THE IMPACT OF EFFORTFUL PROCESSING

ON AUTOMATIC PRIMING

by

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ABSTRACT

There are conflicting findings in the literature regarding the impact of effortful task demands on the availability of automatic semantic priming processes. Woltz and colleagues reported in one experiment that semantic priming effects were eliminated when episodic retrieval demands were added to a sentence completion priming task. This result could reflect sensitivity of automatic priming to effortful processing in general, or it could reflect the impact of changing task set or processing goals. The current experiment tested the general effort explanation in the same sentence completion. A mixed-case manipulation was used to increase attention demands in some target trials. This presumably disrupted the automatic reading process but did not change the processing goals demanded by the task. Response time was slower in the mixed case trials; however, semantic priming was not impacted by the perceptual effort manipulation. This evidence, in combination with previous findings, suggests that automatic priming processes can facilitate performance even under some forms of effortful task demands, and that disruption of priming may depend on the addition of different task goals.

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CHAPTER 1

INTRODUCTION

Through practice, human performance of a task tends to improve with respect to both processing speed and accuracy (Chein & Schneider, 2005). Eventually, very little if any effort or attention is required to maintain proficiency, at which point performance sometimes is described as *automatic*. In contrast, when one is faced with a novel task, conscious effort and resources must be devoted to managing unfamiliar task components (Chein & Schneider, 2005; LaBerge & Samuels, 1974; Schneider & Schiffrin, 1977). The characteristic differences between effortful or controlled processing and automatic processing have been reasonably well established in the literature; however, the research exploring the interplay of these processes is complex, and findings are inconsistent in some cases.

Semantic priming tasks represent a common experimental approach to investigating automatic cognitive processes. Semantic priming refers to facilitation in response time and accuracy when a stimulus is preceded by a semantically related stimulus (McNamara, 2005). For example, a person exposed to the word "doctor" subsequently responds more quickly to the word "nurse" than to an unrelated word such as "rock." Research has supported the automatic nature of such priming effects under a range of experimental conditions (Neely, 1977; 1991; Neely & Kahan, 2001). However, evidence has also shown that semantic facilitation can reflect strategic rather than automatic processes (Neely, 1977). Of importance to the current research, some findings suggest that a task demand that elicits effortful, controlled processing reduces or eliminates semantically mediated facilitative effects (Bermeitinger, Wentura, & Frings, 2011; Chiappe, Smith, & Besner, 1996; Henik, Tzelgov, Freidrich, & Tramer, 1994; Keifer & Martens, 2010; Woltz, Sorensen, Indahl, & Splinter, 2015). Given the available evidence, there is little or no agreement among researchers as to how effortful processing affects the availability of automatic semantic priming processes. Therefore, the question being investigated in the current research is the following: Does the introduction of effortful, controlled cognitive processing reduce or eliminate automatic facilitation due to semantic priming, or is automatic facilitation due to semantic priming resistant to the influence of additional controlled processing? A clear understanding of these issues is important for obtaining a complete view of the dynamic nature of semantic memory operations, because every-day complex cognitive activities such as language comprehension depend on the interplay of both automatic and controlled processes (Chein & Schneider, 2005)

CHAPTER 2

LITERATURE REVIEW

The following literature review will provide an overview of the automatic and effortful processing research as well as a delineation of the inconsistencies among findings relevant to the current research question. In addition, important differences in semantic priming methodologies will be discussed, followed by a theoretical framework and the hypotheses to be tested.

Automatic and Effortful Processes

The characteristic differences between what is considered an effortful versus an automatic process have been well researched and there is general agreement among the researchers. Schneider and Shiffrin (1977) conducted a number of experiments that manipulated consistent versus varied mappings (input to output) of words to explore effortful (controlled) versus automatic processing. Under their framework, effortful processing was viewed as playing a supportive role to automatic processing in many contexts, fading in its necessity as automaticity is gained over extensive practice. Posner and Snyder (1975) likewise explored automatic and effortful processing, focusing mostly on the distinction between conscious control and unconscious or automatic pathway activation. They claimed that with repeated associations, stimulus information automatically activates internal representations, “making the automaticity of a perceptual pathway closely related to the degree of learning or experience the subject has had to particular associations” (p. 63). This view is similar to that of LaBerge and Samuels (1974), who also explored processing differences; however, their focus was on reading. They viewed fluent readers as having mastered or automatized their decoding skills, no longer requiring effortful attentional resources utilized by beginning readers. Unskilled readers lacked practice and were therefore required to devote more attention to basic level codes such as features, letters, sounds to letters, and spelling patterns before the activation of the word meaning could occur. Nonetheless, basic-level visual and phonological processes became automatic with practice, thus freeing up attentional resources and aiding the comprehension process.

