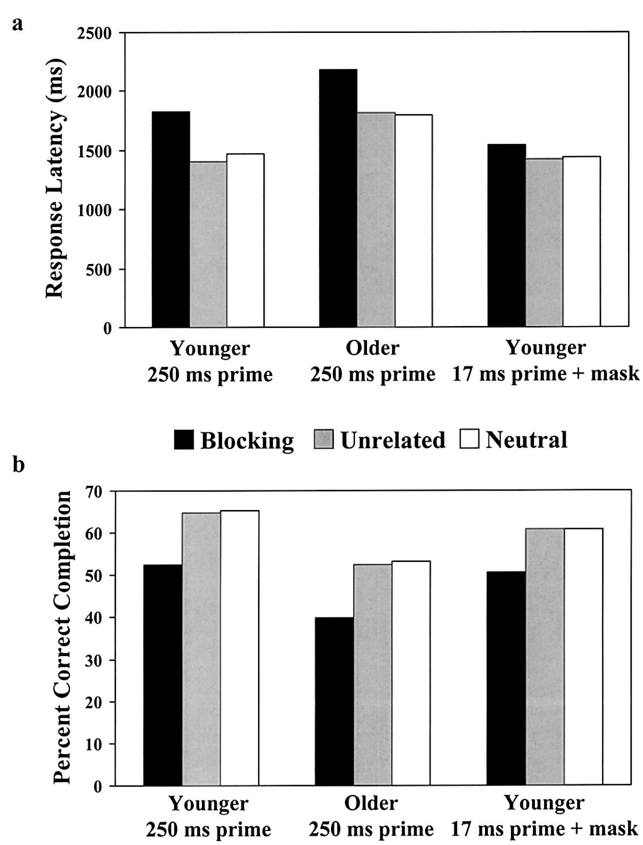

Figure 1. Mean response latencies for correct fragment completions (a) and percent correct fragment completion (b) in Experiment 1 (250-ms prime) and Experiment 3 (17-ms prime + mask).

there was a main effect of age. Younger adults had a significantly higher percentage of correct fragment completion than older adults, $F(1, 64) = 17.61$, $MSE = 420.65$. There was also a significant main effect of prime type, $F(2, 128) = 21.73$, $MSE = 169.07$. Percent correct was significantly lower in the blocking prime condition compared with the unrelated, $t(65) = 6.22$, and neutral, $t(65) = 5.37$, prime conditions, but there was no significant difference between percent correct in the unrelated prime and neutral prime conditions, $t(65) = 0.28$. Again, the Age × Prime Type interaction did not approach significance ($F < 1$).

Intrusion rates. Figure 2a displays the intrusion rate of the blocking prime as a solution for word fragments (out of a total of 12 fragments) as a function of prime type and age group. There was a main effect of age group in that older adults were significantly more likely to make intrusion errors than younger adults, $F(1, 64) = 12.05$, $MSE = 25.84$. There was also a significant main effect of prime type, $F(2, 128) = 7.90$, $MSE = 25.84$, such that there was a higher percentage of intrusions in the blocking prime condition compared with the unrelated, $t(65) = 2.71$, and neutral, $t(65) = 2.78$, prime conditions, with no significant difference between the unrelated and neutral prime conditions, $t(65) = 0.69$. More importantly, there was a significant Age × Prime Type interaction, $F(2, 128) = 4.29$, $MSE = 25.84$, such that only the older adults showed a significant increase in intrusion rates in the blocking prime condition.

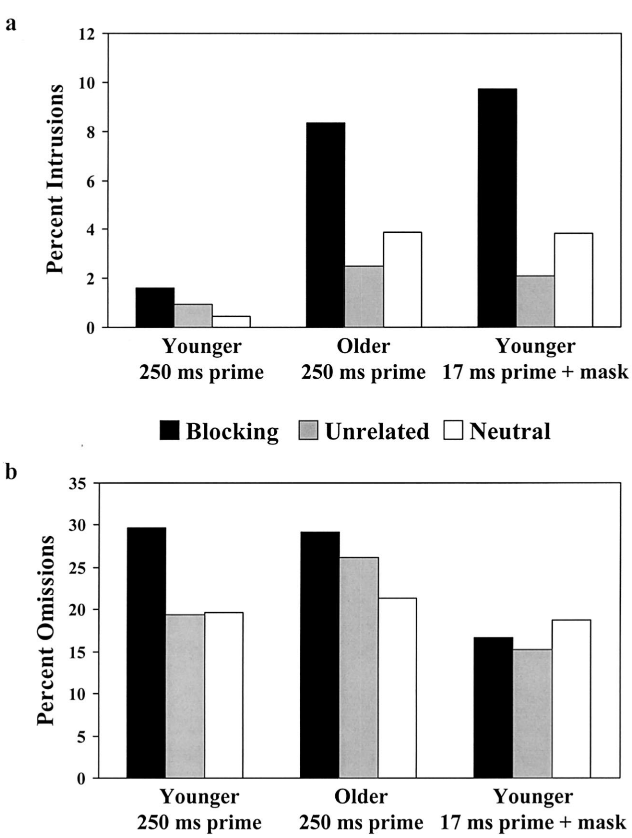

Figure 2. Mean percent intrusions, or use of the blocking prime as a word fragment solution (a), and mean percent omissions, or failures to verbally respond in the 5-s allotted time (b), in Experiment 1 (250-ms prime) and Experiment 3 (17-ms prime + mask).

