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The Effect of Prime Word Processing on the Semantic Priming Effect.

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THE EFFECT OF PRIME WORD PROCESSING ON THE SEMANTIC PRIMING EFFECT

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
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in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Psychology

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ABSTRACT

In three experiments the effect of ease of prime word access on semantic priming was investigated. Ease of prime access was manipulated by prime word frequency, by prime degradation, and by prime repetition. Primes accessed faster (high frequency prime words, repeated primes) should produce larger priming than those accessed more slowly (low frequency prime words, degraded prime words). The time course of priming was also examined by comparing a 150 ms SOA to a 500 ms. The results partially supported the hypothesis. There was a prime word frequency effect on priming in both short and long SOA conditions. High frequency prime words tended to produce greater priming than low frequency prime words regardless of available prime processing time. Slowing or accelerating prime processing speed by degradation and repetition respectively did not have effects on priming. The manipulation of word frequency affects both lexical and semantic processes while manipulations of degradation and repetition affect mainly the lexical process of word recognition. These results suggest that semantic access to prime words, rather than lexical access, has an effect on semantic priming.

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CHAPTER 1: INTRODUCTION

Introduction

The semantic priming effect refers to the faster processing of target words when preceded by semantically related priming words than when preceded by unrelated priming words (e.g., 'NURSE' primes 'DOCTOR,' Meyer & Schvaneveldt, 1971). This robust effect of semantic priming has been used to explore processes and organizations of lexical memory in both monolingual and bilingual individuals (see Neely, 1991, for a review for monolingual semantic priming studies; and Kroll, 1993, for bilingual semantic priming studies).

Theories of Semantic Priming

Theories to account for the effect can be grouped into three camps: Automatic spreading activation, expectancy, and post-lexical checking mechanisms (see Neely, 1991, for an extended review). **Automatic spreading activation** assumes words in a mental representation, or a lexicon, are organized according to semantic similarities, and related words are connected via word nodes. When a word is recognized, or accessed, the activation automatically spreads to word nodes of the related words. Activated words are recognized faster than words which are not activated (c.f., Collins & Loftus, 1975). The **expectancy mechanism** for semantic priming assumes 'expectancy sets' which subjects generate according to the nature of compositions of the list. For example, when a higher proportion of stimulus pairs is related (i.e., a high relatedness ratio), participants are more likely to develop expectancy sets than when only a few pairs are related in meaning (i.e., a low relatedness ratio). The expectancy sets produce facilitation when stimulus pairs are related, and inhibition when unrelated (Becker,

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1980). Theories on **post-lexical priming mechanisms** include the compound cue theory (Ratcliff & McKoon, 1995) and semantic matching model (Neely, & Keefe, 1989). The compound cue theory assumes 'episodic recognition memory' for prime and target pairs. Pairs with high familiarity values (i.e., associated pairs) are recognized faster than those with lower familiarity values (i.e., unrelated pairs and nonwords). The semantic matching model assumes that participants use the prime-target relationship to influence word vs non-word decision. This 'semantic checking' is believed to be performed after lexical access of both prime and target words, but before the word-nonword decision. Participants anticipate that if a pair is related, the correct response is 'word.' Thus, the response times are faster for related pairs than unrelated pairs.

Different theories explain different facets of the phenomena of semantic priming. The nature of the semantic priming effect for the spreading activation is assumed to be automatic and fast acting. The expectancy account and post-lexical checking mechanisms assume controlled, strategic processes. Neither automatic nor strategic process alone seems to be able to fully explain the results across different experimental procedures. It is reasonable to assume multiple processes operate to produce semantic priming(see Neely, 1991, for a table of semantic priming phenomena explained by major theoretical camps). For example, according to Posner and Snyder's (1975) two process theory of attention, both fast-acting automatic processes and slow, controlled processes are at work. Neely and Keefe (1989) included three processes, automatic spreading activation, expectancy sets, and matching processes to accommodate findings on semantic priming.

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Conditions Which Affect Semantic Priming Processes

Three different experimental manipulations have been generally utilized to explore automatic vs. strategic processes: tasks, stimulus onset asynchrony (SOA; i.e., time between the onset of prime presentation and the onset of target presentation) and relatedness proportion (RP; i.e., the proportion of related word pairs in the word stimulus pairs). These manipulations are important in that researchers make inferences whether the effect of a particular variable is automatic, or strategic, depending on the results from these manipulations (Balota & Lorch, 1986; Becker, 1980; Neely et al., 1989; Seidenberg, Waters, Sanders, & Langer, 1984; Shelton & Martin, 1992).

Tasks. Different tasks are considered to reflect different degree of automatic and control processes. In the lexical decision task (LDT) participants respond yes or no to target items followed by primes, judging whether the targets are words or non-words. The response times for the LDT reflect both word recognition and decision times (Balota & Chumbley, 1984). Thus, controlled, or strategic processes (e.g., expectancy and/or post-lexical checking mechanisms) as well as automatic processes are believed to be involved in this task (den Heyer, Briand, & Dannenbring, 1983; Lorch, Balota, & Stamm, 1986; Neely, 1977). In the naming task participants read out target words and the voice key records reaction latencies between the onset of target stimuli and the onset of the vocalization. The latencies for the naming task include both recognition time and vocalization preparation time and are considered to be reflecting more automatic processes than the LDT response times (Balota & Lorch, 1986; Huttenlocher & Kubicek, 1983; Lupker, 1984). The semantic priming effect for the LDT tends to be larger than for the naming task. This difference between the tasks was interpreted to

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indicate that the effects of automatic spreading activation and controlled processes summate and produce larger effects for the LDT (Seidenberg et al., 1984). However, the reaction times from the naming task are also found to be affected by strategy use, that is, naming is not exclusively automatic (Keefe & Neely, 1990).

SOAs. Stimulus onset asynchronies (SOAs) refer to the time between onsets of prime and target items. Since longer SOAs allow time to develop expectations from presented primes before the onset of target items, it is possible for more controlled, strategic processes to be involved than in short SOAs (e.g., den Heyer, Briand, & Smith, 1985). Reaction times from shorter SOAs should reflect more automatic processes than controlled processes (Hodgson, 1991).

RPs. Relatedness proportions refer to the proportion of related word pairs in the overall word stimulus pairs. High RPs are found to produce larger semantic priming than low RPs, which is believed to be due to expectancy formed from more salient semantic relations in the high RP lists (de Groot, 1984; den Heyer et al., 1983; den Heyer et al., 1985; Tweedy, Lapinski, & Schvaneveldt, 1977).

Other factors. In addition to the above three experimental manipulations, target and prime word characteristics and manipulations of target and prime word processing affect the amount of semantic priming. These characteristics, especially prime word manipulations, are the focus of this dissertation. As will be reviewed in the next section, "ease of word access" which is affected by word characteristics and experimental manipulations seems to have effects on semantic priming. For example, target word characteristics, such as word frequency and spelling irregularity, have effects on how quickly or easily a word will be processed and are found to have effects on the size of

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semantic priming. Low frequency target words or irregularly spelled words typically produce longer response times, and other things being equal, low frequency target words produce larger semantic priming than high frequency target words (Becker, 1979; Stone & Van Orden, 1992) and also, irregularly spelled target words produce larger semantic priming than regularly spelled target words (Cortese, Simpson, & Woolsey, 1997). Manipulating target word processing, for example, by degrading target words (e.g., by putting asterisks between letters or reducing a contrast between letters and the background) also affects semantic priming -- in this case by increasing the semantic priming effect for degraded target words as compared with intact target words (Besner & Smith, 1992; Borowsky & Besner, 1991; Borowsky & Besner, 1993; Stolz & Neely, 1995). As argued later, the pattern of results affected by these factors suggests that processing speed and automaticity of processing target words have effects on the amount of semantic priming. For target words, slower processing speed and lower automaticity, which may sound paradoxical, tend to produce larger semantic priming.

Ease of word access of prime words may also affect priming. That is, how primes are processed and their activation levels do seem to have effects on how quickly target words are accessed, resulting in weaker or stronger semantic priming effects. Studies which have investigated prime processing asked participants to perform a task on primes. These studies on the "levels of priming processing" have shown that "deeper" processing (e.g., semantic tasks performed on primes) produces larger priming than "shallower" processing (e.g., letter search tasks in which participants look for a certain letter in the prime performed on primes). Other studies manipulated prime presentation duration. When long and short priming prime presentation durations were

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randomly mixed the semantic priming effect for the primes with short presentation durations was eliminated while the effect for those with long presentation duration was intact. The purpose of the current study is to investigate how speed or ease of access to words affect the semantic priming effect, specifically focusing on prime word processing.

Below, I will first review studies regarding the effect of ease of word access on semantic priming studies: First, how target word characteristics and processing affect semantic priming, then how prime word characteristics and processing affect priming. I use the term 'ease of word access' to include effects of word characteristics (e.g., word frequency) and experimental manipulations (e.g., degradation, tasks performed on primes, and mixed SOAs). For target words, characteristics include word frequency, spelling regularity, orthographic depth, and imageability/concreteness while processing includes degradation studies. For prime words, no studies have examined the effect of prime word characteristics on semantic priming; studies on processing include studies on levels of prime word processing and mixed SOA studies.

The term 'ease of access' may include both lexical access (access to lexical/orthographic forms) and semantic access (access to word meanings). Indeed, one can speculate that spelling irregularity and degradation affect lexical access and word frequency and imageability affect semantic access. However, in the single word recognition paradigm the locus of effects by these different variables has been debated. For example, regarding the effect of word frequency, Besner and his colleagues argued that word frequency effects affect the second stage of word recognition, namely, efficiency of mapping between lexical input and the semantic system in their Multistage

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Activation Model (Besner & Smith, 1992; Borowsky & Besner, 1993; Plourde & Besner, 1997). In the Parallel Distributed Processing model, Seidenberg and McClelland (1989) argued that word frequency rather affects the computation of phonological code. At present any such distinctions are not made, leaving the discussion to a later section of this paper.

Ease of Word Access

Target Words Characteristics

Word frequency. Single word recognition studies have investigated the variables which affect the speed of word access, including word frequency (c.f., Seidenberg & McClelland, 1989). Low frequency words generally take more time to be recognized than high frequency words. If longer word access time leads to greater priming, then one would predict more priming for low frequency than high frequency targets. Indeed, two studies have found an asymmetry in priming with word frequency such that larger benefit is found for low frequency target words than for high frequency target words. Becker (1979) examined the effect of target word frequency and strengths of semantic relations on semantic priming. The semantic priming effect was larger by 42 ms for low frequency target words than high frequency words. Although the three-way interaction between frequency, semantic relation and strength of context did not approach significance, the response times showed a trend for strength of context exerting more effect on low frequency words than high frequency words. There was larger semantic priming under weak semantic context conditions for low frequency words than high frequency words (47 ms vs. 1 ms). Becker used a relatively long SOA (750 ms. prime

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presentation duration and 300 ms. ISI), which may have promoted the use of strategy, especially regarding strengths of relatedness between the stimulus pairs.

Stone and Van Orden (1992) examined the effect of target word frequency on semantic priming with long and short SOA's (2000 ms vs. 200 ms). They included neutral primes ("XXXX") to examine the effects of facilitation or priming benefits (the reaction time difference between neutral prime pairs and related prime pairs) and inhibition or priming cost (the reaction time difference between neutral pairs and unrelated pairs). The statistical analyses were done regarding priming benefits and priming costs. The semantic priming effect was calculated by adding priming benefits and priming costs. The reaction times show the semantic priming effect was larger for low frequency target words than high frequency target words for both long and short SOA conditions. Thus, the asymmetry regarding target word frequency appears even at a short SOA which should restrict controlled processes.

Target word imageability. Compared to target word frequency, the effect of target word imageability on semantic priming is not clear-cut. In single word recognition naming experiments by Strain, Patterson, and Seidenberg (1995), high imageable words (e.g., glove) were responded to faster than low imageable words (e.g., chaos) only when the words were irregular spelling words (e.g., comb), but not when the words were regular spelling words (e.g., coffin). This interaction was explained by the rich semantic representations of high imageable words as compared with low imageable words, which affected phonological computation when that process was slow as in irregular words.

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Cortese, Simpson, and Woolsey (1997) examined these interaction effects on semantic priming in the naming task. They found main effects of spelling regularity, imageability, and relatedness and interactions between spelling regularity and relatedness and between regularity and imageability. Of interest, the interaction between relatedness and imageability was only marginally significant. There was a tendency that the semantic priming effect was larger for low imageable target words than high imageable ones (18 ms vs. 12 ms). As the semantic priming difference between low and high imageability was small and was only marginally significant, additional studies are needed to determine whether imageability affects semantic priming. In Cortese et al.'s experiment spelling regularity was included as a variable and there were significantly higher errors for low imageable irregular target words than high imageable irregular target words (12 % vs. 8 %). Thus, it is possible that overall higher error rates made the reaction time analyses less reliable.

Target word concreteness. Concrete words are words which have tangible referents while abstract words do not have such referents. In the single word recognition paradigm, the concreteness effect has been examined for high and low frequency words and the pattern of results are inconsistent (see Gernsbacher, 1984, for a review). Reviewing the inconsistent patterns, Gernbacher (1984) attributed this inconsistency to familiarity which confounded the data (i.e., familiarity correlates strongly with concreteness and recognition latencies). When controlling familiarity for low frequency words, Gernbacher did not obtain the main effect of concreteness on recognition latencies. Few studies so far have examined the effect of concreteness using a semantic priming task. As a part of cross-language semantic priming experiment, Jin

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(1990) asked English monolinguals to perform a semantic priming task for concrete and abstract target words and did not find any difference between the two. However, a trend in the results suggests that abstract word pairs produced a larger semantic priming effect (75 ms) than concrete word pairs(58 ms).[1]

Bleasdale (1987) examined the effect of concreteness on semantic priming for both prime and target words. Thus, the study included four conditions according to the concreteness of the primes and targets: the concrete-concrete condition (e.g., 'chin-NOSE'); the concrete-abstract condition ('officer-LAW'); the abstract-concrete condition (issue-MAGAZINE); and the abstract-abstract condition (hope-FAITH). In Experiment 1, when using the naming task, the semantic priming effect was found in the conditions in which prime and target words were from the same category (i.e., concrete-concrete and abstract-abstract conditions). When LDTs were used without masking, the semantic priming effect was found in the concrete word prime conditions with a long SOA (1000 ms) (Experiment 2) and in all conditions with a short SOA (206 ms; 177 ms prime presentation + 29 ms machine introduction) (Experiment 3). When the prime presentation duration was short (16.7 ms) and masked, semantic priming was found only in the conditions in which primes and targets were from the same category (Experiment 4) as in Experiment 1. Bleasdale concluded that processing of abstract and concrete words were dissociated when tasks which involve more automatic processes (the naming task and masked LDT) were used.

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[1] Using sentence contexts, Schwenflugel and Shoben (1983) found the semantic context effect only for abstract words, not for concrete words.

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Thus, Bleasdale (1987)'s study suggests that conditions restricting strategy use produce semantic priming for same category pairs, but not for different category pairs and that conditions which allow more controlled processes produce semantic priming for concrete word primes, but not for abstract word primes. However, there are some methodological concerns with respect to this conclusion. The naming task in Experiment 1 involved a considerably long SOA (1000 ms) and naming of primes; naming latencies may well include effects from expectancy. Also, in his experiments Bleasdale presented the same target words three times for each participant (once each in unrelated, related and neutral pairs with counterbalanced presentation orders). Thus, his results are confounded with the effect of repeated presentation (i.e., repetition priming). Further studies are needed to confirm these findings with the necessary methodological changes.

Spelling regularity. Spelling regularity should have a direct effect on phonological assembly and thus access speed. However, irregular spelling words are highly concentrated among high frequency words, and the regularity effect in single word recognition (i.e., slower recognition latencies for irregular spelling words than regular spelling words) is observed only among low frequency words (Seidenberg & McClelland, 1989). Apparently, the regularity effect is affected by familiarity to the words or reading speed. When individuals' reading speed was controlled, the slow reading group exhibited the largest regularity effect while fast readers did not show any regularity effect for both high and low frequency words.

As to the effect of spelling regularity on semantic priming, there is only one published study by Cortese, Simpson and Woolsey (1997) which examined the effect of

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target word spelling regularity on semantic priming, which demonstrated the interactive effect of spelling irregularity with relatedness in one experiment, and no significant effect in another. Comparing the effect of semantic context between regular spelling words (e.g., tile) and irregular spelling words (e.g., glove), the researchers found that the semantic priming effect was larger for irregular words (20.5 ms) than regular words (9.5 ms). However, this result requires caution because the interaction was significant by subject analyses ($p<.01$), but only marginally significant by items analyses ($p<.10$). Also, in their first experiment, using different stimulus words[2], spelling irregularity did not have a significant effect on semantic priming (13 ms for regular words and 17 ms for irregular words).[3]

Cortese et al. used the naming task to investigate the effect of meanings on 'phonological assembly' from spelled words. Reduced error rates and faster naming latencies (in Experiment 2) indicated that activation of related meanings produced faster and more accurate access to the sound of irregular target words. A further study can examine the semantic effect on phonological assembly by comparing it in the LDT which has added word vs. nonword decisions and less emphasis on phonological assembly.

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[2] Cortese et al. (1997) used words with initial plosive phonemes (oral stop consonants, such as /k/, /t/, and /b/).

[3] In both experiment 1 and 2, the error rates indicated significant interactions of spelling irregularity with relatedness; more errors in the unrelated irregular words condition than in the related irregular condition. In effect, as the average error rate for unrelated irregular words reached .125, the naming latency measure may be less stable and the results may need to be qualified by the exclusion of a large number of datapoints due to high error rates.

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Orthographic depth. There is a line of studies investigating "shallow" orthography as compared with "deep" orthography. The "shallowness" of orthography refers to the degree of correspondence between word phonology and orthography. A shallow orthography has consistent correspondence between word sound and spelling while a deep orthography has irregular patterns of orthographic representation of word sounds. For example, in English orthography there are both irregular (opaque words) and regular (transparent) spelling words. Thus, the topic of orthographic depth in effect encompasses the topic of spelling irregularity.

Shallow orthographies include Serbo-Croatian, Korean alphabets, and Japanese kana. Examples of deep orthographies are Hebrew and English (e.g., a letter 'a' has different sound representations as in 'cat', 'calm', 'case', 'about' and in 'gauge'). The orthographic depth hypothesis assumes that readers of deep orthographies develop lexical representations for written word recognition through the "lexical" route or the "addressed route." Readers of shallow orthographies do not develop such representations, but are assumed to read words directly from written letters through the "assembly" route (Katz & Feldman, 1983). The rationale for the hypothesis is that for words of shallow orthographies, lexical variables such as word frequency and semantic context have been shown to exert little or smaller effects than for words of deep orthographies (see Smith, 1997, for discussion about uses of different orthographies and the orthographic depth hypothesis).

Katz and Feldman (1983) examined the semantic priming effect in both LDT and naming tasks for English (a deep orthography) and Serbo-Croatian (a shallow orthography). For English speakers the semantic priming effect was found in both LDT

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and naming tasks; for Serbo-Croatian speakers the effect was found only in the LDT. Katz and Feldman concluded that naming words in a shallow orthography was not affected by internal lexicons.

Frost, Katz and Bentin (1987) examined the effect of lexical factors (word frequency and semantic priming) on recognition response latencies between three levels of depth of orthographies: Hebrew (the deepest of the three; written omitting vowel sounds), English (deep orthography) and Serbo-Croatian (shallow orthography). Frost et al. found decreasing effects of frequency and semantic priming as orthographies became shallower. In the naming task the frequency effect of single word recognition was the largest for Hebrew, followed by English, and was not found for Serbo-Croatian. The frequency effect was found for all conditions in the LDT. The semantic priming effect in the naming task showed the same trend; priming was largest for Hebrew (21 ms), followed by English (16 ms), and was not found for Serbo-Croatian. The priming difference between Hebrew and English was not significant. The authors concluded that the results supported the orthographic depth hypothesis.

<u>Opaque vs. transparent words.</u> Baluch and Besner (1991) challenged the orthographic depth hypothesis using two types of Persian orthography: Opaque and transparent. Opaque words in Persian are the words without specific diacritics (superscripts to show vowel sounds) and transparent words include vowel letters. (Opaque words are like Hebrew words written omitting vowel sounds). Baluch and Besner replicated the previous findings when target stimulus words included nonwords in the naming task as in Katz and Feldman (1983) and Frost et al. (1987). There was the effect of semantic priming for opaque words (21 ms) but not for transparent words.

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However, when nonwords were excluded from the stimuli, the semantic priming effect was found for both types of orthographies (31 ms for opaque words and 21 ms for transparent words). Also, the frequency effect (high frequency words are named faster than low frequency words) was found for transparent words (35 ms) when nonwords were excluded from the targets, but not when nonwords were included. Baluch and Besner reasoned that when Persian readers were asked to read out nonwords which were spelled like transparent words mixed with other transparent and opaque Persian words, the nonlexical route was used for both transparent words and nonwords, eliminating semantic and lexical (i.e., the frequency effect) effects from transparent words. As support, Baluch and Besner pointed out the response time differences in naming between the two conditions: the overall naming times were faster in the nonwords present condition (553 ms) than in the nonwords absent condition (579 ms). Baluch and Besner questioned the orthographic depth hypothesis and suggested that users of shallow orthographies do develop internal lexicons (the addressed route) and use both or either of lexical (or addressed) route and nonlexical (or assembled) routes depending on the context.

Target Word Processing

Target degradation. Degrading target words is a manipulation which affects word recognition. Degraded words are recognized more slowly than intact words. In single-word recognition studies, degrading words is supposed to make participants use phonological information more as compared with orthographical familiarity in lexical decision tasks (c.f., Hino & Lupker, 1996). Thus, the variables interacting with the degradation effect are assumed to be involved with phonological access while those

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having additive effects to the degradation effect affect separate stages other than phonological access (Besner & Smith, 1992; Plourde & Besner, 1997).

In the semantic priming paradigm, target words with reduced visibility typically produce larger semantic priming than normally presented target words. Meyer, Schvaneveldt, and Ruddy (1974) used dot patterns superimposed on target words for degradation and found the degraded condition produced larger priming than the nondegraded condition in both LDT and naming tasks. Becker and Killion (1977) replicated the target word degradation x semantic context interaction using three levels of stimulus intensity (high, medium and low) in both LDT and naming tasks with a rather long SOA (750 ms). The levels of target word presentation intensity interacted with the amount of semantic priming (the largest for low intensity followed by medium and high intensities).

Degradation and baseline conditions. Borowsky and Besner (1991) replicated the degradation x semantic context interaction using an 800 ms SOA and comparing unrelated word primes and asterisk primes as the baseline. When unrelated words were used as the baseline (i.e., unrelated word-word pairs), the semantic priming effect was larger for degraded targets than intact targets (88 ms vs. 50 ms). When asterisks were used as the baseline (asterisk-word pairs), no such interaction was found (44 ms vs. 56 ms). Borowsky and Besner argued that the use of asterisks as the baseline is not equivalent to the use of unrelated words. They did not discuss why asterisk-word pairs produced no significant difference between intact and degraded conditions.

However, when asterisk-word pairs were used as the baseline in a between-subject design, the remaining experimental word-word pairs were all related. Thus, it is

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possible that participants develop expectancy that word primes were followed by related target words if not nonwords. Also, it is possible that using neutral, repetitive primes such as asterisks function differently than non-repetitive, unrelated word primes. Examining uses of different neutral primes as a baseline, Jonides and Mack (1984) argued that repetitive neutral primes such as 'XXXX' or 'BLANK' have poor linguistic-alerting value to signal target words; thus, the response times to the following target words were generally slower than those followed by non-repetitive unrelated word primes. When unrelated word pairs were mixed with asterisk prime-word target pairs (e.g., **** -TEST) in another degradation study by Borowsky and Besner (1993), response times for asterisk prime -word target pairs were slower than those for unrelated pairs in the intact condition, producing larger semantic priming for the asterisk baseline condition than for the unrelated word baseline condition (80 ms vs. 52 ms). In the second experiment when nonword primes were used as the baseline, non-repetitive nonword primes produced a similar pattern as unrelated primes: larger semantic priming for the degraded condition than for the intact condition. Thus, it seems the use of asterisks as neutral primes produces larger semantic priming for the intact condition (but response times for the neutral pairs were about the same in the degraded condition) by inflating the response times for the control condition and this may be due to reduced warning signal values of repetitive asterisk primes.

Degradation and SOA. Besner and Smith (1992) replicated the degradation x semantic context interaction with long (1250 ms) and short (200 ms) SOAs and found the interaction for both long SOA (26 ms vs 123 ms for intact and degraded conditions) and short SOA (9 ms vs. 99 ms) conditions. Borowsky and Besner (1993) included

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neutral conditions (asterisks or nonwords) and found degradation x semantic context interactions in both long (800 ms; 500 ms presentation + 300 ms ISI) and short (200 ms; 100 ms presentation + 100 ms ISI) SOA conditions when the baseline condition was either unrelated pairs or nonword-word pairs, but not when the baseline was asterisks.

Degradation and RP. Stolz and Neely (1995) examined the degradation x semantic context interaction by manipulating relatedness ratios (.25 vs. .5), SOAs (200 ms--150 ms presentation + 50 ms ISI--vs. 800 ms–150 ms presentation + 650 ms ISI), and strengths of association (weak vs. strong). The interaction effect was replicated when RP is high (.5) among strongly related pairs for both short and long SOA durations. The amount of semantic priming was comparable between degraded and intact conditions for low RP conditions and for weakly related pairs. The results indicate that the effect of degradation on semantic priming may be due to expectation as the degradation effect was found only for the high RP condition and for strongly related pairs, not for the low RP and weakly related pairs for both short and long SOA conditions.

