LEXICAL AMBIGUITY PRIMING IN OLDER ADULTS: PARAMETERS OF ENHANCEMENT AND SUPPRESSION

By

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To my father, Michael Jonathan Levy.

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Basal ganglia involvement in cognition has been described as subtly influencing processing by enhancing selected activities and suppressing competing activities via frontal-striatal neural circuitry. Instead of direct involvement in primary language function, the basal ganglia likely modulate cortical information processing. A model proposed by Crosson, Benjamin and Levy suggests that the temporal pattern of lexical priming effects for subordinate meanings of ambiguous primes, may follow the sequence of suppression-enhancement-suppression that has been observed in the corresponding hyperdirect, direct, and indirect pathways of the basal ganglia of macaques. Three studies were performed in the process of investigating the temporal patterns of suppression and enhancement during word processing. First an online survey was used to collect current norms for homographs and associated dominant and subordinate meanings. Resulting homographs that met the established criterion were used in the subsequent priming studies. In the second study, performance of neurologically normal older adults on a semantic priming task was examined. Stimuli were word pairs containing a lexical ambiguity prime and a target in 1 of 4 conditions: Dominant-Related, Subordinate-Related, Dominant-Unrelated, or Subordinate-Unrelated. Reaction times at three stimulus-onset asynchronies (SOAs), short, intermediate and long were compared and results revealed selective priming for the dominant meaning at the short SOA and enhancement of both meanings at the intermediate SOA. To clarify results at the long SOA, which did not replicate previous findings, a third study used three additional SOAs in an identical priming task. Results lend support to the model of suppression-enhancement-suppression of the subordinate meaning but additional research is needed to clarify effects at the long SOA.

CHAPTER 1
INTRODUCTION

Within the past 2 decades, the influence of the basal ganglia on movement has been conceptualized not as primarily involved in the initiation of movement per se, but as facilitating movement in a more subtle fashion through the enhancement of selected movements and suppression of competing movements generated by cortical inputs. This concept of enhancement and suppression has more recently been applied to cognitive activities (Crosson, Benjamin, & Levy, in press), where selected cognitive activities are enhanced while competing cognitive activities are suppressed via the frontal-striatal neural circuitry. Through the study of Parkinson's patients with frontal-striatal compromise it may be possible to delineate further the involvement of the basal ganglia and neurotransmitters (e.g.,, dopamine) during language and related cognitive tasks. However, prior to investigation of these processes in individuals with Parkinson's disease (PD) it is necessary to first establish the pattern of processing in neurologically normal control subjects. The aim of the following three studies is to assess typical language processing through conceptual priming tasks involving lexical decisions about words.

The Basal Ganglia

The basal ganglia form a complex group of structures in the brain and are thought to influence movement and cognition through their interactions with various cortical and thalamic regions (Alexander, DeLong, & Strick, 1986; Middleton & Strick, 2000). In general, frontal-striatal circuits originate in frontal cortical regions such as primary motor cortex, premotor cortex, supplementary and pre-supplementary motor areas, anterior cingulate cortex, dorsolateral prefrontal cortex, and orbitofrontal cortex. Each circuit operates in a closed-loop fashion, beginning and ending at the same target cortical region.

Each basal ganglia circuit can be decomposed into three separate loops (Nambu, Tokuno, & Takada, 2002; Nambu et al., 2000) (Figure 1-1). Activity in the "direct loop" is thought to enhance selected actions and cognitions (Gerfen, 1992; Mink, 1996; Penney, 1986). Activity in the "indirect loop" is thought to suppress actions or cognitions that compete with selected actions and cognitions. More recently, a "hyperdirect" loop has been described (Nambu et al., 2002; Nambu et al., 2000). In this loop, unlike the direct and indirect loops, the cortical component projects directly to its subthalamic nucleus component, bypassing the striatum (an area affected by Parkinson's disease). Action in the hyperdirect loop is thought to have a suppressing effect on actions and cognitions.

Nambu et al. (2000) stimulated primary motor cortex (M1) in macaque monkeys and measured effects on the basal ganglia downstream in the medial globus pallidus. Although the exact time scale certainly does not apply to cognition, Crosson, Benjamin and Levy (in press) suggested the general sequence of events does. Activity in the medial globus pallidus indicates that after M1 stimulation there is an initial suppression of behavior/cognition followed by an intermediate enhancement of behavior, finally followed by a late suppression of behavior. Nambu et al. (2002) suggested that the initial wave of suppression resets the system by allowing it to change ongoing behavior/cognitions to new ones. The intermediate wave of enhancement raises the probability of initiating selected behaviors/cognitions. Finally, the late wave of suppression decreases the probability of competing behaviors/cognitions occurring.

Additional neurotransmitter influences occur from dopaminergic projections via the substantial nigra pars compacta to the striatal component of the frontal-striatal circuitry. While dopaminergic actions are less straightforward than the actions of neurotransmitters elsewhere in the frontal-striatal circuitry, dopamine is thought to influence both the direct and indirect basal ganglia circuitry.

The rationale for outlining basal ganglia circuitry and neurotransmission is that a disease or injury at various points along this circuitry should theoretically display certain types of neurocognitive deficits. Thus, certain disease states or brain injuries should theoretically produce problems with "enhancement" of certain cognitive functions through involvement of the direct basal ganglia circuitry, while others may produce dysfunction along the "suppression" continuum via involvement of the hyperdirect and/or indirect circuitry and related functions. In addition, other types of brain disease or injury may produce more global dysfunction based on implicated neuropathology, affecting both the enhancement and suppression of certain cognitive functions.

Semantic Priming and Lexical Ambiguity Priming

Semantic priming refers to the increased speed and accuracy in recognizing a target when the target is preceded by a related word (the prime) as compared to an unrelated word (Meyer & Schvaneveldt, 1971). Homographs or lexical ambiguities are defined as words with identical spellings but multiple distinct meanings, (Nelson, McEvoy, Walling, & Wheeler, 1980). A common example is the word "bank" which can be a place for money, the shore of a river, or a carom shot in billiards. This ambiguity of meaning is the reason homographs are frequently used in studies of language function and processing. The word "bank" presented in isolation is reportedly more likely to bring to mind "money" (the dominant meaning) than "river" or "carom" (subordinate meanings) according to published norms.

Using a type of semantic priming called lexical ambiguity priming, Simpson and Burgess (1985) paired lexical ambiguities with associated words related to the dominant meaning of the ambiguity (e.g., bank-money) and the subordinate meaning of the word (e.g., bank-river) as well as unrelated word pairs which acted as controls (e.g., glass-money, glass-river). The ambiguous word was presented first and half the time was followed by a pronounceable nonword. They presented these word pairs visually to college students and asked participants to make a lexical decision (word/nonword) about the second word of the pair (the target). They tested college students at various stimulus onset asynchronies (SOAs) and found that at a 16 ms SOA only the dominant meaning showed reaction time facilitation relative to unrelated words, while at intermediate SOAs of 100 or 300 ms facilitation was seen for both dominant and subordinate meanings. At longer SOAs of 500 and 750ms, the subordinate meaning no longer displayed facilitation relative to unrelated words, although the dominant meaning continued to do so. This pattern indicated that the time between the onset of the prime and the onset of the target influenced the effect of the ambiguous prime on recognition of words related to the prime's subordinate meaning. On the other hand, the length of the SOA had no effect regarding the influence of the prime on recognizing words related to its dominant meaning. These data suggest that the mechanisms that control lexical decision in the subordinate condition are dependant on the amount of time allowed for processing. Specifically three different retrieval patterns for the subordinate meaning were revealed; suppression when given only a short amount of time, enhancement at an intermediate time, and suppression at a longer amount of time. Crosson, Benjamin and Levy (in press) have suggested the sequence of activity reported in the basal ganglia by Nambu et al. (2000) maps onto the sequence of lexical ambiguity effects reported by Simpson and Burgess (1985).