Omission rates. Figure 2b displays the mean percentage of omissions or failures to respond (out of a total of 12 fragments) as a function of prime type and age group. There was no main effect of age group, $F(1, 64) = 1.06$, $MSE = 323.19$; however, there was a significant main effect of prime type, $F(2, 128) = 10.61$, $MSE = 131.12$. More omissions were made in the blocking prime condition compared with the unrelated, $t(65) = 3.20$, and the neutral, $t(65) = 4.43$, prime conditions. Again, there was no difference between unrelated and neutral prime conditions, $t(65) = 1.12$. The Age × Prime Type interaction did not reach significance, $F(2, 128) = 1.67$, $MSE = 131.12$.

Discussion

Results from Experiment 1 support the notion that lexical retrieval in both younger and older adults is significantly impaired when a highly similar word is presented for only 250 ms prior to retrieving a target word. On blocking prime trials, both younger and older adults were less likely to retrieve the target word, and even when they were able to retrieve the target, it took much longer. This effect is evidently not due to the presentation of simply any lexical item prior to retrieval of a target word, as no such interference effects were observed in the unrelated prime condition compared with the neutral prime condition. Rather, the effects in completion rate and response latency of target retrieval seem to be sensitive to the high degree of similarity between the prime and target word fragment.

Response latencies increased, and accuracy decreased, in the blocking prime condition compared with the unrelated and neutral prime conditions in both groups, with no age interaction. Instead of a disproportionate increase in these measures in older adults, there appears to be an interesting trade-off between response latencies and error rates. Younger adults were more likely than older adults to systematically make errors of omission in the blocking prime condition, and older adults were more likely to make intrusions. This pattern of data in older adults bears a resemblance to the previously discussed trade-off between response latencies and intrusions observed in early-stage Alzheimer's disease patients performing the Stroop task (Spieler et al., 1996). It may be that older adults performing this task sometimes had more difficulty than younger adults in controlling their output of the blocking prime, resulting in an increased likelihood to intrude the prime, especially the blocking condition. Younger adults also had difficulty in controlling the blocking prime in order to select the appropriate response, but they were evidently more successful in controlling their output of the prime. It could be that, given more time, the omissions, or "time-outs," observed in younger adults would have become very long response latencies in the blocking prime condition; that is, we may be observing not only a trade-off between response latencies and intrusions in older adults, but also a trade-off between response latencies and omissions in younger adults.

In summary, the major age effect we observed in Experiment 1 was a difference in the quality of errors the two age groups were likely to make. Younger adults were more likely than older adults to time out—systematically omit an answer—in the blocking prime condition. Older adults were more likely than younger adults to incorrectly complete word fragments with the blocking prime. This age effect is consistent with the hypothesis that older adults are less able to discriminate and select an appropriate response when a highly relevant competitor is also active in the lexical network; this may contribute to lexical retrieval difficulties in older adults. However, an alternative explanation is possible. It could be that older adults, compared with younger adults, were not as sensitive to realizing that the prime words could never correctly complete the word fragments or that they were more likely to forget this throughout the course of the experiment, making them more likely to use the blocking prime to complete the fragment. Along similar lines, it could also be that older adults are less likely to double-check the appropriateness of their answer before responding to the fragment.

Experiment 2

The second experiment was conducted to determine whether administering a warning against using the prime words to complete the word fragments would improve performance of both younger and older adults, particularly by reducing the intrusion rates of older adults observed in Experiment 1. Warning manipulations or repeated reminders of the task requirements have been shown to reduce age effects in cognitive performance (e.g., Multhaup, 1995; Watson, McDermott, & Balota, 2001). If the age effect in intrusion rates from Experiment 1 is simply due to older adults' degraded ability to establish or maintain the task demands (e.g., "the prime words are never the correct solutions to the word fragments"), an age difference in response bias, or a reduced likelihood of monitoring or double-checking answers before responding among older adults, then a strong and repeated reminder of the task demands presented before and during the task should reduce older adults' use of the blocking prime to complete the word fragments. If, however, the age effect is related to underlying impairments in their ability to appropriately discriminate and select the relevant source of activation in the lexical network (the target word) from the irrelevant source of activation (the blocking prime), then issuing repeated warnings may not reduce intrusion rates in older adults.

Method

Participants. Twenty-seven younger adults (M = 19.0 years, SD = 1.2) were recruited from undergraduate courses at Washington University and received course credit for participating. Thirty-three older adults (M = 74.7 years, SD = 4.6) were recruited from the Washington University Aging and Development Subject Pool and received monetary compensation for participating. Older adults again produced significantly higher Shipley vocabulary scores (M = 19.4, SD = 1.0) than younger adults (M = 18.50, SD = 0.85), $t(58)$ = 3.94. Older adults also had significantly more years of education (M = 15.2, SD = 2.8) than younger adults (M = 12.9, SD = 1.0), $t(58)$ = 4.16.

Apparatus, materials, procedure, and design. Apparatus, materials, procedure, and design were all identical to those in Experiment 1, with one exception. Before beginning the word fragment completion phase of the practice and the actual experiment, participants received an additional sheet of warning instructions detailing the relation between the target words, prime words, and word fragments. This warning explicitly instructed the participant that the prime words (referred to as the *flashed* words) could never correctly complete the word fragments and that each word fragment had only one answer, namely, the target words from the study phase of the experiment. The instructions therefore warned participants against using the blocking prime words to complete word fragments and encouraged participants to use the target words from the study phase of the experiment to complete the word fragments. In addition to these written instructions, during the word fragment completion phase of the experiment, a reminder warning was presented on the screen for 5 s at the beginning of every ninth trial which said, "Remember: the flashed words can never correctly complete the word fragments."

