# SEARCH VERSUS COMPETITION: FACTORS AFFECTING THE PRIME LEXICALITY EFFECT

By

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# DEDICATION

This dissertation is dedicated to the memory of my father, Lorenzo Thomas, my first and greatest mentor.

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# ABSTRACT

The purpose of this dissertation is to investigate the extent to which there is consistent evidence pertaining to the prime lexicality effect. Theoretical claims about the nature of this effect, in which masked nonword form primes produce greater facilitation than word form primes, have been hotly debated in the masked priming literature. Here, there are two major conflicting accounts of visual word recognition to consider. Cascaded activation approaches such as the Interactive Activation model rely on competition between word units to account for word recognition. This view predicts inhibitory effects for word form primes due to competition between word units for the prime and target. In contrast, proponents of the Search Model have maintained that elements in the process of verifying visual input suggest that word primes should produce neither facilitatory nor inhibitory effects during masked presentation.

Evidence that is consistent with both approaches has been reported in the literature. A 1998 study by Forster and Veres looked at long words using a masked lexical decision task and demonstrated strong facilitation from nonword primes and no effect for word primes. A 2006 paper for Davis and Lupker, however, reported that the nonword prime facilitation that they observed using the same task was accompanied by strong word prime inhibition. The presence of this inhibitory effect seems to support the interactive activation account, but it remains unclear why inhibitory effects such as these were not seen in the Forster and Veres work. The present study sought to explore the reliability of the effects that are generated by word form primes. In particular, the

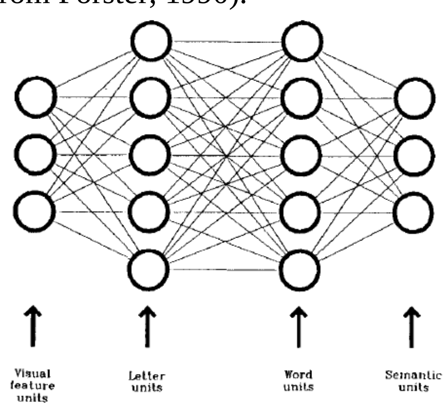
different types of stimuli used in the conflicting papers (i.e. long versus short items) were contrasted. Evaluations regarding their relative discrimination difficulty and performance during masked lexical decision were conducted. The investigation revealed that there is indeed a difference between the output provided by those different stimulus types and that context effects emerge when they are presented together in the same experiment. The implications of these findings for the various views on visual word recognition are discussed.

# CHAPTER 1. INTRODUCTION

## *Differing Accounts of Visual Word Recognition*

The proposed mechanisms by which visual word stimuli are identified and processed have been vigorously contested over the past few decades. Though numerous proposals can be found throughout the word recognition literature, the major division within the field remains between activation-based models and search based models. Activation-based models are based on the notion that neurons only respond to certain types of stimuli. Perhaps the most well-known activation-based account of word recognition is the Interactive Activation model put forth by McClelland and Rumelhart (1981). Here, the processing of lexical information is thought to take place over multiple layers of units in the cognitive system. In the case of visual word recognition, proponents of this theory posit distinct layers of representation for features of letters (e.g. line and curves), individual letter units, and individual word units (see Figure 1).

*Figure 1*. A sample illustration of the interconnectedness of the different levels of representation believed to be involved in visual word recognition in an Interactive Activation account (taken from Forster, 1990).

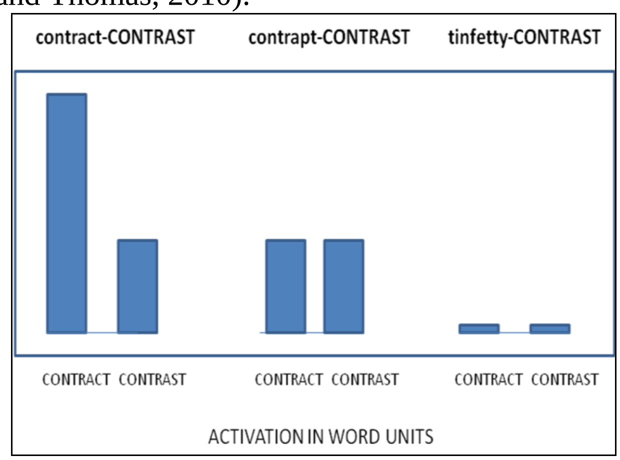


Each node in a given level of representation (e.g. a word or letter) is thought to be represented by neurons or patterns of neurons such that they have a natural "resting level". The nodes within and between levels are said to contain bi-directional connections that can be excitatory or inhibitory, and multiple nodes within a given level of representation can be activated at the same time. When a visual input sends information upstream into the various levels of processing, competition between nodes is believed to arise as both excitatory and inhibitory activation is spread throughout the network. Word recognition, under this scheme, is said to occur when competition between word level representations has been resolved and the node with the highest level of activation has prevailed.

There have been other activation-based models that have been suggested which retain many of the core features of the interactive activation model. For example, The Multiple Read-Out Model (MROM) developed by Grainger and Jacobs (1996) was based on the Interactive Activation model but included a global activation index and deadline time for lexical decision that was intended to better account for responses to lexical stimuli. The Dual-Route Cascaded (DRC) Model is another computational model of reading that incorporates a deadline time into the decision making process (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). Here, both lexical representations and grapheme-to-phoneme correspondences are hypothesized to contribute to the word recognition process. These various computational modeling approaches each make slightly different claims about the nature of lexical decisions.

Despite their differences, the notion of competition as a prerequisite for identification remains a fundamental assumption of activation-based models. One clear implication from any model using competition is that words should always be less effective as masked form primes than nonwords. This is the case because word form primes are thought to have lexical entries encoded as word units, whereas nonword form primes do not. Thus, both types of form primes will generate activation in the word unit associated with the target, but a word form prime will also produce activation in its own word unit, which would then compete with the target representation. This results in a diminished facilitation of the target by the word form prime (see Figure 2 for an illustration).

*Figure 2*. Sample theoretical activation strengths for form primes and their related target (taken from Forster and Thomas, 2010).




An alternative approach to accounting for word recognition can be found with Search Models. In these models, visual input triggers the selection of candidates from the lexicon based on orthographic similarity. A final candidate must be verified for recognition to take place. The search model that has arguably been most pervasive throughout the literature is the “Entry-Opening” Model put forth by Forster (Forster & Davis, 1984). Under this view, the lexicon is thought to be organized on the basis of orthographic information such that fast and efficient search processes are able to scan a large number of alternatives that have been stored in memory. Here, visual stimulation feeds information from the bottom up to the lexical processer. Individual lexical entries must be “opened” before information about the lexical items can be obtained. The processor first elicits orthographically similar candidates for consideration as potential matches to the external stimuli. The lexical entries for these close matches are then opened and submitted for further analysis. The various candidates are then sequentially considered. When a given candidate is eliminated as a potential match, the entry for that candidate is closed. The process of verification continues until an exact match with the visual stimulus is obtained, at which time word recognition is said to have occurred.

For the proponents of the entry-opening model, the potential presence of multiple simultaneously opened lexical entries accounts for the existence of masked priming effects. Under this view, when a target word is preceded by a subliminally presented, orthographically-related word (or nonword), the presentation of the prime word produces candidate lexical entries for the lexical processor to consider. These candidates will have their corresponding lexical entries opened and the entries will remain open while they are being verified. The immediate subsequent presentation of the target stimulus will initiate a new search that generates its own candidate entries. However, since the prime and target are orthographically similar, the entry matching the target will have likely already been opened. This will save the processor time during the verification process, which in turn will facilitate faster recognition of the target (i.e. a priming effect).

The consensus among word recognition models is that multiple candidates are considered during the initial stages of word recognition. The task of proponents of any of these approaches is to provide clear evidence for the extent to which the processing of these candidates should be characterized as involving inhibition-based competition versus search-based operations. These issues can only be resolved by careful examination of the data. In particular, a thorough inspection of the information provided by (masked) priming results may be particularly valuable.

### *Priming Asymmetries*

There is an interesting asymmetry that is observed with priming effects regarding differences that are seen when evaluating form primes in visual word recognition tasks. In priming paradigms, a form prime can refer to a word stimulus or it can consist of a string of letters that is only one letter different from a legitimate word in the language being evaluated. These nonword stimuli typically adhere to the phonographic and orthographic rules of the language such that they could, in theory, represent a word found in the lexicon of the language if they were to be attached to a specific meaning (e.g. ‘baltery’). In recent years, researchers have noted marked differences between the effects seen when using word form primes versus their one-letter different nonword counterparts.

In a 1988 study, Humphreys, Besner, and Quinlan set out to evaluate form priming effects using a perceptual identification task. Here, participants were asked to identify the words that were being flashed on a viewing screen within a given trial during the experiment. Humphreys et al. compared participants' identification performance with related primes when the primes were masked versus clearly visible. They found facilitory priming effects when the primes were masked but obtained no facilitation when the primes were made visible by presenting them for longer durations.