However, there is a difference in degradation manipulation between Stolz and Neely (1995) and Borowsky and Besner (1993). Both used contrast or intensity reduction (Stolz and Neely used dark-gray letters on a black background; Borowsky and Besner reduced the brightness of the letters), but the differences in response times between degraded and intact conditions for unrelated pairs were smaller for Stolz and Neely's experiments than for Borowsky and Besner's (about 100 ms vs. about 200 ms.). Thus, a reason why Stolz and Neely did not obtain the degradation x semantic context

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interaction in low RP and weak associates may be due to weak degradation manipulations.

Summary

Thus far, I have reviewed studies which showed asymmetries in semantic priming due to target word characteristics and target word processing. The variables which affect ease of access affected the size of semantic priming. Low frequency target words produced larger semantic priming than high frequency target words for both short and long SOAs for the LDT. Degraded target words produced larger semantic priming than intact target words for both long and short SOAs and for both the naming task and the LDT. Thus, slowed access to words (processing low frequency words and degraded words) seems to produce larger priming than fast or normal access to words (processing high frequency words and intact words). However, the effects of spelling irregularity, orthographic depth, imageability, and concreteness on the semantic priming effect are not clear-cut. Since these variables produce asymmetrical response times in single word recognition (e.g., recognition times for irregular spelling words and for low imageability words are longer than for regular spelling words and for high imageability words[4]), if speed of access alone produces priming asymmetry, these variables should affect the semantic priming effect uniformly. Since this is not the case, factors other than

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[4] When Gernsbacher (1984) controlled word familiarity, word concreteness did not show any effects. In Cortese et al.'s study on the imageabililty effect, only target word frequency was controlled, not familiarity. As Gernbacher showed in another experiment that word familiarity has more effect on low frequency words than high frequency words, familiarity may need to be controlled for low frequency words. In Cortese et al.'s study, there may be a possibility that low imageability words were less familiar than high imageability words, though word frequency was controlled.

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speed of word access may also be involved in producing asymmetries in semantic priming. A possible factor would be familiarity of words, or processing automaticity. If irregularity words have the same level of familiarity as the regular counterparts, spelling regularity may not exert much effect between the two; in this case recognition latencies may be somewhat longer for the irregular spelling words than regular spelling words, but automaticity of access to phonology and meaning would be comparable. The same may be true for high vs. low imageability words. Thus, automaticity of processing as well as speed may well be involved. The issue of automaticity will be discussed in a later section.

Explaining Asymmetries: Target Word Processing

The three camps of theories on semantic priming discussed earlier can explain the asymmetrical results by target word characteristics (see, Neely, 1991 for a review). Although these theories are not specific about the effect of target word characteristics, by analogy, any variables which affect processing speed, spelling irregularity or imageability, can be included in the explanation. According to Neely, the Automatic Spreading Activation (ASA) theory predicts that low frequency target words produce larger semantic priming than high frequency target words and degraded target words larger than intact target words by assuming that activation thresholds for both related words and high frequency words are lower (closer to recognition thresholds) than those for unrelated words and low frequency words. Also, ASA assumes that degradation of stimulus letters affects speed of activation to recognize letters from visual features of individual letters. The common analogy to explain the effects of low frequency or degraded target words is "a horse race". If a fast horse (high frequency words or intact

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words) races a slow horse (low frequency words or degraded words), the time difference for the two horses is greater when the goal is farther away (i.e., when the distance between the starting activation level and threshold recognition level is greater). Although recognition latencies of low frequency words or degraded words are still slower than that of high frequency words or intact words for related pairs, recognition latencies for their unrelated pairs are much slower. Thus, related pairs of the words of slower recognition would be more facilitated as compared with unrelated pairs.

The expectancy-based priming account assumes that the participants develop expectancy sets according to the make-up of the stimulus lists presented. Recognition latencies for the related targets are facilitated because the expectancy sets direct the lexical search for a target word followed by a prime so that related words will be searched first. The expectancy theory of priming also assumes that lexical search is based on word frequency; high frequency words are searched earlier than low frequency words. Thus, for the related pairs, recognition latencies for both high frequency and low frequency target words are facilitated because of the expectancy sets which direct lexical search for related words; however, for unrelated word pairs, response times to low frequency target words will be longer than those to high frequency target words because low frequency words have a later placement in the lexical search order than high frequency words. The expectancy account also explains the degradation effect by making an analogous assumption that both word frequency and stimulus degradation have no effect on expectancy sets but have effects on speed for a lexical search from visual feature extraction to word recognition. Thus, degradation slows down

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recognition latencies more for degraded unrelated pairs than intact unrelated pairs as compared with related conditions.

Post-lexical checking mechanisms explain facilitatory effects of semantically or associatively related pairs by assuming that in the LDT participants base their yes/no lexical judgement on the prime-target relationships after they have recognized both prime and target words. When the stimulus pairs are related, participants are biased to respond 'yes,' which facilitates their correct response. When targets are unrelated, participants are biased to respond 'no' and they need additional time to execute the correct 'yes'response (the semantic-matching account by Neely and Keefe, 1989). Another explanation is based on familiarity of prime-target word relationships (the compound-cue account by Ratcliff and McKoon, 1995) which differs from the above explanation in assuming familiarity as a basis for lexical decision. Related pairs are more familiar (associations exist in episodic memory) while unrelated pairs and word-nonword pairs are less familiar. The former explanation does not explain the target frequency effect on priming. The latter explains the effect by assuming that the effect of familiarity (or word frequency) among related pairs for low frequency words is greater than for high frequency words. Neither account has not made specific predictions on the degradation effect (but could explain the effect by expanding the assumptions; see, Neely, 1991).

Prime Word Characteristics

Thus far I have discussed how target word characteristics and processing manipulation affect the degree of semantic priming. However, although less researched, prime word characteristics and processing manipulations should also affect degrees of

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semantic priming. According to automatic spreading activation (Collins & Loftus, 1975), if spreading activation from a prime word is blocked or weakened, the access to related target words may not be facilitated. On the other hand, if processing of the meanings of primes is heightened, spreading activation of the meaning may be strengthened and may produce larger semantic priming. Thus, any manipulations which affect prime processing strength should have an effect on semantic priming. If low frequency prime words, for example, are presented with a very short SOA, without leaving enough time to spread activation, the semantic priming effect would be smaller than at a longer SOA. Degrading prime words would have the same effect. Unfortunately, so far no studies have investigated the effect of accessing speed of prime words on the semantic priming effect.

Although no studies have directly examined the effect of prime word characteristics, such as word frequency or familiarity, some evidence may come from cross-language semantic priming studies. In these studies, prime words are either in the first language (L1) or in the second language (L2) crossed with the target word language. Being more familiar and used more frequently, words in L1 should have faster access and stronger activation than those in L2. In effect, the patterns of asymmetries according to both prime and target word characteristics (i.e., native and second languages) have been observed (Kroll, 1993). Cross-language semantic priming is typically larger when the prime word language is the native language (L1) and the target word language is the second language (L2) than when the prime word language is L2 and the target word language is L1. In cross-language semantic priming studies, prime and target languages are crossed, thus the obtained priming effect should include effects

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of both prime and target languages. As L2 is typically processed more slowly than L1, it is possible that the processing speed of target language is responsible to produce the asymmetry. It is also possible that prime word familiarity affects the accessing speed to the target word.

The possibility that word familiarity accounts for asymmetries found in cross-language studies was examined in a cross-language translation study. The asymmetrical results have been also found consistently in translation studies. Typically, translating from L2 to L1 is faster than translating from L1 to L2. Recently, Cheung and Chen (1998) adjusted test item familiarity by using it as an covariate in the translation latency analyses in their post-hoc analyses. The significant difference in translation latencies between the L1-L2 direction and the L2-L1 direction disappeared when familiarity to words was controlled. Thus, there is a possibility that a rather simple variable may be responsible for producing the asymmetry. If prime word characteristics, such as word frequency and familiarity, are found to have effect on semantic priming in cross-language semantic priming studies, then analogous prime word characteristics should exert effect in monolingual semantic priming effects.

<u>Prime Word Processing</u>

Many studies have investigated, however, how processing prime words affects semantic priming. These include "levels of prime processing" studies and "mixed presentation duration" studies. The former involves "shallow" processing of primes (e.g., performing a letter search task on primes, which is supposed to prevent processing words at the semantic level). The latter concerns manipulation of prime presentation durations (e.g., short and long SOAs are mixed in an experiment). 'Shallow' prime

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processing typically eliminates the semantic priming effect. Also, a short prime presentation duration, when mixed with long one, eliminates the effect.

Levels of prime processing. The processing of primes can be manipulated by asking participants to perform various tasks on primes. The letter search task on primes involves searching for a particular letter for each prime (e.g., a letter to be searched is specified above the prime; "RRRR" above "STEAK" to look for a letter "R"). The letters to be searched for are changed for each prime with both positive and negative responses. Immediately after the yes/no responses for the letter search task on primes, target words are presented for the lexical decision task. So far studies on a letter search task have been done using a LDT, and the color naming task (i.e., participants name the color of target words –this produces inhibition for related pairs; Henik et al., 1983), but not for the naming task.

Smith, Theodor, and Franklin (1983) examined the effects of depth of prime processing on the amount of semantic priming. They also compared semantic priming with other episodic recognition memory measures. There were five conditions depending on the tasks performed on primes: visual analysis (to determine whether a star appeared to the left of a prime); letter search; phonemic analysis (to determine whether a prime had more than one syllable); read (to read primes; no response required); and semantic analysis (to determine whether a prime was a living thing). The semantic priming effect was obtained in the phonemic analysis, the read, and the semantic analysis conditions. The amount of semantic priming was largest in the semantic analysis condition (108 ms), followed by the read condition (68 ms), and the phonemic analysis condition (41 ms).

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The results supported the depth of prime processing hypothesis regarding semantic priming. When semantic context was processed more deeply (at the semantic level), a large semantic priming effect was obtained while shallow levels of processing (a visual analysis and a letter search) did not produce the effect (-8 ms and -18 ms, respectively). Recognition memory showed a different pattern. When participants were asked to give a yes/no recognition judgement for prime words, the deeper prime processing produced better recognition; however, related pairs produced better memory than unrelated pairs regardless of tasks performed on primes. Recognition memory for targets was not affected by depth of prime processing (no significant difference in recognition memory for targets between conditions) while there was an effect of relatedness (targets of related pairs recognized better than targets of unrelated pairs). The results indicate that depth of prime processing has an effect on accessing speed for target (i.e., semantic priming), but not recognition memory for targets.

Additional support that "shallow" processing of prime words eliminates priming came from Friedrich, Henik and Tzelgov (1991)'s study which examined both semantic and repetition (identity) priming with the letter search task. In the identity priming experiment, response times for identical pairs (the same words for primes and targets) were compared with unrelated pairs. Friedrich et al. compared identity and semantic priming for the naming condition (pronounce prime words and perform a lexical decision on targets) and for the letter search condition (perform a letter search on primes and lexical decision on targets). They found that while identity priming was observed in both conditions, semantic priming was observed only in the naming condition, not in the letter search condition. As identity priming was observed with a

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letter search task, Friedrich concluded that in the letter search condition primes were processed at the word (lexical) level, not at the individual letter level. However, the primes may not have been processed at the semantic level since semantic priming was not obtained in the condition.

The shallow prime processing explanation assumes that the letter search task on primes does not encourage primes to be accessed at the semantic level. However, there is some evidence that depending on conditions, the letter search task allows "deeper" processing. When the letter search was performed on target words in Smith (1979), the semantic priming effect (measured by faster response times for semantically related pairs when responding to whether a certain letter was in the target word) was obtained while the effect was not found when the same procedure was used for primes. Thus, it seems performing the letter search task itself is not the sole reason for shallow processing. Also, when the letter search task involved searching for a letter common to a prime and a target word presented simultaneously, the response times for the search were slower for the prime-target related pairs, indicating that relatedness interfered performing the letter search task (Besner et al., 1990). Thus, the letter search task per se may not always preclude semantic level processing. Once prime words are processed, performing a letter search on related target word does not prevent from processing its meaning. Expectation formed in processing primes may be needed to obtain semantic priming.

To further investigate the effect of expectation on prime processing, Henik et al. (1994) manipulated SOA durations and relatedness proportions in the letter search task experiments. In both short and long SOA conditions, to make the SOA constant, participants responded to the target items first which immediately followed prime

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words, then responded orally to a letter search task on the prime word. As the response to a letter search task was done after the target word was presented, the SOA was kept constant, as compared with other studies which required participants to respond to a letter search task on primes before target words were presented. The semantic priming effect was eliminated with the letter search task on primes in either short (240 ms) or long (840 ms) SOA conditions when RP was .50 (Experiment1). When using a very long (1700 ms) SOA and letter search responses on primes before the lexical decision for the target, the semantic priming effect was found for high RP (.80) condition, but not found for low RP (.20) condition (Experiment 2). The last experiment replicated the results of the second experiment using a short (100 ms) and a long (700 ms) SOAs (SOA durations were intermixed in a within-subject design). The semantic priming effect was eliminated in the low RP (.20) condition, but was found in the high RP (.80) condition for both durations. Thus, the results show that semantic priming is obtained with a high RP regardless of durations of SOA when a letter search on primes should have induced "shallow" processing of primes. Henik et al. interpreted these results regarding differential levels of prime processing; salience of semantic relations in the high RP condition might induce semantic level analysis during the letter search task. They suggested that some automatic semantic activation does occur during the letter search task on primes, but limited resource capacity is drawn to the letter analysis task, thus reducing or eliminating semantic priming. With a higher RP, the activation level might have increased, thus producing the semantic priming effect.

Chiappe, Smith, and Besner (1996) further investigated the limited capacity account as opposed to the level of processing account. They compared the effect of the

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letter search task on primes with the effect of another task on primes, the color discrimination task. In the color discrimination task on primes, the participants were asked to determine the color of primes (red vs. blue for easy color discrimination and dark vs. light blue for difficult color discrimination). In the letter search condition the semantic priming effect was not found, but in the color decision conditions the effect was reinstated. Chiappe et al. argued against a levels-of-processing interpretation for the elimination of semantic priming by the letter search task on primes.[5] In effect a shallow level of processing of primes by the color discrimination task produced the semantic priming effect. Thus, the authors proposed the activation block account, which explains that the letter search task blocks activations between the letter-level and the semantic-level processing. The color discrimination task operates on a separate domain from the lexical and semantic processing, thus demanding fewer competing processes.

Additional evidence that processing of primes is affected by prime presentation context (timing of task demands) was presented by Stolz and Besner (1996) who inserted a 200-ms delay between a prime (e.g., CONTEXT) and a probe to search for a letter (e.g., NNNNN) with an RP of .5. The semantic priming effect was not found in the simultaneous condition (a prime and a probe were presented simultaneously), but was found in the probe delay condition (55 ms priming). Stolz and Besner interpreted this result as evidence that seeing a prime before a letter search put prime processing at the deeper, semantic level. In the second experiment the simultaneous and the delay condition were randomly intermixed in the within-subject design. In both conditions the

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[5] Chiappe et al. (1996) also pointed out logical inconsistency of the explanation with the Stroop task results, where naming colors is affected by semantic context.

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semantic priming effect was found (30 ms for the simultaneous, 28 for the delay condition). Stolz and Besner concluded that processing primes is not totally automatic, but it is affected by the context in which stimuli are processed.

In summary, the “shallow” processing of primes by the letter search task seems to explain the elimination of the semantic priming effect. Other studies which applied a letter search task on primes typically showed elimination of semantic priming (Besner et al., 1990; Chiappe, Smith, & Besner, 1996; Friedrich, Henik, & Tzelgov, 1991; Henik, Friedrich, Tzelgov, & Tramer, 1994; Smith, 1979; Smith, Theodor, & Franklin, 1983; Stolz & Besner, 1996). To obtain semantic facilitation, primes need to be processed as a “meaningful unit,” not just at the letter level (Smith, 1979).

<u>Prime presentation durations – in mixed vs blocked designs.</u> Further evidence that the experimental task affects the amount of processing, and possibly the way primes are processed comes from mixed prime presentation duration experiments. In mixed prime presentation duration experiments, Smith, Besner and Miyoshi (1994) manipulated short and long prime presentation durations between the between-subject (blocked) and the within-subject (mixed) designs. In the blocked condition different individuals participated in either the short (84 ms prime presentation plus 314 ms ISI) or the long (280 ms prime presentation plus 414 ms ISI) SOA condition. In the mixed condition short and long prime presentation durations were randomly intermixed. The researchers found the semantic priming effect for both short and long prime presentation conditions in the blocked condition.

However, the semantic priming effect for the short prime presentation condition was eliminated in the mixed condition while the effect for the long SOA condition

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remained intact. This result was interpreted according to a signal detection account which assumes different activation thresholds for lexical and semantic levels of processing. Short presentation duration is assumed to produce weak activation as compared with long presentation duration. If there is little variability in activation levels, primes weakly activated would spread from the lexical level to the semantic level. However, if there is variability in activation levels as in the mixed condition, weak activation would not spread to the semantic level, thus, eliminating the semantic priming effect from pairs which had short prime presentation duration. The researchers concluded that spreading activation is not necessarily automatic, but modulated by context which sets "the mode of prime processing." According to their signal detection account, different levels of activation affect the criterion which determines whether activation at the lexical level spreads to the semantic level. When strong activations are mixed with weak ones as in the mixed condition, the criterion is set according to the level of the strong activation; thus, weak activations may not spread to the semantic level.

In this study, the duration of prime presentation was confounded with SOAs (i.e., for the short prime presentation condition the SOA was also short; and for the long prime presentation, the SOA was also long). Stolz and Besner (1996) eliminated this confounding using a constant SOA (716 ms) for short (80 ms) and long (288 ms) prime presentation conditions and replicated the main findings by Smith et al. (1994). Additional experiments manipulated RP in order to test their own hypothesis, the center-surround attentional mechanism, to explain the elimination of semantic priming for short prime duration pairs in the mixed condition. The center-surround attentional

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mechanism was first proposed by Dagenbach, Carr, and Wilhelmsen (1989), stating that strong activation by focused items suppressed the activation of related (surround) items. In the mixed prime duration condition, according to Stolz and Besner, long prime duration related pairs are assumed to produce stronger activation and suppress the activation of short prime duration related pairs. Whether the center-surround mechanism is involved may depend on RP. By reducing RP, the semantic relationship is less salient; thus, participants would be less likely to use the center-surround mechanisms to process related pairs in both short and long durations. They did not find a significant semantic priming effect (9 ms) for the short prime presentation duration condition when short and long durations were mixed within an experiment and when RP was high (.5). However, when RP was low (.25), the same condition re-established the semantic priming effect (17 ms) for the short prime duration condition. Thus, Stolz and Besner concluded that the center-surround attention mechanism explained the results better than the signal detection account.

Further studies may be needed to determine which account would explain the above phenomenon. The results from these studies show that duration and timing, and also, expectation manipulated by salience of relatedness (RP), affect the amount of semantic priming.

In summary, how prime words are processed may have effects on semantic priming. 'Shallow' processing of primes eliminated semantic priming. Also, weaker activation of primes (via a short SOA), when mixed with strong activated primes (via a long SOA), produced little semantic priming. Thus, it is possible that manipulating word

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access speed of prime words have effects on the semantic priming effect when SOAs are varied.

Explaining Asymmetries: Prime Word Processing

The theories of semantic priming are not very specific about how or whether prime characteristics or priming processing ("shallow" processing effects) would affect semantic priming. The ASA account alone does not explain the "shallow" processing effect for it assumes spreading activation should be automatic once a word is recognized regardless of types of tasks performed on prime words. The expectancy account explains the "shallow" process effect by assuming that performing a letter search task on primes interferes with developing expectancy sets, thus eliminating or reducing the facilitatory effect for related pairs. The semantic-checking mechanisms explains the "shallow" processing effect by assuming that a letter search task on primes interferes semantic-checking mechanisms between primes and targets. The compound-cue account also explains the "shallow" processing effect by assuming that performing task interferes accessing combination cues between primes and targets, thus reducing or eliminating the semantic priming effect. These theories seem to offer rather post-hoc explanations, which are not very specific about predicting interactions between different variables (see Neely, 1991).

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CHAPTER 2: OVERVIEW OF EXPERIMENTS

Hypotheses

The literature review clearly shows that the effect of prime word processing on semantic priming is under-researched. The following studies attempt to remedy this situation. By looking at how target words are accessed by manipulating prime word processing, we can investigate how we access word meanings. Target characteristics such as word frequency, imageability, and spelling irregularity have been shown to affect semantic priming. Degradation of target words has been shown to have an effect. However, no published studies have directly investigated the effect of ease of word access of prime words on semantic priming. The current study investigated the effect of prime word processing speed, first through word frequency in Experiment 1. High frequency prime words should be processed faster than low frequency prime words. Processing speed was then slowed via degrading primes in Experiment 2, and accelerated by repeating prime presentation in Experiment 3.

The focus of existing theories of semantic priming is on the explanation of how target words are accessed once primes are accessed, or semantic nodes are activated by primes according to the ASA theory. None adequately explains how differences in initial activation of primes would affect accessing target words. In other words, these theories are not specific about how initial activations spread to the semantic network. I hope this study will give another focus for researchers of semantic priming to incorporate into theoretical frameworks to better understand the processes of meaning access.

In the present study, Experiment 1 first investigated the effect of prime word frequency on the semantic priming effect. Word frequency does appear to have effects

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on how we process words: it has effects on memory (e.g., low frequency words remembered better than high frequency words) and single word recognition (e.g., low frequency words take more time to recognize than high frequency words). High frequency words are those which we encounter more often, thus are more easily activated (or accessed) than low frequency words. Some word recognition theories base their assumption on word frequency (e.g., word search is ordered according to frequency or high frequency words have higher resting activation). In the single word processing studies, high frequency words are accessed more quickly than low frequency words (e.g., Balota & Chumbley, 1985; de Groot, 1989; McRae, Jared, & Seidenberg, 1990). Thus, when high frequency words are the primes, they should be processed faster and thus produce larger semantic priming than when low frequency words are the primes. This effect may interact with SOA. When SOA is very short, high frequency prime words should produce larger priming than low frequency prime words while when SOA is long, low frequency words may have enough time to be processed, thus perhaps producing semantic priming as much as high frequency words did in the short SOA condition. Experiment 1 explored this possible effect of prime word frequency on semantic priming using the lexical decision task. It is assumed that since priming with high frequency primes reach their strong activation points more quickly than with low frequency primes, the increase of priming from the short to the long SOA condition should be larger for priming with low frequency than priming with high frequency.

For the current studies, an SOA of 150 ms was chosen for a short SOA and a 500 ms SOA was chosen for a long SOA. In semantic priming studies, in general researchers use SOAs shorter than 300 ms for short SOAs and SOAs longer than 500

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ms for long SOAs. For example, Stone and Van Orden (1992) used a 200 ms SOA for the short SOA and a 2000 ms SOA for the long in examining the effect of target word frequency on semantic priming. In this study a 150 ms SOA was used for the short SOA so that prime presentation was brief but still consciously noticeable; a 500 ms SOA was used for the long SOA, in which primes were presented long, but still the effect of expectancy should not be big.[6]

In the next two experiments, the effect of ease of word access was further examined by two manipulations which affect word access processes: degradation and repetition of primes. While word frequency possibly affects the processes of semantic access, degradation and repetition of primes are assumed to affect the processes of lexical access. Many language models assume separate stages between lexical or phonological or orthographical processes and semantic or conceptual processes (e.g., Morton, 1969; Plourde & Besner; 1997) and there is evidence these two processes are separable. In the single-word recognition studies, it has been demonstrated that the effects of word frequency and stimulus quality (degradation) are not interactive, but are additive (Becker & Killion, 1977; Borowsky & Besner, 1993; Plourde & Besner, 1997). Word frequency interacted with relatedness. Low frequency target words produced more semantic priming than high frequency target words. Stimulus quality, however, did not interact with relatedness. Both low and high frequency target words produced larger priming when stimulus quality was reduced (i.e., degraded target words) than when they

[6] Neely (1977) examined the effect of expectancy and SOA and found minimum influence of expectancy in the short, 250 ms SOA condition while they found more influence of expectancy (i.e., effects of inhibition) with SOAs longer than 700 ms.

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were intact, and the rates of increase in priming were comparable. Thus, the researcher differentiated the two distinctive stages in word recognition: the lexical process and the semantic access. Stimulus quality, or degradation, affects lexical access, and word frequency mainly affects semantic access processes. Also, in the repetition priming paradigm, repeating words produces faster word recognition due to either elevated lexical access to the repeated words (producing a higher activation level) or accessible episodic traces (e.g., Bodner & Masson, 1997; Forster & Davis, 1984; Kinoshita, 1995; Rajaram & Neely, 1992).[7] Typically, repetition effects are assumed to involve lexical access; no studies address whether the lexical access by repetition also involves semantic activations. Indirectly, studies comparing semantic and repetition effects show that lexical effects and semantic effects are dissociable (for example, Smith et al.(1994) obtained repetition priming, but not semantic priming for the short SOA pairs in the mixed SOA conditions). Thus, ease of access effects produced by repetition of prime words and prime word frequency may be different; the former mostly on lexical access and the latter mostly semantic access.

In Experiment 2 the effect of speed of prime word access was examined by slowing down the word recognition process by degrading prime words. As previously reviewed, degradation has been used for target words in priming experiments to slow down word recognition processes, and typically, degraded target words produces

[7] The size of repetition priming may vary depending on procedures and materials used. Using a LDT, Scarborough, Cortese, and Scarborough (1977) obtained about 100 ms priming (read from a graph) across different time lags (0 to 15 words separate). Kinoshita (1995) obtained repetition priming for attended words about 25 ms and 50 ms for high and low frequency words respectively (read from a graph) using a LDT immediately after the study session.

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greater priming than intact target words. No studies so far examined the effect of degradation on prime processing.

If ease of access to prime words has an additive effect on the size of semantic priming, it should have equal effects for both low and high frequency words. As demonstrated in the single word processing studies on the effect of stimulus quality and word frequency, degradation should affect mostly lexical access in word recognition and be additive to semantic access. Thus, in this experiment, degrading prime words should affect high and low frequency prime words equally. If the accessing speed differences between high and low frequency words produce larger priming for high frequency prime words than for low frequency prime words, then degrading high frequency prime words should produce a similar effect to intact low frequency prime words. Degraded high frequency prime words would produce larger priming for the 500 ms SOA condition than for the 150 ms SOA condition. Degrading low frequency prime words should almost eliminate priming in the short SOA condition and produce small priming in the longer SOA condition.