These early researchers established some basic characteristics of automatic versus effortful processes that many cognitive researchers still acknowledge today. Automatic processing is considered to be fast, parallel, unconscious, unintentional, effortless, and independent of capacity–limited resources and top-down control (i.e., goals, intentions). Controlled processing, on the other hand, is characterized as slow, serial, effortful, conscious, and influenced by top-down factors such as attention, task goals, and intentions (Keifer & Martens, 2010; Posner & Snyder, 1975; Schneider & Shiffrin, 1977).

More recent research by Chein and Schneider (2005) broadened Schneider and Shiffrin’s (1977) earlier work. They performed a meta-analysis of neuroimaging studies that compared brain regions of practiced and unpracticed participants. They also conducted a within-subjects fMRI experiment that contrasted the neural mechanisms of unpracticed (effortful) versus practiced (automatic) performance. They used both verbal and nonverbal paired associates learning tasks. The results of the meta-analysis as well as the experiment indicated that a reduction in activity in the *domain-general control system* (lateral prefrontal, medial frontal, posterior parietal, occipito-temporal, and cerebellar brain areas) occurs with extensive task practice. Research conducted by reading experts is consistent with this and provides evidence that overall brain region activations decrease in skilled readers compared to unskilled readers (Rayner et al., 2001; Shaywitz, 2003). Although there is agreement among cognitive researchers and reading experts that added effort and attentional resources are needed under many task demands, the impact of such effortful processes on automatic processes is still unclear.

As previously mentioned, semantic priming is a common method used by cognitive researchers to investigate automatic and effortful processes, and it can be incorporated in different language processing tasks. The common feature of this approach is the measurement of faster or more accurate responses to a verbal stimulus as a function of previous exposure to a semantically related stimulus. The stimulus event in which facilitation is measured is referred to as the *target,* and the previously presented stimulus is referred to as the *prime* (McNamara, 2005). Various memory models have been put forth to explain semantic priming mechanisms including spreading activation (McNamara, 1992), compound-cue retrieval (Ratcliff & McKoon, 1988), and distributed network activation (Masson, 1995; Plaut & Booth, 2000).

The methods used in the majority of semantic priming research to date has relied on simple, lexical processing tasks that produce short-term priming effects that decline or are eliminated with a single intervening unrelated word (Neely, 1991). The different theoretical models of priming equally explain these short-lived facilitation effects.

Recently, the use of priming tasks with greater semantic processing demands has produced more persistent and robust semantic priming effects (Becker, Moseovitch, Behrmann, & Joordens, 1997; Joordens & Becker, 1997; Tse & Neely, 2007; Woltz, 2010; Woltz, Sorensen, Indahl, & Splinter, 2015; Woltz & Was, 2007). Becker et al. (1997) performed three semantic priming experiments, with increasing word lags up to eight. Due to the fact that priming remained after these lags, it was assumed that actual learning was occurring rather than temporary memory changes. Models including spreading activation and compound cue models that only account for short-term effects cannot explain these longer lasting effects. Currently, only distributed network models that incorporate a persistent rather than temporary change in network weights explain the long-term facilitation effects (Becker et al., 1997). This change in network weights is also congruent with the refining effects (learning) that occur within brain regions, as tasks are practiced (Chein & Schneider, 2005).

Long-term priming effects from experimental tasks of greater complexity provide a longer window of time with which to study priming processes. With respect to the current research, such persistent priming effects make it possible to systematically manipulate the cognitive demands in target events, independent of the processing demands in prime events. This is less feasible in quickly decaying short-term priming. Investigating the impact of effortful processing with longer-lasting priming will also provide a more realistic view of the boundaries of semantic facilitation in a timeframe relevant to many real-world comprehension tasks.

Compatibility of Automatic Priming and Effortful Processing

Early theorists such as Posner and Snyder (1975) and Schneider and Shiffrin (1977) theorized that once a task is learned to the point of automaticity (i.e., attention is no longer required to perform it), effortful or strategic tasks that require attention cannot stop the unconscious automatic process. This view implies that effortful demands during target trial processing should not impact priming effects. Neely and Kahan (2001) agreed that semantic activation is truly automatic in appropriately designed priming tasks. These researchers argued that reduced priming effects due to some task manipulations, such as insertion of a letter search task before the target event, are explained by activation decay rather than disruption of automatic facilitation.