In a related form priming study using a lexical decision task, Veres (1986) also found facilitation when using masked word primes (e.g. *autistic*-ARTISTIC) and no facilitation when the word primes were visible. Veres was also able to collect data using nonword primes. Interestingly, he found an asymmetry in the pattern of results observed with the nonword primes when compared with word primes. Here, nonword primes facilitated performance in both the masked and unmasked conditions. This dissociation between word and nonword priming effects, now known as the prime lexicality effect, indicates that conscious awareness of the prime is not the only factor driving form priming effects. This phenomenon has important implications for the evaluation of varying views on the visual word recognition process.

### *Variable Response Patterns with the Prime Lexicality Effect?*

In a follow-up to the Veres (1986) work, Forster and Veres (1998) sought to further explore the factors affecting the prime lexicality effect, again using the lexical decision task paradigm. Making use of an improved design in which the priming conditions for word and nonword targets were better equated, the researchers investigated the extent to which characteristics of the nonword targets affected the pattern of results observed when comparing word and nonword priming. In four experiments, they contrasted masked and unmasked priming outcomes for word and nonword primes when the experimental trials included either one-letter-different versus two-letter-different nonword distractors (e.g. UNIVORSE versus ANIVORSE). Forster and Veres were only able to obtain a clear prime lexicality effect when one-letter-different distractors were used. Further, the effects observed differed from those observed in the Veres (1986) work. Here, nonword primes always produced more facilitation than word primes independent of whether they were masked (50ms) or unmasked (500ms). When using two-letter different nonword distractors, the prime lexicality effect was disrupted yielding equivalent priming for word and nonword primes.

The authors argue that this new prime lexicality effect pattern emerges as a result of the increased discrimination difficulty that occurs when using one-letter-different nonword targets. These targets more closely resemble actual words of English making the participants' ability to distinguish them from licit English words more challenging. Two-letter-different nonwords, like those used in the original Veres (1986) work, are perceived as being less "wordlike" making the lexical decision easier. This is evident in the overall faster reaction times observed with the two-letter-different nonword condition and the results observed when using the Veres (1986) items.

Forster and Veres go on to speculate about the mechanism by which the alteration of the nonword distractors might influence the configuration of lexicality effects that they observed. They argue that the wordlike nature of the one-letter-different nonword targets may lead to an increased emphasis on (nonconscious) post-access orthographic checking processes by the participants. Recall that in Forster and Davis' (1984) entry-opening model, an orthographically-related prime-target pair will generate two largely overlapping sets of lexical entry candidates. Facilitated recognition of the target is said to result from savings in processing time resulting from the preactivation of lexical entries that were opened during the search that was initiated by the prime. Forster and Veres (1998) suggest that tasks that demand a greater emphasis on post-access orthographic checking may do so by relying on an error correction mechanism that ultimately blocks priming from word form primes. Here, it is suggested that when the lexical processor is faced with a form priming situation involving an orthographically-related word prime, it will encounter two exact matches for what is perceived to be the same visual input. This produces an error signal within the system. Once an error signal is generated, the system is reset and access is attempted once again. When the system is reset, candidate entries that were originally generated by the prime are closed and thus the prime's influence on the target is negated. As a result, word primes under these conditions should not produce facilitation effects. This process allows for the possibility of an inhibitory priming effect, but only if one stipulates that there is a refractory period for recently closed lexical entries that prevents those entries from being opened for some period of time. This potential refractory period would only be relevant for cases involving visible word primes. In cases involving nonword form primes, no exact matches can be generated. As a result, according to this *error correction hypothesis*, nonword primes would not normally succumb to the restart process thus allowing for robust priming effects for this type of stimuli.

Forster and Veres also explored the possibility of individual differences in priming performance. They reasoned that there might be variability in participants' ability to utilize post access-checking in reaction to the presence of one-letter-different distractors. Reduced post-access checking should correspond with both a higher error rate and a lesser prime lexicality effect. A post hoc analysis was conducted on the data pertaining to the masked priming with one-letter-different detractors (Experiment 2). Participants were classified according to error rate by dividing them into "risky" versus "cautious" groups depending on whether their overall error rates were above or below 15%, respectively. Reanalysis of the data revealed that participants in the cautious group displayed data that was consistent with the expected prime lexicality effect while participants in the risky group exhibited roughly equivalent priming for word and nonword primes.

Thus, it appears that cautious participants reset their search apparatuses when an error signal is generated, but only when the task requires high accuracy. Risky subjects, in contrast, seem to ignore the error signals that are generated or generate those signals at a much lower rate. The extent to which these disparate error rate-based performance patterns should be characterized as being a function of cautious responding remains an open question. Forster and Veres did observe faster reaction times for the high error rate group. This would be expected for participants who are placing less emphasis on the accuracy of their responses. Recent work by Andrews and her colleagues (Andrews & Bong, 2009; Andrews & Hersch, 2010; Andrews & Lo, 2011), however, indicate that differences in reading skill can lead to differences in masked priming results. It is possible that these differences in ability could be providing the underlying mechanism behind the differences seen between high and low error rate participants.

The Forster and Veres results indicate that discrimination difficulty and decision-making characteristics of the participant must be added to conscious awareness and lexical status on the list of factors affecting the prime lexicality effect. These varying patterns of results, however, do raise some important questions for proponents of competition-based models of word recognition. Perhaps most notably, one is forced to wonder how such models can account for data that contradict the claim that word primes should always underperform relative to nonword primes.

A 2006 paper by Davis and Lupker looked at issues pertaining to the prime lexicality effect in their attempt to test predictions generated by the interactive activation model. As noted above, the interactive activation model clearly predicts the presence of a strong prime lexicality effect within the context of form priming paradigms. This is because the presence of a form prime should produce facilitatory priming effects due to preactivation of the target on the one hand, while preactivation of the target's competitors should result in inhibitory effects when using orthographically-related word primes on the other. The inhibitory effects from word primes are said to result from the increased competition between word unit candidates and the increased inhibitory signals they produce during the process of resolution. Reacting to the fact that no study using English stimuli had, at that time, been published that found both facilitation from nonword primes and inhibition from word primes, Davis and Lupker set out to demonstrate an inhibitory prime lexicality effect in English. To that end, the authors conducted three masked priming lexical decision experiments, along with computational modeling procedures, making use of stimuli consisting of four and five letter words (e.g. axle/ible-ABLE). Using these stimuli, they were able to obtain strong prime lexicality effects that contained both nonword prime facilitation and word prime inhibition. Inhibitory effects were greater when the word prime and the target shared a neighbor and when nonword foils were high in neighborhood density.

These results were interpreted by Davis and Lupker as having provided support for the role of competition in word recognition processes. The results that they obtained, however, qualitatively differ from those found by Forster and Veres (1998). The Forster and Veres work found no inhibitory priming effects. The Forster and Veres' results are also inconsistent with the result patterns that are predicted by newer activation-based models such as Davis' (2010) Spatial Coding Model (see Table 2 in Chapter 3 for predictions from this model). From the results seen in the literature, we can identify at least two separate types of observed prime lexicality effects with masked primes. Type 1 involves strong facilitation with nonword primes and no effects for word primes. Type 2 involves strong nonword prime facilitation as well as strong word prime inhibition. The fact that Davis and Lupker repeatedly found robust inhibition while Forster and Veres did not constitutes a huge discrepancy in the prime lexicality literature. Such a stark difference in results warrants further investigation and explanation.

There are a number of differences between the paradigms employed by Forster and Veres (1998) and Davis and Lupker (2006). First, Davis and Lupker used a slightly longer stimulus onset synchrony (SOA) (i.e. 57ms) than Forster and Davis (50ms).

Additionally, Forster and Veres presented their stimuli using black letters on a white background while Davis and Lupker used white letters on a black background. These differences might produce discrepancies in prime visibility. Further, Davis and Lupker did not provide trial by trial feedback to participants whereas Forster and Veres did. This could result in differences in the nonconscious strategies that were utilized by participants (for example, see Bechara, Damasio, Tranel, & Damasio, 1997). Perhaps the most substantial difference between the two experimental paradigms is with the type of stimuli they used. Forster and Veres used long (8-9 letters) word stimuli while Davis and Lupker exclusively used short (4-5 letters) words. There could be innate differences between these two distinct types of stimuli (e.g. average neighborhood density, number of saccades, etc.) that would produce differential behavior by participants (see Skarratt, McDonald, & Lavidor, 2008). Given the ramifications of the presence of inhibitory priming effects, and the claims about competition that they provoke, the factors leading to these qualitative variations in the type of prime lexicality effect observed cannot be left unexplored.

## *Goals*

The questions raised above have important implications for the relative appropriateness of different claims about the mechanisms underlying orthographic processing. Davis and Lupker's (2006) inhibitory word priming results, if reliable, appear problematic for advocates of search-oriented models of word recognition. If, however, the Forster and Veres (1998) account of the prime lexicality effect is correct, then the dependability of the Davis and Lupker claims fall into question. Given the importance of these issues for various frameworks within the field, the facts in evidence must be verified. As such, the purpose of the work below is to investigate the relevant facts pertaining to the prime lexicality effect in hopes of gaining clarity on the nature of the phenomenon. One specific aim will be to evaluate the extent to which there is or is not evidence for inhibitory effects for masked word primes. Additionally, there will be an attempt to enumerate and clarify the conditions under which the prime lexicality effect is observed. Questions regarding stimulus length and discrimination difficulty will be addressed throughout. Finally, the implications of new evidence for and against various models of visual word recognition models will be explored, as will suggestions for potential future approaches to characterizing the phenomenon.