In Experiment 3 the effect of speed of prime word access on priming was examined by accelerating word access by repetition. In the experiment participants read half the prime words one by one immediately before the priming task. Assuming repetition affects high and low frequency primes equally, repetition should increase priming for both high and low frequency in the short SOA condition. The effect of word repetition, or accelerated speed of word access, should be less apparent when there is enough processing time as in the long SOA condition. Thus, in the long SOA condition

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the effect of repetition should be weaker for both high and low frequency prime conditions than in the short SOA condition.

Since the same experimental materials were used in all three experiments, the effect of prime word frequency should be present as well as the effects manipulated in Experiment 2 and 3 (i.e., degradation and repetition). In that regard, the hypothesis on the prime frequency effect was tested in all experiments. In Experiment 2 assuming degradation has an additive effect on priming, affecting high and low frequency primes equally, in the short SOA condition degraded high frequency primes were expected to yield decreased priming while degraded low frequency primes would produce little priming because of the floor effect. Thus, in the short SOA condition, the priming difference in Experiment 2 would be smaller than the one in Experiment 1. In the long SOA condition, having more time to process for both high and low frequency primes and also, assuming degradation has an additive effect on semantic priming, the degree of the prime frequency effect on priming should be comparable to the one in the long SOA condition in Experiment 1. In Experiment 3 repetition of prime words should accelerate lexical access for both high and low frequency primes, thus the effect of prime word frequency should be present in the short SOA condition and should be decreased in the long SOA condition, much as predicted in Experiment 1.

In this study, QSS (cue set size) was also included as an variable, while controlling such word characteristics as word familiarity and imageability. QSS was collected by Nelson, McEvoy, and Schreiber (1993) as a "relative index of the set size of a particular word by providing a reliable measure of how many strong associates it has" for an intention of use in memory research, especially in the area of cued recall. It

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was obtained by counting the total number of associative words their subjects (an average of 149) gave for each target word to respond. As each subject gave only one word response and QSS was obtained by counting each different response for a particular word, QSS reflects the number of strong connections rather than the number of connections including weak ones. This index of the number of strong connections should be differentiated from 'strength' of connections. In Nelson et al. (1993)'s norm study, the associative strength was given by the percentage of participants giving the particular associate. An associate has more associative strength when more participants give the word as an associate to a particular target words. Both QSS and associative strength could have effects on semantic priming. In this study, to address specifically to the ASA theory, QSS was included as an experimental variable while associative strength measures were included as a variable to be controlled so that each experimental cell had equivalent average scores for the associative strength measure.

In the semantic priming paradigm, as mentioned previously, the process of word meaning access has been given little investigation by researchers of any of the theoretical camps. Many assume and use the term "spreading activation" from Collins and Loftus (1975); however, the actual activation processes and the variables which affect activations have not been clearly specified in the semantic priming paradigm. Since the ASA theory assumes simultaneous spreading activation and a limited capacity of activation levels for a word, the number of strong connections prime words have should have effects on how meanings of the primes spread to target words. According to the ASA theory, if a word has more strong connections, its activation of meaning diffuses more quickly than if it has fewer strong connections (in accordance with the

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automatic activation theory by Collins & Loftus, 1975). Thus, larger QSS should produce smaller priming than smaller QSS with associative strength held constant. I assume this effect is additive to the word frequency effect so that high frequency low QSS primes would produce the largest priming while low frequency high QSS primes would produce the smallest priming.

High frequency words could have more strong associative connections (i.e., higher QSS) than low frequency words from more frequent daily use with in different contexts. Although the statistics are not provided, in effect, from Nelson et. al's database, it was far easier to select high frequency words with high QSS than with low QSS, and low frequency words with low QSS than with high QSS. Since I am interested in the effect of word frequency regarding word accessing speed on semantic priming, QSS should not be confounded in the effect, especially, when high QSS is biased toward high frequency words. By separating the effect of QSS from the effect of word frequency, this study can control the variable and also test the ASA theory, giving more specific account of spreading activation of meanings.

In addition to the effects predicted from my hypotheses on prime processing, there were four effects which were expected to be found in this study. Although the following effects were not the main focus of this study, they should be obtained which have been demonstrated in previous priming studies : a) the main effect of target frequency (response times to low frequency target words should be slower than those to high frequency target words); b) the relatedness effect or priming (related pairs should produce larger priming than unrelated pairs); c) the target word frequency effect (low frequency target words produce larger priming than high frequency target words);

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d) the effect of SOA (typically, a long SOA produces larger priming than a short SOA) (c.f., Neely, 1991, for a review of semantic priming studies; Stone & Van Orden, 1992, for the effect of target frequency on semantic priming).

In summary, the three experiments examined the following hypotheses on the effect of ease of prime word access and QSS on semantic priming.

1) Prime word frequency would affect the amount of priming when the available prime word processing time is limited in the short SOA condition. a) High frequency prime words should produce larger priming than low frequency prime words in the short SOA condition in Experiment 1 and 3. The priming difference in the short SOA condition in Experiment 2 should be smaller because of the floor effect by degradation. b) The difference in priming between high and low frequency prime conditions should decrease when low frequency prime words have enough time to be processed in the long SOA condition in Experiment 1 and 3. In the long SOA condition in Experiment 2 the priming difference between high and low frequency primes should be small and comparable to the one Experiment 1 and 3. These are tested in Experiments 1, 2, & 3.

2) Degradation would slow down lexical processes of word access. By slowing down the lexical access of high frequency primes by degradation, the degraded high and low frequency prime words should produce smaller priming than the intact high frequency prime words in Experiment 1 (Little priming should be obtained with degraded low frequency primes in the short SOA condition). These are tested in Experiment 2 and compared with the results from Experiment 1.

3) Repetition of prime words should speed up the lexical process of prime word access. a) By accelerating the prime word access process by repetition of prime words,

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for both high and low frequency primes, studied primes should produce larger priming than unstudied primes in the short SOA condition (Hyp 3-a). b) With more processing time available in the long SOA condition, the effect of repetition should be less apparent (Hyp 3-b). This is tested in Experiment 3.

4) According to the ASA theory, activations spread through word nodes. When a word has more strong connections, activations spread more thinly to each node than when it has few strong connections, assuming the same level of activation. Thus, prime words with low QSS should produce larger priming than those with high QSS. The effect of QSS is assumed to be additive to the word frequency effect, producing equal effects to high and low frequency prime word conditions. Thus, priming should be the highest in the high frequency prime -low QSS -low frequency target condition. These were tested in Experiments 1, 2, & 3.

The main effects and interactions predicted from these hypotheses and expected effects from previous effects are described in Figure 1 and the graphic presentations of the predicted results according to the above hypotheses for each experiment are shown in Figure 2.

General Method

In this section the general method used for each experiment will be described. There are procedural differences among three experiments according to their purpose. These differences will be mentioned in each section of the particular experiment.

Experimental Design

In all experiments low and high frequency prime words were crossed with high and low frequency target words as well as high and low QSS in a within-subjects

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	Applicable Experiments	Expected and predicted effects
E 1	Ex1, Ex2, Ex3	target frequency
E 2	Ex1, Ex2, Ex3	relatedness
E 3	Ex1, Ex2, Ex3	target frequency x relatedness
E 4	Ex1, Ex2, Ex3	relatedness x SOA
Hyp1-a	Ex1, Ex2, Ex3	prime frequency x relatedness
Hyp1-b	Ex1, Ex2, Ex3	prime frequency x relatedness x SOA
Hyp 2	Ex2	relatedness x degradation
Hyp 3-a	Ex3	relatedness x repetition
Hyp 3-b	Ex3	relatedness x repetition x SOA
Hyp 4	Ex1, Ex2, Ex3	QSS x relatedness

Figure 1. Expected (E) and predicted effects (Hyp) in Experiment 1, 2, and 3.

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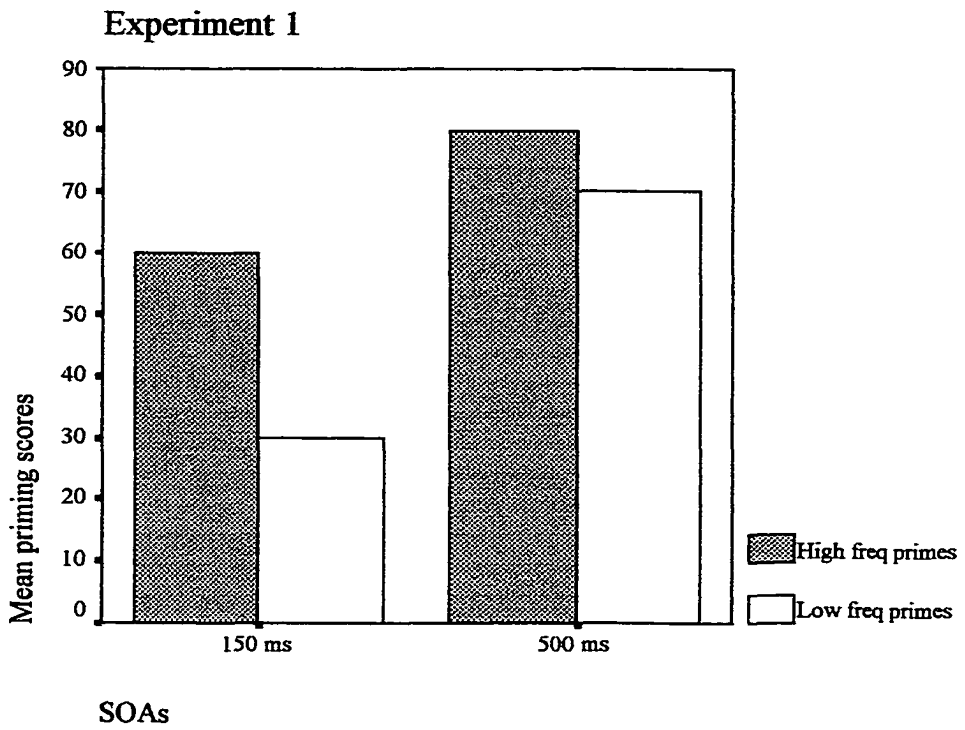

Figure 2 a. Hypothetical results of priming scores according to prime frequency and SOA in Experiment 1.

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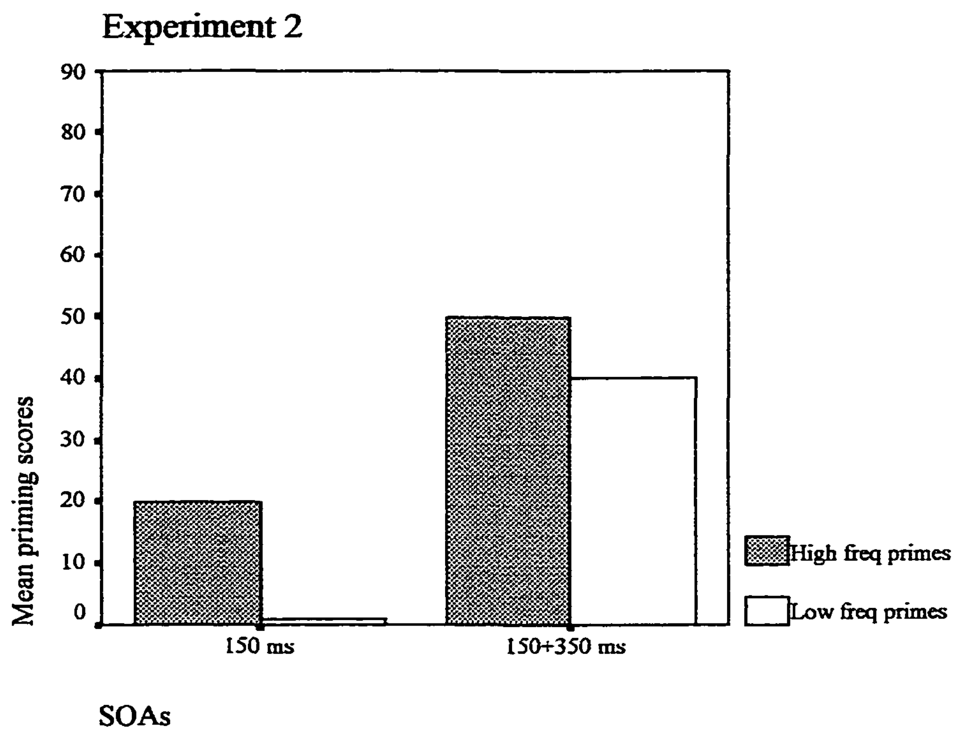

Figure 2 b. Hypothetical results of priming scores according to prime frequency and SOA in Experiment 2.

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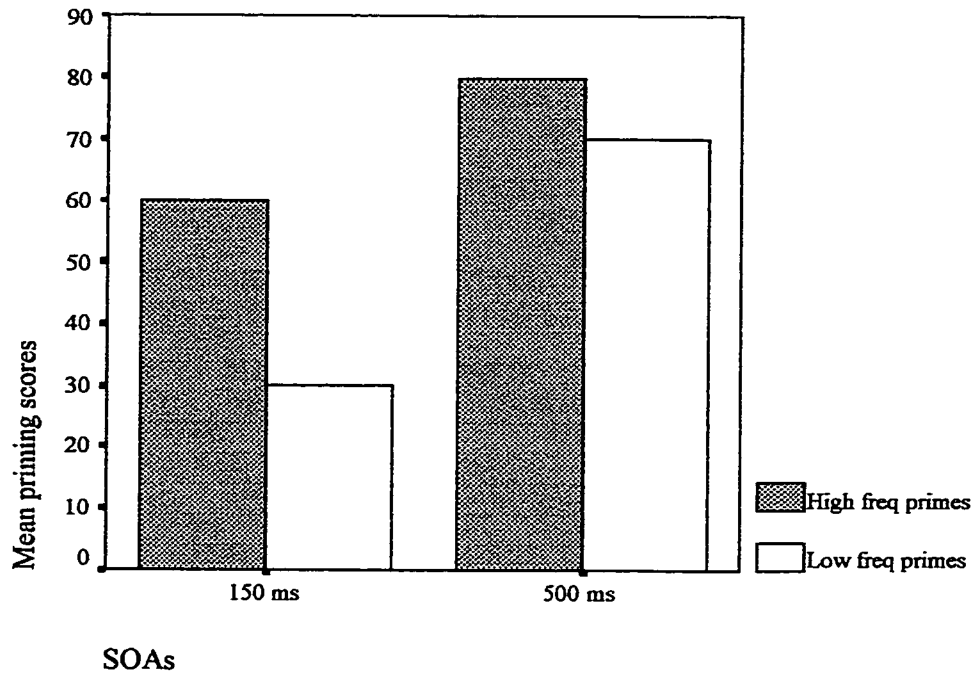
Experiment 3

Unstudied condition



Studied condition

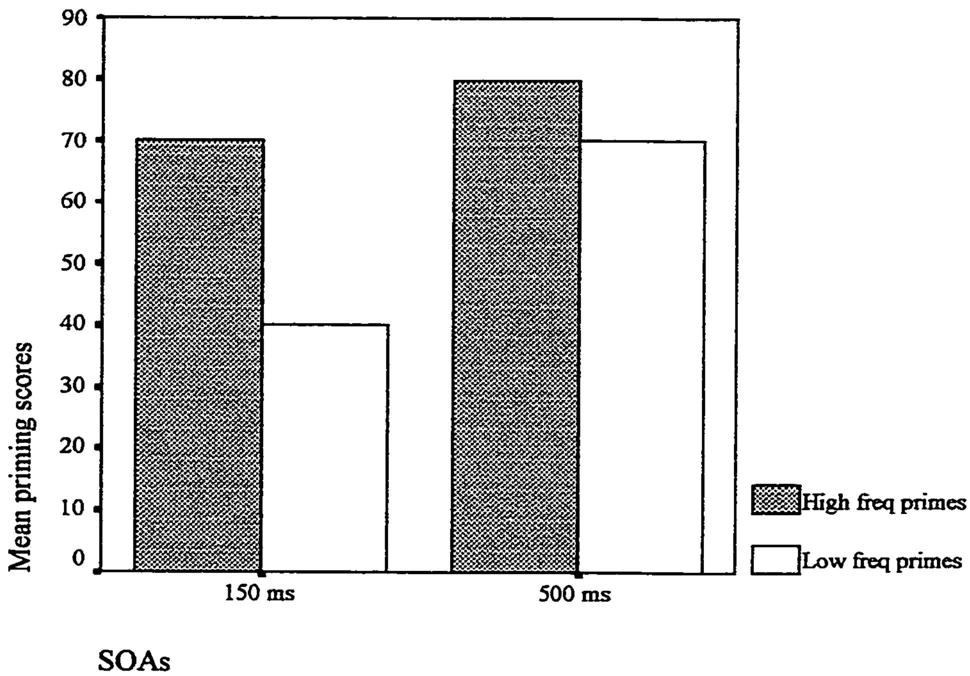


Figure 2 c. Hypothetical results of priming scores according to prime frequency and SOA in Experiment 3.

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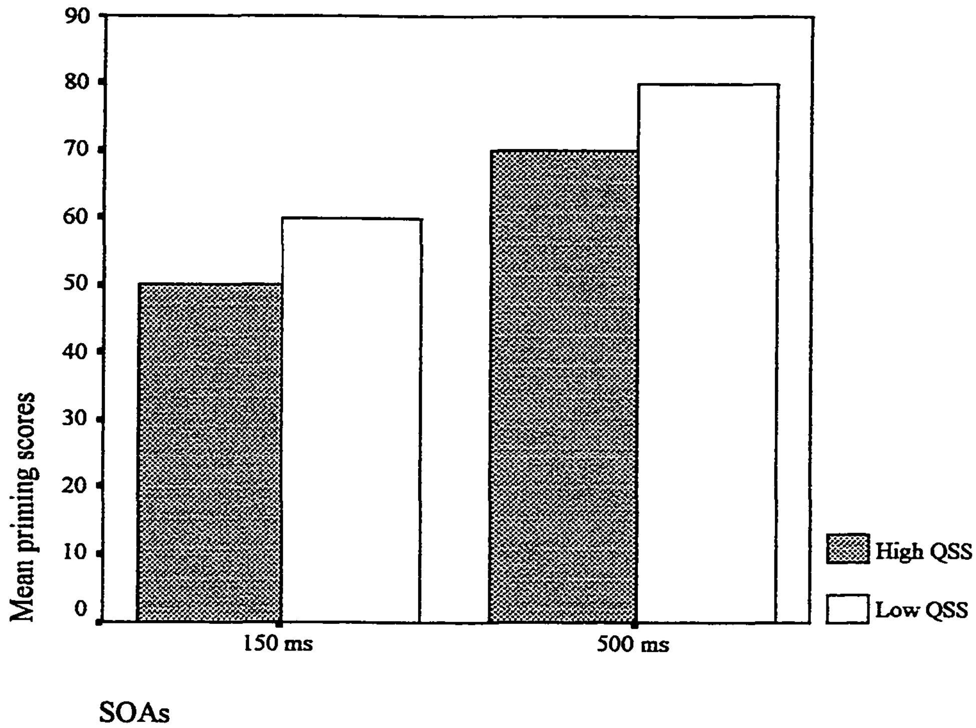

Figure 3. Hypothetical results of priming scores according to QSS and SOA in Experiment 1, 2 & 3.

design. Short and long SOAs were manipulated as a between subjects variable. In Experiment 1 there were three SOA conditions: the short SOA with 150 ms prime presentation, the long SOA (1) with 150 ms prime presentation plus 350 ms blank screen, and the long SOA (2) with 500 ms prime presentation. The two long SOA conditions were included to control prime presentation and SOA durations. Experiment 2 included the short SOA condition and the long SOA (1) condition. Experiment 3 compared the short SOA condition and the long SOA (2) condition. In Experiment 2 degradation was manipulated as a between subjects variable. In the degraded experiments all the primes were degraded. In Experiment 3 repetition of primes was manipulated as a within-subjects variable. Participants responded to half the primes which were repeated and another half which were presented for the first time.

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Apparatus

A PowerMac computer was connected to a response box which had 'yes' and 'no' keys. Participants pressed the 'yes' key with their right index finger and the 'no' key with their left index finger. The response box had 1 ms accuracy. Stimulus presentation and data collection, and the response box were controlled by SuperLab software.

Materials

Experimental stimulus pairs used in this study is given in Appendix C. Stimulus pairs were divided into 8 conditions according to a 2 [prime frequency; High (> 70 per million) vs. Low (<20 per million)] x 2 [target frequency; High (>70 per million) vs. Low (<20 per million)] x 2 [QSS; High (>/=18 connections) vs. Low (</=10 connections)] design. Stimulus pairs were selected from the MRC Psycholinguistic database (1981) and Nelson, McEvoy, & Schreiber's (1993) database using the word characteristics of prime and target word frequency, and QSS as the independent variables. High frequency words had a frequency of greater than 70 counts per million (Kucera & Francis, 1967), and ranged from 74 to 464 with an overall mean of 176.8. Low frequency words ranged from 1 to 20 with a mean of 9.9. High QSS had a value equal to or larger than 18 and the values for low QSS were equal to or smaller than 10. In addition, prime word familiarity and prime word imageability, as well as associative strength (the proportion of subjects who produced the particular associate from a given word) were controlled for as follows: stimulus words were selected from words which had high familiarity values (more than 500 on a scale of 100 to 700; from MRC Psycholinguistic Database) and moderate imageability values (more than 400 on a scale

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of 100 to 700; from MRC Psycholinguistic Database). Associative strengths were in the medium range (.04 to .5).

Examination of Experimental Stimulus Pairs. Originally, as many stimulus word pairs as possible which satisfied these criteria were selected. From those, a semi-final list of stimulus pairs were selected so that for each cell of the 2 x 2 x 2 design the average scores for control word characteristics (imageability, familiarity, frequency, QSS, and associative strength) were approximately comparable.

To see if those norms reflected those in the LSU subject pool, subjective word characteristic norms were collected from a similar population (23 students at LSU who enrolled in a psychology course). Those norms included subjective frequency for target and prime words, imageability ratings and familiarity ratings for prime words and associativeness ratings for related pairs. It was not possible to get QSS estimates from this norming study because the number of participants was too small to obtain that kind of data. Cell means for ratings from LSU students for each variables were calculated and compared with those from Nelson et al (1993)'s norms. The final list of stimulus pairs were created so that the average scores for variables for each cell were as comparable as possible.[8]

Discrepancies between norms and students' ratings. The appendix provides means and medians for each word characteristic according to conditions for the final

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[8] However, because there were so many variables to be controlled and each pair had different scores for each variable, it was not possible to select final pairs which had the same values for those controlled variables for each cell. The selection process was a difficult one especially for those cells which had a limited number of available pairs to start with due to stimulus characteristics (e.g., there were not many words which were high in imageability and familiarity and low in frequency and QSS at the same time).

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list. To examine if all these word characteristic variables were balanced among different conditions for the scores of the norms for the final list, 2 x 2 x 2 repeated measures ANOVAs were performed. For all the word characteristic measures, which included target word frequency, prime word frequency, familiarity, imageability, QSS, and associative strength, none of main effects nor interactions approached significance other than the expected main effects from my experimental design (e.g., a main effect of target word frequency for the target frequency measure, a main effect of prime word frequency for the prime word frequency measure, etc.). However, there was a non-significant tendency ($p>.10$) that for high frequency prime conditions, prime word frequency tends to be higher in high QSS conditions than low QSS conditions (100 vs. 145).

For each subjective measure from LSU students' ratings, again, 2 x 2 x 2 repeated measures ANOVAs were performed to examine if each cell had equivalent scores for each subjective measure. These ANOVAs revealed that the subjective frequency measures were not totally equivalent across high and low prime and target frequency conditions. For the subjective frequency ratings for prime words, there was a significant interaction between prime frequency and target frequency, $F(1, 56)=4,74$, $p<.05$. An inspection of means indicates that prime words in the high frequency prime-low frequency target condition tend to be rated higher in subjective frequency (4.03) than those in the high frequency prime-high frequency target condition (3.56).

In addition, the associative measure and the subjective familiarity measure had marginally significant main effects or interactions, showing that there were tendencies that some of the cells were not balanced according to those measures. For the subjective

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familiarity ratings of prime words, there was a marginally significant interaction between target frequency and prime frequency, $F(1, 56)=2.52$, $p<.10$. An inspection of means shows that subjective familiarity ratings tend to be higher in the high frequency prime-low frequency target condition (4.82) and lower in the low frequency prime-low frequency target condition (4.45).

For the subjective associativeness measure, there were marginally significant main effects of prime frequency, $F(1, 56)=3.02$, $p<.10$, target frequency, $F(1, 56)=2.943$, $p<.10$, and QSS, $F(1, 56)=3.79$, $p<.10$. An inspection of means shows that subjective asssociativeness tends to be higher in the high frequency prime word condition than in the low frequency prime word condition (3.98 vs. 3.77). Also, associativeness ratings tend to be higher for the low frequency target condition than for the high frequency target condition (3.97 vs. 3.78). Lastly, associativeness ratings tend to be higher for the low QSS condition than for the high QSS condition (3.99 vs. 3.76). Although not statistically significant, these main effects seem to reflect a particular cell which has a higher average subjective rating -- i.e., the high frequency prime-high QSS-low frequency target condition.

In summary, for experimental stimulus pairs, such word characteristics as word imageability, familiarity, and associative strength measures taken from normed studies were controlled across experimental conditions. However, there were some discrepancies across conditions among subjective word characteristic ratings taken from LSU students. Subjective frequency ratings were higher in the high frequency prime-low frequency target condition than in the high frequency prime-high frequency target condition. There was a marginally significant trend that subjective familiarity ratings

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were higher in the high frequency prime-low frequency target condition and lower in the low frequency prime-low frequency target condition. Also, there were marginally significant trends that subjective associative measures were higher in the high frequency prime conditions than low frequency prime conditions, in the low frequency target conditions than high frequency target conditions, and in the low QSS conditions than the high QSS conditions. Thus, if we assume frequency and associativeness of related pairs have effects on priming, the problem of experimental stimulus pairs lies particularly in the high frequency prime- low QSS- low frequency target condition (the HLL condition).

