Working Memory Capacity Predicts Strategic, but not Automatic, Semantic Priming

Patrick A. O'Connor

Faculty Sponsor: Bart A. Van Voorhis, Department of Psychology

ABSTRACT

104 individually tested University of Wisconsin, La Crosse undergraduates performed Turner and Engle's (1989) operation span (OSPAN) measure of working memory capacity followed by a single-prime lexical-decision task. Prime type (related: *ELECTION-vote*, unrelated: *DRAWER-vote*, or neutral: *****-*vote*) and stimulus onset asynchrony (SOA_S: 300 msec, SOA_L: 1,250 msec) were manipulated randomly within participants and blocks of trials. Of interest are the novel findings that, despite no overall prime type X SOA interaction, 1) OSPAN was significantly correlated *only* with SOA_L, presumably strategic, priming, and 2) priming with SOA_L was eliminated for the lowest OSPAN quartile, yet fully retained for the highest quartile. This dissociation did not occur for SOA_S priming, which was robust and equivalent for both high and low spans. These results warrant closer attention to individual cognitive differences as moderators of certain semantic priming effects.

INTRODUCTION

Reading is a fundamental activity, one that pervades education, work, and leisure. While effortless for a practiced reader, the visual (and tactile) recognition of words involves extensive cognitive processing. This ranges from encoding orthographic features, to retrieving phonological, lexical, and semantic memories, to using context in ways that maximize recognition speed and comprehension. Given this complexity, the factors influencing visual word recognition have received remarkable attention within cognitive psychology. The role played by a to-be-recognized word's semantic context is one such focus (see Neely, 1991, for a review).

In examining effects of semantic context during word recognition, researchers often implement tasks where participants categorize a string of letters as a "word" or "nonword". During this *lexical-decision task* (LDT), "word"/"nonword" key-press reaction times (RTs) and accuracy serve as dependent measures. Generally, a participant's speed and accuracy of response to a target vary depending on the relation of the *prime* item preceding it. Thus, the target *robin* is recognized more quickly and accurately when preceded by the related prime *BIRD* than by the neutral prime *XXX*. This is termed *facilitation*, whereas slower target response when reading *BIRD…arm* compared to the neutral prime condition (*XXXX…arm)* shows *inhibition* (Neely, 1977). We describe these differences as *semantic priming* effects.

Building a theoretical understanding of semantic priming is valuable because word recognition and meaning underlie reading and language use in general, as well as applications in educational and clinical settings (Van Voorhis, 1996). The latter include dyslexia and other reading disorders, Alzeimer's disease, multiple sclerosis, and schizophrenia (Auchterlonie, Phillips, & Chertkow, 2002; Beatty & Monson, 1990; Minzenberg, Ober, & Vinogradov, 2002; Whatmough & Arguin, 1998).

Several broad theoretical accounts of semantic priming have emerged; two such models are *expectancy* and *automatic spreading activation*. Expectancy is a conscious, resource-demanding mechanism, as it involves prospectively generating an *expectancy set*, or group of related concepts, upon awareness of the prime word. If the target happens to be contained in the set, recognition is enhanced, due to its previous activation or availability in memory (Becker, 1980). For example, upon seeing the prime *cat,* a participant would think of a group of related words, such as *mouse, black,* and *dog*, if given enough time to do so. Participants use expectancy 1) when there is a high proportion of targets related to their primes (high *relatedness proportion; RP*) and 2) when the *stimulus onset asynchrony* (SOA) is relatively long (Hutchison, Neely, & Johnson, 2001). The SOA is the duration from prime to target onset. So, participants must believe that many of the pairs will be related, thus making the strategy useful, and have enough time to use the strategy effectively.

Automatic spreading activation, however, is rapid and occurs involuntarily without consciously controlled attention and resources (Collins & Loftus, 1975). This model supposes that stored semantic concepts interconnect so that activation of one spreads out to associatively or semantically related concepts in the network, facilitating recognition of these related items. For example, *cat* is primed when preceded by *DOG* but not *ARM* because spreading activation from *DOG,* unlike *ARM*, increases *cat's* activation. Links between items in the network vary in strength depending on factors such as category membership, feature overlap, and perhaps frequency of co-occurrence. Both automatic spreading activation and expectancy can cause semantic priming in the LDT, given sufficient conditions.