# CHAPTER 2. LENGTH AND WORDLIKENESS

As noted in Chapter 1, the presence of an inhibitory component in the prime lexicality effect reported by Davis and Lupker (2006) constitutes a stark contrast to the effects obtained by Forster and Veres (1998). In the Forster and Veres work, strong nonword priming was accompanied by a lack of priming from word primes. Davis and Lupker's masked nonword prime results mirrored that of Forster and Veres, but they also found large inhibitory effects in their word prime conditions. The presence of inhibition is an important indicator of the existence of competition-based processes for proponents of activation-based accounts of word recognition. As a result, the apparent disparity between the results obtained by differing camps warrants further attention.

Perhaps the most relevant discrepancy between these two sets of results may reside in the differences between the types of stimuli used. Though both groups used English words and pseudowords as stimuli, the two experiments varied in the length of the specific items that they used. The Forster and Veres work utilized long words that consisted of eight to nine letters. Davis and Lupker, however, used shorter words that had a length of four to five letters. This variation could be significant given that differences in word length can be associated with different lexical characteristics. Shorter words, for example, tend to have higher frequencies of occurrence. They are also more likely to have fewer syllables, fewer morphemes, and a larger neighborhood density than longer words (Skarratt, McDonald, & Lavidor, 2008).

Under most accounts of visual word recognition, a larger neighborhood density for a given prime word should be correlated with a larger number of candidates (or competitors) for the lexical system to consider. The increase in candidates being considered by the lexical processor should then factor into the priming effects observed by mitigating the facilitation of target recognition. For proponents of activation-based accounts, the increased number of candidates would result in greater competition and thus potentially stronger inhibitory forces operating on the entry for the target word. This mitigating (or inhibitory) effect should not be as pronounced for longer words containing fewer neighbors. Thus, it is possible that the differences in the length of the stimuli used in the Forster and Veres (1998) and the Davis and Lupker (2006) papers could be contributing to the variation in the observation of an inhibitory prime lexicality effect.

Additionally, variations in word length might also have an influence on the overall difficulty of the lexical decision task. As was discussed in the Forster and Veres paper, the disruption of masked word priming in their study was attributed to the "close distractor effect" (p. 505). That is, a prime lexicality effect was only observed in the masked priming condition when nonword distractors that closely resembled actual words (i.e. one-letter-different nonwords) were used. The authors reasoned that the greater wordlikeness of the one-letter-different distractors increases the difficulty of the word-nonword discrimination.

Often, the term "wordlikeness" is used to refer to the well-formedness of a letter or sound string with respect to the orthographic or phonological constraints of the language in question (Lupker & Pexman, 2010; Saito, Yoshimura, Itakura, & Lambon

Ralph, 2003). In this case, however, the term wordlike is used more like Stone and Van Orden's (1993) earlier concept of "nonword lexicality" wherein the emphasis is on the nonword's perceived similarity to actual words of English. Forster and Veres argue that for long one-letter different nonwords, their wordlikeness comes from the fact that it is usually obvious which English word the nonword is derived from (e.g. UNIVORSE). This may not be the case for short one-letter-different nonwords (e.g. LELVE). As such, the use of long one-letter-different nonword foils may have the effect of changing the nature of the lexical decision task so that it, in effect, functions more like a misspelling decision task (Forster & O'Connor, 1981). Here, participants are asked to make 'YES' responses to misspelled words (i.e. one-letter-different nonwords) rather than correctly spelled words. From a search model perspective, this task undoubtedly places extra emphasis on the accuracy of a post-access orthographic check. As such, comparing the effects of long and short items using a misspelling decision task may provide useful insights into the extent to which differences in wordlikeness may be affecting prime lexicality effects.

## Experiment 1

The goal of this experiment is to explore the extent to which differences in wordlikeness (as a function of item length) may differentially tax the lexical processor. Here, a misspelling task will be used to evaluate whether discriminating between correctly spelled words and misspelled words is more difficult for short versus long items. If longer misspelled items are more wordlike, then they should be easier to identify as misspelled words than shorter misspelled items. Thus, it was hypothesized that shorter misspelled words would be more often mistaken for nonwords resulting in a higher error rate for those items.

## *Method*

### *Participants*

Thirty-two students at the University of Arizona participated in this experiment. The participants received partial credit towards an introductory psychology course.

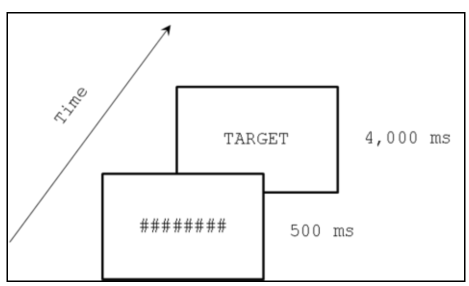
### *Materials and Design*

A total of 120 target items were used. Half of the items were long (8-9 letters) and the other half were short in length (4-5 letters). Items types were broken down into three categories: 60 correctly spelled words, 30 misspelled words (i.e. one-letter-different nonwords), and 30 nonwords (i.e. two-letters-different nonwords). All of the long items were taken from the stimuli used by Forster and Veres (1998). Long correctly spelled words had an average neighborhood density of 18.5 and an average frequency of 1.1 per million. Long misspelled words and nonwords each had an average frequency of 0 and had average neighborhood densities of 1.1 and 0, respectively. Short correctly spelled words and misspelled words were items taken from Davis and Lupker's (2006) Experiment 1. The subset of short correctly spelled words used here had an average neighborhood density of 2.9 and an average frequency of 72.3. Short misspelled words had an average neighborhood density of 3.4 and an average frequency of 0. The Davis and Lupker study did not use short two-letters-different nonwords so those stimuli had to be constructed using the CELEX program such that they matched the average frequency (0) and neighborhood density (0) of their long item counterparts (Baayen, Piepenbrock,, & van Rijn, 1995).

*Procedure*

Each participant was asked to complete a brief Language History Survey before they began the experimental task. After completing the survey, participants entered a sound attenuated room where testing took place. Stimuli were presented as black letters against a white background. Each trial began with a forward mask consisting of a row of hash marks that was presented for 500ms. The forward mask was followed by the presentation of the target, which was shown in upper-case letters for up to 4,000ms or until the subject responded (see Figure 3). The experiment was run on a Pentium PC using DMDX, a windows-based program developed by Forster and Forster (2003).

*Figure 3*. Sample illustration of the item presentation format used in Experiment 1.




The task was a Misspelling Decision task. A block of eighteen practice items was followed by three blocks within which the experimental items were presented in a pseudorandom order. Participants were instructed to think like proofreaders and correctly identify misspelled words, which were defined to them as letter strings that are not words but that would be a valid English word if one letter was changed (e.g. 'ORDAMENT' is a misspelling of the word 'ornament'). If the letter string was a misspelled word, they were to press the 'YES' button. If the letter string was a correctly spelled word (e.g. 'GARAGE') or was a nonword that could not be converted into a word by changing only one letter (e.g. 'FRIGOLIST'), they were to press the 'NO' button. In other words, their job was to identify which targets were one-letter-different nonwords as opposed to legitimate words or two-letters-different nonwords. This is a difficult task and feedback about speed and accuracy was provided after every trial.

*Results*

Given the difficulty of this task, participants were evaluated on the basis of the language proficiency information they provided in the language survey. A total of 8 participants were rejected from inclusion in the study because English was not their first language. The results were analyzed by using linear mixed-effects modeling (Baayen, 2008; Baayen, Davidson, & Bates, 2008; Pinheiro & Bates, 2000). The statistical package R (The R Foundation for Statistical Computing, 2008) was used to perform the calculations. Specifically, the lme4 program was used model fitting (Baayen, et. al., 2008). Incorrect responses were not included in the evaluation of reaction time data. A reciprocal transformation was used on reaction times in order to reduce the marked positive skew typical of reaction times (Kliegl, Masson, & Richter, 2010). The general mixed-effects models that were used were as follows (the total number of observations was 2880): msp.lmer = lmer (invrt ~ len + type + (1 |subj) + (1 |itemN), data=msp); and msperr.lmer = lmer (error ~ len + type + (1 |subj) + (1 |itemN), family=binomial, data=msp).