I must admit that this stimulus pair problem constitute a limitation of this study. To control every possible aspect of word characteristic and relationship of related pairs may be virtually impossible. [9] Thus far, no published studies have examined the effect of prime word characteristics; I hope the results of this study will show researchers of priming which word characteristics of prime words should be controlled in the priming task. Attempts to statistically control this problem were made for results of each experiment.

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[9] In this study, word characteristics such as word familiarity and imageability, and associative strength were controlled as well as subjective (i.e., from LSU student ratings) familiarity, imageability, and associativeness of related pairs, while manipulating QSS, and word frequency for both prime and target words. Since each pair had different scores for each variable, it was not possible to select final pairs which had the same values for those controlled variables for each cell. The selection process was a difficult one especially for those cells which had a limited number of available pairs to start with due to stimulus characteristics (e.g., there were not many words which were high in imageability and familiarity and low in frequency and QSS at the same time).

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Experimental stimulus list construction. For each condition, related pairs were divided in half and the first half was presented as related pairs and another half as unrelated pairs. Unrelated pairs were generated by re-matching the primes and targets among each condition so that they were not related. Thus, in one list condition half the stimulus pairs (32 pairs) were presented as related, and in another list condition another half were presented as related pairs, counterbalancing the related and unrelated pairs for each condition. The relatedness proportion was .5. Sixty-four nonword pairs were created and added to the experimental pairs. For nonword pairs, the prime words were high and low frequency words comparable to the experimental pairs, and the target items were nonwords, which were pronounceable and created by changing one letter from a word. Presentation orders were randomized and each participant received a different randomized order. No participant saw the same word twice in the experimental session.

Procedure

All the stimulus items were presented on the computer screen in white on a black background. Three + signs were presented for 1000 ms which indicated the beginning of each trial. Then a prime was presented for 150 ms in the short SOA condition, for 150 ms and then 350ms blank screen in the long SOA (1) condition, and for 500 ms in the long SOA (2) condition. The target item, presented immediately following the prime or a blank screen, remained on the screen until the participant performed a lexical decision task, by pressing 'yes' for a target word or 'no' key for a nonword target item, which triggered the computer to go on the next trial. Participants

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were tested individually. The experimental session took about 15 min in Experiment 1 and 2, about 25 min in Experiment 3.

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CHAPTER 3: EXPERIMENT 1

Introduction

Experiment 1 investigated the effect of prime word frequency on semantic priming in a lexical decision task. Word frequency is assumed to affect mostly semantic access to words. As summarized in Chapter 2, in the short SOA condition high frequency primes should produce larger semantic priming than low frequency primes (Hyp 1-a) while in the long SOA condition this asymmetry should disappear or become smaller (Hyp 1-b). This is because a very short presentation duration would not give enough time to process low frequency prime words but a longer presentation duration would. Also, if QSS has any effects on priming, low QSS would produce larger priming than high QSS (Hyp 4). This is because spreading activation may be quicker for words with low QSS, having multiple strong connections to prime words, than for those with high QSS. In addition, as previous priming studies showed, low frequency target words should produce larger priming than high frequency target words. Thus, it is predicted that the high frequency prime-low frequency target conditions should have the largest priming. If QSS has additive effects on prime frequency and target frequency, the largest priming should be obtained in the high frequency prime -low QSS -low frequency target condition.

To control prime presentation duration and SOA, there were three SOA conditions. The short SOA condition had the prime presentation duration and the SOA of 150 ms and the long SOA condition (1) had a 500 ms SOA which consisted of the prime presentation duration of 150 ms, followed by a 350 ms blank screen, and then a target word. The long SOA condition (2) had a 500 ms SOA where prime words were

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presented for 500 ms, followed by target words. The effect of prime word processing should be pinpointed in the long SOA condition (1) as compared with the short SOA condition because in both conditions participants saw prime words for 150 ms and the additional 350 ms was added to the processing time in the long SOA condition (1) where participants only saw a blank screen. The long SOA (2), where participants saw prime words for 500 ms, was a method of presentation most priming experiments use where a longer SOA has a longer prime presentation time. Thus, I predicted there would not be a difference in priming between the two long SOA conditions. All prime word and target word characteristics (i.e., prime word frequency, QSS, and target word frequency) and relatedness were manipulated as within- subjects variable while SOA conditions were manipulated as a between-subjects variable.

Method

Participants

Ninety six undergraduate students (32 for the short SOA condition and 32 each for the long SOA condition (1) and (2)) at Louisiana State University participated for extra credit for their psychology courses. All were native English speakers.

Apparatus

The same as described in Chapter 2.

Materials

The same materials as described in General Method.

Procedure

Participants were instructed to press a 'yes' key for a word and a 'no' key for a nonword when they saw a second item on the screen as accurately and as quickly as

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possible. In the short SOA condition, prime words were presented for 150 ms followed by target words. Prime words were presented for 150 ms, followed by 350 ms blank screen, then target words in the long SOA condition (1); they were presented for 500 ms followed by target words in the long SOA condition (2).

Results

In this section, first, a 2 (prime frequency) x 2 (QSS) x 2 (target frequency) x 2 (relatedness) ANOVA was performed for each SOA. Then an ANOVA was performed on the combined data from three SOA conditions. The cell means of response times for the short SOA, long SOA (1) and long SOA (2) conditions are given in Table 1. The statistical analyses were performed on response times; for the purpose of comparisons between conditions a priming score measure was obtained by subtracting the response times to related pairs from those to unrelated pairs. These are shown in Table 2. The summary of results in Experiment 1 is given in Figure 4, and graphical presentations of priming scores according to prime frequency and QSS were given in Figure 5 b and Figure 6 b, respectively along with graphical presentations of hypothetical results in 5 a and 6 a for comparisons which were previously shown in Chapter 2.

Table 1. Response times (in milliseconds), standard deviations according to SOA, target frequency, prime frequency and QSS in Experiment 1.

The150 ms SOA condition

		High freq primes		Low freq primes	
		Unrelated	Related	Unrelated	Related
High freq target	High QSS	546 (83.1)	517 (71.6)	541 (81.1)	545 (76.5)
	Low QSS	537 (88.6)	518 (76.6)	523 (64.9)	551 (84.1)

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(table cont.)

Low freq target	High QSS	589 (80.6)	550 (70.6)	565 (84.9)	551 (78.3)
	Low QSS	615 (95.7)	567 (95.7)	563 (100.3)	567 (77.6)

<u>The 500 ms SOA (1) condition (150 ms prime presentation)</u>

		High freq primes		Low freq primes	
		Unrelated	Related	Unrelated	Related
High freq target	High QSS	485 (67.0)	470 (69.4)	497 (73.4)	505 (97.3)
	Low QSS	504 (84.3)	465 (68.8)	499 (84.9)	481 (69.3)
Low freq target	High QSS	562 (91.4)	530 (85.4)	545 (103.0)	518 (101.5)
	Low QSS	572 (100.4)	509 (79.5)	542 (94.7)	523 (93.7)

<u>The 500 ms SOA (2) condition (500 ms prime presentation)</u>

		High freq primes		Low freq primes	
		Unrelated	Related	Unrelated	Related
High freq target	High QSS	513 (64.2)	512 (55.1)	528 (70.7)	525 (62.5)
	Low QSS	530 (59.9)	502 (71.1)	518 (56.3)	512 (63.2)
Low freq target	High QSS	593 (86.4)	523 (73.6)	552 (84.1)	546 (68.4)
	Low QSS	601 (79.6)	552 (65.1)	569 (77.0)	546 (70.7)

Note: The standard deviations were given in parentheses.

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Table 2. Priming scores according to SOA, target frequency, prime frequency and QSS in Experiment 1.

The150 ms SOA condition

		High freq primes	Low freq primes
High freq target	High QSS	29*	-4
	Low QSS	19	-21+
Low freq target	High QSS	39*	14
	Low QSS	49*	- 4

The 500 ms SOA (1) condition

		High freq primes	Low freq primes
High freq target	High QSS	15	-8
	Low QSS	39***	18+
Low freq target	High QSS	31+	27*
	Low QSS	63**	19

The 500 ms SOA (2) condition

		High freq primes	Low freq primes
High freq target	High QSS	1	3
	Low QSS	28*	6
Low freq target	High QSS	70***	23+
	Low QSS	49**	23+

Note: Priming scores were obtained by subtracting response times to related target words from those to unrelated target words. The following notations were used to indicate p-values: + p<.10; * p<.05; ** p<.01; *** p<.001.

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Condition	Expected effects				Predicted effects			Other effects
	T	R	TxR	Rx SOA	PxR	PxR xSOA	QxR	
150 ms	*** /***	*** /+	+ /ns	n/a	*** /*	n/a	ns	PxT ***/* QxT + /ns
150+350 ms	*** /***	*** /***	+ /ns	n/a	*** /+	n/a	* /ns	PxT *** /+
500 ms	*** /***	*** /***	*** /*	n/a	*** /+	n/a	ns	PxT * /* QxT * /+
Combined	*** /***	*** /*	*** /+	ns	*** /**	ns	ns	SOA * /*** PxT *** /* QxRxSOA + /+

*** p<.001; ** p<.01; * p<.05; + p<.10; ns -- not significant; n/a -- not applicable; P: Prime word frequency; Q: QSS; T: Target word frequency; R: Relatedness

Figure 4. Summary of the obtained main effects and interactions

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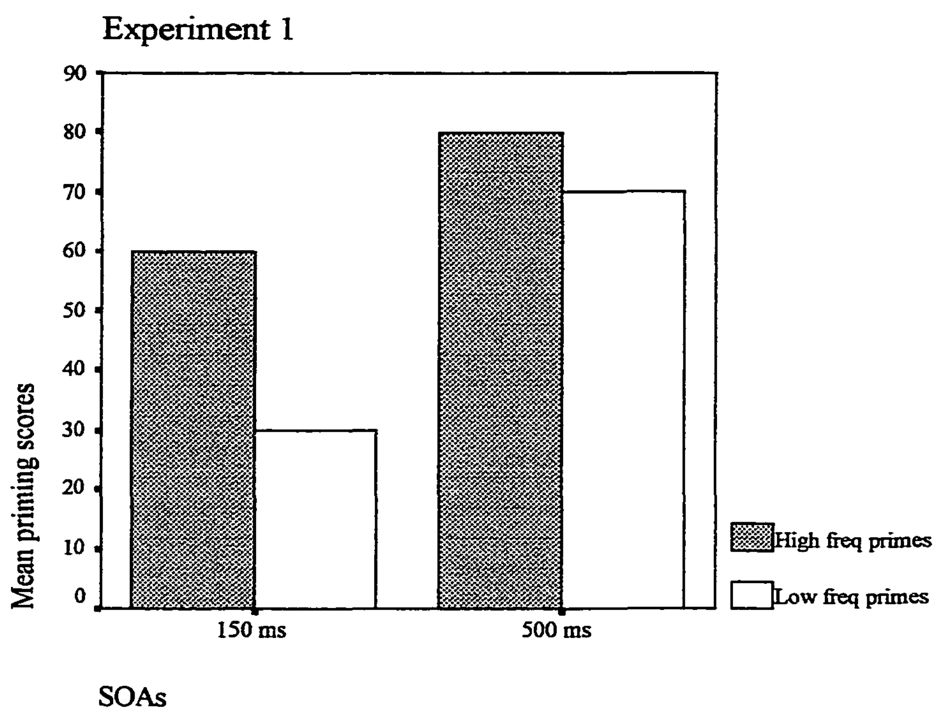

Figure 5 a. Hypothetical results of priming scores according to prime frequency and SOA in Experiment 1.

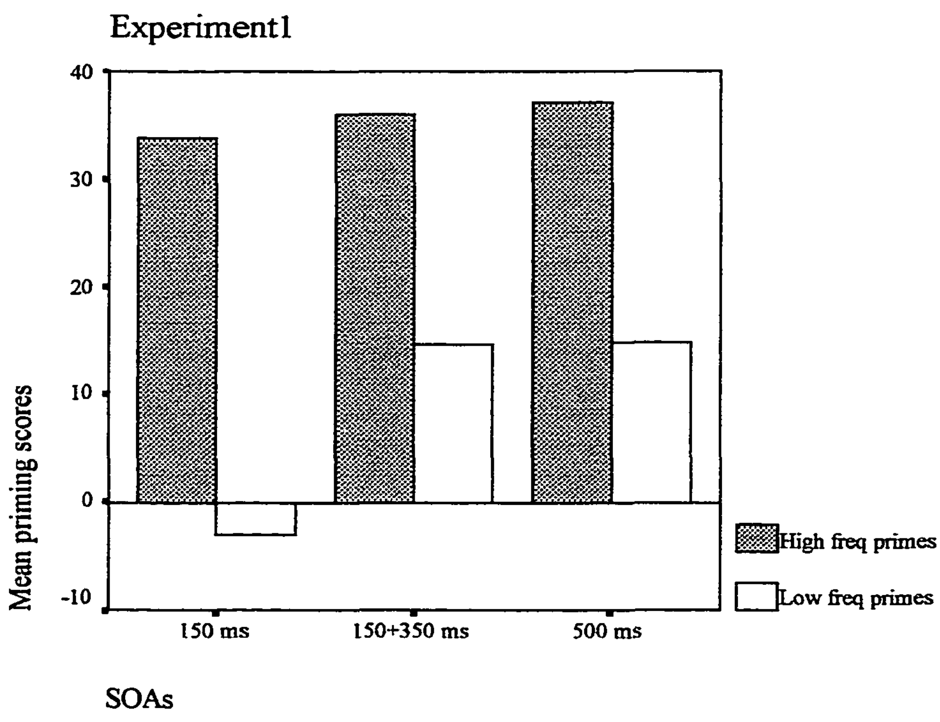

Figure 5 b. Mean priming scores according to prime frequency and SOA in Experiment 1.

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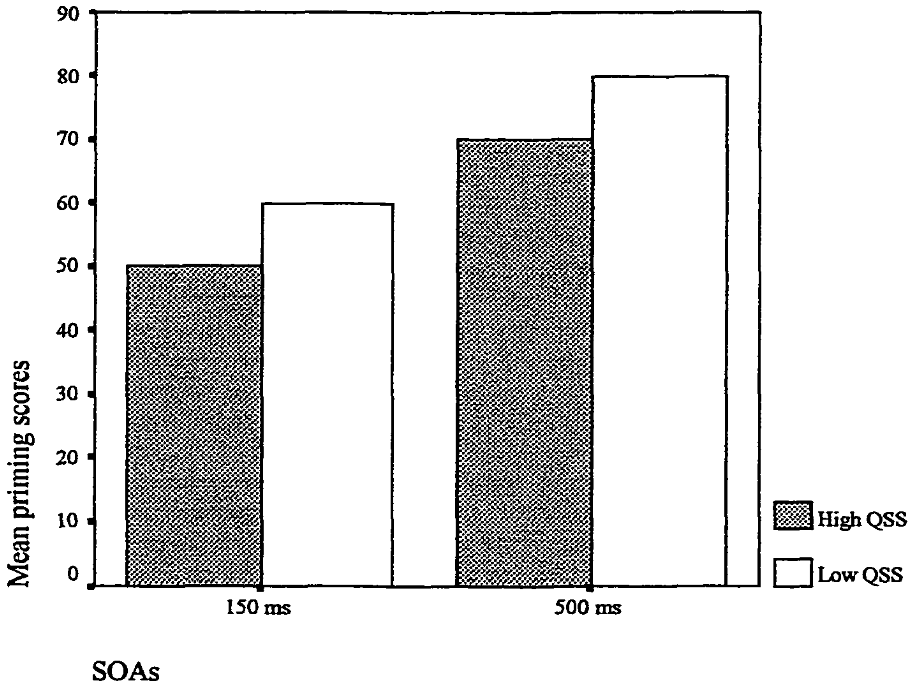

Figure 6 a. Hypothetical results of priming scores according to QSS and SOA.

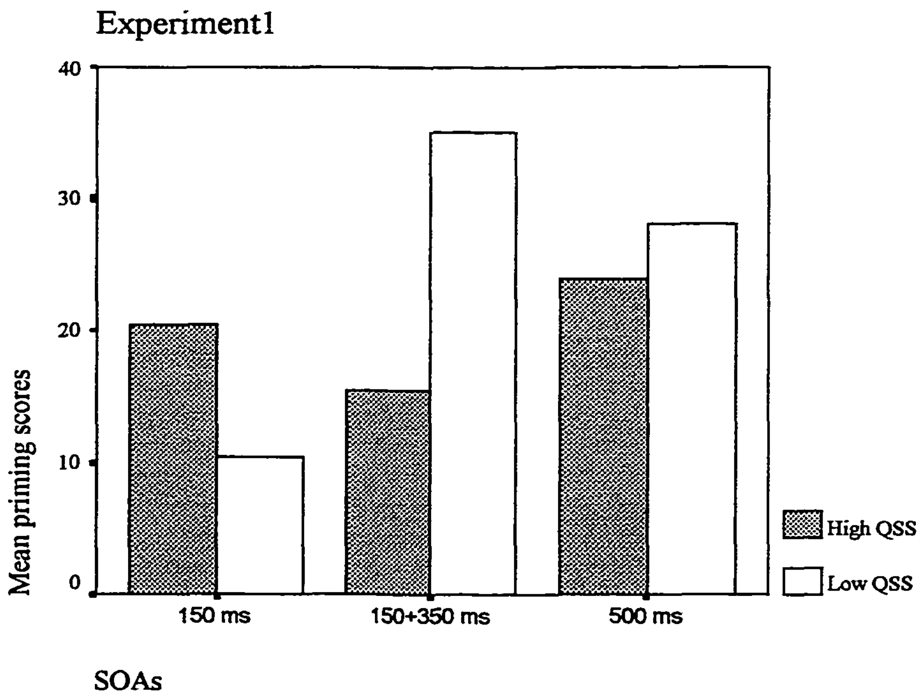

Figure 6 b. Mean priming scores according to QSS and SOA in Experiment 1.

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Treatment of Outliers.

Only the data for correct responses were included in the response time analyses. To control for outliers, response times which were higher than 2000 ms and lower than 300 ms were removed and further those datapoints which exceeded individuals' mean reaction times plus or minus 2.5 STD were counted as missing. Since there were four items each for each condition, a conservative measure was taken so that those participants who had more than 6 % of missing datapoints were replaced. Thirteen individuals in the short SOA condition and eight individual in the long SOA condition were replaced. Also, those individuals whose overall average response times exceeded 800 ms were replaced so that a few individuals whose response rate was much slower than others (on an overall average of about 550 ms) would not bias the results, especially in the items analyses. This procedure affected 2 individuals in the short SOA condition. None exceeded the overall average of 800 ms in the long SOA conditions. With these treatments, the error rate was very low. For the short SOA condition, the error rate was 1.1 % (23 datapoints); 0 datapoints were removed by the 2000/300 cut-off, and 2.8 % (57 datapoints) were removed by the 2.5 standard deviation trimming, resulting in a total of 4 % of the datapoints removed as errors or outliers. For the long SOA (1) condition, the error rate was 1.7 % (34 datapoints); the 2000/300 ms cut-off affected 0 datapoints while 2.8 % (59 datapoints) were removed by the 2.5 standard deviation trimming. Thus, 5 % of datapoints were removed in total as errors or outliers. For the long SOA (2) condition the error rate was 1.5 % (23 datapoints); 0 datapoints were below 300 or above 2000 and 2.6 % (54

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datapoints) were affected by the 2.5 standard deviation trimming procedure, resulting in 4% of the total datapoints were removed as errors or outliers.

The Short SOA Condition

Expected effects. There was a main effect of target frequency, $F1(1,31)=65.28$, $p<.0001$; $F2(1, 56)=31.90$, $p<0001$. High frequency target words were processed faster than low frequency target words (536 ms. vs. 571 ms.). There was also a main effect of relatedness, $F1(1, 31)=8.72$, $p<.01$ by subject analyses and marginal by items analyses, $F2(1, 56)=3.58$, $p<.07$. Related pairs produced faster response times than unrelated pairs (546 ms. vs. 561 ms). An interaction between target frequency and relatedness was marginally significant, by subject analyses alone, $F1(1, 31)=2.92$, $p<.10$). There was more priming (i.e., relatedness effect; the difference scores between response times of unrelated pairs and related pairs) for the low frequency target words than for the high frequency target words. Although only marginally significant by subjects alone, this effect was expected to be a robust effect from previous priming studies.

Predicted effects. There was a significant interaction between prime frequency and relatedness, $F1(1, 31)=16.16$, $p<.0001$; $F2(1, 56)=5.53$, $p<.03$. This interaction was predicted from the hypothesis (Hyp1-a) and indicated that priming with high frequency target primes was greater than priming with low frequency primes (34 ms. vs. -4 ms). None of other predicted two-way interaction regarding QSS (QSS by relatedness) or three-way interactions (prime frequency by QSS by relatedness, prime frequency by target frequency by relatedness) approached significance.

Other effects. There was a significant interaction between prime frequency and target frequency, $F1(1, 31)=16.98$, $p<.0001$ and $F2(1, 56)=6.13$, $p<.02$. Response times

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for the high frequency target words were faster for high frequency primes than for low frequency primes (523 ms vs 540 ms) while those for low frequency target words had the opposite pattern (581 ms vs 562 ms). There was a marginally significant interaction, by subject analyses alone, between QSS and target frequency, $F1(1, 31)=3.20$, $p<.10$. This marginally significant interaction showed that the mean response time for high frequency target words were comparable between high and low QSS (538 ms vs 534 ms) while those for low frequency target words were faster with high QSS primes than with low QSS primes (564 ms vs 578 ms).

The Long SOA Condition (1) --150 ms Prime Presentation

Expected effects. For the long SOA condition, where primes were presented for 150 ms followed by 350 ms blank screen, there was a main effect of target frequency, $F1(1,31)=70.04$, $p<.0001$; $F2(1, 56)=53.16$, $p<0001$. High frequency target words were processed faster than low frequency target words (488 ms vs. 538 ms). There was also a main effect of relatedness, $F1(1, 31)=24.32$, $p<.0001$; $F2(1, 56)=14.10$, $p<.001$. Target words for the related pairs were processed faster than those for unrelated pairs (500 ms. vs. 525 ms). There was a marginally significant interaction between target frequency and relatedness by subject analyses alone, $F1(1, 31)=3.53$, $p<.07l$; $F2(1, 56)=2.03$, $p>.10$. Priming for low frequency target words was larger than for high frequency words (42 ms vs 10 ms).

Predicted effects. An interaction between prime frequency and relatedness was significant by subject analyses, $F1(1, 31)= 9.84$, $p<.001$, but only marginally significant by items analyses, $F2(1, 56)=3.01$, $p<.09$. Priming was greater with high frequency prime words than low frequency primes (37 ms vs. 14 ms). The interaction between

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QSS and relatedness was significant by subject analyses, $F1(1, 31)=6.24$, $p<.02$, but not by items analyses, $F2(1, 56)=1.73$, $p>.10$. Priming with low QSS primes was greater than with high QSS primes (35 ms vs. 17 ms). Those interaction effects which have non-significant or only marginally significant results by items analyses need to be interpreted with caution. The predicted three-way interactions between prime frequency, QSS, and relatedness, and between prime frequency, target frequency, and relatedness did not approach significance.

Other effects. The interaction between prime frequency and target frequency was significant by subject analyses, $F1(1,31)=8.02$, $p<.001$, but only marginally significant by items, $F2(1, 56)=3.43$, $p<.07$. Response times for high frequency target words were faster for high frequency primes than low frequency primes (481 ms vs 496 ms) while those for low frequency target words had an opposite pattern (543 ms vs 532 ms).

The Long SOA Condition (2) --500 ms Prime Presentation

Expected effects. For the long SOA condition where primes were presented for 500 ms, there was a main effect of target frequency, $F1(1,31)=67.54$, $p<.0001$ and $F2(1, 56)=44.02$, $p<0001$. High frequency target words were processed faster than low frequency target words (518 ms. vs. 541 ms.). There was also a main effect of relatedness, $F1(1, 31)=31.10$, $p<.0001$ and $F2(1, 56)=13.88$, $p<.001$. Target words for the related pairs were processed faster than those for unrelated pairs (525 ms. vs. 551 ms). There was a significant interaction between target frequency and relatedness, $F1(1, 31)=12.47$, $p<.001$) and $F2(1, 56)=5.43$, $p<.03$. There was more priming for the low frequency target words (42 ms) than for the high frequency target words (10 ms).

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Predicted effects. The interaction between prime frequency and relatedness was significant by subject analyses, $F1(1, 31)=5.49$, $p<.05$, but only marginally significant by items analyses, $F2(1, 56)=2.97$, $p<.10$. Priming with high frequency primes was greater than priming with low frequency primes (37 ms. vs. 14 ms). The predicted interaction with QSS and relatedness did not approach significance.

Other effects. There was significant interaction between prime frequency and target frequency, $F1(1, 31)= 6.99$, $p<.01$ and $F2(1, 56)=4.00$, $p<.05$. Response times for the high frequency target words were faster for high frequency primes than for low frequency primes (514 ms vs 521 ms) while those for low frequency target words had the opposite pattern (567 ms vs 549 ms).

The interaction between QSS and target frequency was significant by subject analyses, $F1(1, 31)=5.49$, $p<.05$, but only marginally significant by items analyses, $F2(1, 56)= 3.21$, $p<.08$. Response times for high frequency target words with high QSS primes were comparable between those with low QSS primes (519 ms vs. 516 ms) while for low frequency target words those with high QSS primes were faster than those with low QSS primes (549 ms vs 567 ms).