Spreading activation, unlike expectancy, is considered automatic, and hence unconscious, but several recent publications have challenged this assumption (Smith, Besner, & Miyoshi, 1994; Besner, Stolz, & Boutilier, 1997; Stolz and Besner, 1999). In particular, Neely, VerWys, & Kahan (1998) found that a repeated prime condition actually *decreased* semantic priming of the target, contrary to an automatic spreading activation prediction (replicated by Pitzer & Dagenbach, 2001).

According to Hutchison et al. (2001), the possibility that prime repetition interfered with expectancy priming must be considered. Expectancy *may* function at the relatively low relatedness proportion (.25) and short SOA (300 msec) used in the Neely et al. (1998) study. In fact, Hutchison et al. found greater priming with a higher RP (.75) as well as reduced semantic priming due to prime repetition.

Thus, Hutchison et al. (2001) demonstrated expectancy operating at the high RP, but this does not account for reduction of priming when the RP is low, as in Neely et al. (1998). Hutchison et al. note that conclusively demonstrating expectancy at a low relatedness proportion of .25 requires ***a)*** finding more priming at a relatedness proportion of .25 than at .05, or ***b)*** observing slower RTs to targets following unrelated primes relative to neutral (*XXX)* primes. This is because a neutral prime prompts no expectancy set, but an unrelated prime word encourages generation of a wrong set, producing inhibition. Neither of these conditions has yet been tested.

The current study addressed this question. Its resolution has two-fold importance. First, establishing the presence of expectancy with a low relatedness proportion (.25) and short stimulus onset asynchrony (300 milliseconds) would strengthen Hutchison et al.'s (2001) claim that reduced priming due to prime repetition is caused by expectancy failure rather than the absence of automatic spreading activation. Conversely, no observed expectancy in these conditions would weaken that argument. Second, and perhaps of greater general importance, the results would further clarify when expectancy does and does not operate, since it has never been assessed under the current conditions.

Using the lexical decision task, I assessed expectancy with the low relatedness proportion of .25 and short stimulus onset asynchrony of 300 milliseconds. I used a neutral prime condition, along with related and unrelated prime-target pairs. Expectancy would be indicated by slower response to target words following unrelated prime words relative to targets following a semantically neutral prime. Recall that an unrelated prime prompts the wrong expectancy set, slowing down response compared to the neutral condition, which does not cause any expectations.

Additionally, I included an SOA manipulation, as well as a measure of working memory capacity. This was to further clarify whether or not strategic priming is operative, as well as the potential role of individual cognitive differences in the LDT. The SOA was randomized within rather than between blocks of trials, meaning that a participant would not know what kind of a trial was coming next. The rationale for this was to prevent potential discouragement due to the fast pace of many consecutive short-SOA ($\mathrm{SOA_S}$) trials. Convergent evidence of expectancy would be increased inhibition and facilitation with the longer SOA ($\mathrm{SOA_L}$). It is also likely that working memory capacity, as measured by the OSPAN task (Turner & Engle, 1989), influences strategic priming, since expectancy relies on consciously controlled, resource-dependent processing. OSPAN has been found to predict performance on many attention-demanding tasks, including language and reading comprehension, learning of spelling and vocabulary, direction-following, writing, reasoning, note-taking, and complex learning (Engle, Tuholski, Laughlin, & Conway, 1999).

METHOD

Participants

104 undergraduate students at the University of Wisconsin, La Crosse participated in the current study for extra credit in their psychology courses. All of them spoke English as a primary language, had normal or corrected-to-normal vision, and participated only once. OSPAN data for seven participants with operation errors greater than 90% were excluded from the correlation and mixed ANOVA analyses.