Results

Response latencies. Figure 3a displays the mean response latencies for correct solutions to the word fragments as a function of prime type and age group. There are three points to note about the data in Figure 3a. First, there was a main effect of age, in that younger adults were significantly faster than older adults, $F(1, 58)$ = 5.75, MSE = 417,930.00. Second, there was a main effect of prime type, $F(2, 116)$ = 16.12, MSE = 163,182.40, such that mean response latencies for correct answers in the blocking prime condition were significantly slower than in either the unrelated, $t(59)$ = 5.47, or neutral, $t(59)$ = 3.07, prime condition. Third, there was also a significant difference between mean response latencies in the unrelated prime and neutral prime conditions, $t(59)$ = 2.31, which seemed to be carried mainly by the older adults' increased response latencies in the neutral prime condition compared with

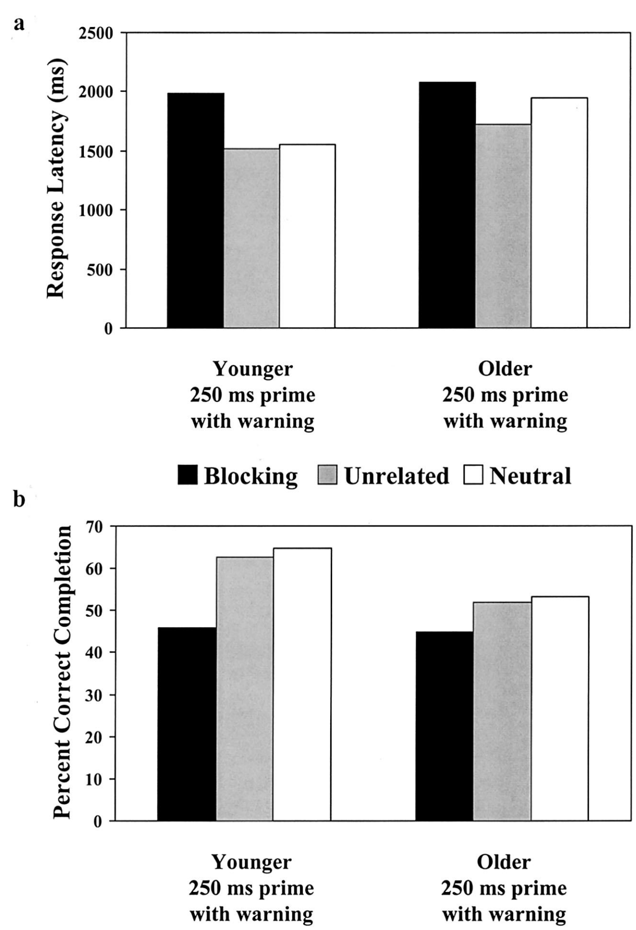

Figure 3. Mean response latencies for correct fragment completions (a) and percent correct fragment completion (b) in Experiment 2 (250-ms prime with warning).

the unrelated prime condition. There was no reliable Age × Prime Type interaction, $F(2, 116) = 2.23$, $MSE = 163{,}182.40$.

Percent correct. Figure 3b displays the percent correct word fragment completions as a function of prime type and age group. There was a main effect of age such that the younger adults were more accurate than the older adults, $F(1, 58) = 7.74$, $MSE = 344.45$. In addition, there was a significant main effect of prime type, $F(2, 116) = 16.95$, $MSE = 191.74$, such that percent correct was significantly lower in the blocking prime condition compared with the unrelated, $t(59) = 4.31$, and neutral, $t(59) = 5.32$, prime conditions, with the latter two conditions not differing, $t(59) = .64$. There was a trend toward an Age × Prime Type interaction, $F(2, 116) = 2.62$, $MSE = 191.74$, $p < .08$, indicating that older adults were producing slightly less blocking than the younger adults.

Intrusion rates. Figure 4a displays the mean percentage of intrusions of the blocking prime as word fragment solutions (out of a total of 12 fragments) as a function of prime type and age group. There was a main effect of age in that older adults were significantly more likely to make intrusion errors than younger adults, $F(1, 58) = 26.24$, $MSE = 37.27$. There was also a significant main effect of prime type, $F(2, 116) = 3.80$, $MSE = 22.27$, such that there was a higher percentage of intrusions in the blocking prime condition compared with the unrelated, $t(59) = 2.75$, but not the neutral, $t(59) = 1.21$, prime conditions. There was a trend toward a significant difference between the unrelated and neutral prime conditions, $t(59) = 1.96$, $p < .06$. The significant Age × Prime Type interaction, $F(2, 116) = 4.84$, $MSE = 22.27$, indicated that only the older adults showed significantly greater intrusion rates in the blocking prime condition, compared to younger adults.

Omission rates. Figure 4b displays the mean percentage of omissions or failures to respond in the time allowed as a function of prime type and age group. There was no main effect of age, $F(1, 58) = 1.37$, $MSE = 384.54$. There was a significant main effect of prime type, $F(2, 116) = 16.13$, $MSE = 147.16$, such that there was a higher percentage of omissions in the blocking prime condition compared with the unrelated, $t(59) = 3.39$, and the neutral, $t(59) = 4.85$, prime conditions. This was qualified by a significant Age × Prime Type interaction, $F(2, 116) = 9.78$, $MSE = 147.16$, indicating that the younger adults showed significantly greater omission rates in the blocking prime condition, compared with older adults.