Indeed, evidence of "enhancement" circuitry compromise was reported by Copland (2000) using a word-triplet priming paradigm in individuals with Parkinson's disease, nonthalamic subcortical vascular lesions, cortical lesions and matched controls patients. Due to reading difficulties of the cortical lesion patients, Copland presented his word-pairs auditorily and judged differences in presentation time as interstimulus intervals (i.e. measured from the end of one word to the beginning of the next) as opposed to SOAs (i.e. measured from the beginning of one word to the beginning of the next). At a short ISI (100 ms), all four groups showed similar priming effects. In contrast, at a longer ISI (1250 ms) nonthalamic subcortical lesion patients lost all priming effects, Parkinson's disease patients showed priming only for the strongest stimuli, and cortical lesion patients showed indiscriminant priming suggesting that basal ganglia compromise weakens or eliminates enhancement effects at the long ISI.

"Suppression" evidence has also been reported in the semantic priming literature. Copland (2003) performed a study using lexical ambiguity priming similar to that of Simpson and Burgess's 1985 study. Using the same patient groups as the above experiment, Copland found that in both control subjects and those with Parkinson's disease at an intermediate ISI (200 ms), priming effects were seen for both dominant and subordinate meanings; but at a longer ISI (1250 ms), controls displayed priming effects only for the dominant meanings while those with PD, (and nonthalamic subcortical lesions), continued to show priming for both the dominant and subordinate meanings suggesting the basal ganglia compromise results in a loss of suppression at the long ISI.

These findings suggest temporal effects during semantic priming follow a suppress-enhance-suppress pattern similar to what has been demonstrated in the basal ganglia circuitry during motor tasks (e.g.,, Nambu et al, 2000, 2002). For example, Simpson and Burgess (1985) found an absence of priming for the subordinate meaning of words at an extremely short SOA despite a priming effect for the dominant words. At an intermediate SOA, similar to the "short" ISIs reported by Copland (2000, 2003), both the dominant and subordinate meanings were primed. In contrast, only the dominant meaning was primed during a longer SOA/ISI (Copland, 2003; Simpson & Burgess, 1985).

Using our theoretical understanding of frontal-striatal circuitry and neurotransmission, reported neurocognitive deficits on language and related cognitive tasks in patient populations with frontal-striatal implications, and the literature regarding conceptual priming paradigms in both patient populations and healthy controls, our overall goal is to use lexical ambiguity priming to examine the performance of healthy controls and patients with Parkinson's Disease on a similar task in order to better conceptualize the relationship between enhancement and suppression, and basal ganglia pathways. As a first step in achieving that goal the following studies intend to clarify language processing in neurologically normal older adults.

Copland's findings (Copland, 2000, 2003) support the theory that the role of the basal ganglia in language processing occurs through enhancement via the direct pathway at the intermediate ISI and suppression via the indirect pathway in at the long ISI. The use of a short SOA in lexical priming of younger neurologically normal adults resulted in selective priming of the dominant meaning and suppression of the subordinate meaning (Simpson & Burgess, 1985) which may be evidence of the influence of the hyperdirect pathway. It is not yet known if this finding will be present in older adults, however the following studies aim to answer that question.

The purpose of the first study, detailed below, is to determine appropriate homographs for use in the priming studies which follow. Research conducted on the norms of associations involved with homographs is more than ten years old, with the most recent large-scale study dating back to 1994 in Canada (Twilley, Dixon, Taylor, & Clark, 1994). In the U.S. however, the most current well-known homograph norming study took place in 1980. The present investigation seeks to update norms established by this research and to establish current norms on association strengths of dominant and subordinate meanings of homographs in a U.S. population sample.

The second study seeks to translate the auditory priming paradigm (Copland, 2003) into a visual task to examine reaction time facilitation for related as compared to unrelated words at short, intermediate and long SOAs. The third study seeks to clarify results from the second study by testing additional intermediate and long SOAs.

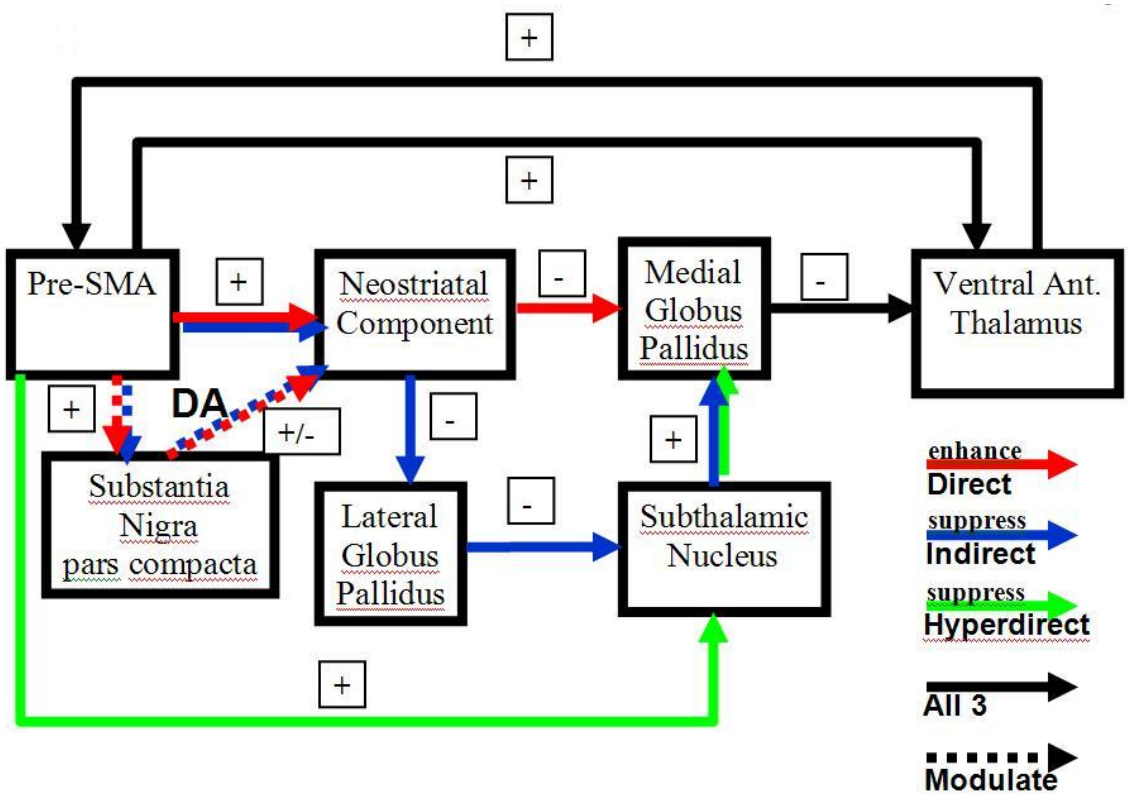

Figure 1-1. The direct, indirect and hyperdirect pathways of the basal ganglia. Reprinted with permission from Crosson, B., Benjamin, M., & Levy, I. (in press). Role of the basal ganglia in language and semantics: Supporting cast. In J. J. Hart & M. Kraut (Eds.), *Neural Basis of Semantic Memory*. New York: Cambridge University Press.