Design

In the LDT, each critical word target was preceded either by a semantically/associatively related, unrelated, or neutral prime item. Thus, the target *butter* followed either *BREAD*, *SILENCE*, or *****, respectively. Additionally, the SOA was either short (300 msec) or long (1,250 msec), each with equal likelihood, randomized within each block of trials. Consequently, each participant experienced the same six critical conditions in this 3 X 2 within-subjects design.

The OSPAN measure was included as a correlate to the RT and accuracy data from the LDT. Additionally, the creation of the high and low quartile groups resulted in a mixed, 3 (prime type) X 2 (SOA) X 2 (OSPAN: High, Low) design, with OSPAN as a between-groups factor.

Stimuli

(Lexical decision) Data were collected from 90 critical word targets. 80 of these targets and their related prime words were taken from Hutchison et al. (2001), and the rest from Van Voorhis and Dark (1995). The latter items were distributed approximately equally in the three critical lists. Each related prime had for its target word the most probable free associate, according to the University of South Florida word association norms (Nelson, McEvoy, & Schreiber).

For every participant, 30 of these critical targets were paired with each type of prime. To control for item effects, three critical lists were constructed, such that a unique third of the targets were paired with each prime type in each list. Thus, in each list every target appeared once and was paired with a different kind of prime. To determine unrelated and neutral prime pairings, the original list of 90 pairs was randomly divided into thirds. One of these thirds served as the related trials in each of the three counterbalanced lists. Another third was assigned the neutral prime in each list, and the remaining third became the unrelated critical condition, via random repairing of targets with other prime words in that third. A similar potential item confound with SOA was controlled by alternating the SOA_L and SOA_S trials for each participant, such that all of participant x's SOA_L trial pairings became participant $x+1$'s SOA_S trial pairings, and vice versa. This resulted in six versions of the experiment, with each of the three critical lists alternating trials between the two SOAs. There were fifteen critical trials per condition, and 104 participants, producing 1,560 observations of each condition.

The 90 critical word target trials were accompanied by 190 buffer trials, including 60 unrelated word/word, 90 word/nonword, 5 neutral/word, and 35 neutral/nonword trials. All of these buffer trials were taken from Hutchison et al. (2001), or created from words used as buffer trials in that study. Of the 120 word prime/word target trials, 30 were related, leaving an RP of .25. 90 out of 180 unrelated pairings had nonword targets, resulting in a nonword ratio (NR) of .5. The neutral trials, which comprised one-fourth of the total (70/280), were not used in calculating the RP or NR. The probability of a nonword target given a neutral prime was one-half (35/70), and the likelihood of a nonword target given a word prime was .43 (90/210). The overall probability of a nonword target was .45 (125/280). These proportions were maintained as closely as possible in the 36-trial practice block, as well as the seven test blocks. Each test block was presented randomly, as were its 40 trials, and the critical pairs were distributed approximately equally in each block.

The text stimuli were black on a white background, in bold 12-pt. “Courier New” font. (OSPAN) Stimuli for the OSPAN measure are from Turner and Engle (1989). The three practice trials consisted of two operation-word strings each, and the twelve test trials contained two, three, four, or five strings each. The order of the test trials was randomized, and identical for each participant. Each set size was represented equally, and no operation or word was repeated. The operation-word strings were black, in bold 20-pt., Times New Roman font, centered on a white background.

Equipment

The same Dell Precision 220 personal computer and Digital standard VGA monitor (x inches) was used for both the lexical decision task and the OSPAN measure. Both testing procedures were developed and implemented with E-Prime software, upgraded to version 1.1 (Schneider, Eschman, & Zuccolotto, 2002).