The mean reaction times and percent error rates for Experiment 1 are presented in Table 1. Evaluation of the overall pattern of results, collapsing short and long items, revealed that reaction times for word targets were significantly faster than nonword and misspelled targets, $t= 9.847$, $p <.001$, and $t= 11.822$, $p < .001$ (respectively). Analysis of error rates, again collapsing short and long items, showed that error rates for nonword targets were higher than they were for misspelled targets, $z= 10.262$, $p < .001$, and word targets, $z= 14.746$, $p < .001$. Error rates for misspelled targets were significantly higher than they were for word targets, $z= 7.604$, $p < .001$. Analyses were further conducted on specific target types in order to directly compare long versus short items. Reaction times were consistently significantly faster for short items than for long items: word targets, $t= 4.516$, $p < .001$; nonword targets, $t= 3.612$, $p < .001$; misspelled targets, $t= 3.141$, $p < .002$. Evaluation of error rates that showed error rates for long word targets were significantly larger than that of short word targets, $z= 2.516$, $p < 05$. Error rates for long misspelled word targets, however, were significantly lower than they were for their short counterparts, $z= 2.466$, $p < .02$. There was no significant difference between the error rates for short and long nonword targets.

Table 1
*Mean reaction times (ms) and percent error rates for word targets as a function of stimuli type for Experiment 1.*

| | | Target Type | | | |
|---|---|---|---|---|---|
| | Correct | Short Words | | Long Words | |
| Item Type | Response | RT | %ER | RT | %ER |
| Misspelled Word | Yes | 1102 | 37.9 | 1208 | 27.4 |
| Nonword | No | 1082 | 59.7 | 1206 | 62.8 |
| Word | No | 833 | 12.5 | 1001 | 16.7 |

*Discussion*

There are marked differences between the reaction time and error rate results for Experiment 1. The reaction time results were not that revealing. As expected, correctly spelled word targets were responded to faster than both misspelled words and two-letters-different nonwords. Reaction times for the two types of nonwords did not differ significantly. Also as expected, reaction times for long items were consistently longer than that of their short item counterparts. The error rate results, however, were a bit more informative. Irrespective of item length, error rates were highest for two-letters-different nonwords. Misspelled word error rates were higher than that of correctly spelled words. When comparing participant performance with long versus short items, two contrasts emerge. First, fewer errors were made identifying short correctly spelled words than long ones. This may simply be reflective of the relatively low frequency of the long words. The second contrast of note is between long and short misspelled words. Participants made significantly more errors identifying short misspelled words. This is consistent with the idea that short one-letter-different nonwords are less wordlike than their long counterparts. The greater number of errors made with those items indicates that discriminating between short words and nonwords is harder than it is with long items. This difference in difficulty of discrimination might help elucidate why Davis and Lupker were able to obtain word prime inhibition while Forster and Veres found no effect.

The error rate results from Experiment 1 suggest that the lesser wordlikeness of short nonword items may tax the lexical processor more than long ones do. This difference might help explain the presence of word prime inhibition seen with short stimuli and the lack of inhibitory effect observed with long stimuli. The error rate discrepancy, however, may not be large enough to fully account for the magnitude of the disparity between word prime effects reported in the literature. Other potential factors, like differences in the modes of presentation used by Forster and Veres compared with that of Davis and Lupker, first need to be ruled out. Experiment 2 was constructed as means of evaluating those potential procedural confounds and is described in Chapter 3.

# CHAPTER 3. LENGTH AND ORDER EFFECTS

The exploration of wordlikeness presented in the previous chapter demonstrates that short and long words may differ in their ability to be quickly differentiated from nonwords of the same length. Given that difficulty of discrimination has been shown to be a key factor in generating a prime lexicality effect, the differences in wordlikeness exhibited by short versus long words may be contributing to the different patterns of prime lexicality effects seen by Forster and Veres (1998) and Davis and Lupker (2006). In particular, the inhibition from word primes seen in Davis and Lupker's work may be a direct effect of their use of short items. One possibility is that interactive activation-based models using competition only predict inhibitory effects with short words. In order to evaluate this issue, a simulation was conducted using the Spatial Coding Model simulator developed by Davis (2010). The parameters for this program were created based on Davis's (1999) self-organizing lexical acquisition and recognition (SOLAR) model, which was an extension of the Interactive Activation model using upgraded orthographic input coding. Items from Experiment 1 were uploaded into the program and reaction times for those targets were simulated. The results of the simulation are presented in Table 2.

Table 2
*Simulated reaction times (ms) for word targets as a function of stimuli type and length for items used in Experiment 1, utilizing the Spatial Coding Model Simulator (Davis, 2010).*

| | Prime Type | | |
|---|---|---|---|
| Item Length | Nonword | Word | Unrelated |
| Long | 86 | 150 | 116 |
| *Priming* | *30* | *-34* | |
| Short | 98 | 158 | 115 |
| *Priming* | *17* | *-43* | |

These modeling results clearly predict strong word prime inhibition for both long and short targets. Those predictions, however, are incompatible with the Forster and Veres word prime data. As mentioned in Chapter 1, there were a number of differences between the procedures used by Forster and Veres in their examination of long words and the procedures used by Davis and Lupker in their studies with short word stimuli. To date, no known study has explicitly compared the prime lexicality effects that are manifested by prime-target pairs of different length. Experiment 2 aims to obtain experimental evidence on the effect of length by directly contrasting the pattern of priming effects observed with short and long words when presented using the same experimental participants and paradigm.

## Experiment 2

The present experiment is designed to distinguish between the types of prime lexicality effects generated by long versus short word stimuli using within-subjects comparisons in a lexical decision task. This approach serves as a more valid means by which to verify and compare the disparate findings observed by Forster and Veres versus

Davis and Lupker. In particular, this experiment is designed to rule out differences between participants and procedures as potential causes for variations in the presence of inhibitory effects with masked form priming. As demonstrated by the modeling results presented above, activation-based accounts clearly predict the presence of priming facilitation with a nonword prime and strong inhibition with a word prime irrespective of word length. According to the Search Model advocated by Forster and Veres, however, the prime lexicality effect should occur only when the importance of post-orthographic checks is emphasized given the nature of the task. If this is the case, differences in priming patterns may be expected when items of different length, and therefore differing levels of discrimination difficulty, are being evaluated. More specifically, the Search Model would predict strong nonword form priming independent of item length and it would predict no priming, but not inhibition, from word form primes.

## *Method*

### *Participants*

Twenty-five students at the University of Arizona took part in this experiment. The participants received partial credit towards their coursework for their participation.

### *Materials and Design*

This experiment consisted of 144 target items. Seventy-two of those targets were long words and nonwords (36 each) that were a subset of the 8-9 letter items used in the Forster and Veres (1998) study. The remaining 72 items were short 5-letter words and nonwords derived from items used in the Davis and Lupker (2006) paper. Nonword targets were one letter different from legitimate words of English (e.g. UMBROLLA). Each word target was assigned three types of primes: 1) a word prime (e.g. junction-FUNCTION), 2) a one-letter-different nonword prime (e.g. bunction-FUNCTION), and 3) an unrelated word prime (e.g. mushroom-FUNCTION).

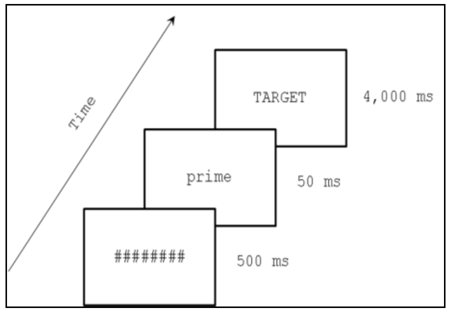
Nonword targets were each assigned the same types of primes except that the nonword primes for these items consisted of two-letters-different nonwords (e.g. unbrolna-UMBROLLA). The short items taken from Davis and Lupker were taken primarily from their Experiment 2, where word primes were consistently higher in frequency than word targets, to maximize the possibility of obtaining inhibitory effects. Since Davis and Lupker did not use nonword primes in that experiment, related one-letter different word primes had to be created for each target. This, however, only provided 24 word target items and 24 nonword target items (and their accompanying primes). In order to get the additional short item targets needed to match the number of long items being used, 12 words and 12 nonwords were taken from the items used in Davis and Lupker's Experiment 1. In some cases, words that had been used as primes had to be switched with their targets in order to maintain the frequency relationship between prime and target that had been established with the items from Davis and Lupker's Experiment 2. In those cases, new nonword primes had to be created so that they were one letter different from the new targets being used. All targets had low-density orthographic neighborhoods. The average number of neighbors for the different prime types were as follows: short words= 3.0 (average frequency= 7.2), short nonwords= 3.4 (average frequency= 0), long words= 1.3 (average frequency= 16.1), long nonwords= 1.1 (average frequency= 0). Twelve additional short and twelve additional long practice items (with equal numbers of word and nonword targets) were constructed in the same manner above.

Three sets of materials were constructed in order to counterbalance the type of prime that was presented with the target. Thus, each target occurred once in all three sets of materials, each time occurring with a different type of prime (i.e. word, nonword, or unrelated word).

*Procedure*

As with Experiment 1, participants completed a brief Language History Survey before taking the experiment in a sound attenuated room. Stimuli were presented in the same manner as that used by Forster and Veres (1998). Items were presented as black letters with a white background. Each trial began with a forward mask that consisted of a row of hash marks being presented for 500ms. This was followed by presentation of the prime, in lower case letters, for 50ms. Finally, the target appeared in uppercase letters and served as a backward mask for the prime. The target was present for 4,000ms or until the participant responded (see Figure 4). As with Experiment 1, the experiment was run on a Pentium PC using DMDX, a windows-based program developed by Forster and Forster (2003).