CHAPTER 2
STUDY 1: A STUDY OF HOMOGRAPHS

Introduction

Homographs are defined as words with identical spellings but multiple distinct meanings, (Nelson et al., 1980). This ambiguity of meaning is the reason homographs are frequently used in studies of language function and processing. The word "bank" presented in isolation is reportedly more likely to bring to mind "money" (the dominant meaning) than "river" or "carom" (subordinate meanings) according to rather out-of-date published norms.

Previous research involving the norming of homographs has generally involved the use of free association tasks. (Nelson et al, 1980, Twilley et al, 1994). In their study, Nelson, McEvoy, Walling, & Wheeler (1980) asked forty-six research participants to perform a free association task in which they were to "write down the first word that comes to mind" for each of 320 homographs. Although this study has supplied data on homograph norms in a U.S. population, the data are over 25 years old and it is unclear if these norms are still valid today. The more current research performed by Twilley, Dixon, Taylor and Clark in 1994 also involved a free association task. Their norms are based on a sample of 192 subjects who performed a free association task to a list of 566 homographs. While this study is more recent and involves a larger number of homographs, some of the primary associations found by the study appear to be very time-specific (e.g., Vice-Miami and Desert-Storm). In addition, as the study took place in Canada, it is unclear if the results can be generalized to a U.S. population. A review of the literature indicates that there is a growing need for current up-to-date norms on homograph associations that can be generalized to a U.S. population. The goal of this study is to generate norms which will provide important background information for future studies of language and cognitive processes.

From a cumulative list of potential homographs used in previous norming studies (Nelson et al., 1980; Twilley et al., 1994), 518 homographs were chosen by, Moore and colleagues at Emory University for use in the current norming study.

Methods

Participants

Participants were enrolled in an undergraduate psychology class and elected to volunteer for research participation in partial fulfillment of their course requirements. A total of 177 participants 18 years old or older completed the online survey. Informed consent was obtained electronically prior to participation in the web based survey.

Procedures

A web-based word survey was created through the University of Florida's Psychology Department. The survey was administered and scored by a SONA Systems software also used to manage the Participant Pool and authenticates its users. A sample of the survey can be found in Figure 2-1. Participants were required to have web access and be a native English speaker. After consenting to participate, individuals were shown three words: a homograph and two word choices associated with meanings of the homograph (e.g., "BANK: MONEY RIVER"). Two versions of the survey were used. In the first, participants were instructed to click on the button indicating the word related to the dominant or more commonly used meaning, and in the second they were instructed to choose the subordinate or less commonly used meaning of the homograph. A total of 518 such word triplets, were presented to each participant. The order of presentation of the homographs was randomized for each participant. There were 94 participants who received the dominant instructions and 83 participants who received the subordinate instructions.

Results

In order to determine the strength of association between a given homograph and each of the two words related to its meanings, word choice data was examined and percentages were calculated across participants to establish how often each meaning was chosen. The goal was to collect homographs with strong dominant meanings and weak but plausible subordinate meanings for use in the semantic priming studies discussed in Chapters 2 and 3. Homographs with one word of the presented pair chosen as related to its most common meaning by between 70%-80% of participants, and consequently the other word chosen as related to its most common meaning by 20-30% of participants, were determined to have adequate dominant and subordinate meanings. Homographs with meanings chosen as dominant by greater than 80% of the participants were excluded because the subordinate meanings of such homographs might not be represented well enough to elicit a priming effect, and homographs with meanings chosen as dominant by more than 30% but less than 70% of participants were excluded because the strengths of the associations was determined to be too equivalent and might not be distinguishable in semantic priming experiments.

In the survey in which participants were asked to choose the more common used meaning (the dominant survey), a total of 335 homographs were excluded while 183 homographs met the 70%-80% criterion. In the alternative survey in which participants were asked to choose the less commonly used meaning of the homograph (the subordinate survey) only one homograph met the criterion for inclusion. The number of homographs in each category based on word choice across participants for each version of the survey for can be found in Table 2-1.

Discussion

In creating two versions of the survey with differing instructions the goal was to compare those words that were chosen as dominant meanings of the homographs to those chosen as subordinate meanings. However examination of the data collected revealed that while the dominant version of the survey appeared to provide numerous examples of homographs with clear dominant as well as subordinate meanings, the subordinate version of the survey was unable to provide additional information regarding differential strengths of associations between homographs and meanings. The reason for the difference between the two surveys is not entirely clear but may be in part because of the inherent difficulty in asking someone to choose a less common meaning of a word. This decision involves first thinking about the more common meaning and then actively contemplating alternative meanings that are less frequently used. The process of attending to the less common meaning may increase its level of activation. Thus, to the extent that participants use differential activation as a tool to discriminate between the dominant and subordinate associations, attending to the subordinate association may have decreased the subjective difference between the two associations, thereby making it difficult to distinguish between them.

While the subordinate survey results were unusable, the results from the dominant survey appeared to clearly discriminate between strongly and weakly associated meanings of the homographs. For those words that were chosen by 70-80% of participants as related to the dominant meaning of a homograph, there were also 20-30% of participants who chose the alternative word. Because of the strength of this split it was decided that these words could still be seen as having a moderately strong relation to the meaning of the homograph which in essence categorized them as subordinate meanings of the homograph.

Table 2-1. Number of homographs meeting criteria based on word choice across participants

Survey Type	N	31%-69%	70%-80%	81%-100%	Total
Dominant	94	211	183	124	518
Subordinate	83	517	1	0	518

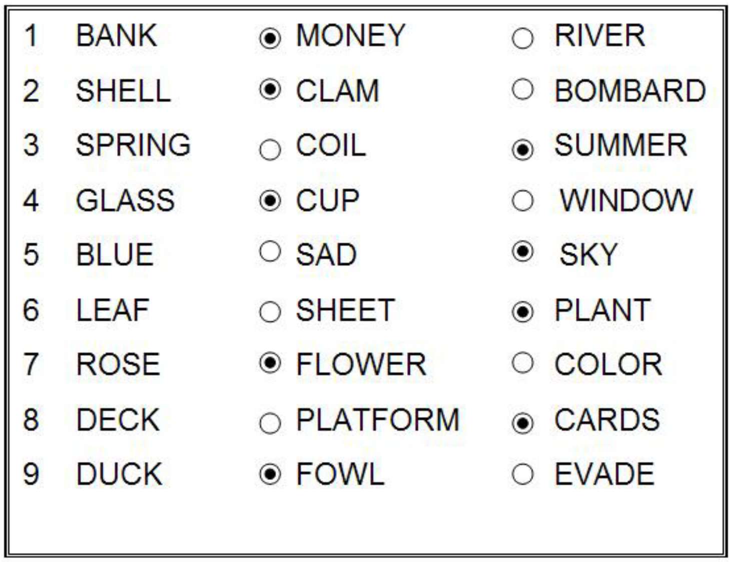

Figure 2-1. Sample of online survey presentation of homographs and associated meanings.