Procedure

After being greeted and given a consent form to fill out, each individually tested participant (P) performed the OSPAN test followed by the LDT. For the OSPAN portion, the experimenter read the instructions aloud, answered any questions, administered the stimuli via button presses, and recorded the number of “yes/no” errors made. In each trial, Ps read a math equation followed by a common word (operation-word string) aloud, such as, “IS (3/1) –2 = 3? CLOUD”. After reading the equation and solving the problem, they said “yes” or “no”, and then immediately named the subsequent word. The instructions prohibited pausing before reading an equation aloud and before naming the subsequent word. Directly after naming, a new operation-word string or "???" appeared, controlled by an experimenter's button press. When the former appeared Ps repeated the process, but "???" cued them to write *all* the words from that set on a response sheet in their correct serial position. P's were instructed to leave a blank space for forgotten words, and were told they would not be penalized for guessing.

Operation accuracy was emphasized, and the data from Ps with 4 or more errors were excluded from the analysis. Points were accrued for each set equal to that set's size if *all* the words in that set were written in their correct serial position. Then, points for each set were summed to give a total score, possibly ranging from 0 to 42 points. All Ps were told they did a good job upon completing the task, which took approximately 15 minutes including the instructions.

Directly following the OSPAN measure, all Ps performed the LDT. They silently read the LDT instructions, which were also paraphrased by the experimenter. Speeded responses consisted of "/?" with the right index finger for a "word" response and "z" with the left index finger for a "nonword" response. Instructions emphasized paying attention to the prime item and silently reading it if it was a word, and responding to the target as quickly and accurately as possible. The random change in SOA was also mentioned, worded as, "a short or longer delay." This was to ensure that participants stayed focused, rather than wondering if the change was intentional or not (e.g., "a computer glitch?"). Six example trials were included in the instructions, followed by a break screen describing the practice and test blocks.

Each trial consisted of the following six visual slides: **1)** a 250-msec "+" fixation, **2)** a 300-msec blank-screen inter-stimulus interval (ISI), **3)** the prime, which was either "*****" or an UPPERCASE English word for 150 msec, **4)** another a 150-msec or 1,050-msec ISI, **5)** a lowercase 2,500-msec target, which was either a related English word, an unrelated English word, or an English word with one or two letters changed, which terminated upon response, and **6)** a blank 2,000-msec intertrial interval. The SOA was changed by altering the second ISI, so as to keep the prime duration constant in both conditions. After the thirty-six practice trials and after every forty test trials a self-paced break was given. The LDT portion took approximately 35 to 40 minutes including instructions.

Upon LDT completion Ps answered three brief subjective interview questions and then were shown their mean RTs and accuracy for the critical conditions. Often Ps predicted their results for the various conditions during the preceding brief interview, which led smoothly into the simple data analysis presentation and debriefing. The whole session lasted approximately 55 minutes.

RESULTS

Data from seven participants were excluded from the correlation and mixed ANOVA analyses due to high error rates on the OSPAN measure. LDT data are presented for the critical, correct, word target trials remaining after a trimming procedure. Trials with RTs less than 300 msec or longer than three standard deviations above the across-conditions mean RT were excluded, resulting in a loss of 2.1% of the critical, correct, trials. Due to positive skewness, geometric mean RTs for each of the six conditions were calculated for each participant (Neely et al., 1998; Hutchison et al., 2001). Arithmetic means were then calculated from these and used in the following analyses. All results are significant with $p < .05$ unless otherwise indicated.

The accuracy data showed patterns of priming consistent with the RT data, and will not be discussed here.

A 2 X 3 ANOVA with SOA and prime type as within-subjects factors was conducted on the latency data, showing a main effect of prime [F (2, 206) = 82.54, $MS_e = 1103.77$; see Table 1]. Newman-Keul's comparisons indicated that RTs to targets were longer following neutral primes than unrelated primes, and shorter following related primes than unrelated primes. This pattern reflects a semantic priming effect, but not inhibition. The interaction between prime and SOA was also significant [F (2, 206) = 14.76, $MS_e = 908.85$]. This was due to the neutral condition showing a pattern opposite of the other two prime types: longer RTs with SOA_S, which decreased with SOA_L (see Table 1). To examine potential differences in priming based on SOA, we conducted another ANOVA excluding the neutral prime condition, which eliminated the interaction found above.