*Figure 4*. Sample illustration of the item presentation format used in Experiment 2.




The task was a masked lexical decision task. Participants were asked to identify whether or not the letter strings presented in uppercase case letters were words of English by pressing a 'YES' or a 'NO' button. Feedback about the speed and accuracy of their responses was provided after every trial. The experimental stimuli were divided into two blocks, each containing 72 of the target items being evaluated. The first block consisted all of the short target items (word and nonword), with 12 short practice items being presented before the onset of the first block. The short items were presented first and grouped together in order to preserve the item-type consistency used by Davis and Lupker. Block 2 was also preceded by 12 practice items and consisted of all of the long items, preserving the mode of presentation used by Forster and Veres. Given the stimuli used and the style of presentation, Block 2 was essentially designed to be a direct replication of Experiment 2 from the original Forster and Veres work.

*Results*

Linear mixed-effects modeling was used to analyze the results as in Experiment 1. Participants were rejected if their overall error rate exceeded 20% and additional participants were tested to replace them as needed. A total of 7 participants were rejected from this experiment for excessive error rates. Incorrect responses were not included in the analysis of reaction time. Reaction times above 1500ms or below 300ms were rejected (>0.01% of word data and >0.03% of nonword data). A reciprocal transformation was applied to the reaction time values and the general mixed-effects models used for word data were as follows: words.lmer = lmer (invrt ~ prime * length + (1+prime|subj) + (1+prime|itemN), data=words); and wordserr.lmer = lmer (error ~ prime * length + (1+prime|subj) + (1+prime|itemN), family=binomial,data=words).

The mean reaction time and percentage error rates for Experiment 2 are presented in Table 3. Analysis of the short word targets revealed a significant inhibitory effect for word primes, $t$= 2.046, $p < .05$, and surprisingly no effect for nonword primes when compared to the unrelated condition, $t$= .371, $p = .7$. Short word targets also demonstrated a significant inhibitory error rate effect with nonword primes, $z$= 3.758, $p < .001$, and no effect for word primes, $z$= .814, $p = .4$. Long word targets also produced unexpected results, with both nonword primes, $t = 3.547$, $p < .001$, and word primes, $t$= 2.545, $p < .05$, producing strong facilitation. There were no significant effects for long word target error rates. For nonword targets, there was a nearly significant trend towards an inhibitory effect with nonword primes, $z$= 1.864, $p = 0.06$. No other nonword target effects approached significance.

Table 3
*Mean reaction times (ms) and percent error rates for word and nonword targets as a function of stimuli type for Experiment 2.*

| | Target Length | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Short Words (Block1) | | | | Long Words (Block 2) | | | |
| Prime Type | RT | Priming | %ER | Priming | RT | Priming | %ER | Priming |
| Word Targets | | | | | | | | |
| Nonword | 573 | 1 | 9.7 | 1.9*** | 598 | 45*** | 8.3 | -0.9 |
| Word | 597 | -23* | 18.5 | -6.9 | 615 | 28* | 8.3 | -0.9 |
| Unrelated | 574 | | 11.6 | | 643 | | 7.4 | |
| Nonword Targets | | | | | | | | |
| Nonword | 661 | 1 | 18.5 | 3.3 | 713 | 4 | 19.0 | -3.0! |
| Word | 668 | -6 | 17.6 | 4.2 | 718 | -1 | 13.4 | 2.8 |
| Unrelated | 662 | | 21.8 | | 717 | | 16.2 | |

*Note*: *= p < .05, ***= p < .001, != trend.

*Discussion*

The results obtained in this experiment are surprising for both Search Model and Interactive Activation accounts of visual word recognition. Both theories predict the presence of a prime lexicality effect for short and long items, but the specific pattern of facilitation and inhibition effects observed here are inconsistent with either scheme. From an Interactive Activation perspective, a Type 2 Prime Lexicality Effect (PLE) should have been obtained. That is to say that there should have been robust facilitation for nonword primes and robust inhibition for word primes throughout. Though inhibitory effects were observed with short word primes, long word primes produced facilitation. Further, strong nonword form priming was present, but only for long words. Short nonword primes produced neither facilitation nor inhibition.

These results are problematic for Search Model accounts as well. Under a Search Model view, the expected outcome would have been a Type 1 PLE in which there is strong nonword priming and no priming for word primes across both item lengths. Here, we not only have the short word prime inhibition and the lack of short nonword priming mentioned above, but we also have strong priming for both word and nonword primes with the long items. Consequently, it appears that presenting both long and short items to the same participants and using the same experimental design provides mixed support at best for both the Forster and Veres and the Davis and Lupker accounts of word recognition.

Though these results are at least partially incompatible with each of the theories of word recognition being discussed, one common overall relationship persists. Namely, nonword primes consistently outperform word primes. The direction of this relationship is crucial for all views of visual word recognition. The specific manifestations of this relationship (i.e. whether and when facilitation or inhibition should occur), however, may provide the information necessary to determine which account is most representative of actual human lexical processors. It therefore may be beneficial to specify and track additional patterns of priming effects that can be observed. To that end, I will use the term Type 3 Prime Lexicality Effect to refer to result patterns in which there is facilitation from both word and nowords primes, provided that the nonword priming is numerically superior to word priming. Additionally, I will identify result patterns that include inhibitory word priming without facilitory nonword priming as Type 4 Prime Lexicality Effects (see Table 4 for illustration).

Table 4

*Illustration of observed prime lexicality effect (PLE) types as indicated by the presence of facilitation (+) and inhibition (-).*

| PLE Type | Nonword Priming | Word Priming |
|---|---|---|
| Type 1 | + | 0 |
| Type 2 | + | - |
| Type 3 | + | + |
| Type 4 | 0 | - |
| General pattern | Nonword Priming > Word Priming | |

The results obtained here are not only interesting in terms of the conflicts they present for various theories, but also because of the extent to which they do or do not replicate the results seen in the Forster and Veres and the Davis and Lupker papers. As stated above, items of different length were blocked to preserve the presentation format from both studies. Though the lack of nonword priming found in block 1 (with short words) is surprising and contrary to the results Davis and Lupker found using those items, it is possible that the discrepancy can be attributed, in part, to differences in the procedures used (e.g. trial-by-trial feedback, SOA, etc.). The items and mode of presentation for block 2 (long words), however, were virtually identical to the procedure used by Forster and Veres. Thus, there was an expectation that the results from Experiment 2 would constitute a replication of the Forster and Veres findings. Though this was true for nonword primes, it was not so for word primes. Here, we found strong significant priming for word primes. The only noticeable difference between the procedures used was that in this work long words were presented after participants were exposed to a block of short words. This raises the question of the extent to which order of presentation may be affecting the type of prime lexicality effect that occurs when comparing long versus short items. This issue will be explored further in the experiments that follow below.

Given that Forster and Veres found variability among participants in the extent to which they showed a PLE, a similar post hoc evaluation of individual differences was conducted. Subjects that had been excluded from analysis due to their overall high error rates were reincorporated into the subject pool so that participants could be divided into low versus high error rate groups. Participant data with an overall error rate of 15% or lower was assigned to the Low Error Group (N=9). Participant data with an overall error rate of 20% or higher was assigned to the High Error Group (N=7). The mean reaction times and error rates for these analyses are presented in Table 5.

For the Low Error Group, analysis of reaction time data for word targets revealed significant nonword priming for long items, $t= 2.989$, $p < .002$ , and a $p= .09$ trend ($t= 1.664$) towards inhibition for word primes with short items. No other reaction time or error rate comparisons were significant for word targets. When looking at nonword target comparisons, participants in the Low Error Group also exhibited significant priming for word primes with short items, $z= 2.452$, $p < .01$, and for nonword primes with short items, $z= 2.109$, $p < .04$. No other error rate or reaction time comparisons were significant with nonword targets for this group.

The High Error Group demonstrated a very different pattern of results. Here, analysis of word targets only showed significant priming for word primes corresponding to long items, *t*= 2.133, *p* < .05. Significant word target error rate comparisons for this group were only obtained with nonword primes for short items, *z*= 2.319, *p* < .05, and word primes for short items, *z*= 2.077, *p* < .05. No other comparisons reached significance for word or nonword targets with this group.