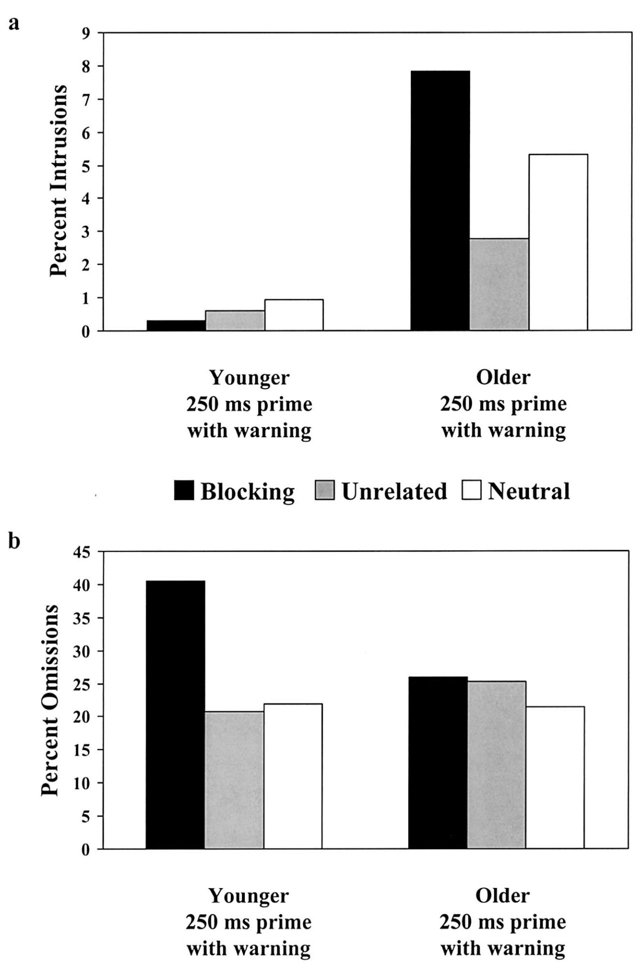

Figure 4. Mean percent intrusions, or use of the blocking prime as a word fragment solution (a), and mean percent omissions, or failures to verbally respond in the 5-s allotted time (b), in Experiment 2 (250-ms prime with warning).

Discussion

Results of Experiment 2 indicate that repeatedly administering a warning not to produce the prime had little effect on younger or older adults' performance. There was a trend toward younger adults showing a greater completion rate decrease in the blocking prime condition compared with older adults, but this did not reach significance. An age effect in intrusion rates was once again observed, such that older adults continued to incorrectly complete word fragments with the blocking prime even with repeated warnings not to do so. In addition, there was a qualitative difference in the types of errors made by younger adults and older adults in the blocking prime condition. Younger adults were more likely to withhold their response in the blocking prime condition compared with the unrelated and neutral prime conditions, whereas older adults showed no such preference.

Experiment 3

The third experiment had three goals in exploring the basis for the interference effects observed in the two previous experiments. One goal was to explore the role of conscious control of the blocking prime by placing younger adults under subthreshold priming conditions. If conscious processing of the blocking prime is necessary to introduce response competition and interference, younger adults in the current experiment should show no interference effects; that is, they should not show the slowed response latencies, decreased accuracy, and omission errors in the blocking prime condition demonstrated by the younger adults in Experiments 1 and 2. If conscious processing of the prime is not necessary, younger adults should show interference effects similar to those observed in Experiments 1 and 2.

The second goal of Experiment 3 was to further explore the role of controlling the blocking stimulus in lexical retrieval of the targets. Placing younger adults under subthreshold priming conditions was expected to impair their ability to consciously process the prime item, thereby impeding their ability to attach appropriate source information to the prime and control its activation. If an impairment in one's ability to discriminate relevant activation from irrelevant activation in a lexical network plays a role in producing the blocking effect, intrusion rates of younger adults should be similar to those of older adults in Experiments 1 and 2. In other words, we presume that masking of the prime and aging could be similar in that they are both situations in which one is impaired in the ability to discriminate between irrelevant and relevant sources of activation and select the appropriate response for output.

Experiment 3 also served to test an alternative hypothesis regarding the age effects we observe in error rates. It could be older adults have more difficulty visually resolving the fragments, making them less likely to realize that a certain word (such as an intrusion) does not correctly complete the fragment. If the age effects are not due to an impaired ability to control output of the blocking prime, and instead are due to decreased visual acuity, we should not see an increased intrusion rate in younger adults under subthreshold priming conditions, because the target and fragment presentation duration are identical in Experiment 3 and the previous experiments.

Method

Participants. Twenty-four younger adults ($M = 19.6$ years, $SD = 1.2$) were recruited from undergraduate courses at Washington University and received course credit for participating. The participants' mean Shipley Vocabulary score was 18.3 ($SD = 0.8$). Participants had an average of 13.2 years of education ($SD = 1.1$).

Apparatus, materials, procedure, and design. Apparatus, materials, procedure, and design were all identical to those used in Experiment 1, with the following exceptions. In the word fragment completion phase of the experiment, the primes were preceded by a brief tone and a row of asterisks presented on the screen for 500 ms, after which the screen was cleared for 500 ms. Primes were then presented for a 17-ms duration and were immediately followed by a 100-ms pattern mask 15 characters in length (i.e., @#@#@#@#@#@#@#@). Participants were simply told that they would see something flash before the fragment.