Table 1. Latencies, Priming, and Inhibition for SOA$_L$ and SOA$_S$ in msec

	SOA$_S$: 300 msec	SOA$_L$: 1,250 msec	SOA$_L$ – SOA$_S$
Related Prime	523.38	532.23	8.85
Unrelated Prime	543.30	552.67	9.37
Priming	*19.92**	*20.44**	*0.52*
Neutral Prime	579.00	560.29	-18.71
Inhibition	*-35.70*	*-7.62*	*28.08*

* Significant at $p < .05$

An additional interest was to test the hypothesis that working memory capacity as measured by OSPAN predicts priming, but more specifically, presumably strategic priming with SOA$_L$. Semantic priming, as a dependent variable, was calculated by subtracting latencies for related trials from those in unrelated trials. Three Pearson's correlations were calculated for OSPAN and overall priming (collapsed across SOA), SOA$_S$ priming, and SOA$_L$ priming. There was a small, marginally reliable ($r = .16$, $p = .058$, one tailed) relationship between OSPAN and overall priming. OSPAN did not correlate with SOA$_S$ priming, but did correlate with SOA$_L$ priming ($r = .23$, $p = .011$, one tailed).

To pursue this relationship further, two OSPAN groups were created, consisting of approximately the top and bottom quartiles of OSPAN scores. The low group had scores of 7 or less (26 Ps), and the high group had scores of 16 or greater (24 Ps). Priming effects based on OSPAN were then examined by performing a mixed, 2 X 2 ANOVA with priming (SOA: short, long) within subjects and OSPAN (high, low) as a between-groups factor. Priming and OSPAN interacted significantly [F (1, 48) = 4.53, MS_e = 1,705.51]. As indicated in Table 2, SOA$_S$ priming was robust and equivalent for both OSPAN groups. However, with SOA$_L$, priming for the low spans was absent, but retained for the high spans. One-sample T-tests indicate that all the means are significantly greater than zero, except for the low spans' SOA$_L$, which is statistically zero.

Table 2. Priming for High and Low Spans with SOA$_S$ and SOA$_L$ in msec

		SOA$_S$: 300 msec	SOA$_L$: 1,250 msec
LOW SPANS	Unrelated Prime	559.40	560.52
	Related Prime	532.23	560.24
	Priming	*27.17**	*0.28*
HIGH SPANS	Unrelated Prime	530.75	553.31
	Related Prime	512.44	526.69
	Priming	*18.31**	*26.62**
	Difference in Priming for High vs. Low OSPAN	8.86	26.34

* Statistically greater than zero, $p < .05$

DISCUSSION

The first question of this research, the issue of whether or not expectancy operates under the current conditions, is not answerable based on these results. The most clear-cut indication of this strategy is not present – the neutral condition was slower than both of the other prime conditions, although a relationship *approaching* inhibition occurred with SOA$_L$.

There are at least two possible explanations for that interaction. One is that participants were using a strategy such as expectancy more often at SOA$_L$, which explains why the unrelated RTs were longer at this SOA. This explanation cannot account for the apparent driver of the interaction, though, which is a faster mean RT for neutral trials with SOA$_L$. Another account is that participants suffered less from the perceptual overlap of the neutral prime (*****) and target at SOA$_L$, such that interference akin to masking from the neutral prime was diminished when the SOA was long. This easily handles the fact that neutral trials were faster with SOA$_L$, and is consistent with subjective interview data indicating that many people felt the neutral prime was distracting. However, many participants also indicated that the neutral condition felt (subjectively) "easier", as evidenced by their claims that they were better able to concentrate on the target, given the lack of a distracting prime word.

While there are ways to potentially address this issue, it is fair to say that neutral primes are problematic in general and probably should not be used (Jonides & Mack, 1984) Another way to test the presence of expectancy under these conditions still remains, which is comparing priming with RPs of .25 and .05. This method, however, is undesirable on pure practical and statistical grounds; either the number of trials or the number of people needed would be enormous, and would probably require multiple sessions.