CHAPTER 3
STUDY 2: LEXICAL AMBIGUITY PRIMING (TAKE 1)

Introduction

The present study uses a lexical ambiguity priming paradigm modeled after that of Copland (2003), and Simpson and Burgess (1985). Using an auditory paradigm Copland was only able to examine the intermediate and longer stimulus presentation times, so the goal of the current study is to expand his results first in neurologically normal older adults, and if results are replicated, the paradigm will be tested on those with PD in a future study. While Simpson and Burgess (1985) previously performed a version of this study, the results for the short SOA (16ms) are questionable given the computer and monitor equipment available at that time. Additionally, the 1985 study was performed on younger adults and it is unlikely that results will generalize to an older population who eventually will be the comparison group for individuals with Parkinson's disease.

Based on the results from previous studies (Copland, 2003; Simpson & Burgess, 1985) it is hypothesized that participants will show priming effects for both the dominant and subordinate meanings at the intermediate SOAs but only the dominant meanings at the short and long SOAs.

Methods

Research Participants

Six older adults (4 females, 2 males) with a mean age of 73.67 and mean number of years of education of 13.67 volunteered to participate in the study. All participants had English as a first language, no previous diagnosis of a learning disorder or neurological disease or head trauma and were self-reportedly right handed. All participants gave written informed consent in accordance with procedures established by the University of Florida Health Science Center Institutional Review Board.

Apparatus

Stimuli for the priming experiments were presented to subjects using a desktop computer running Windows98 software, a 19 inch ViewSonic VX922 LCD monitor with two millisecond video response time, and a two button mouse. Words were presented in white Arial font on a black background with word size approximately one inch when displayed on the screen. The experiment was programmed and performed using Presentation® software (Version 9.50, www.neuro-bs.com) which is capable of presenting stimuli and collecting response time data with tenth of a millisecond accuracy.

Materials

The current task involved visually presented word pairs. The first word presented was either a lexical ambiguity (homograph) or a non ambiguous word which served as the prime. The prime was followed by a target word which was either a real word, related or unrelated to the prime, or a pronounceable nonword. Of the 183 homographs that met our criteria of 70-80% strength of association for a dominant meaning in the homograph study (Chapter 1), 144 were selected for use in the priming tasks. Homographs were chosen that contained between three and eight letters (M=4.89), and no more than three syllables (M=1.32). Of the chosen homographs, 72 were used to create pairs of words comprised of a homograph prime and a target word from one of four conditions: a word associated with the dominant meaning of the prime (dominant related); a word associated with a subordinate meaning of the prime (subordinate related) and two unrelated conditions (dominant unrelated and subordinate unrelated) in which the ambiguous prime (homograph) was combined with the dominate and subordinate targets semantically associated to a different prime. A total of 288 word pairs resulted. The possible targets consisted of 144 words, each repeated twice, presented as part of a related and an unrelated word pair. There were also 288 nonword pairs constructed; half were comprised of two sets of 72 additional homographs followed by a different pronounceable nonword and two sets of 72 unambiguous words followed by a pronounceable nonword. The 72 nonwords were created by jumbling or replacing the letters of previously used homographs while maintaining pronouncability, and the same set of nonwords was repeated four times throughout the experiment.

All possible words pairs were divided into three equal lists, each to be presented at a different SOA. Each list contained 24 word pairs and the lists were balanced using the online MRC Psycholinguistic Database (Wilson, 1987) on average length of word, number of syllables, frequency of use in the English language (Kucera & Francis, 1967), imagibility values, as well as the strength of association to the homograph determined by the homograph study (Chapter 1). No significant differences were found between word lists on any of the measured variables ($p>.05$).

Words pairs were presented in 24 blocks of 24 trials (12 word pairs, 12 nonword pairs) at one of three potential SOAs (50 ms, 300 ms, 1550 ms) determined by list membership. Blocks of SOAs as opposed to random presentation times, were used so that participant attention was not influenced by expectations regarding presentation times. The probability of seeing a word or a nonword target was .50 for any trial. The order of word and nonword trials was pseudorandomized within each block with the condition that no more than three real words or nonword targets were presented in succession. Additionally, pairs were sequenced so that repetitions of homographs or targets were at least 10 trials apart. The blocks were pseudo-randomized such that groups of three sequential blocks included one block presented at each of the three SOAs, and no more than two blocks in a row used the same SOA.

In order to control for word and order effects, three versions of the task were constructed which included the same lists of words pairs, but altered the SOA assigned to each list. In this way a given subject saw all three lists but between subjects the lists were presented at different SOAs. Three additional versions of the task were constructed to control for the effect of the dominant word pair or related word pair appearing first. Participants were tested using one of these six possible presentation orders.

Procedure

Participants were seated directly in front of the computer monitor with their right index finger on the left mouse button in preparation for quick responses on the go-no-go task. Participants were instructed that they would see two words one after the other and they were to click the mouse button as quickly as possible after determining that the target was a real word, and do nothing if the target was a nonword. The task began with 16 practice trials consisting of eight real word pairs (two of each condition) and eight nonword pairs. Targets were displayed at one of the three SOAs, and feedback was provided during the practice session only. If the participant's performance was at least 80% correct the experiment was started, otherwise, instructions and the practice trials were provided for a second time.

Following Simpson and Burgess (1985) paradigm, participants were shown a red warning dot for 400ms indicating a word pair was about to be presented. The prime then appeared on the screen in lower case letters and was replaced by the target in all capital letters after the designated SOA. Reaction time (RT) of the lexical decision was measured in tenths of a millisecond from the time the target was displayed to the time the mouse button was clicked. The click of the mouse button initiated a 2500ms inter-trial-interval (a black screen) and was followed by another warning dot preceding the next trial. Five seconds was allotted for possible response time when the mouse button was not clicked. After each block of 24 trials, the experiment was paused and participants were given the option to take a break or continue. On average the full task was completed in one hour.

Results

Analyses were carried out on reaction times for correct responses to real word pairs. For a given subject, 288 critical word pairs were analyzed including responses to targets from all four conditions (Dominant Related, Dominant Unrelated, Subordinate Related, Subordinate Unrelated) presented at three SOAs (50 ms, 300 ms, 1550ms). On 1728 critical trials (including responses from all subjects) a total of 24 real word errors (no response indicated) were made (1.39%). Outliers (responses differing from each subject's mean RT per condition by >2 SD) were replaced by the value of the mean RT plus or minus 2 SDs for that particular subject and condition. Ninety-nine outliers (5.81% of total correct responses) were replaced across subjects.