In contrast to the view of these theorists, there are researchers who claim that semantic priming and semantic activation are not completely automatic and that priming can be disrupted or mediated by tasks that manipulate attention (Chiappe, Smith, & Besner, 1996; Henik, Friedrich, Tzelgov, & Tramer, 1994; Keifer & Martens, 2010, Maxfield, 1997; Smith & Besner 2001). A letter search task is assumed to require more effort and attention than a lexical decision task (LDT) or word naming task because it draws the focus of attention to the lower or more basic letter or feature level and away from the automatic processing of word meaning (Maxfield, 1997). Chiappe, Smith, and Besner (1996) suggested that when the reader's focus of attention is at the letter level (versus lexical or semantic levels), it limits the word recognition system important for semantic activation. They proposed that domain-specific processing due to letter search makes demands on attentional resources resulting in a blockage of semantic activation.

Smith and Besner (2001) further explored whether or not higher semantic-level activation could be disrupted or prevented by priming lower lexical or letter levels or representations. In their study, Smith and Besner (2001) first directed their 155 undergraduate participants to read the prime word, and then the color of the target directed their attention to perform a LDT (is the target a word?) or a letter search task (does the target contain a double letter?). Priming was only evident in the LDT task, with attention focused on words rather than letters. These researchers used a language processing framework called the interactive activation model (McClelland & Rumelhart, 1981, see Figure 1) to explain how the effortful task of letter search might block semantic activation. This model assumes that with visual word processing, activation spreads both forward and backward between letter, lexical, and semantic levels. Smith and Besner (2001) postulated that a between-level activation block occurs with letter search. The attentional focus on the letters prevents, or blocks, the associative flow of information from the higher semantic level (prime) to the lexical level (target) needed for priming. Consistent with this view, their findings revealed that letter search was not impacted by relatedness to prime, but the LDT was impacted.

Another example of priming being disrupted by attentional focus on surface features of words is the research by Blum and Johnson (1993), who conducted several lexical processing experiments. Although holistic models that assume letter detection in LDTs is mediated by preceding word recognition predicted that word priming would not only facilitate related words, but also facilitate the processing of letters, they found it did not. In Experiments 2, 5, and 7, lexical processing was facilitated when participants were asked if the target was a word or nonword. However, in Experiments 1, 3, 4, 6, and 8, the lexical processing of prime words did not facilitate letter-level processing of targets as predicted by holistic models. Both primes and target words were displayed on the screen in uppercase letters. The target letter was spoken aloud by the experimenter. Subjects were simply asked to indicate whether or not a given letter was in the presented target word. The results were similar in each experiment: When asked if the letter was in the word, letter facilitation did not occur. These results were consistent with the idea that a letter-level focus may block the facilitative effects of semantic activation, as proposed by Smith and Besner (2001).

Although these findings can be seen as support for the Smith and Besner (2001) explanation, it may not be necessary to assume semantic activation is "blocked" by attention demands to surface features of the stimuli. It could be simply that letter search is a poor measure of semantic facilitation. That is, semantic activation may exist at the word level during primed letter search trials, but word level activation may not be instrumental in letter search performance. Not all target tasks may depend on word level activation, and the perceptual search for a target letter may be an example of this. If so, the existence of activation in lexical representations due to semantic priming would not be expected to affect performance, and primed and unprimed letter search trials should be equivalent.

Somewhat related to this explanation, another possible attentional factor affecting priming is task set, or mental set, in preparation for a given task. Henik et al. (1994) stated, "If the features of the task to be performed on the next trial are known, the subject may allocate resources according to task priorities in advance" (p. 166). A task set is considered an orientation for processing information that can occur with cues or task instructions and has been shown to influence priming effects (Bermeitinger, Wentura, &

Frings, 2011; Gilbert & Sigman, 2007; Keifer & Martens, 2010;). Neuroscientists too are aware of the influence of task set:

> We have learned that the function of any area of the cerebral cortex, including that of primary visual cortex, is subject to top-down influences of attention, expectation, and perceptual task… Even the prefrontal cortex, arguably the highest order area in hierarchical views, can be set in different modes depending on task requirements. (Gilbert & Sigman, 2007, pp. 677-678)