Leaving the neutral condition aside, the results from the LDT present an ambiguous picture. I found no interaction between SOA and prime type, which brings up several issues regarding the two accounts of priming discussed in the introduction – expectancy and automatic spreading activation. If it is assumed that expectancy was not operating under the low RP, then it is difficult to say why priming persisted with SOA_L, since activation should have dissipated by then. Either activation persists much longer than normally believed, or some other strategy – dependent on a longer SOA, but still useful with a low RP – is operative to cause the equivalent SOA_L and SOA_S priming. It is also possible that expectancy is operative with an RP of .25, but that SOA_S prohibited it, whereas SOA_L allowed it. This account handily attributes the SOA_S priming to automatic spreading activation, and the SOA_L priming to expectancy. Assuming this is the case, the reduction in priming due to prime repetition found by Neely et al. (1998) cannot be explained by a failure of expectancy.

Despite these problems, the current research does make a significant contribution to the semantic priming literature as well as suggests a tentative account of the anomalous finding of reduced priming from prime repetition. The important finding is the role of working memory capacity, as measured by OSPAN, in the LDT. Given the assumptions of expectancy and working memory models (e.g., Engle, Tuholski, & Laughlin, 1999), it is not surprising that SOA_L priming correlates with OSPAN, while SOA_S priming does not. The interaction between priming (SOA: long, short) and OSPAN (high, low) shows this difference more dramatically: SOA_S – presumably automatic – priming was equal for both OSPAN groups, but SOA_L – presumably strategic – priming was not.

The main implication of these findings is that individual cognitive differences, here measured by OSPAN, can influence an experiment in important ways, especially if conditions sufficient for strategizing obtain. Important patterns in the data may be hidden and undiscovered before an analysis of task-relevant individual differences.

In the current study, OSPAN predicted whether or not priming with SOA_L would occur. One account, mentioned above, is that high spans were using a strategy, such as expectancy, while low spans were not. Here it is assumed that automatic spreading activation is equal in both groups, an assumption consistent with the theories of working memory and automaticity. However, while the automatic activation dissipates to the same extent for both groups, the high OSPAN group implements a conscious strategy, whereas the low group does not. This explanation is attractive, as there is no reason to believe automatic activation should be dependent on the consciously controlled processing associated with OSPAN. Another account, consistent with the current data, exists, however. It could be that activation does dissipate in the assumed time frame for low spans, but not high spans. Perhaps the trace of the prime is much stronger for the latter, and is still active even after 1,250 msec. Related to this account, high spans may rehearse the prime during SOA_L, resulting in a kind of repetition priming, whereas low spans fail to do so, because they get distracted or just forget the prime.

Assuming these relevant cognitive differences exist, it is possible that the prime-repetition paradigm is subject to the phenomena found in this study. That is, upon closer inspection, it could be that a certain portion of participants are responsible for the reduction, either because they do not or cannot strategize in the same way as the others, or because they are distracted by the task requirements.

In summary, the OSPAN dissociation in SOA_L priming found here indicates that cognitive differences are surely important in certain priming tasks, but on its own does not explain exactly what kind of performance difference working memory capacity makes. I am currently running a similar study with SOA manipulated between halves of the LDT, rather than within blocks. Low spans may retain priming with SOA_L under decreased task demands. If priming were retained here, however, the question would still remain open as to whether either high or low spans were using an expectancy strategy or rather maintaining the prime itself throughout SOA_L. A logical follow-up to that study is to replicate both SOA manipulations using a high RP: if priming increases for either group at an RP of .75 compared to the current .25, then expectancy is operating in that group.

Apart from the current study, future research needs to focus on the role of working memory capacity in word recognition. To the best of my knowledge, there are no published studies looking at this, although such differences have been acknowledged in many other cognitive domains.