Reaction time data from the six participants was averaged for each SOA (50 ms, 300 ms, 1550 ms), each target type (dominant, subordinate), and each condition (related, unrelated) and differences in reaction time facilitation between the unrelated and related conditions were used as measures of the priming effect. Mean reaction times, priming effects and standard deviations can be found in Table 3-1. For the dominant condition, responses to related word pairs were faster than unrelated word pairs at both the short SOA and the intermediate SOA, $t(5) = 3.25$, $p < .05$, d = 1.33. Although the priming effect did not reach significance ($p = .08$) at the short SOA, there was a medium effect size (d = .65). In contrast, at the long SOA there was little difference ($p = .50$) in response times to related and unrelated words and only a small effect size (d = -.30). For the subordinate condition, as expected, no priming effect was found at the short SOA, ($p = .18$), and in fact responses to the unrelated words were faster than related words. Although the related word pairs were faster than the unrelated pairs for both the intermediate, and long SOAs, these priming effects did not reach significance ($p > .05$), however a medium effect was found at the intermediate SOA (p = .20, d = .60) and a medium/large effect at the long SOA (p = .11, d = .79). Although four out of six of these priming effects do not reach significance, this is likely due to the small number of participants and given that all but one comparison produced a medium effect size, recruiting more participants should improve results. A post-hoc power analysis (paired t-tests) suggested that for the dominant meaning at the short SOA, a sample size of 19 would achieve sufficient power (≥ .80) to detect a significant ($p < .05$) priming effect (unrelated – related) given known means and SDs (Table 3-1). Using the same criteria, additional power estimates suggested a sample size of 20 would be needed for sufficient power in the subordinate meaning at the short SOA. A sample size 5 was suggested for the dominant meaning at the intermediate SOA and 22 for the subordinate meaning. For the long SOA, a sample size of 91 was suggested for the dominant meaning and 13 for the subordinate meaning. Based on these results it seems reasonable to continue to investigate priming effects at the short (50 ms) and intermediate (300 ms) SOAs but the fact that the results at the 1550 ms SOA are the mirror image of what was hypothesized indicates the need for further investigation of the long SOA.

Figure 3-1 illustrates the average priming effects across the six pilot subjects at each SOA. Individual subject data is reported in Table 3-2.

Discussion

The goal of this study was to first replicate previous lexical ambiguity priming results therefore an attempt was made to replicate as strictly as possible the methods used in previous studies (Copland, 2003; Simpson & Burgess, 1985). Our aim was to replicate Copland's results in the intermediate and long stimulus presentations for neurologically normal adults and add the additional short SOA with the future goal of comparing these responses to individuals with PD. To examine responses to the short SOA (50 ms), it was necessary to make one important change to Copland's paradigm by presenting the stimuli visually instead of auditorily. Studies have shown that 300 ms is the approximate time that they eyes fixate on a word while reading (Rayner, 1998), so by adding 300 ms to Copland's ISIs we aimed to translate them into SOAs. This would have meant using an intermediate SOA of 500 ms and a long SOA of 1550 ms, however examination of Simpson and Burgess' results with 100ms, 300ms, and 500ms suggested that the priming effect at an SOA of 300 ms was stronger than at 500 ms. For this reason it was decided to use an intermediate SOA of 300 ms and a long SOA of 1550 ms in addition to the 50 ms short SOA.

Results of this experiment showed the hypothesized selective priming for the dominant meaning at the short SOA, followed by facilitation of both the dominant and subordinate meanings at the intermediate SOA. This supported our hypothesis of enhancement of both meanings at the intermediate SOA, however at 300 ms the priming effect was weaker and did not reach significance in the subordinate meaning (p =.20) suggesting that a slightly longer SOA might reveal a stronger effect. It had been hypothesized based on previous studies (Copland, 2003; Simpson & Burgess, 1985) that presentation of the word pairs at a longer SOA would again produce selective facilitation of the dominant meaning, yet the results of this experiment did not support that hypothesis. Instead, no priming effect was found for the dominant meaning while the subordinate meaning maintained the priming affect exhibited at the intermediate SOA.

There are many potential reasons for this disparity. Although every attempt was made to replicate the methods used in previous studies, it is possible that in converting the auditory paradigm to a visual paradigm there was an additional factor not considered. One possibility is that there was silence between the spoken prime and target in the auditory paradigm but in the visual paradigm the prime was left on the screen for the duration of the SOA before being replaced by the target. This additional time to attend to the prime may have affected lexical processing by increasing the activation associated with the subordinate meanings, effectively strengthening the association between the homograph and a subordinate meaning. This may even have had the opposite effect on the dominant meaning which might explain the negligible difference between the related and unrelated conditions at the long SOA. Another possible reason for the difference in results at the long SOA may be that it was simply too long. Simpson and Burgess used long SOAs of only 500 ms and 700 ms when testing younger neurologically normal adults and although older adults may require additional time to make a lexical decision, there also may come a point after which the pattern of selective priming is no longer consistent.

In order to further clarify the pattern of priming in both dominant and subordinate meanings across different SOAs, a second study was proposed to investigate both the question of length of SOA and the manner in which the prime was presented.

Table 3-1. Group mean RTs (ms) for lexical decisions in word pair targets as a function of target type, SOA, and semantic relatedness (R=related, U=unrelated).

	Target Type											
	Dominant						Subordinate					
SOA (ms)	R	U	Priming	SD	d	~N	R	U	Priming	SD	d	~N
50	929.82	965.92	36.10	55.73	0.65	19	1095.71	1033.75	-61.95	97.73	-0.63	20
300	827.76	909.97	82.21*	61.87	1.33	5	928.45	982.96	54.50	90.94	0.60	22
1550	885.18	877.79	-7.39	25.04	-0.30	91	957.71	998.96	41.25	52.37	0.79	13

Note: Priming = Unrelated RT - Related RT; t-tests are 1-tailed; significant priming (p <.05) marked with an *; d = effect size; ~N = estimated N needed to reach a power of .8

Table 3-2. Individual subject priming data: mean RTs (ms) for lexical decisions as a function of SOA, target type and semantic relatedness (R=related, U=unrelated)

SOA (ms)	Target Type							
Subject	Dominant				Subordinate			
50	R	U	Priming	SD	R	U	Priming	SD
1	1000.33	1107.06	106.74	308.85	1247.11	1053.90	-193.21	528.40
2	1140.47	1078.05	-62.42	349.27	1238.83	1114.54	-124.30	468.17
3	887.65	946.68	59.03	302.01	996.99	969.15	-27.84	461.74
4	825.76	875.23	49.47	367.09	1052.55	964.05	-88.49	786.08
5	775.65	800.78	25.13	214.93	970.70	940.65	-30.05	542.46
6	949.08	987.73	38.65	265.79	1068.05	1160.22	92.18	531.37
300								
1	811.74	899.47	87.73	219.18	874.05	948.59	74.53	216.80
2	923.68	1030.91	107.22	509.31	1039.87	1129.41	89.54	709.04
3	837.91	804.87	-33.04	204.65	908.17	865.50	-42.67	441.18
4	729.51	883.10	153.60	348.62	873.84	1065.68	191.84	673.78
5	773.71	859.84	86.13	281.88	826.99	892.55	65.56	319.16
6	890.03	981.62	91.59	457.31	1047.81	996.02	-51.79	717.02
1550								
1	893.28	893.67	0.39	196.34	950.47	1033.19	82.72	321.37
2	976.06	939.49	-36.57	387.86	1156.06	1183.31	27.25	813.18
3	880.37	846.21	-34.16	250.61	924.41	922.34	-2.07	283.15
4	788.95	818.79	29.84	244.94	806.36	923.82	117.46	357.92
5	872.40	875.96	3.55	415.13	946.15	991.08	44.92	392.97
6	900.04	892.63	-7.41	211.84	962.83	940.05	-22.78	243.80