The construct of task set differs from effortful processing in that it describes a configuration of cognitive state in preparation for an upcoming task or instructional goal, whereas effortful processing refers more generally to processing that is nonautomatic or requires attention (Bermeitinger, Wentura, & Frings, 2011; Sakai & Passingham, 2003). For example, in Besner and Smith's (2001) study, subjects were presented with a color during the target phase, which was a cue to process the information as directed rather in an unspecified way. To show how task set can more explicitly influence our processing, Sakai and Passingham (2003) used fMRI to measure neural correlates of task set. They instructed their subjects to remember either a sequence of four letters or a sequence of four spatial positions (location of displayed red squares). On half the trials, they were instructed to remember the forward sequence, and the reversed sequence on the other half. fMRI measurements were recorded during instructions and throughout the tasks. The delay between instruction and first task item varied from 4 to 12 seconds. Depending on the domain of the task given, corresponding regions of the brain became active upon receiving instructions for upcoming task. For example, spatial areas (Brodman's 8 and superior parietal lobule) became active when spatial task instructions were given (before the task was performed), and verbal processing areas (Broca's area and inferior frontal gyrus) became active when verbal memory task instructions were given (before the task was performed). These results reveal that anticipation of attention being devoted to specific stimulus features can activate relevant areas of the brain. Similary, Bermeitinger, Wentura, and Frings (2011) provided evidence that task set can be an influencing factor. Using a category priming task (natural and artifactual categories) in their semantic priming experiment, these authors induced a mindset that focused their subjects' attention on either perceptual features (natural category) or functional features (artifactual). This was accomplished by using a second task that required either a perceptual (symbol identification) or action feature (symbol movement) focus to shift attention. When subjects were given a perceptual focus task during the priming task, words with a perceptual focus (from natural versus artifactual categories) showed a priming effect, whereas those with an action focus during the priming task only showed priming of action-related words. The authors suggested that mind set can act as a modulator of concept representations, and their results revealed that an attentional induction of perceptual focus versus an action focus can affect priming results. Relatedly, research has shown that if subjects can learn to implicitly predict what a target will be or can predictively match the target back to the prime, semantic priming effects will be impacted (McNamara, 2005).

Many of the studies previously discussed provided evidence of reduced or modulated priming effects under task conditions that manipulated attention allocation; however, there is also research that demonstrated an increase in priming effects associated with attention-demanding task manipulations. Thomas, Neely, and O'Connor (2012) reported an increase in automatic priming effects when using degraded versus clear targets with both lexical decision and pronunciation tasks. Priming effects were greater for degraded compared to clear targets when prime-target pairs represented backward associations (e.g., *small shrink*) and symmetrical associations (e.g., *east west*), but the effect was not found for forward asymmetrical word pairs (e.g., *keg beer*). Other researchers have found increased priming effects, as well. Becker and Killion's (1977) participants, after viewing a single prime word, viewed strings of letters and were asked to decide if a stimulus was a word or a nonword. A visual intensity manipulation that varied the plotting time per point on the display resulting in varied contrasts of .024, .084, and .24 cd/m^2 for each display point to degrade the targets. This type of visual manipulation resulted in increased priming in the degraded condition compared to the nondegraded condition. The effect of visual intensity was about 35 msec. Similarly, Meyer, Schvaneveldt, and Ruddy (1975) used a visual noise manipulation, in this case, placing a dot pattern on top of the presented words and nonwords letters. Lexical decisions were made to both primes and targets; however, only the targets were displayed in the visual noise or no visual noise condition. The degraded, or visual noise condition resulted in larger priming effects than the nondegraded condition. When these same degraded stimulus experiments were performed, but the targets were pronounced instead, similar increased priming results were obtained. Such evidence contradicts other studies that conclude that a reduction or elimination of priming occurs when task complexity, perceptual demands, or general effort is increased.

Evidence that effortful or controlled processing can both increase and decrease the availability of automatic priming processes has been provided with respect to short-term priming. Another example of incompatibility between automatic priming and controlled processing was recently reported from a task that produced long-term semantic priming effects (Woltz, Sorensen, Indahl, & Splinter, 2015). Participants performed a sentence-completion task by choosing one of two words to complete a proposition (e.g., *consumers purchase* _______: *products* or *insects*). In some of the trials, participants were subsequently asked to indicate whether or not the content of the target sentence was similar in meaning to one that was seen 15-30 minutes earlier (e.g., *shoppers buy* __________: *merchandise* or *bugs*). This secondary question was used to examine whether facilitation in RT of primed targets could be attributed to explicit recognition of prime trial processing. In addition to evidence suggesting that priming effects were independent of recognition, other evidence was pertinent to the current question. Subjects were slower to respond when they knew they would subsequently be asked to recall previous material. More importantly, there was robust sentence completion priming in target trial blocks that did not include the recognition questions and little or no priming in blocks that included the recognition demand.