Table 5
*Reanalysis of reaction times (ms) and percent error rates for word and nonword targets as a function of stimuli type for participants in Experiment 2, classified according to error rates.*

| | Group Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | High Error Group | | | | Low Error Group | | | |
| Prime Type | RT | Priming | %ER | Priming | RT | Priming | %ER | Priming |
| Short Words (Block1) | | | | | | | | |
| Nonword | 546 | 15 | 13.1 | 3.6* | 615 | 5 | 8.3 | 3.7 |
| Word | 538 | 23 | 23.8 | -7.1* | 642 | -22! | 12.0 | 0 |
| Unrelated | 561 | | 16.7 | | 620 | | 12.0 | |
| Long Words (Block 2) | | | | | | | | |
| Nonword | 527 | 29 | 15.5 | -2.4 | 644 | 72** | 4.6 | 0 |
| Word | 514 | 42* | 13.1 | 0 | 695 | 21 | 7.4 | -2.8 |
| Unrelated | 556 | | 13.1 | | 716 | | 4.6 | |
| Short Nonwords (Block1) | | | | | | | | |
| Nonword | 637 | 20 | 19.1 | 2.3 | 707 | 9 | 12.0 | 7.4 |
| Word | 649 | 8 | 25.0 | -3.6 | 737 | -21 | 11.1 | 8.3* |
| Unrelated | 657 | | 21.4 | | 716 | | 19.4 | |
| Long Nonwords (Block 2) | | | | | | | | |
| Nonword | 618 | -19 | 36.9 | -3.6 | 824 | -14 | 14.8 | -2.8 |
| Word | 629 | -30 | 39.3 | 6.0 | 808 | 2 | 7.4 | 4.6* |
| Unrelated | 599 | | 33.3 | | 810 | | 12.0 | |

*Note*: *= p < .05, **= p < .01, != trend

The results of the individual differences analyses are consistent with those of Forster and Veres. Here, participants in the Low Error Group show a robust prime lexicality effect for the reaction times in the long item block. This group also showed a trend towards a Type 3 prime lexicality effect (p < .09 for word prime inhibition) in the short item block.  Participants in the High error group actually showed a reverse pattern, where word primes produced more priming than nonword primes.  Note that the overall reaction times for the Low Error Group are consistently higher than that of the High Error Group.  The results with these small sample breakdowns appear to confirm Forster and Veres' notion that the prime lexicality effect appears when participants are more cautious with their responses.  Participants who exhibit more of a risk-taker approach (e.g by consistently responding more quickly) fail to generate the general prime lexicality pattern that is predicted by both search and interactive activation models.

As was mentioned, the presence of inhibitory word priming with short items provides partial support for the interactive activation approach.  This inhibition is also problematic for Search Models which do not predict inhibition unless the notion of a refractory period is stipulated (see Forster & Veres, 1998, p. 499).  The presence of strong word priming with long items under these task conditions, however, is problematic for both views of word recognition.  The fact that this word facilitation is obtained only for long words is confounded with the fact that this effect was only seen in the second block.  This allows for the possibility that the unexpected prime lexicality effect pattern may be evidence of some sort of learning or fatigue effect.  As a result, Experiment 3 was conducted to investigate this possibility.

## Experiment 3

The blocking strategy used in Experiment 2 produced unexpected patterns of results which warrant further investigation.  In particular, the strong masked word priming that was seen in Block 2 is inconsistent with previous work using the same stimuli. Therefore, Experiment 3 was designed to see if that unusual Type 3 prime lexicality effect would be reproduced if long items were presented at the beginning of the experiment rather than in Block 2. Further, if order effects are factoring into the result patterns seen with these stimuli, changing the presentation order so that short items are encountered last might provide more information about the resiliency of the inhibitory effects seen with short word primes.

Experiment 3 also presented itself as an opportunity to explore online data collection methods. The data for this experiment was collected during a summer session at the University of Arizona in which the subject pool consisted of students taking a web-based Research Methods course. Since a large number of the potential participants were unable to physically come to the laboratory and take the experiment, an online version was constructed and administered. It should be noted that there are potential differences between online and in-person administration of experiments (e.g. participant motivation, time of day/night of participation, testing environment, etc.). It was believed that these potential differences would have a minimal effect on the results at best, especially given that the presentation of stimuli would be controlled by an updated version of the DMDX programming used in the previous experiments. Thus, it was hypothesized that presenting long items in Block 1 should result in a Type 1 prime lexicality effect (i.e. without word prime facilitation) for long items if order effects are involved. There were no specific hypotheses for the effects that would be generated by short items. If order effects were not contributing to the result patterns from Experiment 2, then those patterns should reemerge despite the re-ordering of the blocks.

## *Method*

### *Participants*

Twenty-five undergraduate students in a web-based summer session introductory Research Methods course at the University of Arizona took part in this experiment.

### *Materials and Design*

The materials and experimental task of this experiment were identical to that of Experiment 2.

### *Procedure*

This experiment differed from Experiment 2 in two major ways. First, the order of the presentation blocks was switched such that Block 1 now contained the long items and Block 2 contained the short items. In all other respects, the features of the lexical decision task were the same. A second major change, however, involved the mode of presentation. Whereas Experiment 1 was conducted in a controlled laboratory setting, Experiment 3 was administered online via a University of Arizona website that was hosted by an online Research Methods course. Interested participants were given the web link for the experiment as well as a unique, randomly generated Experiment ID number to use when accessing the experimental materials. Upon accessing the experiment's website, participants were directed through the consenting process and automatically assigned to one of the three counterbalanced materials lists outlined in Experiment 2.

They were also provided written instructions for the task which were the same as in Experiment 2, except as follows. Since participants would be using their own computers, 'YES' responses were to be made by pressing the right control key and 'NO' responses were to be made with the left control key (rather than using the labeled button boxes used in the in-person procedure). The spacebar was used to start the experiment and advance through duplicate instructions that were presented once the experiment began.

To start the experiment, participants were directed to press a link that downloaded an application file containing version 4.0.4.2 of DMDX. The DMDX program was not installed onto the participant's computer. Instead, the program was simply run (enabling the presentation of stimuli), collected and sent the results to a secure server at the end of the experiment, and then deleted itself from the host computer. The participants were required to enter their unique Experiment ID number (rather than their names) before the experiment began. They were also informed that they could abort the session at any time by pressing the escape key. Participants were given course credit from their instructor after completing the experiment and completing an online version of the Language History Survey that included questions about their online experiment experience.

There was one other crucial difference in stimuli presentation between this online experiment and the in-person version from Experiment 2. When used in a laboratory setting, DMDX can be accurately used and monitored to ensure consistent presentation timing via control over display screen refresh rates. This was how an SOA of 50ms was maintained for primes in Experiment 2. Experiment 3 was intended to mimic this 50ms SOA. However, subsequent evaluation of the information submitted from the online records revealed that the online version of DMDX consistently allowed an extra screen refresh such that an SOA of 67ms was generated. By the time this discrepancy had been identified, it was too late to adjust the refresh parameter given the small number of participants available in the online course that served as a subject pool (and the narrow time window allotted to test them). Thus, the prime durations for Experiment 3 were kept at 67ms.

*Results*

Experiment 3 used the same linear mixed-effects modeling procedures and equations that were used in Experiment 2. Here, four subjects were rejected for having overall error rates above the 20% threshold. Less than 0.6% of word data and less than 0.8% of nonword data was lost as a result of data trimming procedures. Reaction time and percentage error rate comparisons are presented in Table 6. Reaction time comparisons only yielded significant results with nonword primes for long word targets, $t = 2.152$, $p < .05$. Error rate comparisons were just shy of significance with nonword primes for long nonword targets, $z = 1.958$, $p = .05$. No other contrasts were significant.

Table 6
*Mean reaction times (ms) and percent error rates for word and nonword targets as a function of stimuli type for Experiment 3.*

| | Target Length | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Long Words (Block1) | | | | Short Words (Block 2) | | | |
| Prime Type | RT | Priming | %ER | Priming | RT | Priming | %ER | Priming |
| Word Targets | | | | | | | | |
| Nonword | 606 | 25* | 9.9 | -1.6 | 612 | 4 | 15.1 | -4.4 |
| Word | 633 | -2 | 8.7 | -0.4 | 623 | -7 | 17.1 | -6.4 |
| Unrelated | 631 | | 8.3 | | 616 | | 10.7 | |
| Nonword Targets | | | | | | | | |
| Nonword | 708 | 3 | 24.2 | -1.6! | 679 | 15 | 21.4 | -4.4 |
| Word | 712 | -1 | 20.2 | -0.4 | 683 | 11 | 17.5 | -6.4 |
| Unrelated | 711 | | 16.3 | | 694 | | 16.7 | |

*Note*: *= p < .05, != trend (p= .05)

As with Experiment 2, an individual differences analysis was conducted on participants with low versus high error rates. Participants were again regrouped according to whether or not they had overall error rates below 15% (N=11) or greater than or equal to 20% (N=8). The results of these analyses are presented in Table 7. No reaction time comparisons for word or nonword targets reached significance for either group after the cutoffs were applied. Evaluation of error rate comparisons revealed negative effects with nonword primes, $z$= 2.689, $p$ < .01, and word primes, $z$= 2.501, $p$ < .05, for long word targets for those in the Low Error Group. There was also a trend towards significance with word prime effects for short word targets in the Low Error Group, $z$= 1.703, $p$ < .09. No other error rate effects were significant.