Note: Priming = Unrelated RT - Related RT

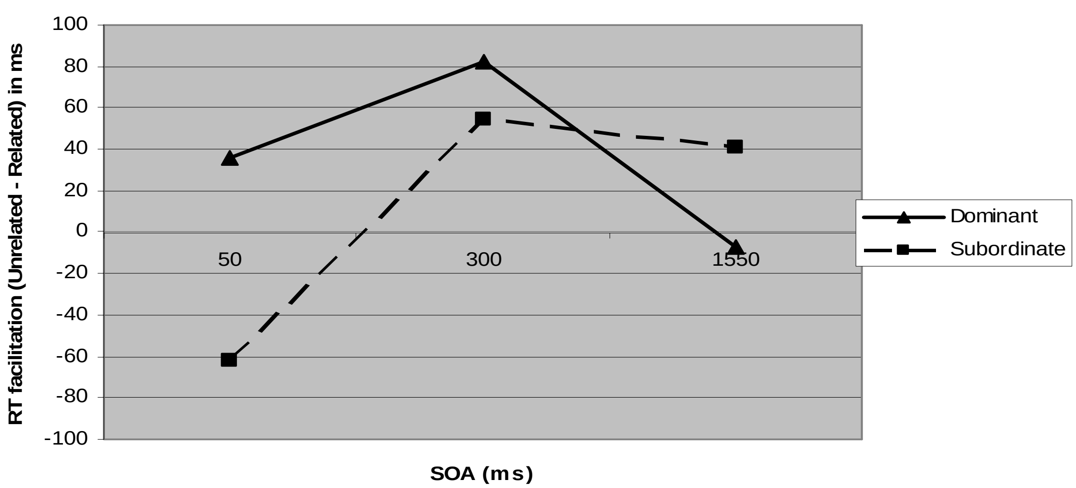

Figure 3-1. Mean RT facilitation of dominant and subordinate targets at short (50 ms), intermediate (300 ms) and long (1550 ms) SOAs.

CHAPTER 4
STUDY 3: LEXICAL AMBIGUITY PRIMING (TAKE 2)

Introduction

In conjunction with the previous experiment the purpose of this study is to further elucidate the pattern of priming effects for dominant and subordinate meanings of homographs. In light of the disagreement between results of our previous study and results from other lexical ambiguity priming studies (Copland, 2003; Simpson & Burgess, 1985), our aim in this experiment is to use additional intermediate and long stimulus onset asynchronies (SOAs) as well as a condition which better approximates the auditory paradigm used by Copland to examine the changes in priming effects.

Methods

Research Participants

Six older adults (5 females, 1 male) with a mean age of 70.5 and mean number of years of education of 14.83 volunteered to participate in the study (refer to Table 4-1 for participant demographics). No significant difference in age or years of education was found between participants in this and the last study. All participants had English as a first language, no previous diagnosis of a learning disorder or neurological disease or head trauma, were right handed and had not participated in the previous study. All participants gave written informed consent in accordance with procedures established by the University of Florida Health Science Center Institutional Review Board.

Materials

The apparatus and word lists used in this study were identical to the previous study. For each of the six possible versions of the task, the short SOA was replaced with a 400 ms SOA and the intermediate SOA was replaced with a 1250 ms SOA. The long SOA (1550 ms) was retained; however the presentation was adjusted such that the prime only appeared on the screen for 400 ms followed by a black screen for 1150 ms.

Procedure

Participants were seated directly in front of the computer monitor with their right index finger on the left mouse button in preparation for quick responses on the go-no-go task. Instructions were identical to the previous study and included the same 16 practice trials adjusted to conform to the three new SOAs.

Results

Analyses were carried out on reaction times for correct responses to real word pairs using the same procedures as the first study. The reaction times for the 288 critical word pairs were analyzed by target type (dominant or subordinate) and semantic relatedness (related, unrelated) for each of the three SOAs (400 ms, 1250 ms, 1550ms) per subject. On 1728 critical trials (including responses from all six subjects) a total of 10 real word errors (no response indicated) were made (0.58%). Outliers (responses differing from each subject's mean RT per condition by >2 SD) were replaced by the value of the mean RT plus or minus 2 SDs for that particular subject and condition. Ninety outliers (5.25% of total correct responses) were replaced across subjects.

Reaction time data from the six participants were averaged and differences in reaction time facilitation between the unrelated and related conditions were used as measures of the priming effect. Mean reaction times, priming effects and standard deviations can be found in Table 4-2. Two tailed t-tests were calculated given the hypothesized direction of the effects. At the 400 ms intermediate SOA, although the effects did not reach significance, responses to the related targets were faster than the unrelated targets for the dominant meaning, (p = .09, d = .84, and the subordinate meaning (p = .30, d = .22).

At the 'long' SOAs, significant effects were found for the dominant meaning at 1250 ms, $t(5) = 2.55$, $p < .05$, d = 1.04, and 1550 ms SOA, $t(5) = 3.42$, $p < .05$, d = 1.40. For the subordinate condition, the priming effects did not reach significance ($p > .05$), however, responses to the related targets were generally faster than the responses to the unrelated targets. Calculation of effect sizes indicated a small effect for the 400 ms ($p = .61$, d = .22), and medium effects for the 1250 ms ($p = .31$, d = .46) and 1550 ms ($p = .44$, d = .33) SOAs with slightly greater facilitation observed at the 1250 ms SOA as compared to the 400 and 1550 ms SOAs. Figure 4-1 illustrates the average priming effects across the six subjects at each SOA. Individual subject data are reported in Table 4-3.

Post-hoc power analyses (paired t-tests) determined that to achieve a power of .80 with a significance of $p < .05$, at the 400 ms SOA, 12 subjects would be needed for the dominant meaning and 158 for the subordinate meaning. At the 1250 ms SOA, it was suggested that 8 subjects would be needed for the dominant meaning and 38 for the subordinate meaning, while at the 1550 ms SOA, 5 would be needed for the dominant meaning and 71 for the subordinate meaning.

Discussion

In an attempt to clarify the results of our first lexical priming study, this experiment used three new SOAs: an intermediate SOA of 400 ms, a long SOA of 1250 ms and a long SOA of 1550 ms that only displayed the prime for 400 ms. In the first study we hypothesized a pattern of suppression of the subordinate meaning at a short SOA, followed by enhancement at an intermediate SOA, and finally suppression at a long SOA. This hypothesis was based on a conceptual model proposed by Crosson, Benjamin, and Levy (in press) suggesting that the temporal pattern of lexical priming effects (Copland, 2003; Simpson & Burgess, 1985) may follow the sequence of enhancement and suppression observed in the basal ganglia of monkeys (Nambu et al., 2002).