The possibility that effortful processing is incompatible with automatic semantic facilitation is just one explanation for the elimination of priming in experiments such as that reported by Woltz et al. (2015). The demand for episodic recognition (i.e., recall of previous material) could be more than just an attention demand; it could have initiated a task set of an incompatible memory process rather than just effortful processing. Would a similar effect occur if, rather than an additional memory demand, there was an additional perceptual demand during the sentence completion targets that did not change the task set? If so, this would be inconsistent with the task set or incompatible memory demand explanation for the finding. The current experiment tested the prediction that automatic semantic priming in sentence completion would be disrupted by the addition of perceptual rather than memory demands. Such an outcome would be consistent with a view that automatic priming processes in this task are incompatible with effortful processing demands of any variety.

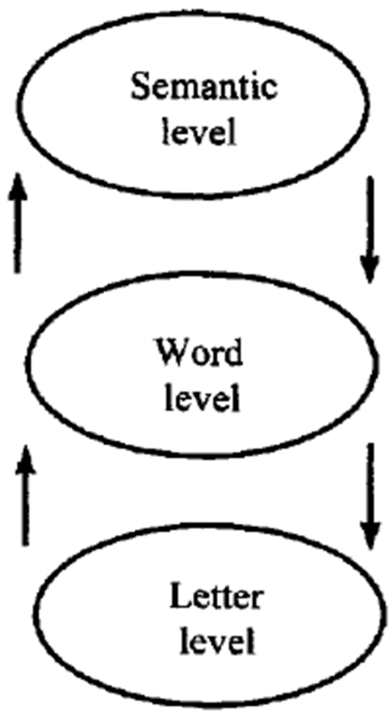

Figure 1. Based on McClelland and Rumelhart's 1981 interactive activation model.

CHAPTER 3

OVERVIEW OF THE EXPERIMENT

There are conflicting findings in the literature regarding the impact of effortful task demands on the availability of automatic semantic facilitation processes. The general question addressed by the current research was whether semantic priming manipulations that have generated relatively long-lasting facilitation effects under comprehension conditions that are primarily automatic in nature can facilitate performance under conditions that disrupt normal reading processes.

Letter search tasks are the most common semantic priming manipulations used to promote the effortful, perceptual processing of stimuli. A letter search task requires perceptual effort by drawing attention to letter-level processing (Maxfield, 1997). However, some studies have manipulated perceptual effort using text distortion. Martens and Jong (2006) used a mixed case format (e.g., mIxEd cAsE) in their task to examine the disruption of orthographic knowledge in children (18 beginning readers and 27 advanced readers in Grades 2, 4, and 5) using one-syllable pseudowords. They found that the distorted text format impaired reading speed and orthographic knowledge acquisition in both beginning and advanced readers. These researchers assumed the primary effect of the mixed case manipulation was the breaking up of multiletter units. This in turn slowed reading by inducing more serial or letter-by-letter processing. Similarly, Braet and

Humphreys (2006), using Transcranial Magnetic Stimulation (TMS) methods, found that using case mixing as a distortion required the added recruitment of the right parietal lobe in their participants. The authors suggest that this type of manipulation may include a mental transformation of the text into a common format, which requires the added resources and makes the processing serial and, therefore, effortful for the reader. Related neuroscience research has provided evidence that some degraded conditions activate not only the common language areas of the brain used for automated reading such as ventral occipital-temporal pathway, but also those areas needed to decipher shapes and serial letter processing such as the dorsal parietal attention system (Cohen, Dahaene, Vinckier, Jobert, & Montavont, 2008). Evidence from degraded and mixed-case conditions suggest that forms of text distortion can disrupt the automaticity of reading, even for advanced readers, and make the reading process unfamiliar and effortful again (Braet & Humphreys, 2006).

In the current experiment, I assumed that by encountering the mixed-case manipulation, participants' processing of targets would be slowed, and the automaticity of reading would be disrupted in comparison to the normal, lower case condition. It was hypothesized that:

1. The mixed-case manipulation of target trials would result in a reduced priming effect in comparison to the normal-case condition due to the allocation of attention to letter-level perceptual processing of unfamiliar text.
2. Since the participants were advanced readers, as they become increasingly exposed to and practiced in deciphering words in the

mixed case condition, the predicted impact of the unfamiliar text on priming would decrease over trial blocks.

CHAPTER 4

METHOD

Participants

One hundred one undergraduate students (72% female) participated in the experiment and received partial course credit in an introductory educational psychology course. Ages ranged from 18 to 47 years, with a median age of 23. Five participants were omitted due to high error rates, leaving 96 participants for the analyses.