Table 7

*Reanalysis of reaction times (ms) and percent error rates for word and nonword targets as a function of stimuli type for participants in Experiment 3, classified according to error rates.*

| | Group Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | High Error Group | | | | Low Error Group | | | |
| Prime Type | RT | Priming | %ER | Priming | RT | Priming | %ER | Priming |
| Long Words (Block1) | | | | | | | | |
| Nonword | 549 | 31 | 11.5 | -6.3 | 624 | 13 | 8.3 | -2.2** |
| Word | 565 | 15 | 13.5 | -8.3 | 632 | 5 | 6.8 | -0.7* |
| Unrelated | 580 | | 5.2 | | 637 | | 6.1 | |
| Short Words (Block 2) | | | | | | | | |
| Nonword | 574 | -17 | 16.7 | -3.2 | 611 | 5 | 12.9 | -3.1 |
| Word | 574 | -17 | 20.8 | -7.3 | 626 | -10 | 15.9 | -6.1! |
| Unrelated | 557 | | 13.5 | | 616 | | 9.8 | |
| Long Nonwords (Block1) | | | | | | | | |
| Nonword | 664 | 4 | 29.2 | 2.1 | 709 | 10 | 21.2 | -6.8 |
| Word | 649 | 19 | 28.1 | 3.2 | 716 | 3 | 16.7 | -2.3 |
| Unrelated | 668 | | 31.3 | | 719 | | 14.4 | |
| Short Nonwords (Block 2) | | | | | | | | |
| Nonword | 608 | 27 | 31.3 | 2.0 | 679 | 13 | 12.1 | -0.7 |
| Word | 642 | -8 | 36.5 | -3.2 | 676 | 16 | 11.4 | 0.0 |
| Unrelated | 634 | | 33.3 | | 692 | | 11.4 | |

*Note*: *= p < .05, **= p < .01, != trend

*Discussion*

The results of Experiment 3 are consistent with the notion that order effects may be interacting with prime lexicality effects. Here long items produced strong nonword form priming and word primes produced no significant effect at all. Thus, when long items occurred in the first block, they produced exactly the Type 1 PLE that is predicted by the search model. The results for the short items, however, are much less straightforward. Here, the numerical values somewhat resemble those obtained in Experiment 2, but none of the effects were significant. The evaluation of individual differences revealed virtually the same trends that were seen in Experiment 2. Again the

Low Error Group had slower reaction times and displayed a general prime lexicality effect pattern with word targets as expected (though that numerical pattern was not significant in this case). The High Error Group also seemed to have numerically superior nonword priming for long items in the first block, but their performance with the Block 2 short items showed no distinction between word and nonword primes.

The results for the long items here are consistent with the search model perspective, but the short item results aren't readily explainable from the perspective of any of the major word recognition theories. Could order of presentation account for the lack of effects for short words? Though that remains a possibility, recall that Experiment 3 differed from Experiment 2 in ways other than order of presentation. The current study not only used online data collection, but it used a 67ms SOA as well. This longer prime duration may have allowed the prime to be visible for some participants. This is consistent with work by Ferrand and Grainger (1994) that indicates that orthographic priming effects diminish as the prime duration increases. Further, as was shown in the Forster and Veres (1998) and Veres (1986) studies, form priming patterns can change if participants are consciously aware of the prime. Given these potential confounds, Experiment 4 was conducted to more directly compare the effects demonstrated by items of different length when order of presentation is manipulated.

## Experiment 4

The data from Experiment 3 suggests that there may be a relationship between the type of prime lexicality effect that is exhibited by stimuli of different lengths and the order in which they are presented. Block 2 items, however, once again generated unexpected findings. The current experiment was designed to serve as a retest of Experiment 3; this time using a standard in-person laboratory setup that was identical to the one used in Experiment 2, and which used a 50 ms prime duration. Hence, if order of presentation is not contributing to result patterns, the findings here should mirror what was observed in Experiment 2 despite that fact that long items are being presented first. If order effects are a factor, it was hypothesized that long items would produce the same Type 1 prime lexicality effect that they did in Experiment 3. No clear predictions were made regarding how short items would perform when presented in the second block with a 50ms prime duration.

## *Method*

### *Participants*

Fifty-two students in an introductory psychology class at the University of Arizona took part in this experiment. The participants were given partial course credit for their participation.

### *Materials and Design*

The materials and design of this experiment were identical to that of Experiment 2.

*Procedure*

The instructions to participants and methods of presentation were identical those used in Experiment 2 with one exception. Here, long items were presented in Block 1 and short items were presented in Block 2.

*Results*

The modeling and data trimming procedures used in Experiment 4 were the same as those used in Experiment 2. Twenty participants were rejected from the data analysis for having overall error rates above 20%. Data trimming procedures resulted in a loss of less than 2% of the observations for word target data and less than 3.5% of the observations for nonword target data. The results of these analyses are presented in Table 8. Evaluation of the word target data revealed significant nonword reaction time priming for both long items, $t= 2.291$, $p < .05$, and short items, $t= 3.616$, $p < .001$. Both nonword primes, z= 2.910, $p < .01$, and word primes, $z= 2.052$, $p < .05$, yielded significant error rate effects for long items. With short word targets, only word primes yielded a significant effect, $z= 3.119$, $p < .01$. For nonword targets, only nonword primes for long items approached significance, $t= 1.704$, $p < .09$.

Table 8
*Mean reaction times (ms) and percent error rates for word and nonword targets as a function of stimuli type for Experiment 4.*

| | Target Length | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Long Words (Block1) | | | | Short Words (Block 2) | | | |
| Prime Type | RT | Priming | %ER | Priming | RT | Priming | %ER | Priming |
| Word Targets | | | | | | | | |
| Nonword | 654 | 22* | 6.8 | 4.8** | 627 | 42*** | 15.1 | -4.2 |
| Word | 670 | 6 | 8.1 | 3.4* | 666 | 3 | 19.0 | -8.1** |
| Unrelated | 676 | | 11.5 | | 669 | | 10.9 | |
| Nonword Targets | | | | | | | | |
| Nonword | 729 | 11! | 14.6 | -1.6 | 721 | 13 | 10.4 | -0.5 |
| Word | 736 | 4 | 13.3 | -0.3 | 730 | 4 | 13.3 | -3.4 |
| Unrelated | 740 | | 13.0 | | 734 | | 9.9 | |

*Note*: *= p < .05, **= p < .01, ***= p < .001, != trend

Subjects that had previously been rejected because of their error rates were again reincorporated so that an individual differences analysis could be conducted. As before, participants with less than 15% for their overall error rates comprised the Low Error Group (N=20). Participants were placed in the High Error Group if they had an overall error rate between 20 and 35% (N=18). This new 35% upper limit was added so that participants with error rates near 50% would not distort the subsequent analyses (these rare participants presumably did not understand the instructions for the task). The mean reaction times and percentage error rates for these analyses are presented in Table 9. For the High Error Group, significant nonword priming was obtained for long word targets, $t$= 1.982, $p$ < .05, and a mild trend towards significance was seen with nonword primes for long nonword targets, $t$= 1.729, $p$= .08. No other significant effects were obtained for this group. For the Low Error Group, significant error rate effects were obtained with nonword primes for long word targets, $z$= 2.406, $p$ < .05, and word primes for short word targets, $z$= 4.037, $p$ < .001. Reaction time comparisons for this group revealed only trends with nonword primes for long word targets, $t$= 1.666, $p$= .09, and nonword primes for short word targets, $t$= 1.841, $p$ < .07. No other word target or nonword target effects approached significance for this group.

Table 9

*Reanalysis of reaction times (ms) and percent error rates for word and nonword targets as a function of stimuli type for participants in Experiment 4, classified according to error rates.*

| | Group Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | High Error Group | | | | Low Error Group | | | |
| Prime Type | RT | Priming | %ER | Priming | RT | Priming | %ER | Priming |
| Long Words (Block1) | | | | | | | | |
| Nonword | 536 | 16* | 13.0 | 3.7 | 665 | 20! | 5.0 | 4.2* |
| Word | 556 | -4 | 17.6 | -0.9 | 681 | 4 | 7.1 | 2.1 |
| Unrelated | 552 | | 16.7 | | 685 | | 9.2 | |
| Short Words (Block 2) | | | | | | | | |
| Nonword | 529 | 13 | 24.5 | 2.8 | 666 | 29! | 10.0 | -0.8 |
| Word | 527 | 15 | 25.5 | 1.8 | 696 | -1 | 15.0 | -5.8*** |
| Unrelated | 542 | | 27.3 | | 695 | | 9.2 | |
| Long Nonwords (Block1) | | | | | | | | |
| Nonword | 596 | 21! | 32.4 | 0.0 | 740 | 17 | 12.1 | -3.8 |
| Word | 618 | -1 | 34.7 | -2.3 | 752 | 5 | 9.6 | -1.3 |
| Unrelated | 617 | | 32.4 | | 757 | | 8.3 | |
| Short Nonwords (Block 2) | | | | | | | | |
| Nonword | 583 | -4 | 27.3 | 8.8 | 745 | 18 | 5.8 | -0.4 |
| Word | 584 | -5 | 40.7 | -4.6 | 752 | 11 | 7.5 | -2.1 |
| Unrelated | 579 | | 36.1 | | 763 | | 5.4 | |

*Note*: *= p < .05, ***= p < .001, != trend

*Discussion*

In Experiment 4, robust Type 1 prime lexicality effects were observed for both long and short items. These results are consistent with search model predictions and appear to confirm the notion that the order of stimulus presentation has an effect on the type of prime lexicality effects that are manifested when evaluating items of different length. The results of the individual differences analyses were once again consistent with Forster and Veres's view about cautious versus risky responding. Here, participants in the Low Error Group had longer reaction times and exhibited trends towards Type 1 prime lexicality effects with both word lengths. Those in the High Error group demonstrated a prime lexicality effect in Block one, but showed no difference between word and nonword primes in Block 2. Overall, the results of Experiment 4 are particularly problematic for the Interactive Activation model. No inhibitory effects emerged for word primes with items of either word length. Further, it is not clear how activation-based models (or the Search Model for that matter) can account for the fact that the pattern of results seems to vary with the order of stimulus presentation.