ACKNOWLEDGMENTS

I would like to take this opportunity to first thank Bart Van Voorhis, my faculty adviser, for his assistance during all stages of this project. I would also like to gratefully acknowledge Dr. Van Voorhis's research assistants, in alphabetical order: Steve(-O) Arnold, Rachael Manincor, and Nathan Roehrig. Jim Neely and Keith Hutchison also deserve thanks for offering helpful comments and suggestions throughout various steps in the process. All of the professors who gave their students the opportunity to participate deserve acknowledgment, as well as the undergraduate participants. My friends and family deserve mention here as well, especially Christine, for being supportive and willing to discuss these matters. Finally, I want to thank the UW-L Undergraduate Research Committee for giving me this opportunity, Bill Gresens, and the Honors Program in Psychology at UW-L, specifically Dr. Betsy Morgan and Lois Stuhr.

REFERENCES

Auchterlonie, S., Phillips, N., & Chertkow, H. (2002). Behavioral and electrical brain measures of semantic priming in patients with Alzeimer's disease: Implications for access failure versus deterioration hypotheses. Brain and Cognition, 48, 264-267.

Beatty, W. W., & Monson, N. (1990). Semantic priming in multiple sclerosis. Bulletin of the Psychonomic Society, 28, 397-400.

Becker, C. A. (1980). Semantic context effects in visual word recognition: An analysis of semantic strategies. Memory and Cognition, 8, 493-512.

Besner, D., Stolz, J. A., & Boutilier, C. (1997). The stroop effect and the myth of automaticity. Psychonomic Bulletin and Review, 4, 221-225.

Collins, A. M., & Loftus, E. (1975). A spreading activation theory of semantic processing. Psychological Review, 82, 407-428.

Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. A. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. Journal of Experimental Psychology: General, 128(3), 309-331.

Hutchison, K. A., Neely, J. H., & Johnson, J. D. (2001). With great expectations, can two "wrongs" prime a "right"? Journal of Experimental Psychology: Learning, Memory, and Cognition, 27, 1451-1463.

Jonides, J. & Mack, R. (1984). On the cost and benefit of cost and benefit. Psychological Bulletin, 96, 29-44.

Minzenberg, M. J., Ober, B. A., & Vinogradov, S. (2002). Semantic priming in schizophrenia: A review and synthesis. Journal of the International Neuropsychological Society, 8, 699-720.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading of activation and limited-capacity attention. Journal of Experimental Psychology: General, 106, 226-254.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. U. Humphreys (Eds.), Basic processes in reading: Visual word recognition (pp. 69-93). Hillsdale, NJ: Erlbaum.

Neely, J. H., VerWys, C. A., & Kahan, T.A. (1998). Reading "glasses will prime "vision" but reading a pair of "glasses" will not. Memory and Cognition, 26, 34-39.

Pitzer, K. D., & Dagenbach, D. (2001). A constraint on eliminating semantic priming by repeating a prime. American Journal of Psychology, 114, 43-53.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). E-Prime User's Guide. Pittsburgh: Psychology Software Tools Inc.

Smith, M. C., Besner, D., & Miyoshi, H. (1994). New limits to automaticity: Context modulates semantic priming. Journal of Experimental Psychology: Learning, Memory, and Cognition, 20, 104-115.

Stolz, J. A., & Besner, D. (1999). On the myth of automatic semantic activation in reading. Current Directions in Psychological Science, 8, 61-65.

Turner, M. L., & Engle, R. W. (1989) Is working memory capacity task dependent? Journal of Memory and Language, 28, 127-154.

VanVoorhis, B. A. & Dark, V. J. (1995). Semantic matching, response mode, and response mapping as contributors to retroactive and proactive priming. Journal of Experimental Psychology: Learning, Memory, and Cognition, 21(4), 913-932.

VanVoorhis, B. A. (1996). The locus of post-lexical semantic matching effects on semantic priming: Biasing a binary response or a binary decision? (Doctoral dissertation, Iowa State University, 1996). Dissertation Abstracts International: Section B: The Sciences and Engineering, 56 (12-B), 7073.

Whatmough, C., & Arguin, M. (1998). Semantic mediation of auditory priming in dyslexia. Brain and Cognition, 37, 86-88.