Apparatus

Participants performed the experimental task using PCs with SVGA monitors and standard keyboards. Programming of all tasks was completed using E-prime software (Schneider, Eschman, & Zuccolotto, 2002).

Procedure

The materials and task were similar to those in Woltz et al. (2015) Experiment 4. The primary experimental stimuli consisted of 96 pairs of semantically similar propositional expressions, each having two predicate object choices: one valid and one invalid (e.g., *credit unions loan finances/rankings; banks lend funds/reputations*). Each proposition had an active or passive voice expression alternative (e.g., *credit unions loan* *finances/rankings; finances/rankings are loaned by credit unions*). An additional set of single sentences acted as filler propositions. They were similar in format to the other sets; however, they were semantically unrelated to the experimental sets. These unrelated trials were presented at the beginning of each block (warm-up trials) and as filler trials between prime and target trials.

Although the stimuli were used from the Woltz et al. (2015) Experiment 4, the following modifications were made to the task: 1) there was no recognition component that required participants to judge previous content, 2) half of the primed and unprimed target trials were displayed in distorted text format, and 3) up and down arrow keys were used in place of the *T* and *B* keys for answering questions.

Instructions to the sentence completion task were provided with two active voice and two passive voice examples, followed by a block of 12 practice trials. Participants were instructed to respond quickly and to choose the most appropriate word from two alternative words to fill in the missing word of each expression.

Each trial began with a row of asterisks displayed at the center of the screen (for one second), then an incomplete sentence (proposition) such as *banks lend* _______ replaced the asterisks. Below the sentence, the two response alternatives were displayed one above the other (e.g., *funds* and *reputations*). Participants were instructed to use the UP and DOWN arrow keys to select their response. As in the previous example, sentences were presented in active voice, or in passive voice (e.g., ______ *are lent by banks*). Summary performance feedback of average RT and percentage correct was provided after each experimental block.

The experimental task began with three trial blocks of prime trials (20 trials in each block). All prime trials were presented in lower case. Following the prime blocks, a filler task was presented. This task was unrelated to the prime and target task. Participants were asked to identify words from scrambled letters. For example, the word *ducer* was displayed near the top of the screen. Just below it, on either side, two word choices *duck* and *crude* were displayed for the participant to choose from. Their task was to identify which of the two words could be formed from the scrambled letters at the top using the RIGHT or LEFT arrow keys to respond. Participants received average RT and percentage correct feedback at the end of the each of four blocks of 24 trials. This intervening task allowed an approximately 15-minute lag between prime and target trials of the sentence completion task.

The final part of the experiment contained the target sentences (propositional expressions) consisting of six trial blocks. Each block began with four warm-up trials and 16 target trials, half primed and half unprimed. These blocks were preceded by instructions similar to those in the initial prime blocks, except mixed-case examples were used in place of regular lower case examples. Half of the primed and unprimed trials were presented with a mixed-case text display. For example, half the trials displayed two word choices such as *fInAnCeS* and *rAnKiNgS* with the proposition _______*aRe lOaNeD bY cReDiT uNiOnS.*

No words were repeated among the prime and target propositions. The target propositions were designed to be semantically related to only one prime proposition, and were therefore assumed to be independent of the influence of contextual priming. The assignment of experimental stimuli to primed and unprimed conditions, and to mixed versus normal case presentation was counterbalanced across subjects. Order of trials was random in each block.

The experimental task was completed in a room with separated sound-deadening computer carrels, in groups of one to four participants. The experimental session lasted approximately 1 hour.

CHAPTER 5

RESULTS

A within-subjects analysis of variance on both RT and errors was conducted. The initial analysis represented a 2x2x6 design (priming x case x block). However, the block factor did not interact with either the case or priming condition ($p > .160$), so results are reported for an analysis of only the priming and case factors.

Figure 2 presents the mean response time and mean error by condition with 95% confidence intervals. As seen in the left panel, there was a large main effect for case, $F(1,88)=86.25$, $p < .001$, $\eta_p^2 = .50$. The mixed-case RT mean was over 200 ms slower than that for lower-case. There was a smaller main effect for priming, $F(1, 88) = 11.62$, $p < .001$, $\eta_p^2 = .12$. On average, the priming effect was approximately 80 ms. Of primary importance, there was no evidence for the hypothesized interaction between case and priming, $F(1,88) < 1$. The priming effect difference between the two case conditions was less than 5 ms.