Results

In order to determine whether primes were indeed subthreshold for participants, an additional group of 13 younger adults participated in the same experiment. However, instead of completing the word fragments, they were asked to report any information they could discern about what was flashed before the fragments and were encouraged to guess. On average, out of 24 prime words presented, participants were only able to accurately report 5.1% of the prime words, with no significant difference in reporting blocking prime words ($M = 5.5\%$, $SD = 7.3\%$) and unrelated prime words ($M = 4.8\%$, $SD = 7.2\%$; $F < 1$). Note that the 5.1% level occurs under the best of situations in which participants are directing their attention toward detection of the prime instead of completion of the fragment. Therefore, unlike participants in Experiments 1 and 2, participants in Experiment 3 were very unlikely to be able to consciously read the prime words during the word fragment completion task. We now turn to the main results of the 24 participants in Experiment 3.

Response latencies. Figure 1a displays the mean response latencies for correct solutions to the word fragments as a function of prime type. There was no main effect of prime type ($F < 1$).

Percent correct. Figure 1b displays the percentage of correct word fragment completions per condition. There was a significant main effect of prime type, $F(2, 46) = 5.34$, $MSE = 151.93$, such that percent correct was significantly lower in the blocking prime condition compared to the unrelated, $t(23) = -2.71$, and neutral, $t(23) = -2.90$, prime conditions. The means in the unrelated and neutral prime conditions did not differ, $t(23) < 0.001$.

Intrusion rates. Figure 2a displays the mean percentage of intrusions of the blocking prime as word fragment solutions (out of a total of 12 fragments) per condition. There was a significant main effect of prime type, $F(2, 46) = 6.91$, $MSE = 55.73$, such that there was a higher percentage of intrusions in the blocking prime condition compared with the unrelated, $t(23) = 3.82$, and the neutral, $t(23) = 2.13$, prime conditions, with no difference between the latter two conditions, $t(23) = -1.16$.

Omission rates. Figure 2b displays the mean percentage of omissions or failures to respond (out of a total of 12 fragments) per condition. There was no main effect of prime type ($F < 1$).

Discussion

The results of Experiment 3 reveal that lexical retrieval can be negatively affected by even a brief, highly masked presentation of an orthographically similar word. As in Experiments 1 and 2, younger adults were significantly less likely to correctly complete the word fragments in the blocking prime condition compared with the unrelated and neutral prime conditions. Unlike Experiments 1 and 2, however, there was no reliable blocking effect in response latencies, indicating that the blocking effects observed may have at least two contributing factors. One factor could be tied to the automatic activation of the blocking prime word in the lexical network, producing additional activation to compete with the earlier activation of fragment solutions encoded in the first half of the experiment. This effect of automatic activation may be involved in producing the blocking effect in completion rates observed in all three experiments. A second contributing factor may stem from conscious processing of the prime, resulting in withholding of the response to the fragment with the consciously processed blocking prime, thus producing the increased response latencies in the blocking prime condition in Experiments 1 and 2.

It also appears that impaired visual acuity is not the underlying cause of the age effects we observed in intrusion rates, as younger adults in Experiment 3 showed an intrusion rate very similar to that of older adults in Experiments 1 and 2, even though the fragments were presented in an identical fashion across experiments.

General Discussion

The results of the present set of experiments indicate that a brief presentation of an orthographically related word can interfere with subsequent retrieval of a target in both younger and older adults. This disruption of lexical retrieval of a target can occur outside conscious awareness of the blocking word, as shown in the results of Experiment 3, when younger adults were placed under highly masked priming conditions. With regard to age effects, older adults were more likely to use the blocking prime as a solution to the word fragments (Experiments 1 and 2), even when explicitly and repeatedly warned against doing so (Experiment 2). Data patterns showing older adults' increased intrusion rates in Experiments 1 and 2, as well as younger adults' increased intrusion rates in Experiment 3 when their ability to consciously process the prime was minimized, support the hypothesis that the ability to resolve relevant and irrelevant sources of activation in the lexical network plays an important role in successful target word retrieval. Before discussing the implications of the present results, we briefly discuss some alternative accounts of the present data.

Recollection Deficit

One might argue that older adults' increased intrusion rates in the blocking prime condition are due to a recollection deficit of the earlier presented words; that is, older adults are likely to have poorer memory for the target words studied in the first phase of the experiment (e.g., ALLERGY) and therefore must guess more often than younger adults, with guesses biased by the recently activated prime word (ANALOGY). It is also possible that older adults have poorer memory for the prime word. In order to address these possibilities, we attempted to match fragment completion performance across younger and older adults. If differences in memory contribute to age effects in our data, when participants are matched in fragment completion performance in conditions in which there is no bias to use the blocking prime, these age effects should diminish. Therefore, pooling participants in Experiments 1 and 2, we averaged the completion rates in the unrelated and neutral prime conditions for each subject for an index of memory performance. We then equated younger adults ($n = 44$) and older adults ($n = 44$) on this index ($M_{\text{younger}} = 59.3\%$, $M_{\text{older}} = 58.7\%$). The two groups were equated by eliminating one top-scoring and one bottom-scoring participant from each group until the averages of the unrelated and neutral prime conditions were approximately equal in both groups. Results based on the equated groups are shown in Figures 5 and 6.