Combined Analyses with All Three SOAs

The data from the short and long SOA conditions were combined in a 2 (prime frequency) x 2 (QSS) x 2 (target frequency) x 3 (short vs long-150 +350 ms, long- 500 ms SOAs) ANOVA, confirming what was found in the individual SOA analyses.

Expected effects. The combined analysis yielded significant main effects of target word frequency, $F1(1, 93)=197.86$, $p<.0001$; $F2(1, 56)=62.77$, $p<.0001$, and relatedness, $F1(1, 93)=61.23$, $p<.0001$; $F2(1, 56)=10.76$, $p<.002$. High frequency target

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words were responded to faster than low frequency words (513 ms vs 556 ms) and related target words were responded to faster than unrelated target words (524 ms vs 546 ms). The interaction between target frequency and relatedness was significant by subjects analyses, but only marginally significant by items analyses, $F1(1, 93)=14.36$, $p<.0001$; $F2(1, 56)=2.98$, $p<.09$. An examination of means shows that low frequency target words produced more priming than high frequency target words. The expected interaction between relatedness and SOA did not reach significance.

Predicted effects. There was a significant interaction between prime frequency and relatedness, $F1(1, 93)=34.41$, $p<.0001$; $F2(1, 56)=10.76$, $p<.02$. Priming with high frequency prime words was greater than with low frequency prime words. The predicted two way interaction between QSS and relatedness did not approach significance. The predicted interaction between prime frequency, relatedness and SOA did not reach significance, either.

Other effects. There was a main effect of SOA, $F1(1, 93)=3.46$, $p<.05$; $F2(2, 112)=76.71$, $p<.0001$. The overall mean response time was slowest in the short SOA condition (553 ms), followed by the long SOA -150 + 350 ms - condition (539 ms). The mean response time was fastest in the long SOA -500 ms- condition (514 ms). Tukey HSD tests were performed on the difference scores between the three SOA conditions and the results indicated all three differences were statistically significant ($p<.001$). The interaction effect of SOA duration was marginally significant with QSS and relatedness, $F1(1, 93)=2.76$, $p<.07$; $F2(2, 112)=2.85$, $p<.07$. A comparison of means shows that priming with high QSS primes was comparable between conditions (20 ms, 17 ms, and 24 ms for the 150 ms, 150+350 ms, and 500 ms conditions, respectively) while priming

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with low QSS primes was smaller in the short SOA condition than the long SOA conditions (11 ms, 35 ms, and 27 ms).

There was a significant interaction between prime word frequency and target word frequency, $F1(1, 93)=31.10$, $p<.0001$; $F2(1, 56)=6.63$, $p<.02$. A comparison of means shows that response times for the high frequency target words were faster for high frequency primes than for the low frequency primes while response times for low frequency target words had the opposite pattern.

Discussion

In this experiment the main effect of target frequency (E 1) and of relatedness (E 2), and the interaction between target frequency and relatedness (significant by subjects but only marginally significant by items) (E 3) were demonstrated as in previous studies on priming and target frequency (e.g., Becker & Killion, 1977; Stone & van Orden, 1992). However, the effect of SOA on semantic priming (i.e., larger priming in the long than short SOA condition) was not significant.

The hypothesis on prime frequency was partially supported. This can be seen in the comparison of the predicted (Figure 5 a) to the actual results (Figure 5 b). In all conditions, high frequency primes produced larger priming than low frequency primes (although significant by subjects, but only marginally significant by items in the long SOA conditions), confirming the hypothesis (Hyp 1-a). However, availability of prime processing time did not affect these differences in priming. As seen in Figure 5 b, the priming difference between high and low frequency primes appeared to decrease with SOA, however, this is not significant. Thus, the hypothesis (Hyp 1-b) is not supported. The difference in priming scores between high frequency primes and low frequency

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primes did not decrease significantly with more processing time in the long SOAs. It is possible that the 350 ms difference between short and long SOA conditions may not have been enough to produce a large effect of processing time difference.

The hypothesis on QSS was again only partially supported. It was hypothesized that primes with low QSS with fewer strong connections should produce larger priming than those with high QSS. A comparison of the predicted (Figure 6 a) and the obtained results (Figure 6 b) about the effect of QSS on semantic priming shows that the predicted effect of QSS was only observed (significant only by the subjects analysis) in the long SOA (1) while the short SOA condition the direction was reversed. When analyses were done on the data with three SOA conditions combined, there was an interaction between QSS, relatedness, and SOA, significant by subjects and marginally significant by items. Priming tended to be larger with low QSS in the long SOA conditions. Thus, the effect of QSS seems to be affected by time course. This suggests that high QSS primes initially may have produced activations as strongly as low QSS primes, but with time the activations created by high QSS primes may have spread out and peaked more quickly than the activations by low QSS primes. However, this account is inconclusive because of the marginally significant results by items and non-significant results in the other long SOA condition.

There were negative priming scores obtained in the short SOA condition, which is contrary to any prediction on priming effects. One-sample t-tests were performed to examine whether priming scores were different than zero. The result is shown in Table 2. Significant priming was obtained for the HHH, HLH, and HLL conditions ($p<.05$).

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The negative priming (-21 ms) in the LHL condition was marginally significant ($p<.10$) and the reason for obtaining negative scores is a puzzlement.

Subjective associativeness ratings of stimulus pairs. As discussed in Chapter 2, there were some unbalanced cells in the experimental design in subjective ratings. Especially discrepancies in subjective associativeness ratings were of concern since priming may well be affected by the associative measure, taken from the same sample population as in this study. Though only marginally significant, subjective associativeness ratings were higher for the high frequency prime -low QSS -low frequency target condition (4.39 as compared with means of other conditions, which ranged from 3.57 to 3.82). Thus, there is a possibility that subjective associativeness was the hidden cause of the effects obtained in this experiment. In effect, that is the condition where high priming was constantly found (and also, that is the condition for which my hypothesis predicts the highest priming). A remedy would be to control subjective associativeness statistically. However, since associativeness ratings were available to each item, it seems difficult to control associativeness ratings as a covariate by subjects analyses where means were pooled by each individual, not by each item. Thus, only items analyses for the combined data were performed for priming scores with subjective associative ratings as a covariate, under an assumption that subjective associativeness ratings for unrelated pairs were uniform. When subjective associativeness scores were factored out, the effect of target frequency, $F2(1, 55)=58.179$, $p<0001$, interactions between prime frequency and target, $F2(1, 55)=6.38$, $p<.02$ were significant. The effect by relatedness seems generally weakened; the effect of relatedness was only marginally significant, $F2(1, 55)=3.16$, $p<.09$, and the

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interactions between prime frequency and relatedness, and between target frequency and relatedness were not significant, $F2(1, 55)=2.38$, $p<.13$, $F2(1, 55)=1.96$, $p<.17$. The interaction between QSS, relatedness, and SOA was, however, marginally significant as in the previous analysis, $F2(2, 110)=2.95$, $p<.06$. The effect of SOA was not significant, $F2(2, 110)<1$. It seems that subjective associativeness accounted for some significant part of variance in the priming effect. The covariate analysis urges the necessity of control of the subjective associativeness measure, and this has become the limitation of this study.

Since subject analyses controlling subjective associativeness seem difficult, and the problematic cell in the design was the HLL cell, an ANOVA excluding low QSS items for the combined data was performed to see whether the prime frequency effect on priming was still observed. The interaction between prime frequency and relatedness was significant only by subjects, $F1(1, 93)=8.43$, $p<.005$; $F2(1, 28)=1.75$, $p<.20$. Thus, the effect of prime frequency on priming was still present across subjects, but could not be generalized to items for high QSS prime conditions.

Conclusion

The results from Experiment 1 showed robust effects of target frequency and relatedness for most of conditions as demonstrated in priming studies so far. The interaction effect of relatedness and target frequency, which was also expected, did not seem as robust as the two main effects. The main hypothesis of prime word frequency on semantic priming was partially supported. The hypothesis on prime frequency and prime (Hyp 1-a) was supported. High frequency prime words produced larger priming than low frequency prime words. However, the hypothesis on time course of activations

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by high and low frequency primes (Hyp 1-b) was not supported. The effect was found in both short and long SOA conditions, and the analyses of the combined data did not show significant increase of priming with low frequency primes in the long SOA condition. Thus, the available time did not have effects on priming.

This effect of prime frequency, however, should be qualified by lack of strict control of subjective associativeness ratings over stimulus pairs. The covariate analysis by items showed the importance of controlling subjective associativeness measure. When subjective associativeness scores were factored out as a covariate by items analyses, the effect of prime frequency on priming did not reach significance. Also, in an ANOVA, excluding items with low QSS primes where the problem seems to lie, the prime frequency effect was observed only by subjects, not by items. Thus, in order to demonstrate the prime frequency effect, more strict control of subjective associativeness is necessary. The results of Experiment 1 need to be interpreted with caution.

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CHAPTER 4: EXPERIMENT 2

Introduction

As previously mentioned, word frequency affects word accessing speed either through lexical access or through semantic access. If ease of access has an effect on how meanings are processed depending on available processing time, manipulation of prime word accessing speed should affect priming. Experiment 2 examined effects of ease of access to prime words using degradation of prime words. By reducing visibility of prime words, lexical access to prime words should be slowed down. Thus, in the short SOA condition, both degraded high and low frequency prime words should produce smaller priming than intact high frequency primes in Experiment 1. In the long SOA condition, both degraded high and low frequency primes should produce larger priming than in the short SOA condition (Hyp 2).

Method

Participants

Sixty four undergraduate students at Louisiana State University participated in this experiment for extra credit for their psychology courses. There were 32 participants in each SOA condition.

Apparatus

The same as described in General Method.

Materials

The same materials as described in General Method.

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Procedure

The same as described in General Method except that the primes were degraded in the degraded condition by reducing the darkness contrast between prime letters (in a gray scale) and the background color (black). The gray scale letters were created by McPaint. The degree of the darkness contrast was determined so that letters were visible, but very hard to read in the 150 ms SOA to assure minimal amount of priming. For the long SOA condition, primes were presented for 150 ms, followed by a 350 ms blank screen and then by target words (i.e., the long SOA condition (1) in Experiment 1).

Results

In this section a 2 (prime frequency) x 2 (QSS) x 2 (target frequency) x 2 (relatedness) ANOVA was performed separately for each SOA condition. Then, further analyses were performed on the data combining the two SOA conditions together, and also on the combined data from Experiment 1 and 2. The mean response times for each condition are given in Table 3. As in Experiment 1, the statistical analyses were performed on response times; however, for the purpose of comparisons between conditions, priming score measures were shown in Table 4. The summary of results in Experiment 2 is given in Figure 7. The graphical presentations of the results according to prime frequency and SOA, and according to QSS and SOA are given in Figure 8 b and 9 b , respectively. Graphical presentations of the hypothetical results according to prime frequency and SOA, and according to QSS and SOA are given in Figure 8 a and Figure 9 b, respectively, for the purpose of comparisons which were previously shown in Chapter 2.

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Table 3. Response times (in milliseconds) according to SOA, target frequency, prime frequency and QSS in Experiment 2.

The150 ms SOA condition

		High freq primes		Low freq primes	
		Unrelated	Related	Unrelated	Related
High freq target	High QSS	532 (77.9)	512 (69.9)	534 (77.3)	522 (80.9)
	Low QSS	539 (92.5)	520 (89.3)	529 (70.0)	523 (94.5)
Low freq target	High QSS	584 (91.8)	548 (68.3)	572 (95.7)	564 (67.4)
	Low QSS	574 (88.5)	550 (73.2)	574 (82.2)	577 (101.6)

The 500 ms SOA condition

		High freq primes		Low freq primes	
		Unrelated	Related	Unrelated	Related
High freq target	High QSS	514 (71.2)	495 (89.3)	525 (81.9)	495 (80.2)
	Low QSS	514 (90.8)	496 (99.2)	514 (99.7)	493 (85.3)
Low freq target	High QSS	565 (101.9)	553 (87.4)	561 (112.8)	528 (101.9)
	Low QSS	604 (88.2)	537 (99.9)	558 (100.4)	550 (95.9)

Note: The standard deviations were given in parentheses.

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Table 4. Priming scores according to SOA, target frequency, prime frequency and QSS in Experiment 2.

The150 ms SOA condition

		High freq primes	Low freq primes
High freq target	High QSS	21*	12
	Low QSS	19	6
Low freq target	High QSS	36**	8
	Low QSS	24*	-3

The 500 ms SOA condition

		High freq primes	Low freq primes
High freq target	High QSS	19+	30**
	Low QSS	17	20*
Low freq target	High QSS	12	33**
	Low QSS	67**	8

Note: Priming scores were obtained by subtracting response times to related target words from those to unrelated target words. The following notations were used to indicate p-values: + $p<.10$; * $p<.05$; ** $p<.01$; *** $p<.001$.

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Condition	Expected effects				Predicted effects				Other effects
	T	R	TxR	Rx SOA	PxR	PxR xSOA	R xDeg	QxR	
150 ms	*** /***	*** /*	ns	n/a	* /ns	n/a	n/a	ns	
150+350 ms	*** /***	*** /***	ns	n/a	ns	n/a	n/a	ns	PxQx R ** /ns PxTxR */ns
Exp2 Combined	*** /***	*** /**	ns	+ /+	* /ns	ns	n/a	ns	SOA ns /*** PxSOA +/* PxQxR + /ns PxTxR * /ns PxTxSOA + /* PxQxRxSOA + /+
Exp 1 & 2 Combined	*** /***	*** /**	** /ns	* /+	*** /+	ns	* /+	ns	SOA * /*** Deg ns /*** PxT ***/ns QxT +/ns TxSOA * /** SOAxDeg ns /*** PxQxR * /ns PxRxDeg */+ PxRxSOA +/ns PxTxDeg ** /** QxRxSOA* /+ PxQxTxSOAxDeg +/+ QxTxSOAxDeg * /+ QxTxRxSOAxDeg ns/+

*** p<.001; ** p<.01; * p<.05; + p<.10; ns -- not significant; n/a -- not applicable; P: Prime word frequency; Q: QSS; T: Target word frequency; R: Relatedness; Deg: Degradation

Figure 7. Summary of the obtained main effects and interactions

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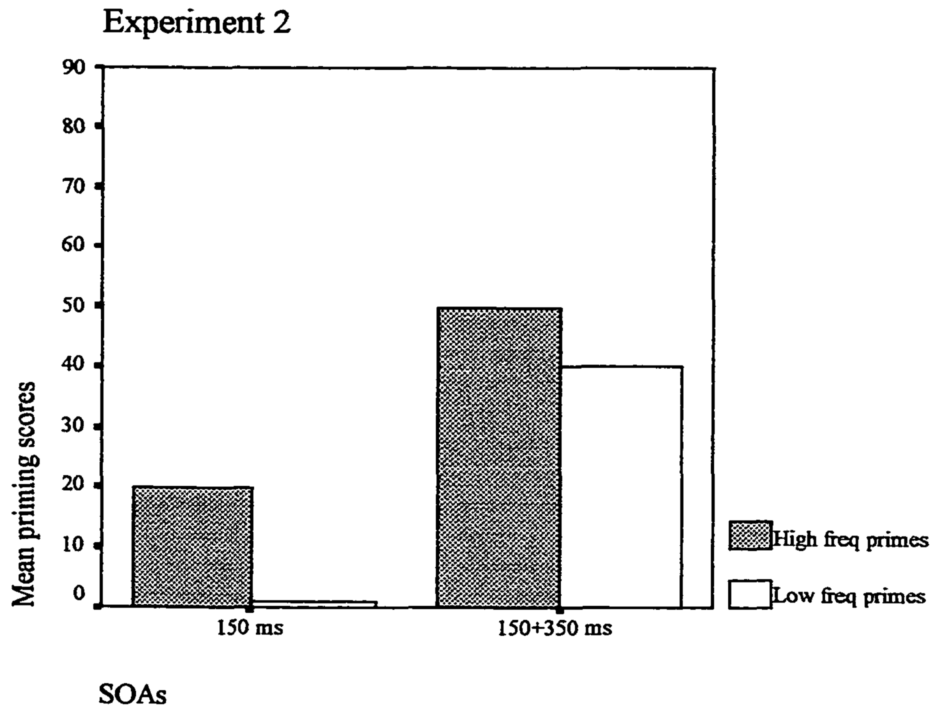

Figure 8 a. Hypothetical results of priming scores according to prime frequency and SOA in Experiment 2.

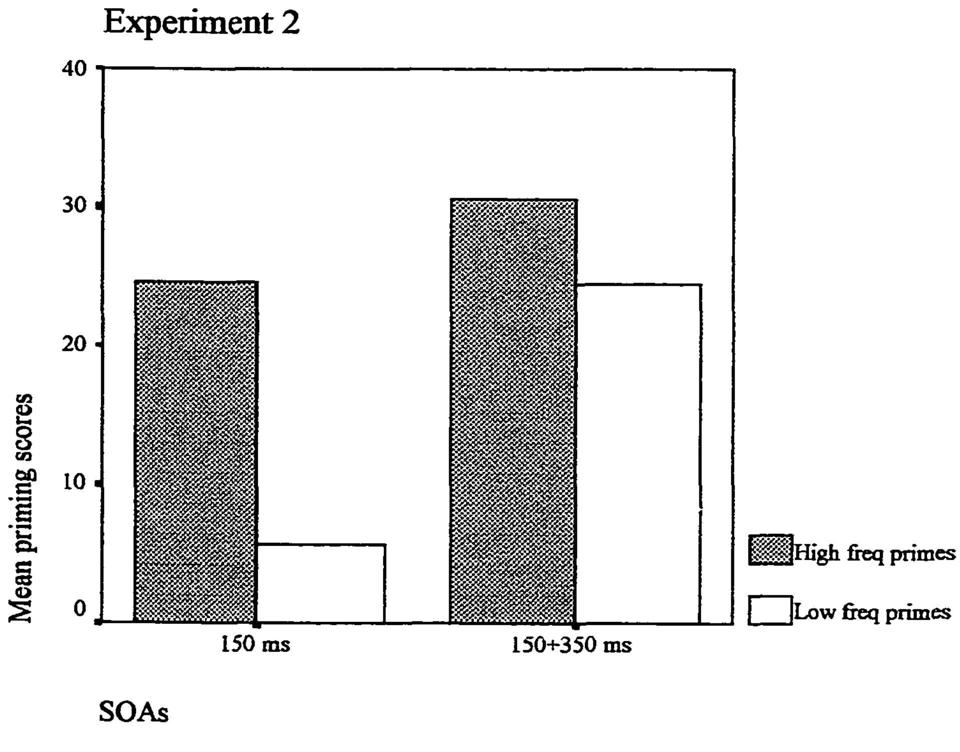

Figure 8 b. Priming scores according to prime frequency and SOA in Experiment 2.

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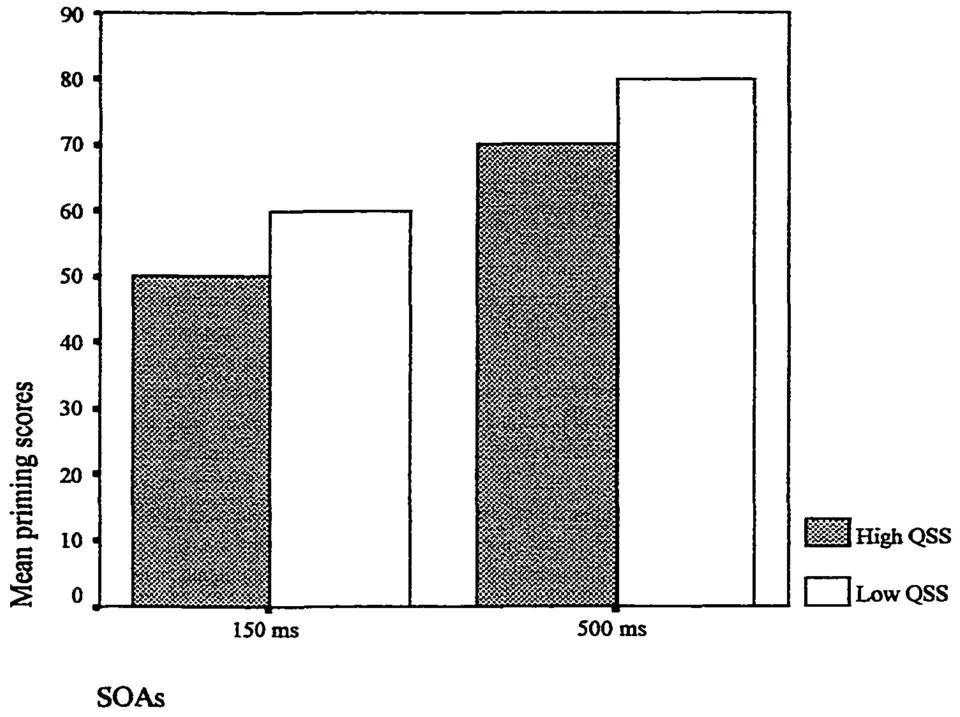

Figure 9 a. Hypothetical results of priming scores according to QSS and SOA.

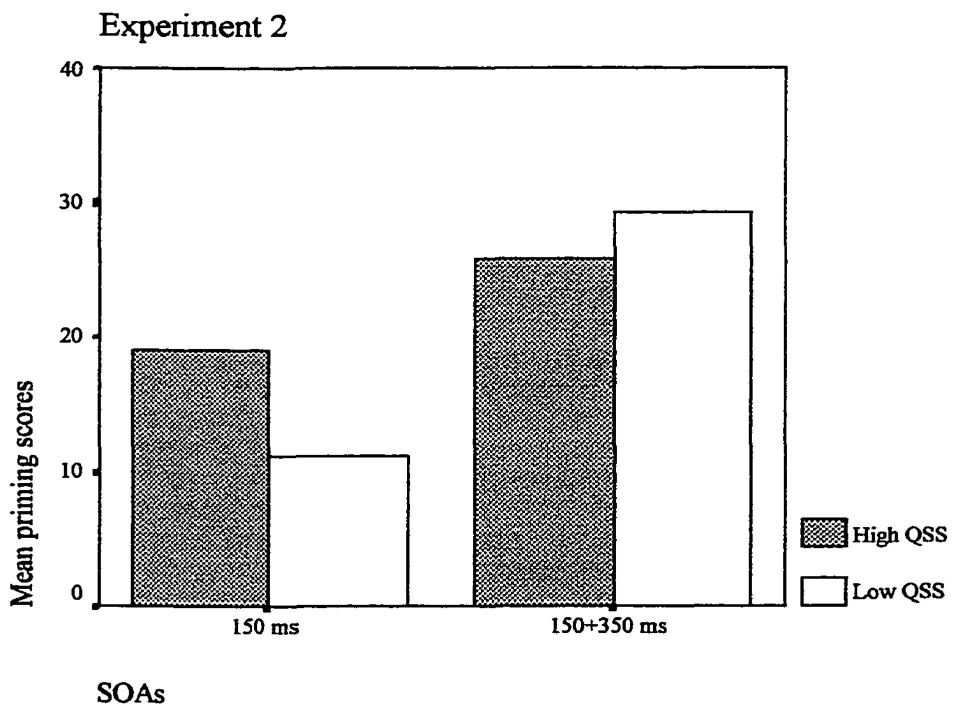

Figure 9 b. Priming scores according to QSS and SOA in Experiment 2.

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Treatment of Outliers

The same criteria for datapoints and subjects inclusion were used as in Experiment 1. Twelve individuals in the short SOA condition and 10 individuals in the long SOA condition were replaced, who had more than 6 % missing datapoints. No individuals had overall mean response times exceeding 800 ms. The 2000/300 ms cut-off treatment affected no individuals in both short and long conditions. For the short SOA condition, the error rates were 1.1 % (23 datapoints) and 2.6 % (53 datapoints) of datapoints were affected by the 2.5 standard deviation trimming treatment; thus in total 3.7 % of datapoints were removed as errors or outliers. For the long SOA condition, the error rate was 1.8 % (36 datapoints) and the 2.5 standard deviation trimming affected additional 2.5 % of datapoints (52 datapoints). In total, 4.3 % of datapoints were removed as errors or outliers in the long SOA condition.

The Short SOA Condition

Expected effects. There was a main effect of target frequency, $F1(1,31)=106.11$, $p<.0001$; $F2(1, 56)=39.21$, $p<0001$. High frequency target words were processed faster than low frequency target words (526 ms. vs. 568 ms.). There was a main effect of relatedness, $F1(1, 31)=16.21$, $p<.0001$; $F2(1, 56)=4.06$, $p<.05$. Target words with related primes were responded to faster than those with unrelated primes (539 ms vs. 555 ms). The expected two-way interaction between target frequency and relatedness was not significant, F's <1.

Predicted effects. There was a significant interaction between prime frequency and relatedness only by subject analyses, $F1(1, 31)=5.00$, $p<.05$; $F2(1, 56)=1.60$, $p>.10$. This interaction indicates that high frequency primes produced greater priming than low

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frequency primes (25 ms vs. 6 ms). However, the lack of effect in items analyses shows that this effect cannot be generalized across items. The interaction effect by QSS with relatedness did not reach significance.

Other effects. No other main effects or interactions approached significance.

The Long SOA Condition

Expected effects. There was a main effect of target frequency, $F1(1,31)=123.82$, $p<.0001$; $F2(1, 56)=56.35$, $p<0001$. High frequency target words were processed faster than low frequency target words (505 ms vs. 544 ms). There was a main effect of relatedness, $F1(1, 31)=29.88$, $p<.0001$; $F2(1, 56)=12.60$, $p<.001$. Target words for the related pairs were processed faster than those for unrelated pairs (519 ms vs 545 ms). The expected two-way interaction between target frequency and relatedness did not approach significance.

Predicted effects. Neither of the two-way interactions between prime frequency and relatedness or between QSS and relatedness reached significance.