The right panel of Figure 2 presents mean error percentage by condition. As can be seen from the figure, there was no effect of the case manipulation, $F(1, 88) < 1$. There was also no effect of priming, $F(1,88) < 1$. Again, there was no evidence for the hypothesized interaction between case and priming $F(1, 88) < 1$. As evident in Figure 2, participants made about 6% errors regardless of trial condition.

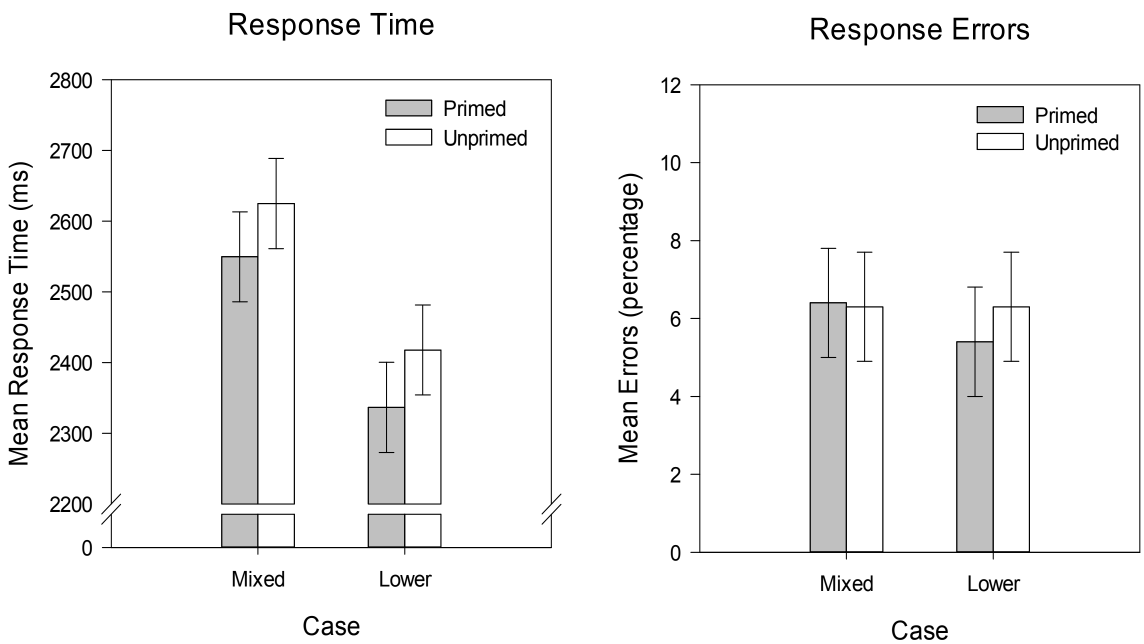

Figure 2 Mean RT and mean error by condition. Error bars represent 95% confidence intervals for within subjects design based upon work from Loftus and Masson (1994).

CHAPTER 6

DISCUSSION

The main hypothesis evaluated in this experiment was whether priming was impacted by the disruption of the automatic reading process. Three data comparisons in the target trials were of primary interest in evaluating this hypothesis. The first comparison contrasted the control condition, in which participants read regular, lower-case text propositions with word choices, and the experimental condition, which incorporate mixed-case propositions with word choices. This contrast represented a manipulation check to verify that a disruption in the automatic reading process did indeed occur. As presented in Figure 2, there was a statistically significant 200 ms increase in sentence completion processing time due to mixed case, which is consistent with a disruption in the automatic reading process. This disruptive effect on processing time was not coupled with a higher error rate. Participants were able to accurately complete the sentences presented in mixed case, they just needed more time to decode the novel letter format.

The second comparison was between primed and unprimed target trials. This contrast replicated the overall long-term priming effects reported by Woltz et al. (2015). As previously presented, long-term priming effects of about 80 ms were found across all conditions. Given the presence of an intervening task between prime and target trials, and the number of prime and target trials, the average prime-target lag was approximately 30 min. Semantic priming effects are considered long-term when facilitation persists beyond one unrelated, intervening trial. This distinction exists because models of temporary priming such as spreading activation and compound cue retrieval cannot explain effects with more than one intervening trial (McNamara, 2005). These results represent highly persistent priming effects compared to most other evidence of long-term semantic priming. As such, they are only explained by a distributed network model of long-term priming that incorporates learning mechanisms rather than temporary activation to account for memory changes from prime events (Becker et al., 1997).