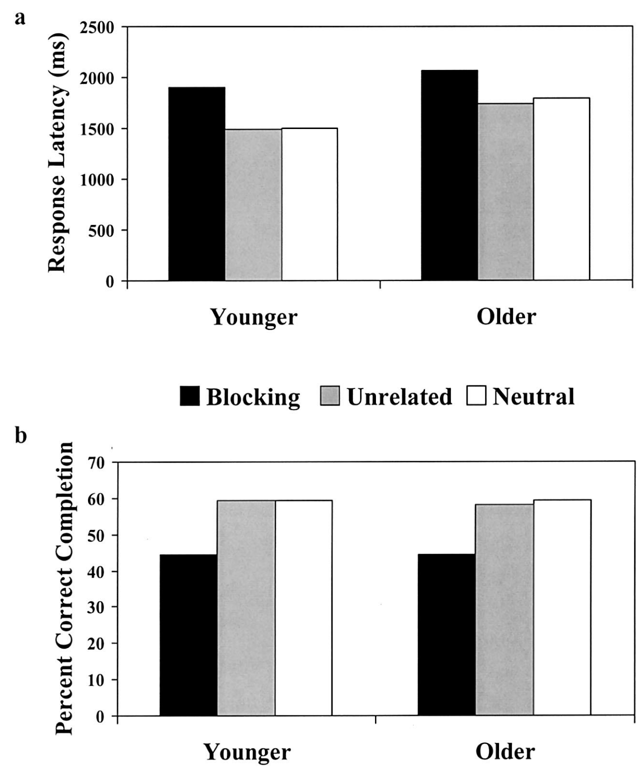

Figure 5. Mean response latencies for correct fragment completions (a) and percent correct fragment completion (b) for participants in Experiments 1 and 2 who have been equated for average fragment completion performance in the unrelated and neutral prime conditions.

Figure 5 shows response latency and completion rate data for the equated groups, indicating that younger and older adults were indeed equated on completion rate performance in the unrelated and neutral prime conditions. The data in Figure 6 show that, even when younger and older adults are equated on fragment completion performance in the unrelated and neutral prime conditions, age effects in intrusions, $F(2, 172) = 6.02$, $MSE = 19.04$, $p < .01$ (Figure 6a), and omissions, $F(2, 172) = 3.39$, $MSE = 134.27$, $p < .04$ (Figure 6b), are still evident. That is, older adults equated to younger adults in unbiased fragment completion performance still tended to intrude the prime as a response in the blocking prime condition and younger adults were still more likely to withhold their response in the blocking prime condition compared with the unrelated and neutral prime conditions.

It should also be noted that a recollection deficit account has difficulty explaining the results from Experiment 3, which used highly masked priming conditions with younger adults. These masked priming conditions were intended to minimize younger adults' ability to consciously control the prime. In this experiment, the intrusion rates for the younger adults were strikingly similar to those of older adults in Experiments 1 and 2.

In contrast to the present study, Jacoby and colleagues (Hay & Jacoby, 1999; Jacoby, 1999) have provided evidence to support the notion of a recollection deficit in a somewhat similar paradigm (Jacoby, 1999). For example, in a recent study by Jacoby (1999), younger and older adults studied a list of paired associates, such as "bed sheet," after which they completed a cued recall test for the pairs (e.g., "bed s_ee_"). Prior to each cued recall trial, a congruent ("sheet"), incongruent ("sleep"), or neutral prime (&&&&&) item was presented. The relevant findings were that older adults were more likely to rely on the prime words, rather than recollection of the previously studied word pairs, as a basis for responding on the cued recall test. Since older participants used the congruent (or correct) prime word as an answer as often as they used the incongruent prime word, Jacoby (1999) concluded that the prime word's influence was on guessing, not memory.

The findings of the current study are different from those of Jacoby (1999) because of the different relation between the primes and fragments in the two studies. Primes used in Jacoby were sometimes congruent primes; that is, sometimes the primes could be relied on as a correct completion to the fragment. In the present study, the primes never completed the fragment. Moreover, in the Jacoby study, the incongruent primes ("sleep") could complete the fragment ("s_ee_"), even though participants were instructed to use only the studied words ("sheet") to complete the fragment. Both of these factors should increase participants' reliance on the prime as a solution, thereby increasing the likelihood for an intrusion when recollection failed. In contrast, the current study addressed the extent to which a related prime can be controlled when it is definitely not the correct solution to a fragment. Contrary to Jacoby, primes in the current study could never correctly complete the fragments, and participants were repeatedly warned of this