Other effects. A three-way interaction between prime frequency, target frequency, and relatedness was significant by subject analyses, $F1(1, 31)= 4.60$, $p<.05$, but not by items analyses, $F2(1, 56)<1$. Priming was greater for low frequency target words with high frequency primes than low frequency primes (40 ms vs. 21 ms) while for high frequency target words priming was comparable with high and low frequency primes (19 ms vs. 25 ms). There was a significant interaction between prime frequency, QSS and relatedness by subject analyses, $F1(1, 31)=8.04$, $p<.01$, but not by items analyses, $F2(1, 56)=2.23$, $p>.14$. Priming with high frequency primes was greater when QSS was low than when QSS was high (40 ms vs. 19 ms) while for priming with low

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frequency primes the pattern was reversed (14 ms vs. 32 ms). The interpretation of these two interactions needs caution because of the lack of significant results by items analyses.

Comparison Between Degraded Short and Long SOA Conditions

A 2 (prime frequency) x 2 (QSS) x 2 (target frequency) x 2 (SOA) ANOVA was performed on the combined data from the short and long SOA conditions to examine the effect of SOA.

Expected effects. As expected, there were significant main effects of target frequency, $F1(1, 62)=229.81$, $p<.0001$; $F2(1, 56)=56.09$, $p<.0001$, and of relatedness, $F1(1, 62)=46.01$, $p<.0001$; $F2(1, 56)=9.28$, $p<.005$. As in individual analyses on degraded data, the expected interactions between target frequency and relatedness was not found in this analysis on the combined data, either, F's<1. There was a marginally significant two-way interaction between relatedness and SOA, $F1(1, 62)=3,23$, $p<.08$; $F2(1, 56)=3.15$, $p<.08$. Priming tended to be larger in the long SOA condition than in the short SOA condition (26 ms vs16 ms).

Predicted effects. The interaction by prime frequency by relatedness was significant by the subjects analysis, $F(1, 62)=4.79$, $p<.05$, but not by items, $F2(1, 56)<1$. High frequency primes produced larger priming than low frequency primes. The two-way interaction of QSS with relatedness was not significant.

Other effects. The three-way interaction between prime frequency, target frequency, and relatedness was significant only by the subjects analysis, $F1(1, 62)=4.13$, $p<.05$; $F2(1, 56)<1$. Priming was larger for low frequency target words with high frequency primes than low frequency primes while for high frequency target words

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priming was comparable between high and low frequency primes. A three-way interaction between prime frequency, QSS, and relatedness was marginally significant only by the subjects analysis, $F1(1, 62)=3.41$, $p<.07$; $F2(1, 56)<1$. A comparison of means shows that priming was larger with low QSS than with high QSS for high frequency primes (33 ms vs 23 ms) while the trend was opposite for low frequency primes (8 ms vs 21 ms). The prediction concerning QSS seems to be observed only for high frequency prime words, but opposite for low frequency prime words.

There was a four-way marginally significant interaction with SOA by prime frequency, QSS, and relatedness, $F1(1, 62)=3.27$, $p<.08$; $F2(1, 56)=3.11$, $p<.09$, suggesting QSS may be affected by time course of activation. A comparison of means shows that priming tended to be larger with high frequency primes than with low frequency primes in the short SOA condition (29 ms and 22 ms for high frequency primes with high QSS and low QSS, respectively, while 10 ms and 2 ms for low frequency primes with high and low QSS). In the long SOA condition there was more priming for high frequency primes with low QSS than with high QSS (42 ms vs 19 ms) while there was more priming for low frequency primes with high QSS than with low QSS (33 ms vs 16 ms). To examine this interaction effect was reliable, post-hoc tests were performed on priming scores using paired t-tests with a correction by the Bonferroni procedure for the long SOA condition where the difference was found by an ANOVA performed separately in the previous section. A comparison of priming scores between high frequency primes with low QSS (42 ms) and high QSS (19 ms) was significant, $t(31)=2.52$, $p<.02$. However, a comparison between low frequency primes with low (33 ms) and high QSS (16 ms) did not reach significance, $t(31)=2.35$, $p<.03$

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with the Bonferroni correction although it was close. Thus, the predicted effect of QSS (i.e., more priming with low than high QSS) may be found only for high frequency primes in the long SOA condition. However, being only a marginally significant effect, the interpretation of this interaction needs caution.

A couple of effects by SOA, which were mostly marginally significant, were found in this combined analysis. There was a significant main effect of SOA by the subjects analysis alone, $F1(1, 62)<1$; $F2(1, 56)=34.47$, $p<.0001$. Response times were slower in the short SOA condition than in the long SOA condition (547 ms vs 532 ms).

Other significant effects related to SOA included prime frequency by SOA, $F1(1, 62)=2.97$, $p<.09$; $F2(1, 56)=4.59$, $p<.05$, and prime frequency by target frequency by SOA, $F1(1, 62)=3.25$, $p<.08$; $F2(1, 56)=5.10$, $p<.03$. The former interaction showed that in the short SOA condition, response times with high frequency prime words were slower than with low frequency prime words (535 ms vs 528 ms) while in the long SOA condition, the trend was the opposite (545 ms vs. 550 ms). The latter interaction was due to the trend that in the short SOA condition, response times for the low frequency target words were faster with high frequency primes than with low frequency primes (564 ms vs. 572 ms) and in the long SOA condition response times were slower with high frequency primes than with low frequency primes (565 ms vs. 549 ms).

Combined Analyses with Intact Conditions from Experiment 1

A 2 (prime frequency) x 2 (QSS) x 2 (target frequency) x 2 (SOA) x 2 (degradation) ANOVA was performed of data combining the results from Experiment 1 (the 150 ms SOA and 150 + 350 ms conditions) to see the effect of degradation as well as SOA durations.

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Expected effects. As expected, the robust main effects of target frequency and of relatedness were significant, $F1(1, 124)=337.12$, $p<.0001$; $F2(1, 56)=62.10$, $p<.0001$, and $F1(1, 124)=76.99$, $p<.0001$; $F2(1, 56)=9.12$, $p<.005$. The two-way interaction between target frequency and relatedness was significant by subjects analyses alone, $F1(1, 124)=6.78$, $p<.01$; $F2(1, 56)<1$. Low frequency target words produced larger priming than high frequency target words. An interaction between relatedness and SOA was significant by subjects, $F1(1, 124)=5.49$, $p<.05$, but only marginally significant by items, $F2(1, 56)=3.12$, $p<.09$. There was more priming in the long SOA condition than in the short SOA condition (26 ms vs 18 ms).

Predicted effects. The interaction between prime frequency and relatedness was significant by subjects analyses, $F1(1, 124)=25.64$, $p<.0001$, but only marginally significant by items, $F2(1, 56)=2.86$, $p<.10$. High frequency primes produced larger priming than low frequency primes. A three-way interaction between prime frequency, relatedness, and SOA was only marginally significant by subjects alone, $F1(1, 124)=2.97$, $p<.09$; $F2(1, 56)=1.79$, $p>.18$. A comparison of means show that there tends to be more priming in the long SOA condition than in the short SOA condition for low frequency primes while for high frequency primes priming was comparable between short and long SOA conditions. The interaction between QSS and relatedness was not significant.

Other effects. A three-way interaction between prime frequency, relatedness, and degradation was significant by subjects, $F1(1, 124)=4.08$, $p<.05$, but only marginally significant by items, $F(1, 56)=3.96$, $p<.06$. The difference in priming between the high frequency prime condition and low frequency prime condition was greater in

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the intact conditions (36 ms vs 5 ms) than in the degraded condition (27 ms vs 15 ms). Thus, degradation seemed to reduce the prime frequency effect on priming. A three way interaction between prime frequency, QSS, and relatedness became significant by subjects analyses alone, $F1(1, 124)=5.08$, $p<.03$; $F2(1, 56)<1$. Priming seems larger with low than high QSS only for high frequency primes (49 ms vs 29) and for low frequency primes there seems little priming with both high and low QSS (8 ms vs 3 ms). The interaction between prime frequency and target frequency was significant by the subjects analysis alone, $F1(1, 124)=14.41$, $p<.0001$; $F2(1, 56)=2.34$, $p>.13$. The effect of target word frequency (i.e., response times were slower for low than high frequency target words) was greater with high frequency primes (509 ms and 564 ms for high and low frequency target words) than low frequency primes (518 ms and 554 ms for high and low frequency target words).

Regarding the effects by SOA, several effects became significant, though mostly marginally by either subjects or items. There was a significant main effect of SOA, $F1(1, 124)=4.70$, $p<.05$; $F2(1, 56)=165.49$, $p<.0001$. Response times were faster in the long SOA condition than in the short SOA condition (523 ms vs 550 ms). There was a significant interaction between target frequency and SOA, $F1(1, 124)=6.66$, $p<.05$; $F2(1, 56)=8.54$, $p<.005$. The effect of target word frequency was greater in the long SOA condition (548 ms and 497 ms for low and high frequency target words) than in the short SOA condition (570 ms and 531 ms for low and high frequency target words). A three-way interaction between QSS, relatedness, and SOA was significant by subjects analyses, $F1(1, 124)=5.44$, $p<.05$, but only marginally significant by items, $F2(1, 56)=3.79$, $p<.06$. The predicted effect of QSS was found in the long SOA conditions

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(32 ms priming with low QSS and 21 ms priming with high QSS primes) and not in the short SOA conditions (12 ms priming with low QSS and 20 with high QSS primes).

Regarding the effect of degradation, a main effect of degradation was significant by items analyses alone, $F1(1, 124)<1$; $F2(1, 56)=16.52$, $p<.0005$. Response times were faster in the intact conditions than in the degraded condition (534 ms vs 540 ms). This main effect may be considered in regard to an interaction by degradation by SOA, though only significant by items analyses, $F1(1, 124)=1$; $F2(1, 56)= 39.56$, $p<.0001$. Response times were faster for degraded primes than for intact primes in the short SOA conditions (547 ms vs 553 ms) while those were slower for the degraded than for the intact primes in the long SOA conditions (532 ms vs. 513 ms). There was a significant three-way interaction between prime frequency, target frequency and degradation, $F1(1, 124)=7.48$, $p<.01$; $F2(1, 56)=9.20$, $p<.005$. In the intact conditions, response times for high frequency words were faster with high frequency primes than with low frequency primes (502 ms vs 518 ms) but for the low frequency target words, the pattern was the opposite (562 ms vs 547 ms). In the degraded conditions, there was little differences between high and low frequency primes (515 ms vs 517 ms for the high frequency target words, 565 ms vs 561 ms for the low frequency target words). A four-way interaction between QSS, target frequency, SOA, and degradation was significant by subjects, $F1(1, 124)=3.99$, $p<.05$, but only marginally significant by items, $F2(1, 56)=3.47$, $p<.07$. A comparison of means show that for both high and low frequency target words response times were comparable between high and low QSS for all the condition except for the intact condition with a short SOA, where response times for low frequency target words were faster for high QSS than low QSS (564 ms vs. 578 ms). There were

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other weak effects only marginally significant.[10] A two-way interaction between QSS and target frequency was marginally significant by the subject analysis alone, $F1(1, 124)=3.28$, $p<.10$; $F2(1, 56)<1$. A three-way interaction between prime frequency, relatedness, and SOA was marginally significant by the subjects analysis alone, $F1(1, 124)=2.97$, $p<.10$; $F2(1,56)=1.79$, $p>.10$. A five-way interaction between prime frequency, QSS, target frequency, SOA, and degradation was marginally significant, $F1(1, 124)=3.21$, $p<.10$; $F2(1, 56)=2.88$, $p<.10$. Also, a five-way interaction between QSS, target frequency, relatedness, SOA, and degradation was marginally significant by the items analysis alone, $F1(1, 124)=1.77$, $p>.10$; $F2(1, 56)=2.87$, $p<.10$.

Discussion

Experiment 2 examined the effect of slowed speed of lexical access to prime words by degrading primes. It is assumed that by slowing down the process of prime word access, degraded high frequency words should be processed like intact low frequency words in the short SOA condition and little priming should be obtained with degraded low frequency words. The results did not support the hypothesis on the effect degradation on semantic priming. A comparison of the predicted (Figure 8 a) to the obtained results (Figure 8 b) about the effect of prime frequency on priming shows that the predicted effect of degradation was not observed; especially, for the low frequency primes, priming was not depressed as compared with those in Experiment 1. Contrary to my original hypothesis that slowing down lexical process affects priming, it seems that degraded primes in the short SOA condition produced similar results to those with

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[10] Since these interactions were weak and complex effect and not related to the hypotheses in this study, interpretations of these effects were not described.

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intact primes in Experiment 1. In the degraded short SOA condition, degraded prime words in effect produced reliable overall priming (i.e, a significant relatedness effect was obtained). Despite the reduced visibility of primes, participants did process prime meanings, especially with high frequency primes. This result seems to indicate that accessing meaning is a very fast and automatic process; degraded primes, even with a short SOA, produced reliable priming.

Degraded target words produce slower response times, indicating target word processing is slowed (e.g., Besner & Smith, 1992; Plourde & Besner, 1997; Stolz & Neely, 1995). Since this experiment did not measure response times to degraded stimuli, there is no data concerning if degradation manipulation was strong enough. A reason why reliable priming was obtained from degraded primes may be because participants adjusted prime processing speed accommodating to degraded primes. Since this experiment was conducted in a within-subject design, participants were presented only degraded primes, thus they may have been accustomed to the level of degradation. This assumption may be applicable to the short SOA condition, where overall response times to targets were faster in the degraded condition (though significant only by items analyses) than in the intact condition while in the long SOA condition, overall response times to target words were slower in the degraded conditions than in the intact conditions.

Priming with degraded high and low frequency primes should produce larger priming in the long SOA condition than in the short SOA condition. This was only supported by a marginally significant result. There was a trend that priming was larger in the long SOA condition than in the short SOA condition.

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When a comparison was made between degraded and intact conditions from Experiment 1, there was an effect of degradation interacting with prime frequency and relatedness (significant by subjects and marginally significant by items). A comparison of means shows that the priming difference between high frequency prime words and low frequency prime words was greater in the intact condition than in the degraded condition. This interaction of degradation was due to a opposite trend that priming with high frequency prime words decreased from the intact to degraded conditions (36 ms and 27 ms priming in the intact and degraded conditions) while priming with low frequency prime words increased (5 ms and 15 ms).

To examine if this interaction effect was reliable, post-hoc tests were performed on priming scores using t-tests with a correction by the Bonferroni procedure. For the short SOA condition, comparisons of priming scores between degraded and intact conditions for both high and low frequency primes did not reach significance, $t(62)=1.03$, $p>.10$, for high frequency primes; and $t(62)<1$, for low frequency primes). Neither comparison approached significance for the long SOA condition for high and low frequency primes, $t(62)<1$ for high frequency primes; and $t(62)=1.18$, $p>.10$. Thus, the simple effects did not hold for the three way interaction between prime frequency, relatedness, and degradation.

Regarding predictions on prime frequency and QSS, Experiment 2 produced a similar pattern of result as in Experiment 1. A comparison of the predicted (Figure 9 a) and the obtained results (Figure 9 b) about the effect of QSS on semantic priming shows that the predicted direction was observed in the long SOA condition. The predicted effect of QSS on priming was not significant in either short or long SOA condition.

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Subjective associativeness ratings of stimulus pairs. In this section, a covariate analysis and an analysis without low QSS items will be performed to examined the effect of unbalanced cells concerning subjective associativeness ratings, as was done in Chapter 3. A 2 (prime frequency) x 2 (QSS) x (target frequency) x 2 (SOA) x 2 (degradation) ANOVA for items with subjective associativeness ratings as a covariate was performed on the data combining both degraded and intact conditions. The results seem comparable to those from the items analyses without the covariate except for losing a few marginally significant effects. Concerning the effects by relatedness, the main effect of relatedness was significant, $F2(1, 55)=4.31$, $p<.05$. An interaction between relatedness and prime frequency did not reach significance, $F2(1, 55)<1$, nor did the interaction between relatedness and SOA, $F2(1, 55)=1.88$, $p>.10$. A three-way interaction between relatedness, prime frequency, and degradation was marginally significant, $F2(1, 55)=3.92$, $p<.06$. The trend was the same as discussed in the above result section (i.e., priming differences seem to be greater for intact than degraded condition due to the opposite trend shown by high and low frequency primes). Also, there was a significant three-way interaction between relatedness, QSS, and SOA, $F2(1, 55)=5.22$, $p<.05$. Thus, with increased power by combining data, results of items analyses seem to become more stable.

A 2 (prime frequency) x 2 (QSS) x (target frequency) x 2 (SOA) x 2 (degradation) ANOVA, excluding low QSS items, was performed to examine the effect of prime frequency without the problematic the HLL condition. The interaction between prime frequency and relatedness was significant only by subjects, $F1(1, 124)=5.71$, $p<.02$, $F(1, 28)<1$. The three-way interaction between prime frequency, relatedness, and

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degradation did not reach significance, $F1(1, 124)=2.05$, $p<.12$; $F(1, 28)=2.11$, $p<.16$. However, the interaction between prime frequency, relatedness, and SOA became significant by subject analyses, $F1(1, 124)=4.71$, $p<.05$, and marginally significant by items analyses, $F2(1, 28)=3.10$, $p<.09$. Comparing only the high QSS conditions, in the short SOA condition priming was greater with high frequency primes than low frequency primes (32 ms vs 8 ms) while in the long SOA condition priming was comparable between high and low prime conditions (20 ms vs 21 ms). This pattern of results was in effect predicted from the original hypothesis, which was not found in an analyses with both high and low QSS items. Thus, the pattern of results analyzed here with high QSS items alone seem a little different from that from analyses with low and high QSS items together. However, it seems that the effect of prime frequency was not solely caused by the unbalanced cell which had highest mean subjective associativeness rating.

Conclusion

In conclusion, the hypothesis on the effect of slowed prime processing by degradation was not supported for priming with both high and low frequency primes. According to the hypothesis, degraded conditions should decrease priming in both short and long SOA conditions, as compared with intact conditions in Experiment 1. High frequency primes produce reliable priming in the short SOA condition. Degraded low frequency primes did not produce reliable priming in the short SOA condition while producing reliable priming in the long SOA condition.

The covariate analysis on items to control unbalanced cells concerning the subjective associativeness measure seems more stable with increased power by

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combining data from the intact and degraded conditions. An ANOVA performed excluding low QSS, which included a problematic cell, showed an interaction by prime frequency, relatedness and SOA, significant by subjects, but only marginally significant by items. This effect seems to indicate that there was more difference in priming between high and low prime frequency conditions in the short SOA conditions than in the long SOA conditions. Thus, although a caution is needed because of lack of significant results in items analyses, the effect of prime word frequency on priming may not totally be due to unbalanced cells regarding the subjective associativeness measure.

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CHAPTER 5: EXPERIMENT 3

Introduction

In Experiment 3 the effect of speed of access to prime words was examined by accelerating the word access process by repetition of primes. In the repetition priming paradigm words which are previously encountered were recognized faster than words which are presented without repetition (e.g., Kirsner & Smith, 1974; Scarborough, Cortese, & Scarborough, 1977). As previously discussed, this repetition effect involves mainly the lexical process, which could be based on perceptual processes. Thus, in this experiment when participants see primes which were presented before in the same manner (i.e., same setting-- same font, same size, etc.), they should access those words quicker than the words which were not presented before. To make a comparison between studied and unstudied prime words, this experiment was conducted in a within-subjects design. In Phase I of Experiment 2 participants read out words presented on a computer screen. These words later served as primes for half the trials in the LDT in Phase II. The rest of the primes in Phase II were new words. Also, in this experiment, the long SOA condition had a prime presentation duration of 500 ms, the same duration as the SOA.

If speed of lexical access to prime words has an effect on how fast target words are recognized, related pairs with studied primes should produce larger priming than those with unstudied primes when available time is limited in the short SOA condition (Hyp 3-a). In the long SOA condition, where both low and high frequency prime words have enough time to process, an advantage of prime word repetition might disappear, producing little effect for repetition (Hyp 3-b). If ease of access to prime words has an

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additive effect on the size of semantic priming, it should have equal effects for both low and high frequency words. For the unstudied conditions, the results should be comparable to those of Experiment 1.

Method

Participants

Sixty four undergraduate students at Louisiana State University participated in this experiment for extra credit for their psychology courses. There were 32 participants in each SOA condition.

Apparatus

As described in General Method.

Materials

The same stimulus set used in Experiment 1 was used. Half of the prime words from the stimulus pairs in each condition were randomly selected to be presented in Phase I for one half of the participants and the other half of the participants received the other half of the prime words. Additionally, to prevent participants from forming expectations that the words presented in Phase I should appear in Phase II, thirty two filler words were presented with the prime words randomly; these fillers were not presented in Phase II. Thus, each participant received 32 prime words plus 32 filler words in the Phase I to read out loud. Relatedness and QSS were counterbalanced as in Experiment 1, producing 4 list conditions. No words were repeated in any list condition. Presentation orders were randomized in both Phase I and Phase II. Each participant received a different randomization sequence.

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Procedure

In Phase I participants were instructed to read out each word which was presented on a computer screen. Each word stayed on the screen for 1.5 sec. with a 2-sec ISI (inter-stimulus interval). Immediately after Phase I, participants received instructions for Phase II which involved the LDT. The procedure for Phase II was the same as in Experiment 1, described in General Method. In the short SOA condition, prime words were presented for 150 ms, followed by target words. In the long SOA condition, prime words were presented for 500 ms, followed by target words (i.e., the same condition as the long SOA (2) in Experiment 1).

Results

A 2 (prime word frequency) x 2 (QSS) x 2 (prime word frequency) x 2 (relatedness) x 2 (repetition) repeated measures ANOVA was performed separately for the short and long SOA conditions, followed by an analysis on combined data with both SOA conditions.

Table 5 shows mean response times in each condition and Table 6 shows priming scores in each condition. The summary of results is given in Figure 10 and the graphical presentations of the results according to prime frequency and SOA, and also according to QSS and SOA are given in Figure 11 b and 12 b. Also, for a comparison, graphical presentations of the hypothetical results are shown in Figure 11 a and Figure 12 a, which were previously shown in Chapter 2, along with the graphs of the obtained results.

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Table 5. Response times (in milliseconds) according to SOA, target frequency, prime frequency and QSS in Experiment 3.

The150 ms SOA condition

Unstudied

		High freq primes		Low freq primes	
		Unrelated	Related	Unrelated	Related
High freq target	High QSS	520 (92.8)	499 (68.9)	530 (86.3)	520 (71.1)
	Low QSS	525 (112.9)	520 (91.8)	534 (77.0)	534 (96.8)
Low freq target	High QSS	574 (93.2)	550 (96.8)	558 (89.6)	561 (103.7)
	Low QSS	615 (106.1)	548 (95.3)	575 (123.4)	558 (72.1)

Studied

		High freq primes		Low freq primes	
		Unrelated	Related	Unrelated	Related
High freq target	High QSS	533 (83.1)	502 (78.4)	537 (89.5)	516 (87.6)
	Low QSS	530 (83.3)	519 (87.2)	530 (99.0)	520 (116.0)
Low freq target	High QSS	569 (82.0)	528 (81.1)	562 (114.8)	534 (76.6)
	Low QSS	581 (96.7)	539 (93.8)	558 (119.0)	571 (102.1)

The 500 ms SOA condition

Unstudied

		High freq primes		Low freq primes	
		Unrelated	Related	Unrelated	Related
High freq target	High QSS	549 (116.8)	526 (103.2)	554 (92.0)	542 (78.8)
	Low QSS	543 (90.7)	524 (98.9)	562 (138.1)	521 (105.0)

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(table cont.)

Low freq target	High QSS	578 (100.1)	578 (89.3)	568 (138.2)	571 (120.7)
	Low QSS	642 (137.3)	561 (96.6)	585 (916.0)	563 (108.3)

Studied

		High freq primes		Low freq primes	
		Unrelated	Related	Unrelated	Related
High freq target	High QSS	537 (96.7)	529 (100.7)	553 (118.7)	538 (94.5)
	Low QSS	547 (91.4)	525 (92.7)	535 (103.9)	527 (91.3)
Low freq target	High QSS	579 (104.0)	572 (142.7)	602 (101.0)	562 (101.2)
	Low QSS	624 (99.0)	573 (108.1)	591 (146.0)	566 (85.4)

Note: The standard deviations were given in parentheses.

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Table 6. Priming scores according to SOA, target frequency, prime frequency and QSS in Experiment 3.

The150 ms SOA condition

Unstudied

		High freq primes	Low freq primes
High freq target	High QSS	22	10
	Low QSS	6	0
Low freq target	High QSS	24	-3
	Low QSS	67**	16

Studied

		High freq primes	Low freq primes
High freq target	High QSS	31*	21
	Low QSS	11	11
Low freq target	High QSS	41*	28
	Low QSS	42*	-13

The 500 ms SOA condition

Unstudied

		High freq primes	Low freq primes
High freq target	High QSS	23	13
	Low QSS	19	42+
Low freq target	High QSS	0	-3
	Low QSS	80**	21

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(table cont.)

Studied

		High freq primes	Low freq primes
High freq target	High QSS	8	15
	Low QSS	22	8
Low freq target	High QSS	6	40*
	Low QSS	52**	25

Note: Priming scores were obtained by subtracting response times to related target words from those to unrelated target words. The following notations were used to indicate p-values: + p<.10; * p<.05; ** p<.01; *** p<.001.

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Condition	Expected effects				Predicted effects					Other effects
	T	R	TxR	Rx SOA	PxR	PxR xSOA	RxRep	RxRep xSOA	QxR	
150 ms	*** /***	*** /**	ns	n/a	* /+	n/a	ns	n/a	ns	Q +/+ QxRxRep +/ns
500 ms	*** /***	*** /**	ns	n/a	ns	n/a	ns	n/a	+ /ns	Px T * /ns Qx T * /ns PxQ + /ns
Exp 3 Combined	*** /***	*** /**	ns	ns	+ /ns	ns	ns	ns	ns	SOA ns /*** Q + /ns Px T ** / ns PxQ + /ns Qx T * /ns QxSOA ns /+ QxRxSOA + /ns QxTxR + /ns QxRxRep + / + PxQxTxR + / +

*** p<.001; ** p<.01; * p<.05; + p<.10; ns -- not significant; n/a -- not applicable; P: Prime word frequency; Q: QSS; T: Target word frequency; R: Relatedness; Rep: Repetition

Figure 10. Summary of the obtained main effects and interactions.