Finally, the third comparison tested the primary hypothesis, which predicted an interaction in the form of substantial priming in the lower-case target trials and little or no priming in the mixed-case target trials. As Figure 2 displays, the interaction did not occur and this hypothesis was not supported. Although processing did slow and some components of automatic reading appeared to be disrupted, semantic priming still facilitated the comprehension and decision processes demanded by the sentence completion task.

A demand for episodic memory retrieval (Woltz et al., 2015) and a demand for effortful reading of unfamiliar text format (i.e., perceptual demand) appear to have different effects on the recruitment of primed semantic memory representations. The current findings suggest that automatic semantic facilitation can be compatible with effortful processing demands of some forms. Therefore, the nature of competing attention processes or the mental set created by additional task demands may determine the availability of semantic facilitation processes rather than effort per se. The evidence from previous short-term priming experiments suggests that if the task demands a perceptual evaluation and decision, facilitation from semantic primes is absent (e.g., in Blum and Johnson's experiments, when asked if the letter was in the word, facilitation did not occur). However, semantic priming was evident or even increased when perceptual manipulations were embedded in tasks that demanded lexical evaluations (e.g. in Thomas, Neely, and O'Connor's (2012) LDT's tasks, priming effects were greater for some degraded target tasks than clear target tasks) Consistent with this pattern, the current experiment manipulated perceptual processing demands in a task that required semantic evaluations, and the magnitude of priming was not diminished by the added perceptual demands.

The interpretation of task set determining when semantic priming effects are found and when they are absent requires an explanation of why Woltz et al. (2015) found no priming when a memory recognition demand was added to sentence completion target trials. The primed target trials in that work were identical to those in the current experiment, other than the respective added demands of each experiment. If semantic facilitation from previous primes is available whenever the target task requires lexical or semantic evaluations, why was it absent when memory recognition was demanded after the semantic evaluation? This cannot be answered definitively without additional evidence. However, it is possible that during sentence completion, participants were already evaluating whether they had seen a similar trial before. The recognition decision was more difficult than the preceding sentence completion decision, as indicated by error rates that exceeded 25% compared to approximately 5% errors in sentence completion. In addition, the anticipation of an impending recognition decision increased sentence completion times by 400-500 ms. It is conceivable, then, that the recognition evaluation was already in progress, and may have taken priority given its difficulty, during the sentence completion trial. If automatic semantic facilitation from primes only facilitates semantic or lexical evaluations, it would not be expected to affect episodic retrieval processes, and those processes may have been a focus of attention during the sentence completion responses.

An alternative explanation to that proposed here is that automatic semantic priming effects are eliminated only when the disruptive attention demands are severe. The perceptual complexity imposed by the mixed case manipulation slowed sentence completion processing, but only by approximately 200 ms (8% average increase in RT). The recognition demand in the Woltz et al. (2015) experiment slowed sentence completion responses by at least twice that amount (400-500 ms; approximately 18% average increase in RT). While the previous explanation of the differing priming effects is favored because it also explains discrepant evidence from short-term semantic priming experiments, the severity of disruption explanation cannot be discounted by current evidence.

These two accounts for the discrepancy between the current evidence and that from Woltz et al. (2015) roughly correspond to two explanations proposed in previous research for how secondary task demands affect semantic priming. The severity of disruption account resembles the explanation investigated by Smith and Besner (2001) and Blum and Johnson (1993) that semantic facilitation is incompatible with effortful processing, given that the task demands for effortful processing are substantial. The alternative account proposed that semantic facilitation from priming occurs only when the primary task demands lexical or semantic evaluations, not when it demands perceptual or memory evaluations. This resembles the task set effects hypothesized by Bermeitinger, Wentura, and Frings (2011), Gilbert and Sigman (2007), and Keifer and Martens (2010). Thus, the resolution of these two accounts for the sentence completion task has direct relevance to differing explanations for semantic priming effects found in the short-term priming literature.

Future studies could utilize the insights gained from this study and resolve competing explanations with further investigation. One way to further investigate the semantic priming operations involved in the sentence completion task would be to increase the degree of perceptual distortion in order to see if increasing the severity of disruption impacts priming. Another possible avenue for further clarifying the priming inconsistencies gleaned from studies discussed might manipulate task set or mind set. A future experiment could use the same sentence completion task; however, instructions could similarly induce a task set or mind set that will explicitly direct the focus of attention and signal whether evaluation is for meaning or perceptual features. If priming is then impacted with this change then, it will provide evidence that priming can be modulated by task instructions.

The interaction of effortful and automatic processes is a part of our daily cognition and language comprehension process. This study attempted to clarify the dynamic nature of semantic memory operations and attention demanding operations; however, there is much more to be learned.

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