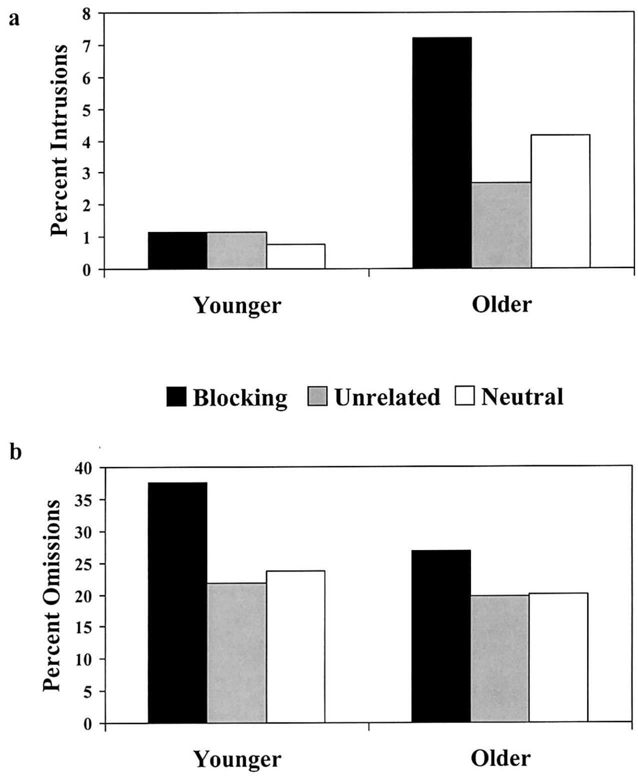

Figure 6. Mean percent intrusions, or use of the blocking prime as a word fragment solution (a), and mean percent omissions, or failures to verbally respond in the 5-s allotted time (b), for participants in Experiments 1 and 2 who have been equated for average fragment completion performance in the unrelated and neutral prime conditions.

(Experiment 2). Therefore, it appears that age effects observed in the current study are more likely attributable to deficits in control of the blocking prime stimulus, because even when recollection was equated, the age effects persisted.

Impairments in Visual Acuity

As discussed in Experiment 3, another alternative explanation of the observed age effects in intrusion rates is that older adults had more difficulty visually perceiving the fragment and hence were more likely to intrude the related primes as solutions to the fragments. This account is also not supported by the current findings. If older participants did have difficulty discerning the word fragments, then it is unclear why, in Experiment 3, data patterns in younger adults were remarkably similar to those of older adults, even though the fragments were presented in their normal fashion.

The Role of Control in Producing Lexical Retrieval Difficulties

We suggest that the lexical retrieval difficulties observed in the present paradigm are due to competing sources of relevant (target) and irrelevant (prime) activation within the lexical network. In order to successfully retrieve a target word in such a situation, it is necessary to discriminate activation that is relevant from activation that is irrelevant. Increasingly higher demands are placed on selection as the sources of relevant and irrelevant activation increase in similarity or relatedness, resulting in both slower and less accurate retrieval in younger and older adults.

The present results also indicate that there are age-related changes in the ability to discriminate different sources of activation. Although in Experiments 1 and 2 both age groups showed a proportional decrease in accuracy in the blocking prime condition compared with the unrelated and neutral prime conditions, the nature of these errors was quite different. We believe that this difference is important in understanding a mechanism underlying lexical retrieval difficulties in aging. For example, an analysis of errors indicated that younger adults in Experiments 1 and 2 most commonly made errors of omission, for example, if they were unable to retrieve the target word, they withheld any response. Younger adults made a disproportionate number of such omissions on the blocking prime trials compared with the unrelated and neutral prime trials (see Figures 2 and 4); older adults did not. Older adults were actually more likely to make errors of commission, such that they used the blocking prime as a word fragment completion, even when explicitly warned and reminded that they should avoid doing so. It appears that the activation was sufficiently great to overcome the task demands, and therefore older participants actually output the prime instead of withholding the incorrect response. Analysis of other types of errors revealed no systematic differences between younger adults and older adults, as shown in Table 2.

This account is consistent with previous studies that have used implicit versions of this task (Kinoshita & Towgood, 2001; Lustig & Hasher, 2001; Smith & Tindell, 1997). These researchers used some of the same materials that we used (from Smith & Tindell, 1997) and observed similar interference effects in younger adults as we demonstrate here, for example, less accurate word-fragment completion and increased intrusion rates. These results are consistent with the data found in the current Experiments 1 and 2 with older adults and in Experiment 3 with younger adults under subthreshold priming conditions. One might argue that converging data patterns found using implicit processing instructions, subthreshold priming, and superthreshold priming in older adults

Table 2
Types of Errors by Prime Type (in Percentages) in Younger and Older Adults

Prime type	Younger	Older	Younger, 17-ms prime + mask
Incorrect solutions (nonintrusions)			
Blocking	4.4 (6.7)	8.6 (10.2)	10.8 (13.6)
Unrelated	4.4 (5.8)	8.1 (7.8)	8.7 (11.1)
Neutral	3.7 (6.1)	9.0 (9.6)	5.6 (7.6)
Voice key errors			
Blocking	8.5 (9.6)	8.2 (8.8)	10.8 (10.3)
Unrelated	7.7 (9.4)	8.6 (9.9)	11.8 (12.0)
Neutral	8.1 (10.0)	8.7 (9.9)	10.1 (12.0)

Note. Data are means, with standard deviations in parentheses.

suggest that these variables operate in much the same way in this paradigm. One common factor that implicit tasks, subthreshold priming, and aging may share in this task is that they offer a more limited opportunity for explicit, controlled processing (i.e., recollection of the studied items and comparison of the prime to the target) to influence performance. In this way, findings from manipulations of implicit processing, subthreshold priming, and age seem to support a role of attention in distinguishing among multiple, activated candidates for lexical retrieval (see Jacoby, 1999, for a similar argument).

Studies of healthy aging and Alzheimer's disease in standard Stroop color naming also provide converging evidence for the current account of the data. As discussed above, in a study of Stroop (Stroop, 1935) task performance in younger adults, older adults, and patients with DAT, Spieler et al. (1996) found increased interference effects in incongruent color–word trials for older adults, which were linked, through a process-dissociation procedure, to increased word process estimates. That is, older adults had more difficulty suppressing the "word" pathway than younger adults, resulting in disproportionately longer response latencies in the incongruent condition. However, individuals with early-stage DAT showed increased intrusion errors as well as a disproportionate increase in facilitation on congruent color–word trials. These results were viewed as consistent with the hypothesis that healthy older adults were able to withhold the response in the incongruent condition, thereby increasing interference effects. On the other hand, individuals with early-stage DAT were unable to control the prepotent word response and produced an intrusion (see Balota & Ferraro, 1993, for a similar pattern in speeded word naming).