In study 2 we found support for the initial suppression of the subordinate meaning at a short SOA of 50 ms in which responses to related words were faster than unrelated words when the target was a dominant meaning of the homograph, but responses to the subordinate meaning showed the opposite pattern. At an intermediate SOA of 300 ms the results showed clear evidence of the hypothesized priming for the dominant meanings: however, given that the effect did not reach significance in the subordinate condition, a question was raised of whether 300 ms was the ideal SOA to measure the true strength of the intermediate enhancement effect. For this reason a longer intermediate SOA of 400 ms was tested in the current lexical priming experiment. Responses to the dominant meaning revealed a significant priming effect although the magnitude and effect size (priming = 31.52 ms, d = .84) were smaller than those of the 300 ms SOA (priming = 82.21 ms, d = 1.33). Responses to the subordinate meaning at the both the 400 ms and 300 ms SOAs did not show significant priming effects; however, once again the magnitude and effect size of priming at the 400 ms SOA (priming = 9.03 ms, d = .22) were much smaller than the 300 ms SOA (priming = 54.5 ms, d = .60). This comparison of two different SOAs suggests that 300 ms may be the more ideal SOA for capturing the strength of the intermediate priming effect. In the absence of significant effects for subordinate priming at either intermediate SOA we turned to the power analysis to determine if using one of the SOAs might achieve significance with more subjects. To achieve a power of at least .80, a 2-tailed paired t-test power analysis suggested that 22 subjects would be needed to detect a significant ($p < .05$) priming effect (unrelated – related) for the 300 ms SOA and 158 subjects would be needed for the 400 ms SOA. The greater effect size and greater power achieved with fewer subjects at the 300 ms SOA suggest that the intermediate SOA will be well represented by a 300 ms SOA.

At the long SOA of 1550 ms in the earlier experiment, the explanation for the pattern of results was unclear. Our hypothesis, that we would find selective priming for the dominant meaning, as well as suppression of the subordinate meaning, was not confirmed by the data. Instead we found no priming effect for the dominant meaning (priming = -7.39 ms, d = -.30) and a non-significant but medium-large effect (priming = 41.25 ms, d = .79) for the subordinate meaning. Although the reasons for this difference between our data and previous priming data at a long SOA are unknown, two possibilities were suggested: that the overall SOA might be too long, and that leaving the prime on the screen for the full duration of the SOA might affect patterns of activation associated with semantic priming in older adults. For this reason the current experiment examined responses at a shorter SOA of 1250 ms in which the prime was left on the screen for the full SOA and a 1550 ms SOA in which the prime was replaced with a black screen after 400 ms until the target appeared. Responses to the dominant meanings at the 1250 ms SOA revealed a significant priming effect (priming = 45.42 ms) with an effect size of 1.04 and were slightly weaker than the significant effect found for the new version of the 1550 ms SOA (priming = 34.69 ms) with an effect size of 1.40. The priming effect obtained from responses to the subordinate meanings at the 1250 ms SOA was weaker (priming = 19.62 ms, d = .46) than that of the dominant meaning at 1250 ms but stronger than the effect for the subordinate meaning at the new 1550 ms SOA (priming = 11.78 ms, d = .33). In order to examine the selective priming for the dominant meaning at the long SOA, a strong priming effect for the dominant meaning and a weak effect for the subordinate meaning are needed. Given the pattern of priming and the large difference between effect sizes for the dominant and subordinate meanings, these data suggest that the 1550 ms SOA with the prime present for 400 ms may provide a more accurate illustration of the expected divergence between priming effects at the longer SOA than the 1250 ms SOA. Again a power analysis was performed which indicated that more subjects (N=71) would be needed to achieve significance ($p < .05$) at a power of .80 in the 1550 ms SOA than the 1250 ms SOA (N=38). Because a weaker effect is in fact hypothesized in this case, these results support the 1550 ms SOA as a sui 'long' SOA.

Results from these two experiments indicate that use of a 50 ms 'short' SOA, a 300 ms 'intermediate' SOA and a 1550 ms 'long' SOA will provide the best method for further examination of the temporal patterns of semantic priming effects.

Table 4-1. Demographics of participants in priming experiments by study.

Study	N	Sex	Age	Education
1	6	M=2, F=4	73.67	13.67
2	6	M=1, F=5	70.50	14.83

Table 4-2. Group mean RTs (ms) for lexical decisions in word pair targets as function of target type, SOA, and semantic relatedness (R=related, U=unrelated).

	Target Type											
	Dominant						Subordinate					
SOA (ms)	R	U	Priming	SD	d	~N	R	U	Priming	SD	d	~N
400	669.73	696.27	26.55	31.52	0.84	12	723.87	732.90	9.03	40.42	0.22	158
1250	683.13	728.55	45.42*	43.60	1.04	8	734.07	753.69	19.62	42.67	0.46	38
1550	667.24	701.94	34.69*	24.83	1.40	5	709.23	721.01	11.78	35.22	0.33	71

Note: Priming = Unrelated RT - Related RT; t-tests are 1-tailed; significant priming (p <.05) marked with an *; d = effect size; ~N = estimated N needed to reach a power of .8

Table 4-3. Individual subject priming data: mean RTs (ms) for lexical decisions as a function of SOA, target type and semantic relatedness

SOA (ms)	Target Type							
Subject	Dominant				Subordinate			
400	R	U	Priming	SD	R	U	Priming	SD
1	524.97	572.82	47.85	156.93	633.00	581.91	-51.09	330.57
2	832.19	800.85	-31.34	308.84	857.02	862.45	5.44	415.92
3	557.34	616.45	59.11	156.91	566.61	597.74	31.13	170.19
4	610.62	642.84	32.22	126.04	643.00	654.13	11.12	111.50
5	784.24	804.17	19.93	169.80	856.16	844.54	-11.62	238.80
6	708.99	740.50	31.52	140.69	787.40	856.62	69.22	542.46
1250								
1	556.71	622.36	65.66	164.84	598.22	683.51	85.28	222.14
2	787.43	803.97	16.55	208.94	904.73	932.50	27.77	508.39
3	568.63	552.30	-16.33	107.28	569.16	589.19	20.03	142.86
4	644.44	679.82	35.38	173.52	685.34	676.65	-8.69	134.24
5	858.28	967.53	109.25	259.69	915.97	874.74	-41.23	233.14
6	683.30	745.28	61.98	97.64	730.99	765.56	34.57	143.50
1550								
1	527.78	557.66	29.87	112.84	593.11	615.43	22.32	200.88
2	800.82	822.16	21.34	432.23	809.63	853.62	44.00	550.52
3	519.60	543.64	24.04	107.44	562.61	568.66	6.05	159.06
4	650.83	658.86	8.03	215.12	627.72	654.46	26.74	171.95
5	850.20	896.57	46.37	314.47	959.89	904.18	-55.71	280.75
6	654.22	732.73	78.51	95.40	702.40	729.69	27.29	136.27