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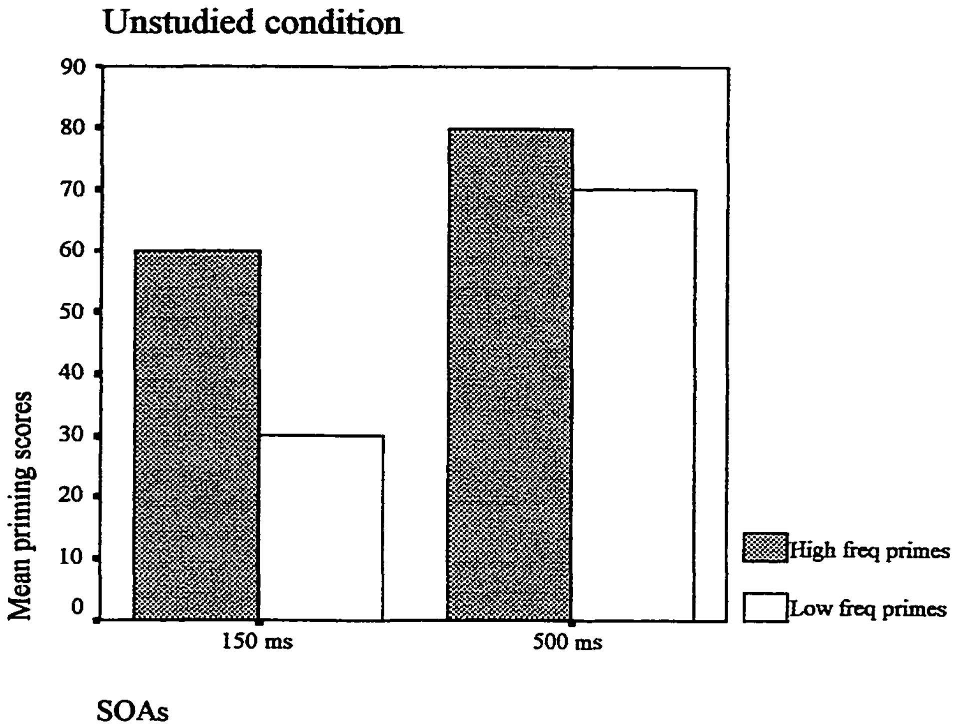

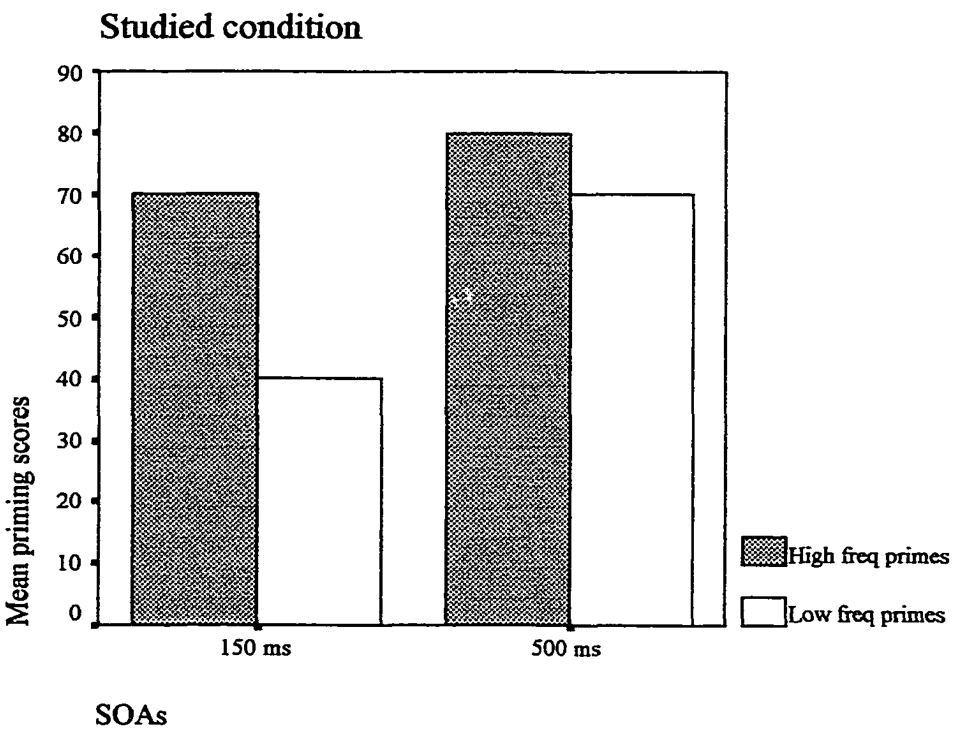

Figure 11 a. Hypothetical results of priming scores according to prime frequency and SOA in Experiment 3.

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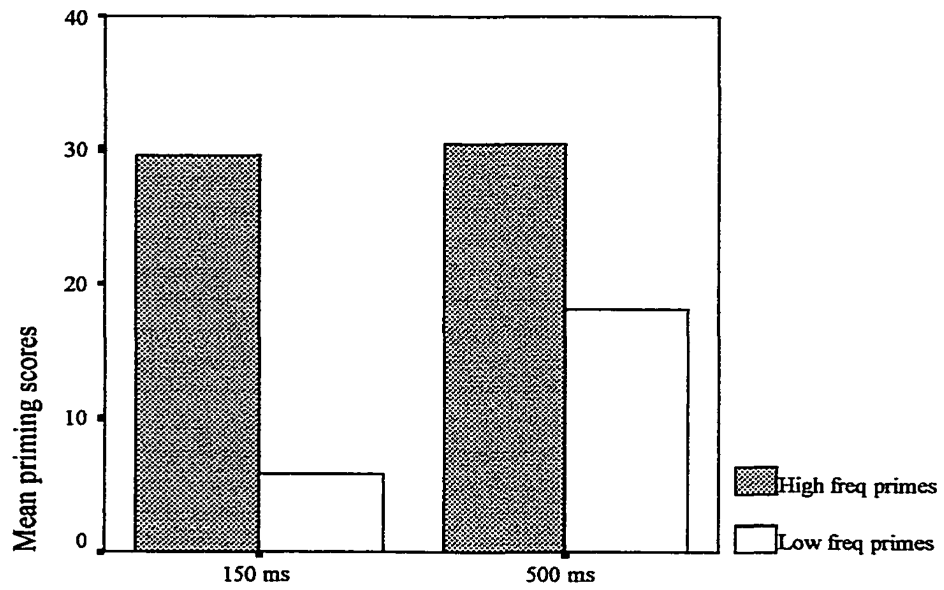
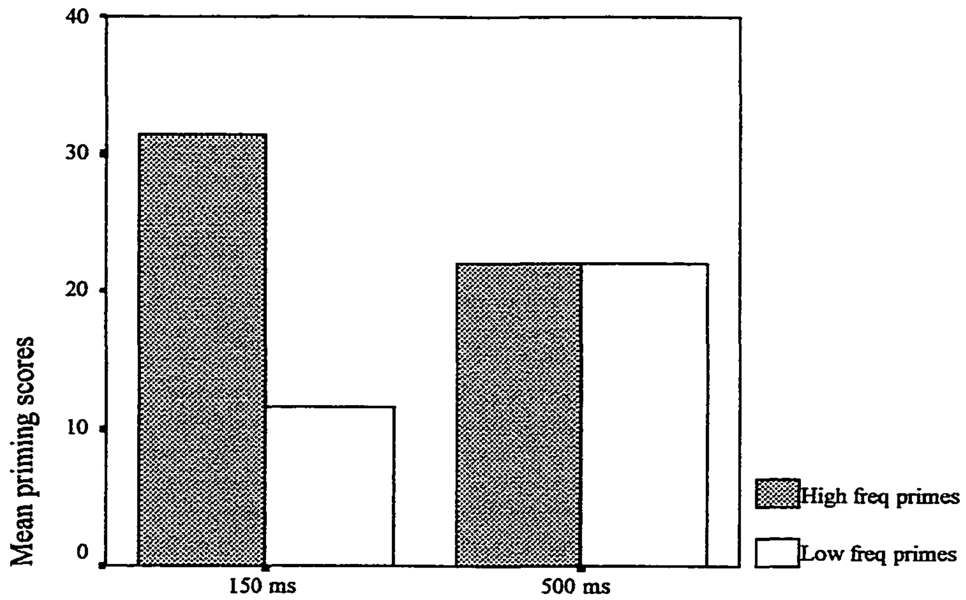
Unstudied condition



SOAs

Studied condition



SOAs

Figure 11 b. Mean priming scores according to prime frequency and SOA in Experiment 3.

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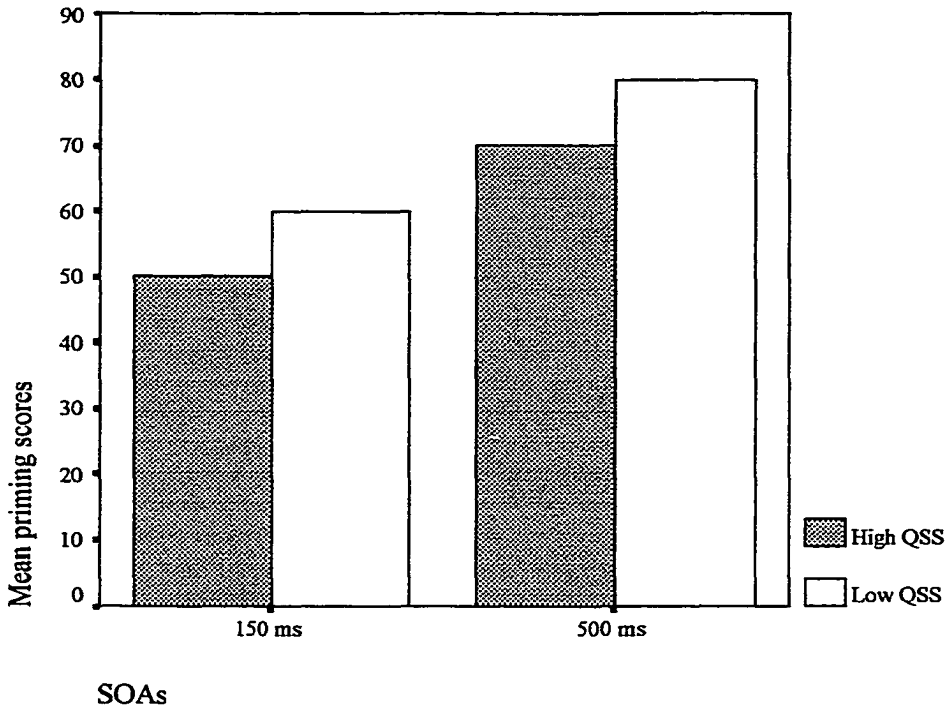

Figure 12 a. Hypothetical results of priming scores according to QSS and SOA.

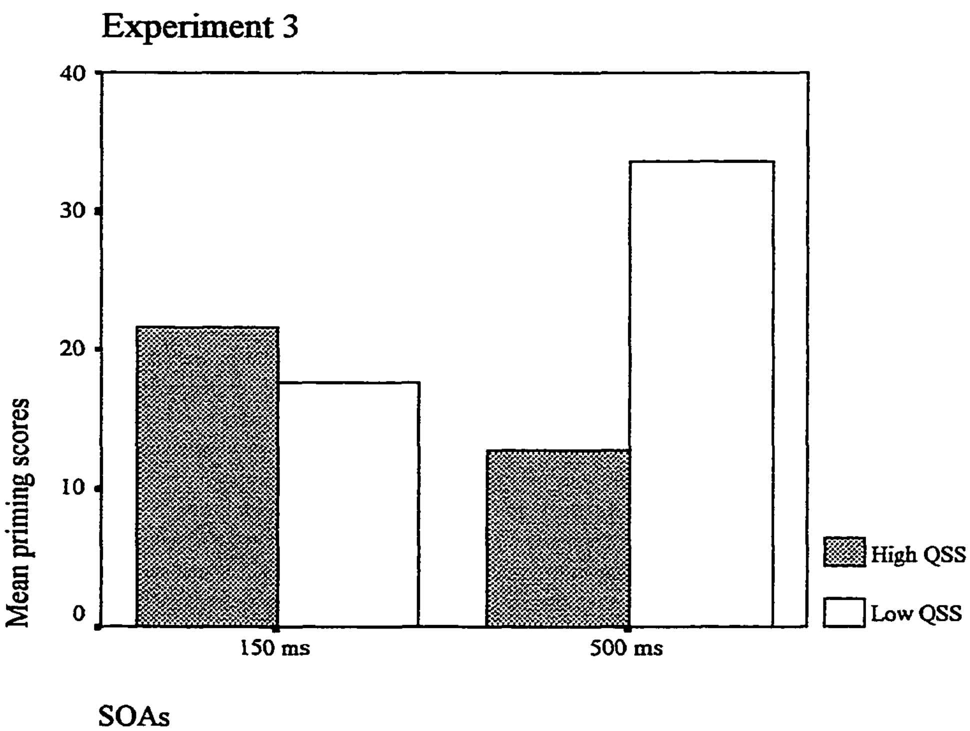

Figure 12 b. Mean priming scores according to QSS and SOA in Experiment 3.

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Treatment of Outliers

The same subjects inclusion and outlier treatment were done in the analyses of this experiment. Two individuals in the short SOA condition and 1 individual in the long SOA condition were replaced, whose overall response times exceeded 800 ms. Also, those individuals who had more than 6 % missing datapoints were replaced, which affected 18 individuals in the short SOA condition and 13 individuals in the long SOA condition. The error rates were 1.5 % (31 datapoints) in the short SOA condition, 1.3 % (26 datapoints) in the long SOA condition. The 2000/300 cut-off affected 1 datapoints for the short SOA condition and 0 data points for the long SOA condition. The 2.5 standard deviation trimming affected additional 2.6 % of datapoints (53 datapoints) in the short SOA condition and 2.5 % (52 datapoints) in the long SOA condition. In total, 4.2 % of datapoints in the short SOA condition and 3.8 % of datapoints in the long SOA condition were removed as errors or outliers.

The Short SOA Condition

Expected effects. There were significant main effects of target word frequency, $F(1, 31)=61.41$, $p<.0001$; $F2(1, 56)=47.74$, $p<.0001$, and relatedness, $F1(1, 31)=34.20$, $p<.0001$; $F2(1, 56)=11.45$, $p<.005$. High frequency target words were responded to faster than low frequency target words (523 ms. vs. 561 ms.). Related pairs were recognized faster than unrelated pairs (532 ms vs. 552 ms). The predicted interaction between target frequency and relatedness did not reach significance.

Predicted effects. The interaction between prime frequency and relatedness was significant by subjects, $F1(1, 31)=4.39$, $p<.05$, but only marginally significant by items, $F2(1, 56)=3.53$, $p<.07$. Priming with high frequency prime words was larger than

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priming with low frequency prime words (31 ms vs 9 ms). The predicted interactions between relatedness and repetition and between QSS and relatedness did not approach significance.

Other effects. There was a marginally significant main effect of QSS, $F1(1,31)=3.08$, $p<.06$; $F2(1, 56)=3.33$, $p<.08$. Target words with high QSS primes were responded to faster than those with low QSS primes (537 ms vs 547 ms). There was a marginally significant three-way interaction between QSS, relatedness, and repetition only by subjects analyses, $F1(1, 31)=3.46$, $p<.08$; $F2(1, 56)<1$. Priming was smaller with high QSS than low QSS in the intact condition (13 ms vs 22 ms) while in the studied condition the opposite trend was observed (30 ms vs 13 ms).

The Long SOA Condition

Expected effects. There were significant main effects of target word frequency, $F1(1, 31)=71.53$, $p<.0001$; $F2(1, 56)=40.72$, $p<.0001$, and of relatedness, $F1(1, 31)=15.48$, $p<.0001$; $F(1, 56)=7.29$ $p<.01$. High frequency target words were responded to faster than low frequency target words (538 ms vs. 582 ms) and related pairs were recognized faster than unrelated pairs (549 ms vs. 572 ms). An interaction between target frequency and relatedness was not significant.

Predicted effects. There was a marginally significant interaction, by subject analyses alone, between QSS and relatedness, $F1(1, 31)=3.39$, $p<.08$; $F2(1, 56)=1.49$, $p>.10$. Priming tended to be larger with low QSS than high QSS (34 ms vs 13 ms). The predicted interaction between prime frequency and relatedness, and between relatedness and repetition did not approach significance.

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Other effects. There were significant two-way interactions by subjects analyses alone between prime frequency and target frequency, $F1(1, 31)=6.05$, $p<.02$; $F2(1, 56)=1.84$, $p>.10$, and between QSS and target frequency, $F1(1, 31)=5.38$, $p<.03$; $F2(1, 56)=1.59$, $p>.10$. Response times for the high frequency target words were faster for high frequency primes than low frequency primes (535 ms vs 542 ms) and for the low frequency target words the trend was the opposite (588 ms vs 576 ms). Also, response times for high frequency target words were comparable between high QSS and low QSS conditions (541 ms vs 536 ms) while those for low frequency target words were faster with high QSS than with low QSS (576 ms vs 588 ms). An interaction between prime frequency and QSS was marginally significant by the subjects analysis alone, $F1(1, 31)=3.76$, $p<.07$; $F2(1, 56)=1.49$, $p>.10$. High frequency primes response times tended to be faster in the high QSS condition than low QSS condition (556 ms vs 567 ms) while with low frequency primes the trend were the opposite (561 ms vs 556 ms).

Combined Analyses with the Short and Long SOAs

A 2 (prime frequency) x 2 (QSS) x 2 (target frequency) x 2 (relatedness) x 2 (repetition) x 2 (SOA) ANOVA was performed on the combined data of the two SOA conditions to see the overall trend with increased power.

Expected effects. There were significant main effects of target frequency and of relatedness, $F1(1, 62)=131.12$, $p<.0001$; $F2(1, 56)=52.62$, $p<.0001$, and $F1(1, 62)=39.84$, $p<.0001$; $F2(1, 56)=13.48$, $p<.0001$. High frequency target words produced faster response times than low frequency target words. Also, related pairs were responded to faster than unrelated pairs. As in the separate analyses, the expected

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interaction by target frequency by relatedness did not reach significance. The expected interaction between relatedness and SOA was not obtained.

Predicted effects. An interaction between prime frequency and relatedness was marginally significant only by the subjects analysis, $F1(1, 62)=3.25$, $p<.08$; $F2(1, 56)=1.41>.20$. High frequency primes seem to have produced more priming than low frequency primes. The predicted interactions between QSS and relatedness, between relatedness and repetition, and between relatedness, repetition and SOA did not reach significance.

Other effects. There was a significant main effect of SOA by the items analysis alone, $F1(1, 62)=1.11$, $p>.30$; $F2(1, 56)=39.43$, $p<.0001$. Response times in the short SOA conditions were faster than those in the long SOA conditions (542 ms vs 560 ms). There were significant interactions by subjects analyses only between prime frequency and target frequency $(1, 62)=7.60$, $p<.01$; $F2(1, 56)=2.16$, $p>.14$, and between QSS and target frequency $F1(1, 62)=4.23$, $p<.05$; $F2(1, 56)=1.30$, $p>.25$. Response times for high frequency target words were faster with high frequency primes than low frequency primes (527 ms vs 535 ms) while for low frequency primes, the trend was the opposite 576 ms vs 567 ms). Also, response times for high frequency target words were comparable between high and low QSS conditions (530 ms vs 531 ms) while for low frequency target words, response times were faster with high than low QSS (565 ms vs 578 ms). None of the effect of repetition reached significance except for a three-way interaction between QSS, relatedness, and repetition, which was only marginally significant, $F1(1, 62)=3.08$, $p<.09$; $F2(1, 56)=3.24$, $p<.08$. A comparison of means indicates that repetition produced more priming with high QSS primes (from 14 ms

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priming in the intact condition to 24 ms in the studied condition) while priming actually decreased with low QSS primes (from 31 ms in the intact condition to 20 ms in the repeated condition). There were other weak effects that were only marginally significant. A two-way interaction between QSS and SOA was marginally significant by the items analysis only, $F1(1, 62)=1.0$, $F2(1, 56)=3.22$, $p<.08$. There was a marginally significant interaction by the subjects analysis alone between prime frequency and QSS, $F1(1, 62)=3.33$, $p<.08$; $F2(1, 56)<1$. There was a marginally significant main effect of QSS by the subject analysis alone, $F1(1, 62)=3.80$, $p<.06$; $F2(1, 56)=2.06$, $p>.10$. There were marginally significant three-way interactions by subjects analyses alone between QSS, relatedness, and SOA, $F1(1, 62)=2.85$; $F(1, 56)=1.21$, $p>.27$, and between QSS, target frequency and relatedness, $F1(1, 62)=3.27$, $p<.08$; $F2(1, 56)=1.30$, $p<.30$. There was a marginally significant four-way interaction between prime frequency, QSS, target frequency, and relatedness, $F(1, 62)=3.81$, $p<.06$; $F2(1, 56)=2.83$, $p<.10$.

Discussion

The results from Experiment 3 showed the expected main effects of target frequency and relatedness. The expected target frequency x relatedness interaction did not reach significance. The unstudied conditions in this Experiment should replicate the results in Experiment 1. However, the obtained results seem generally weaker than those in Experiment 1, with effects mostly marginally significant. Also, the effect of QSS, though weak, seems to be more apparent, interacting with other variables, which were not predicted from my hypothesis. These differences are probably due to unstable data with more complicated design (a 2x2x2x2 ANOVA).

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Regarding the hypothesis on the prime word frequency, a comparison of the predicted (Figure 11 a) to the obtained results (Figure 11 b) shows that the predicted effect of prime frequency was different in the short SOA condition (significant by the subjects analysis but only marginally significant by the items). The difference in priming between high and low frequency primes was smaller in the long SOA condition, producing non-significant results; however, the effect of SOA on priming was not significant by the analyses combining the results from the two SOAs.

A comparison of the predicted (Figure 12 a) and the obtained (Figure 12 b) shows that the predicted effect of QSS on semantic priming is apparent in the long SOA condition. The interaction effect of QSS by relatedness was marginally significant by the subjects analysis alone, only in the long SOA conditions.

Although weak findings, above two effects of prime frequency and QSS follow the pattern of results found in the previous two experiments: The effect of prime frequency on priming tended to be stronger in the short SOA conditions, and the effect of QSS on priming tended to be found in the long SOA conditions alone.

None of effects by repetition reached significance except for QSS, relatedness, and repetition, which was only marginally significant by the subjects analysis alone in the short SOA condition. An analysis on the combined data also showed the effect only marginally significant by subjects and items analyses. Primes with high QSS had a tendency to produce larger priming when studied than unstudied while primes with low QSS did not show the effect of repetition. According to the ASA theory, the strength of activation is divided when multiple nodes are activated at one time, thus each node receives less activation when a word has more connections than fewer connections, thus

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predicting stronger activations for primes with low QSS. With the ceiling effect (primes with low QSS might show large priming without repetition), the repetition effect might have only shown for the primes with high QSS which might have had weaker activations.

Figure 11 compares mean priming scores between the unstudied and studied conditions, showing little effect of repetition on priming (for repeated high frequency primes, priming seems depressed in the long SOA condition as compared with non-repeated high frequency primes). None of predicted effects were significant. According to the original hypothesis, studying prime words immediately before the priming task should benefit priming, especially in the short SOA condition. A numerical observation shows that in the short SOA condition, priming with low frequency primes increased for the studied primes; in the long SOA condition priming with low frequency primes was as large as priming with high frequency primes for the studied primes. Although these observations were concordant with the original hypothesis, none were supported by statistical analyses. When the two SOA conditions were combined, the effect of SOA condition on priming and prime word frequency did not reach significance. Thus, the results of repetition on priming did not support the hypothesis of the effect of repetition. A reason for this may be due to unstable data since there were only two items in each condition and the standard deviations were large, ranging between 69 ms to 143 ms according to conditions.

<u>Subjective associativeness ratings of stimulus pairs.</u> As was done in Chapter 3 and 4, a 2 (prime frequency) x 2 (QSS) x 2 (target frequency) x 2 (SOA) x 2 (repetition) ANOVA for the items analysis was performed with subjective

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associativeness ratings as a covariate. There was a significant main effect of target frequency, $F2(1, 55)=47.21$, $p<.0001$. There were a significant three-way interaction between QSS, relatedness, and repetition, $F2(1, 55)=6.47$, $p<.02$, and a marginally significant three-way interaction between prime frequency, target frequency, and repetition, $F2(1, 55)=2.89$, $p<.10$. None of other effects, including the main effect of relatedness, reached significance.

Again, a 2 (prime frequency) x 2 (target frequency) x 2 (SOA) x 2 (repetition) ANOVA was performed excluding low QSS items. There were significant main effects of target frequency, $F1(1, 62)=67.08$, $p<.0001$; $F2(1, 28)=16.24$, $p<.0005$, and of relatedness, $F1(1, 62)=13.81$, $p<.0001$, $F2(1, 28)=4.73$, $p<.05$. A main effect of SOA was significant by the items analysis only, $F1(1, 62)=1.6$, $p>.20$; $F2(1, 28)=33.21$, $p<.0001$. Also, there was a marginally significant three-way interaction between target frequency, SOA, and repetition, $F(1, 62)=2.88$, $p<.10$. None of other effects reached significance.

Conclusion

In Experiment 3 the repetition priming paradigm was used to manipulate speed of lexical access to prime words. Participants studied half the prime words immediately before the priming task. According to the repetition priming paradigm, studied prime words should be accessed more quickly than unstudied prime words. The results did not support the hypothesis. Numerically, a slight non-significant increase in overall priming was observed for both short and long SOA conditions. However, none of effects by repetition on priming reached significance except for a weak effect involving QSS. Since there were only two items in each cell, the results seem unstable, with large standard

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deviations. The covariate analysis and an analysis excluding low QSS items did not find any consistent patterns. The effect of repetition may be transient, or unlike the effect of word frequency, which includes both lexical and semantic access, accelerated lexical access created by repetition may have a limited effect on priming.