According to this framework, the likelihood of intruding a response versus taking more time to respond depends on the integrity of one's ability to control information that interferes with the target response, the strength of the competing responses, and the time pressure to respond. For example, even younger adults will intrude an incorrect response when the source of the competitor is unavailable to the control system, as in the highly masked priming conditions of Experiment 3. We believe that a 250-ms prime duration is clearly sufficient for conscious processing of the prime words in both younger and older adults (see Balota et al., 1992; Burke, White, & Diaz, 1987). However, older adults have difficulty controlling (e.g., discriminating and selecting between) the two sources of activation. This produces the increased intrusions in older adults seen in the present Experiments 1 and 2.

Finally, it is important to note that a similar phenomenon has been observed in patients with frontal lobe damage. Burgess and Shallice (1996) compared performance of patients with frontal lobe damage with that of controls in a sentence completion task (Hayling test; see Burgess & Shallice, 1996). When asked to generate an unrelated word to complete a sentence such as "Most sharks attack very close to ______," patients with frontal lobe damage were more likely than controls to produce intrusions in the form of semantically related words (e.g., *sea* or *fishes* vs. an unrelated response such as *pencils*; Burgess & Shallice, 1996). Such errors have at least surface similarity to the intrusion errors in the present study. In both cases, participants are intruding a highly activated—but irrelevant—response. Of course, the similarity between performance of frontal patients and older adults on other tests has been reported in the literature (e.g., Craik, Morris, Morris, & Loewen, 1990; Dempster, 1992; Moscovitch & Winocur, 1995; Perfect, 1997; Veroff, 1980; West, 1996). In this light, it is possible that impairments in the ability of older adults to discriminate relevant activation from irrelevant activation in the lexical network may in part be mediated by a frontally based executive control network involving mechanisms for the maintenance and manipulation of relevant information in order to accomplish task demands.

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(*Appendix follows*)

Appendix

List of 36 Triplets of Target Words, Prime Words, and Corresponding Word Fragments

Target word	Blocking prime	Unrelated prime	Fragment
ALLERGY	ANALOGY	MAXIMUM	A_L_ _GY*
BAGGAGE	BRIGADE	DUCHESS	B_G_A_E*
BLOCKADE	BOOKCASE	WAITRESS	B_O_KA_E
BRACELET	BROCCOLI	SHEPHERD	BR_C_L_ _
CANISTER	CONSTANT	RESOURCE	C_N_ST_ _
CATALOG	COTTAGE	LEATHER	C_TA_ _G*
CHAMPION	CAMPAIGN	RESPONSE	C_AMPI_N
CHARITY	CHARTER	ROUTINE	CHAR_T_*
CONQUEST	CONTEMPT	FRICTION	CON_ _E_T
COUNTRY	CLUSTER	ANTIQUE	C_U_TR_*
CULPRIT	CRUMPET	GARLAND	CU_P_ _T*
DIGNITY	DENSITY	EMOTION	D_ _NITY*
DISGUISE	DIALOGUE	INVASION	DI_GU_ _E
DISPOSAL	DIPLOMAT	MECHANIC	DI_PO_A_
DIVISION	DEVIANCE	SOLITUDE	D_VI_ _ _N
ELASTIC	ELUSIVE	SURFACE	EL_S_I_
ELEGANCE	ELEPHANT	GASOLINE	ELE_AN_ _
EPIDEMIC	EVIDENCE	POSITION	E_IDE_ _C
EXTERIOR	EXERCISE	VACATION	EX_ERI_ _
FAILURE	FIXTURE	BLOSSOM	F_I_URE*
GARRISON	GREETING	TEMPLATE	G_R_I_ _N
GUARDIAN	GUIDANCE	SURPRISE	GU_ _D_AN
HISTORY	HOLSTER	CURTAIN	H_ST_R_*
HOSPITAL	HERITAGE	APPETITE	H_ _ _ITA_
MAGAZINE	MAGICIAN	PHARMACY	MAG_ _IN_
MIDPOINT	MIDNIGHT	SPECTRUM	MID_ _I_T
MOISTURE	MISTRESS	SANDWICH	M_IST_RE
ORDINARY	ORNAMENT	BULLETIN	OR_ _NA_ _
OPPOSITE	OPPONENT	CORRIDOR	OPPO_ _T_
PARTICLE	PATIENCE	LAUGHTER	PA_TIC_E
PROPHECY	PROPERTY	ADDITION	PROP_E_Y
SCHEDULE	SCULPTOR	BLIZZARD	SC_ _ _UL_
SYMPATHY	SYMPHONY	OBSTACLE	SYMP_ _HY
TANGENT	TONIGHT	PROMISE	T_NG_ _T*
TRAGEDY	TRILOGY	PARADOX	TR_G_ _Y*
VOLTAGE	VOYAGER	TORPEDO	VO_ _AGE*

Note. Fragments with an asterisk (*) indicate targets, blocking primes, and fragments used by Smith and Tindell (1997); unrelated prime words were constructed by the authors.

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