Note: Priming = Unrelated RT - Related RT

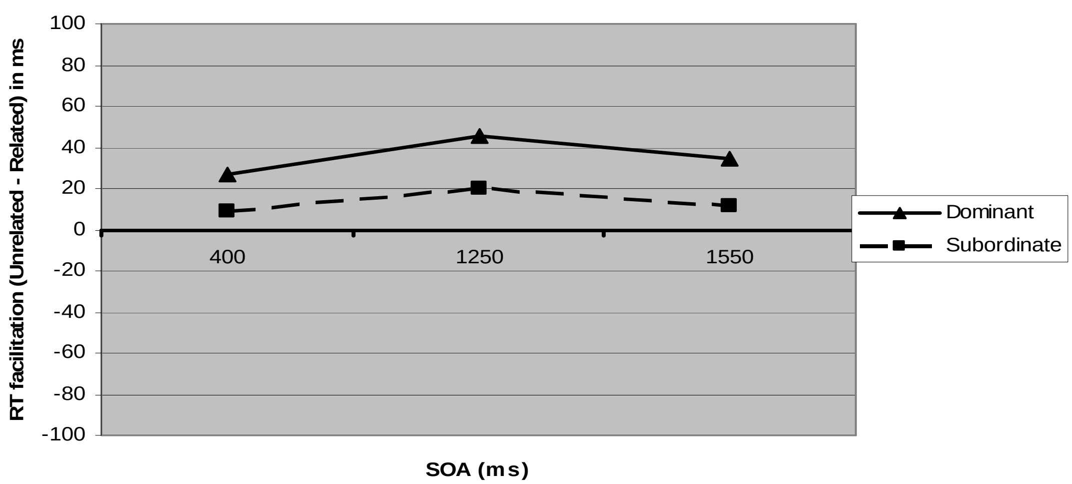

Figure 4-1. Mean RT facilitation of dominant and subordinate targets at an intermediate (400 ms), a long SOA (1250 ms) and a long SOA (1550 ms) in which the prime was removed from the screen after 400 ms.

CHAPTER 5
DISCUSSION

Although an abundance of research exists that examines the role of the basal ganglia in movement, fewer studies have focused on the influence of the basal ganglia on cognitive processing. Although the previously described studies did not physically measure basal ganglia activation, findings from these studies provide support for a theoretical model of basal ganglia function in cognition (Crosson et al., in press). This model has proposed that the temporal pattern of lexical priming effects for subordinate meanings of ambiguous primes (Copland, 2003; Simpson & Burgess, 1985), represented by short, intermediate, and long SOAs may follow the sequence of suppression-enhancement-suppression that has been observed in the corresponding hyperdirect, direct, and indirect pathways of the basal ganglia of macaques (Nambu et al., 2002).

Three related studies were outlined in the previous chapters. First, new homograph norms were needed to determine dominant and subordinate meanings appropriate for use in the subsequent priming experiments. Second, priming effects were examined in 'short' (50 ms), 'intermediate' (300 ms) and 'long' (1550 ms) SOAs. Finally, due to questions raised by the priming results, a second priming study was performed examining a 400 ms 'intermediate' SOA a 'long' SOA of 1250 ms and a 'long' SOA of 1550 in which the duration of the visibility of the prime was cut short to 400 ms.

In order to obtain new homograph norms, an online survey was conducted which provided data on 518 homographs and associated meanings from 177 participants. From this data 183 homographs were collected that had a meaning selected by 70%-80% of participants as dominant and an alternative meaning selected by 20%-30% of participants as subordinate. These homographs were used in the subsequent priming experiments.

In a computer task using lexical ambiguity priming, 6 neurologically normal older adults were tested at three SOAs (50 ms, 300 ms, 1550 ms). Results of this experiment showed selective priming for the dominant meaning at the 'short' SOA, enhancement of both meanings at the 'intermediate' SOA and suppression of the dominant but enhancement of the subordinate meaning at the 'long' SOA. Given our hypothesis based on results from previous studies (Copland, 2003; Simpson & Burgess, 1985) that we would find selective priming for the dominant meaning at the 'long' SOA, results which showed the opposite pattern of priming suggested the need for an additional study.

Using the same computer task with 6 different neurologically normal adults, lexical ambiguity priming was tested at a new 'intermediate' SOA of 400 ms and two versions of a 'long' SOA; one slightly shorter (1250 ms) and one with the prime visually displayed for 400 ms of the 1550 ms SOA. Results of a power analysis suggesting fewer subjects needed, combined with a greater effect size indicated that the strength of the 'intermediate' priming effect was better illustrated by the 300 ms SOA used in the first priming experiment than the 400 ms SOA. Interestingly the effect of the 400 ms SOA was closer to what had been predicted for the 'long' SOA. For both 'long' SOAs, strong priming effects for the dominant meaning and much weaker effects for the subordinate meaning were found. The disparity between these effects was greater for the 1550 ms SOA with the prime displayed for 400 ms than the 1250 ms SOA as indicated by a power analysis. The power analysis determined that for the 1250 ms SOA, 8 subjects would be needed to achieve a significant effect with a power of .80 for the dominant condition while 38 subjects would needed for the subordinate condition. For the 1550 ms SOA the power analysis determined that only 5 subjects would be needed for the dominant condition but 71 would be needed for the subordinate condition. At the long SOA our model predicts enhancement of the priming effect for the dominant condition but suppression of the priming effect for the subordinate condition, and results for the 1550 ms SOA with the prime displayed for 400 ms, revealed a weaker priming effect size (increased suppression) and a greater number of subjects needed for the subordinate condition to achieve significant power as compared to the 1250 ms SOA. Therefore, these results suggest the divergence between priming effects may be better illustrated using the ‘long’ SOA of 1550 ms with the prime displayed for 400 ms.

These data appear to provide support for the suppress-enhance-suppress pattern of basal ganglia influence on cognitive processing suggested by (Crosson et al., in press), however additional research is needed in patient populations to further understanding of this topic. In a future study lexical ambiguity priming will be used with individuals with Parkinson’s disease and their performance at ‘short’, ‘intermediate’ and ‘long’ SOAs will be compared to the responses of neurologically normal adults. Because Parkinson’s disease involves damage to the striatum and its pathways, it is suspected that the normal ability to suppress competing cognitions will be affected in these individuals. Based on what is known about the three basal ganglia pathways and their involvement in enhancement and suppression, it is hypothesized that individuals with Parkinson’s disease will display normal suppression of the subordinate meaning at the ‘short’ SOA (given that the hyperdirect pathway bypasses the striatum), normal enhancement of both meanings at the ‘intermediate’ SOA and lack of normal suppression of the subordinate meaning at a ‘long’ SOA. These data will help to further conceptualize the role of the basal ganglia in language processing.

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BIOGRAPHICAL SKETCH

Ilana Fawn Levy received her Bachelor of Arts degree in cognitive science from the University of Virginia (Charlottesville) in May 2003. Ilana worked at the National Institutes of Mental Health in the Laboratory of Brain and Cognition from 2003 to 2005 after receiving a post-baccalaureate intramural research training award from the NIH. Using techniques such as fMRI, EEG, and eye-tracking, she participated in research examining the underlying mechanisms that contribute to the differences in social cognition among children with Autism Spectrum Disorder, their families, and control subjects. She entered the Clinical and Health Psychology doctoral program at the University of Florida (UF) in 2005 with a concentration in clinical neuropsychology. While at UF, she has worked in the Brain Imaging Rehabilitation and Cognition lab under the mentorship of Bruce Crosson, Ph.D.