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CHAPTER 6: GENERAL DISCUSSION

The Ease of Prime Word Access Hypothesis

In three experiments I have examined the effects of ease of prime word access. It was my assumption that if limited time is available to access prime words, prime words which require more processing time would be processed only at a shallow level, thus producing smaller priming than those prime words which are processed more quickly. Thus, if the ease of word access to prime words has effects on priming, the effect should appear in the condition where access time to primes is limited (i.e., in the short SOA condition). With more available time to access prime words, the effect of ease of word access should be reduced or eliminated. This effect of ease of word access to prime words was tested using three manipulations: word frequency, degradation, and repetition. The effect of word frequency was assumed to involve more semantic access in word recognition while degradation and repetition were assumed to involve more lexical access.

Four hypotheses were tested in this study. The first hypothesis was the effect of prime word frequency on the semantic priming effect. If the ease of prime word access has an effect on processing target words with a limited processing time, high frequency prime words, which have faster response times, should produce greater priming than low frequency prime words with a short SOA (Hyp1-a). When there is more time available with a long SOA, the priming difference between high and low frequency words should become smaller (Hyp 1-b). This hypothesis was tested in Experiment 1, 2, and 3. The second hypothesis concerned the effect of degradation on semantic priming. If the ease of prime word access hypothesis holds, degrading prime words, by slowing

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down lexical processes of word recognition, should produce smaller semantic priming with both high and low frequency primes (Hyp 2). This hypothesis was tested in Experiment 2. The third hypothesis concerns the effect of accelerated processing by prime word repetition on semantic priming. Repeated primes should produce larger priming than non-repeated primes with a short SOA (Hyp 3-a). With a long SOA this advantage of repetition should be smaller (Hyp 3-b). This hypothesis was tested in Experiment 3. In addition to the ease of prime word access hypothesis, the forth hypothesis concerned the effect of QSS. QSS of a word indicates the number of strong nodes: A word with high QSS has more strong connections while a word with low QSS has fewer. Thus, according to the ASA, prime words with low QSS should produce larger priming than prime words with high QSS in which each connection has thinner spreading activation (Hyp 4).

The results supported the first part of the first hypothesis on the effect of prime frequency (Hyp 1-a). High frequency prime words did produce larger priming than low frequency prime words in the short SOA condition in Experiment 1. The effect was weaker in Experiment 2 and 3, where it was significant by the subject analysis but only marginally significant (Experiment 2) or non-significant (Experiment 3) by the items analysis. The second part of the first hypothesis regarding the time course of prime processing (Hyp 1-b) was not supported. In Experiment 1 in the long SOA condition, the effect of prime word frequency on priming was present (significant by the subjects analysis, but only marginally significant by the items analysis). In both Experiment 2 and 3 the effect of prime frequency on semantic priming was not found in the long SOA condition; however, no analyses comparing between short and long SOA conditions

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showed a significant interaction effect of SOA on prime word frequency and priming. Thus, availability of processing time did not seem to affect the amount of priming with high and low frequency primes. It is possible that the 350 ms difference between the short and the long SOA conditions may not have been enough to produce the priming difference between the high and low frequency primes. With a longer SOA (for example, 800 ms), the overall amount of priming by low frequency primes may increase to the level of priming by high frequency primes.

The second hypothesis regarding the effect of degradation on semantic priming (Hyp 2) was not supported by the results in Experiment 2. In the short SOA condition the reduction in priming between the degraded and the intact conditions was not substantial. In effect, the degraded primes in Experiment 2 produced comparable priming with the intact primes in Experiment 1 in the short SOA conditions despite the reduced visibility of the primes.

The pattern of results in Experiment 2 suggests that degradation did not work as expected, especially for the high frequency primes, which produced similar results to those in the intact conditions. In target word degradation studies, degradation has been demonstrated to slow down target word processing. It is odd to assume it did not work the same way to slow down the prime word access process. In that regard, the level of degradation may not have been strong enough. Also, the experiment used degradation as a within-subjects variable; all the presented primes were degraded. Thus, participants may have become accustomed to degraded primes and able to see them toward the end.

The third hypothesis regarding the effect of prime word repetition on semantic priming was not supported by the results of Experiment 3. The predicted interaction

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between repetition and relatedness was not found. Neither was the interaction of SOA with repetition and relatedness.

The forth hypothesis about QSS and relatedness was only partially supported. The effect of QSS on priming was found in the long SOA condition in Experiment 1 and 3 while it was not found with degraded primes in Experiment 2. The effect seems to be a weak one (significant by subjects, but marginally significant in Experiment 1; only marginally significant by the subjects analysis alone in Experiment 3), and only found in the long SOA condition with intact primes. It seems activations of meanings of high QSS words spread more quickly, giving an advantage to high QSS at short SOAs, but becoming weaker over time while activations of meanings of low QSS words spread more slowly, giving an advantage at long SOAs.

In summary, three experiments examined the effect of ease of prime word processing on semantic priming. The prime frequency effect does not seem very robust, as it was found in Experiment 1, but only significant by the subject analysis and only marginally significant or non-significant by the items analysis in Experiment 2 and 3. However, the persistent pattern of results is intriguing and suggests further exploration. The hypothesis on semantic activations of high and low frequency primes over a time course was not supported. The amount of priming by prime frequency was not affected by having more processing time. Although significant by subjects and only marginally significant by items, the priming difference between the high and low prime frequency was still found in the long SOA condition. Priming by low frequency primes in the long SOA condition increased from the short SOA condition, but the increase was not statistically significant. It is possible with much longer processing time (e.g., 1000 ms),

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low frequency words may produce as much priming as high frequency words. It is also possible that word frequency has an effect on strength of activations such that high frequency words have inherently stronger activations than low frequency words. If this is valid, ease of processing by itself may not explain all the differences in the amount of priming by different word characteristics including word frequency. In that case, the account for activation over time needs to be reconsidered.

Other Expected Effects Examined in this Study

This study manipulated target frequency and relatedness as well as other variables tested specifically in each experiment. Thus, effects regarding target frequency, relatedness, and SOA found in previous studies should also be found in this study. Low frequency target words should produce longer response times than high frequency target words (E 1). Target words of related pairs should produce faster response times than those of unrelated pairs (the priming effect; E 2). Low frequency target words should produce larger priming than high frequency target words (the target frequency effect; E 3). Also, priming should be larger in the long SOA condition than in the short SOA condition (E4).

The robust results of the effect of target frequency (E1) and the relatedness effect were found in all experiments. However, the target frequency effect on priming was reliably obtained only in the long SOA (2) condition in Experiment 1. It was marginally significant by subjects analyses only in the short and long SOA (1) conditions in Experiment 1 and not found in Experiment 2 and 3 at all. The target frequency effect on priming does not seem as robust as expected. It is possible that although the mean frequency counts between high and low target frequency words were significantly

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different, the difference may not have been large enough. Stone and Van Orden (1992) obtained the robust target word frequency effect possibly because their difference in frequency counts between high and low frequency target words was larger than in this study. Although not giving means for overall low and high frequency target word frequency, their criterion of low frequency target words was lower (less than 9 per million as compared with 20 in this study) and that of high frequency target words was higher (more than 90 per million as compared with 70 in this study). Compared to their response time results, the response times in this study to both high and low frequency target words seem generally faster. In Stone and Van Orden's study the response times ranged from 597 ms to 713 in the 200 ms SOA condition while in this study those ranged from 517 ms to 615 ms in the 150 ms SOA condition. This may be due to difference in target words frequency distributions between the two studies. Also Stone and Van Orden (1992) used a longer ISI (2000 ms) compared with this study (1000 ms). This faster pace may have contributed to the reduction of the target frequency effect.

The effect of SOA on semantic priming (E 4) was not a strong one. It was obtained only in Experiment 2 as a marginally significant result and only significant by the subject analysis and marginally significant by the items analysis in the analyses combining Experiment 1 and 2. It was not found in Experiment 3. It is possible that the time difference between the short and long SOAs was not large enough.

Theories of Semantic Priming

The results of this study are consistent with the ASA theory. The results regarding the effect of prime frequency indicated that high frequency primes produced

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more priming in the short SOA condition, and this tendency was also observed in the long SOA condition; having more prime access time had little effect on semantic priming for both high and low frequency prime words. Although there is a possibility that manipulations in this study were not strong enough, it is also possible that prime word characteristics per se, such as word frequency, affect how activations spread to target words. The ASA theory assumes that related words are stored close together, and that related target words or high frequency target words have lower thresholds for activations (Collins & Loftus, 1975). The theory explains how activations spread to target words once a prime word is activated and it is not specific about whether or how the initial activation by a prime affects the spreading of its meaning. If high frequency words, because of their frequent encounters, activate target words more strongly regardless of target word frequency, activation processes prescribed by the ASA theory can become more specific and may not be totally 'automatic'.

Although this study specifically examined priming according to the ASA theory, the other theories of semantic priming vary in how well they can explain the prime frequency effect. The compound cue theory assumes the familiarity value of related pairs together in memory contributes to faster response times for related target words. High frequency related pairs should have higher familiarity values than low frequency related pairs, thus producing more priming. However, the expectancy theory of priming may have difficulty explaining the effect since it assumes that the expectancy sets are ordered according to target word frequency for the difference in priming. In this study high and low frequency primes have both high and low frequency target words, thus

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both high and low frequency primes with low frequency target words should produce larger semantic priming. This was not the case in the current study.

The account of QSS was introduced in this study to examine the ASA theory. The QSS x relatedness interaction was found in the long SOA (1) conditions in Experiment 1 and 2 by subjects analyses alone. It was only marginally significant by the subject analysis alone in Experiment 3. Although the results were not exactly what was expected, with modification the ASA theory can explain the effect obtained on QSS. Low QSS seems to affect priming in the later stage of activation. Activations by high QSS primes may spread more quickly than those by low QSS. Thus, in a longer SOA, primes with low QSS may produce more priming than those with high QSS.

As for the other theories of semantic priming, the expectancy theory can explain these results about QSS by assuming that the number of target words to be searched in the expectancy sets for low QSS primes is reduced as compared with high QSS primes; thus target words with low QSS would be accessed faster than those with high QSS. The compound cue theory may have a difficulty explaining these results because the familiarity value of stimulus pairs may not be different according to QSS. Thus, the results obtained in this study seem more concordant with the ASA theory. However, as the effect of QSS found in this study was weak (items analyses did not reach significance; and the effect was not found in the long SOA (2) condition in Experiment 1), more studies on QSS may be needed to examine whether the account of QSS will explain how activations by prime words will spread in accordance to the ASA theory.

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Further Studies

The results from manipulating speed of prime word access by repetition and degradation did not show the predicted effects for ease of prime word access on semantic priming. It is possible that effects by the lexical access manipulations are subtle; an improved study may require stronger manipulation of the variables. Also, an improved design with more items per cell will provide more stable data. Specifically, the repetition experiment in this study was conducted with repetition as a within-subject variable, which made a direct comparison of the effect between repeated and non-repeated words; however, this design reduced the number of stimulus pairs per experimental cell to 2, resulting in the unstable results.

Also, a weakness of this study lies in stimulus selection, as discussed in Chapter 2. There were unbalanced cells concerning subjective ratings of relatedness. The HLL (high frequency primes / low QSS /low frequency targets) had a higher rating in subjective relatedness than other cells. It was a problem interpreting the results since this is the condition showing reliably high priming in all experiments. Thus, although statistical remedies were attempted, there still remains a possibility that the effects assigned to prime frequency are actually due to subjective associativeness.

To pursue further whether the ease of prime word access is a valid explanation for the mechanism of semantic priming, improvements in experimental designs and further studies are discussed in the following section.

<u>More control on stimulus pairs.</u> In this study, where four variables (i.e., prime frequency, QSS, target frequency, and relatedness) were controlled in a single design, the number of items per experimental cell was very small (4 for Experiment 1 and 3, 2

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for Experiment 2), producing results with rather large variability, thus unstable results. The remedy would involve reducing variables manipulated at one time in order to obtain more stimulus pairs per cell. For example, since this study did not obtain an interaction between target frequency, prime frequency, and relatedness, the target frequency variable could be removed. Also, the analyses on discrepancies between normed and subjective ratings demonstrated more control over subjective associativeness ratings is necessary to obtain clearer results.

Strong lexical access manipulations. The kind of manipulation of lexical access might be a reason for the weak results found in this study. If lexical access affects semantic priming, then a stronger manipulation of lexical access processing, such as using more reduced contrast for degraded primes or using much shorter and much longer SOAs (e.g., 60 ms vs. 1000 ms) might would sharpen the lexical processing on priming, which otherwise would be a very fast process.

Manipulations of semantic access processes. Since slowing and accelerating prime lexical access processes by degradation and repetition did not seem to affect semantic priming, the ease of prime word access hypothesis may only be applicable to semantic access processes, rather than lexical access processes. As this study showed, it is possible that manipulation of lexical access processes may not affect semantic priming. A further study can examine whether manipulations of primes at the semantic level rather than the lexical level affects the amount of semantic priming. This dichotomy of lexical and semantic processes and its implications for the ease of prime word access hypothesis will be discussed in the later section. Manipulating such word characteristics as word familiarity and imageability, which are more related to semantic

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access processes, may provide a better insight into the mechanism of semantic priming and meaning access in word recognition.

The stimulus words used for both high and low frequency words in the current study were relatively familiar words. Gernsbacher (1984) reported that there are more discrepancies in familiarity for low frequency words than for high frequency words. She found a main effect of familiarity using low frequency words in a series of experiments. This finding suggests that low frequency unfamiliar words have much slower semantic access than low frequency familiar words. Thus, using the familiarity value to manipulate ease of access at the semantic access level rather than word frequency for low frequency words may produce a stronger effect on semantic priming.

Another possible study to examine the effect of the semantic access of prime words might involve manipulating prime word imageability. In a single-word recognition study, de Groot (1989) investigated effects of word frequency and imageability. de Groot assumed that two factors affect word recognition processes: the strength and the number of associative links originating from a source. According to de Groot, the former is determined by word frequency and the latter by word imageability. Demonstrating that imageability affects speed of producing associated words (high imageability words produced shorter production latencies while frequency did not affect the production latencies), de Groot concluded that high imageability words have more numerous connections than low imageability words. Since de Groot asked the participants to report as many associated words as possible, her measure of the number of associative links includes both strong and weak connections unlike QSS which is the measure for strong connections. Thus, in accordance with the ASA theory, high

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imageability prime words should produce smaller semantic priming than low imageability prime words when word frequency is controlled.

Conclusion

This study has shown that prime word processing affected processing of meanings of target words. High frequency primes produced more priming than low frequency primes in the short and long SOA conditions (although in the long SOA condition, the effect was marginally significant by the items analysis).

The effects of degradation and repetition should have attenuated or helped the lexical process of prime word access. However, neither manipulation produced the predicted results. While it is possible the manipulations did not work as intended, it is also possible that lexical access is a very quick, automatic process so that to produce an effect, manipulations needed to be very strong (i.e., very short SOAs, greater degradation, or use of low familiarity words). Another possibility for the failure to find the effect by repetition and degradation may lie in the difference between lexical vs semantic access. Repetition and degradation would affect lexical processing of words while word frequency involves both lexical and semantic processing. Since manipulation of word frequency involves both lexical and semantic processing, the amount of priming may be more influenced by variables which affect semantic access rather than lexical access.

Thus, further examination into the ease of word access hypothesis is necessary. At present, the difficulty of obtaining priming differences by manipulations of lexical access while still obtaining the prime word frequency effect seems to further confirm the dichotomy of lexical and semantic processes. It appears that the ease of access account

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of prime processing needs to be more specific about the two levels of word processing. Access to phonology (or orthography) of words may be more automatic and faster than access to meaning. Semantic priming may be more susceptible to the manipulations of ease of word access at the semantic access level rather than at the lexical access level.

Many word recognition models assume dual processes between lexical or phonological access and semantic access. For example, the ASA model of Collins and Loftus (1975) assumes spreading activations for both semantic and lexical representations. Morton (1969)'s Logogen Model also assumes two separate routes for word recognition. As both models assume associative links or networks, frequencies of word encounters play a role in word recognition. Foster (1976) assumes serial search from lexical to semantic level for word recognition is organized according to word frequency. The multistage activation model by Besner and Smith (1992) also assumes separate lexical and semantic systems in which word frequency affects the latter. The results of this study suggest separate lexical and semantic stages for word access and the effect of word frequency. As lexical manipulations had little impact on semantic priming, lexical access seems faster and more automatic than semantic process. Word frequency seems to affect semantic access processes. Frequent encounters of a word may make word access faster and more automatic. Further pursuing whether ease of word access at the semantic level may show how we access and learn words, including words in a foreign language.

In conclusion, the contribution of this study in the area of semantic priming and word recognition has been to advance research into a neglected area in the research of semantic priming: prime word processing. Although the effect of prime word frequency

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on priming was not conclusive, the persistent pattern of results suggests further studies on the effect of prime word processing could extend theories on semantic priming and how words are accessed.

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APPENDIX: EXPERIMENTAL STIMULUS PAIRS

prime	sassoc	sfreq	sfam	fam	imag	qss	freq	target	astrg	freq	sfreq	p-freq	qssc	t-freq
corner	2.91	3.26	4.70	556	556	22	115	street	0.14	244	4.17	H	H	H
face	3.70	3.82	4.87	612	581	20	371	eyes	0.13	394	3.96	H	H	H
land	2.83	3.17	4.74	574	566	25	217	sea	0.18	95	2.35	H	H	H
mouth	4.17	3.61	4.87	572	613	19	103	teeth	0.19	103	3.70	H	H	H
door	3.13	3.78	4.91	630	599	23	312	open	0.18	319	4.04	H	H	H
fight	4.26	3.26	4.61	561	543	24	98	war	0.06	464	2.87	H	H	H
money	4.52	4.74	4.91	631	604	19	265	rich	0.05	74	3.87	H	H	H
nature	4.04	3.26	4.65	535	513	19	191	earth	0.03	150	3.52	H	H	H
M	*3.70*	*3.61*	*4.78*	*583*	*572*	*21*	*209*		*0.12*	*230*	*3.56*			
hair	4.22	4.35	5.00	575	580	19	148	comb	0.15	6	3.43	H	H	L
love	3.74	4.70	4.96	619	569	18	232	kiss	0.06	17	4.22	H	H	L
science	3.70	3.70	4.65	577	423	18	131	biology	0.21	7	3.17	H	H	L
water	4.04	4.70	5.00	641	632	18	442	swim	0.06	15	2.74	H	H	L
doctor	4.39	3.83	4.83	573	600	19	100	nurse	0.38	17	3.09	H	H	L
friend	4.30	4.70	5.00	603	587	22	133	pal	0.09	2	2.35	H	H	L
hall	3.43	3.09	4.74	592	559	19	152	corridor	0.10	17	1.43	H	H	L
secretary	3.48	2.74	4.43	528	563	21	191	boss	0.16	20	3.09	H	H	L
M	*3.92*	*4.36*	*4.90*	*603*	*551*	*18*	*238*		*0.12*	*11*	*3.39*			
station	3.78	1.91	4.39	548	554	10	105	train	0.32	82	2.74	H	L	H
son	4.09	3.43	4.61	607	560	6	166	boy	0.10	242	4.00	H	L	H
summer	4.48	4.35	4.96	612	618	10	134	sun	0.12	112	4.52	H	L	H
round	4.22	2.91	4.65	563	559	7	81	ball	0.16	110	3.30	H	L	H
bridge	3.57	3.04	4.61	561	608	10	98	river	0.20	197	3.52	H	L	H
town	3.00	3.00	4.65	589	553	10	212	country	0.11	324	3.22	H	L	H
winter	4.57	3.70	4.83	615	621	4	83	cold	0.28	171	4.04	H	L	H
young	3.35	4.17	4.96	609	521	9	385	child	0.14	213	4.22	H	L	H

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M	*3.62*	*3.48*	*4.76*	*594*	*576*	*8*	*195*		*0.18*	*226*	*3.75*			
prime	sassoc	sfreq	sfam	fam	imag	qss	freq	target	astren	freq	sfreq	p-freq	qssc	t-freq
feet	4.26	3.96	4.70	611	597	10	183	toes	0.47	19	3.65	H	L	L
hot	4.43	4.35	5.00	607	551	8	130	burn	0.03	15	3.13	H	L	L
stop	4.52	4.74	5.00	563	452	8	153	halt	0.05	10	1.74	H	L	L
thin	4.78	3.87	4.74	570	502	5	92	skinny	0.13	9	4.00	H	L	L
gas	4.57	4.61	4.83	558	532	10	98	fuel	0.15	17	3.48	H	L	L
key	4.35	4.17	4.87	603	618	9	88	lock	0.26	23	3.52	H	L	L
rose	4.09	3.35	4.87	556	623	10	86	thorn	0.05	3	2.22	H	L	L
wife	4.30	3.74	4.61	585	575	8	228	spouse	0.05	3	3.35	H	L	L
M	*4.41*	*4.10*	*4.83*	*582*	*556*	*9*	*132*		*0.15*	*12*	*3.14*			
balloon	3.30	2.57	4.61	520	583	21	10	air	0.19	257	3.74	L	H	H
marry	4.30	3.74	4.65	557	523	21	18	husband	0.06	131	3.65	L	H	H
smash	3.83	2.26	4.35	536	518	20	4	break	0.18	88	3.65	L	H	H
stain	2.65	2.78	4.61	534	533	24	6	clothes	0.04	89	4.74	L	H	H
bean	3.39	3.13	4.61	549	538	19	5	green	0.15	116	3.65	L	H	H
poison	3.65	2.61	4.65	504	513	18	10	death	0.32	277	3.26	L	H	H
singer	4.13	3.96	4.83	548	575	20	10	music	0.11	216	4.78	L	H	H
tunnel	3.68	2.13	4.39	541	578	18	10	dark	0.25	185	4.26	L	H	H
M	*3.62*	*2.90*	*4.59*	*536*	*545*	*20*	*9*		*0.16*	*170*	*3.97*			
jewel	4.09	2.48	4.26	519	621	20	1	diamond	0.35	8	3.26	L	H	L
pants	3.83	4.65	5.00	575	630	22	9	jeans	0.14	1	4.70	L	H	L
rope	3.22	2.30	4.70	539	596	21	15	string	0.13	9	2.22	L	H	L
monkey	4.04	2.39	4.35	531	588	22	9	ape	0.17	3	2.00	L	H	L
bite	4.13	2.96	4.57	593	553	19	10	chew	0.10	2	3.39	L	H	L
drain	3.22	2.70	4.35	510	540	19	18	clog	0.08	2	2.17	L	H	L
patch	3.61	1.83	4.26	528	529	21	13	fix	0.08	14	3.43	L	H	L
tourist	3.96	2.61	4.43	536	577	25	16	visitor	0.07	13	3.57	L	H	L
M	*3.76*	*2.74*	*4.49*	*541*	*579*	*21*	*11*		*0.14*	*7*	*3.09*			

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prime	sassoc	sfreq	sfam	fam	imag	qss	freq	target	astren	freq	sfreq	p-freq	qssc	t-freq
clock	4.04	4.22	4.91	608	614	7	20	watch	0.09	81	4.43	L	L	H
dentist	3.57	2.83	4.65	563	622	8	12	pain	0.08	88	3.74	L	L	H
sleeve	3.39	2.91	4.52	560	550	10	11	arm	0.26	94	3.78	L	L	H
thumb	4.00	2.70	4.39	601	599	8	10	hand	0.28	431	3.91	L	L	H
crown	3.74	1.61	4.26	531	602	8	19	head	0.08	424	3.70	L	L	H
exit	4.13	3.43	4.74	616	512	8	7	leave	0.28	205	4.13	L	L	H
leaf	4.30	3.22	4.91	556	608	10	12	plant	0.04	116	3.57	L	L	H
tribe	3.61	1.70	3.96	503	515	6	4	group	0.04	390	3.39	L	L	H
M	*3.85*	*2.83*	*4.54*	*567*	*578*	*8*	*12*		*0.14*	*229*	*3.83*			
banker	3.74	2.48	4.26	524	565	9	10	teller	0.13	4	2.48	L	L	L
cigar	3.43	2.17	4.00	536	619	7	10	stink	0.04	3	3.13	L	L	L
mouse	3.91	2.39	4.43	520	615	10	10	rat	0.09	6	2.43	L	L	L
stew	3.35	2.00	4.17	522	587	10	5	soup	0.24	16	2.70	L	L	L
calf	3.09	2.39	4.57	511	565	7	11	thigh	0.05	9	3.22	L	L	L
shiver	4.35	2.04	4.39	517	578	8	4	shake	0.14	17	3.13	L	L	L
toad	3.09	1.96	4.22	516	591	4	4	wart	0.06	11	1.65	L	L	L
yawn	4.52	3.52	4.91	567	545	9	2	sleepy	0.24	6	4.35	L	L	L
M	*3.68*	*2.37*	*4.37*	*527*	*583*	*8*	*7*		*0.12*	*9*	*2.89*			

**sassoc (subjective associativeness); sfreq (subjective frequency); sfam (subjective familiarity); fam (familiarity norm); imag (imageability norm); qss (cue set size norm); freq (frequency norm); astren (associative strength norm); sfreq (subjective frequency); p-freq (prime frequency condition); qssc (cue set size condition); t-freq (target frequency condition)

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VITA

Satomi Imai, native of Japan, obtained her bachelor of arts degree in psychology from Coe College in 1987, a master of arts degree in psychology from Wake Forest University in 1989, and another bachelor's degree in anthropology from Appalachian State University in 1995. Currently, she is a candidate for the degree of Doctor of Philosophy in psychology conferred in May 2001. Her interests include language processes, bilingualism, human memory, and cognitive development.

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DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Satomi Imai

Major Field: Psychology

Title of Dissertation: The Effect of Prime Word Processing on the Semantic Priming Effect

Approved:

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

Date of Examination:

December 15, 2000

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