Advocates of the search model have argued that task demands, such as discrimination difficulty, are at the heart of prime lexicality effects. There is now evidence that order of presentation should be listed among those relevant task demands. This raises questions about how and why the blocking procedure is having an impact on the results. Intuitively, the stimuli appearing in the first block should not be affected by the blocking procedure and should perform as they would if they were being presented by themselves. When looking across Experiments 2-4, this seems to be more or less the case. In Experiment 1, when short items were presented first, there was inhibitory priming for word primes and no effect for nonword primes. Though the lack of effect for nonword primes is anomalous (for all known theories), the inhibitory word priming is consistent with the Davis and Lupker studies from which most of those items were taken.

For Experiments 3 and 4, where Block 1 consisted of long items, the Type 1 prime lexicality effects that were observed match up directly with Forster and Veres work that generated those items. The real question, then, is why are unexpected results being produced for items occurring in the second block?

One could argue that the real contrast of interest is between the results from Experiment 2 and Experiment 4. Experiment 3 used a different prime duration and mode of stimulus presentation (i.e. online presentation such that there was no control over things like the type of display screen being used, although most subjects probably used laptops, i.e. LCD screens). Experiments 2 and 4, however, were conducted in exactly the same manner. When comparing these experiments, a couple of themes begin to emerge. First, long items never exhibit significant inhibitory priming. This is contrary to explicit predictions made by competition-based approaches like the spatial coding model mentioned above. Another emergent theme is that, in the case of word primes, inhibitory effects for a given item length seem to get weaker in the second half of the experiment (or conversely, facilitation seems to get stronger). For example, when short items appear in the first block they exhibit inhibitory word priming effects. Those effects disappear when short items appear in Block 2. Word primes for long items produce no effects when presented in the first block, but then produce significant facilitation when presented in Block 2. It appears then that the mechanism for whatever caused short word prime inhibition in Block 1 seems to be weakening as the experiment progresses through time. The experiments discussed in Chapter 4 were designed to investigate the extent to which fatigue and/or habituation might account for the temporal dampening of this inhibitory effect.

# CHAPTER 4. FATIGUE AND HABITUATION

The results of Experiments 2 through 4 demonstrate that order effects need to be taken into account when evaluating the types of prime lexicality effects that are observed with long versus short stimuli. More specifically, when items are presented in the last half of an experiment, the pattern of results is different if they were preceded by items with a different word length. At present it is unclear why this might be the case. There are, however, multiple potential explanations worth considering.

One possibility is that the types of decision-making procedures that are established in the first half of the experiment somehow become less effective for the different stimulus type that is encountered in the second half of the experiment. For example, it may be the case that the criteria that participants use for making their decisions with long items may be different than those used with short items. Thus, subjects may inadvertently continue to use a (nonconscious) strategy that is less efficient for the new type of stimuli being presented in the latter half of the task. A second possibility might be that after being exposed to many trials, participants may simply be getting fatigued. If, as Forster and Veres (1998) argue, prime lexicality effects are contingent upon careful post-access checking, fatigued participants may be becoming less careful towards the end of a long experiment. Fatigue might even be explainable with an interactive activation model approach. From Davis and Lupker's competition-based perspective, fatigue may manifest itself as participants beginning to use a more liberal criterion for their activity thresholds as the experiment goes on (see Davis and Lupker, 2006, p670).

A third, related possibility presents itself when considering Forster and Veres's error correction hypothesis. Recall that under this view, no word form priming is expected because an error signal is generated when orthographically related primes and targets each create candidates that are exact matches for one another. This error signal triggers the lexical processor to reaccess the target, which eliminates any benefits that would have come from the word form prime. If this proposed mechanism is correct, it may be the case that fatigue from a long experiment may manifest itself as habituation to that error signal such that it is ignored in latter stages of the experiment. This would account for the greater word prime facilitation (or lesser inhibition) exhibited by both long and short items when they appear in the second presentation block.

The experiments described in this chapter were constructed to evaluate fatigue and habituation as potential explanations for the order effects that were observed above. Two additional stimulus sets of long items were constructed to serve as Block 1 filler items. Long filler items were presented in the first block so that when the original long items were presented in Block 2, they could be evaluated without having been preceded by short items. This allowed any effects that arise as a function of being presented in the last block to be distinguished from effects that might occur only when long items follow short items. The only difference between the two sets of long filler items is that one had the exact same priming conditions as the long items that have been used thus far, while the other lacked word primes for word filler targets. The latter set of filler items was used to disrupt the possibility of word prime error signal habituation. Long items were used to test these hypotheses for two reasons. First, the result patterns observed with these items have been more consistent than that of the short items used in this study. Second, there are slightly more long words and nonwords that can be generated with the necessary shared neighbor prime specifications that are available for short items. The details of these experiments are described below.

## Experiment 5

The goal of this experiment was to investigate the extent to which the order effects observed with prime lexicality effect patterns can be explained by fatigue. To test this possibility, a block of long filler items was presented before a block of the same long items used in Experiments 2 through 4. Since it is possible that Block 1 error signal habituation could be contributing to Block 2 effects, word primes for word filler targets were removed so that there would be no possibility of an exact match error signal being generated in the first block. Hence, error signal habituation was no longer confounded with simple fatigue. Standard nonword facilitation was expected for the Block 1 filler word targets. Block 2 was expected to produce either a Type 1 or a Type 3 prime lexicality effect. A Type 3 effect with long items in Block 2 would mirror the results from Experiment 2 and would be consistent with fatigue-based account of the order effect. If, however, no word priming is produced in Block 2 and a Type 1 pattern is observed, then simple fatigue can be ruled out as a possible explanation.

## *Method*

### *Participants*

Thirty-seven students at the University of Arizona took part in this experiment and received course credit for their participation.

### *Materials and Design*

The number of targets, conditions, and method of counterbalancing was the same as Experiment 2, with two alterations. Here, the short items that were in Block 1 were replaced with another set of long items. These new long Block 1 filler items were compiled by first adding 12 words and 12 nonwords (8-9 letters long) that were left over from the Forster and Veres (1998) stimuli used to create the Block 2 long items. An additional 15 word target items and an additional 17 nonword target items (one of which was 10 letters long) were taken from stimuli provided by Forster and Veres which had the same design as the stimuli in the present experiment. The remaining 16 long filler items (and practice items) were constructed with the aid of the CELEX program such that Block 1 once again had a total of 72 targets (36 words and 36 nonwords), each with a corresponding related word prime, a related nonword prime, and an unrelated control word prime. Thus, the initial composition of the Block 1 long filler item types was designed to be qualitatively identical to the Block 2 long items that were carried over from Experiment 2. Once this first pass at a filler list was created, word primes for word targets were converted into two-letters-different nonwords to address the possibility of potential error signal generation. Thus, the primes associated with word targets in Block 1 were as follows: a related one-letter different nonword prime, a related two-letters-different nonword prime, and an unrelated control word prime (e.g. ilterval-ilterdal-promptly-INTERVAL).

*Procedure*

The instructions given to participants and methods of presentation were identical to those used in Experiment 2 except that here long filler items were presented in Block 1 (without word primes for word targets) and the original set of long items were presented in Block 2.

*Results*

The modeling and data trimming procedures used in Experiment 5 were the same as those used in Experiment 2. Eleven participants were rejected from the data analysis for having overall error rates above 20%. Data trimming procedures resulted in a loss of less than 0.6% of the observations for word target data and less than 1.6% of the observations for nonword target data. The results of these analyses are presented in Table 10. Somewhat surprisingly, there were no significant effects for reaction times or error rates with the Block 1 filler items. There was significant nonword prime reaction time facilitation for long Block 2 word targets, $t = 2.251$, $p < .05$. There were no other significant comparisons for Block 2 word targets. Block 2 long nonword targets showed significant word prime effects for reaction times, $t = 1.958$, $p = .05$, and error rates, $z = 2.056$, $p < .05$. No other Block 2 nonword effects were significant.

Table 10
*Mean reaction times (ms) and percent error rates (in parentheses) for word and nonword targets as a function of stimuli type for Experiment 5.*

| | Target Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Filler Words (Block1) | | | | Long Words (Block 2) | | | |
| Prime Type | RT | Priming | %ER | Priming | RT | Priming | %ER | Priming |
| Word Targets | | | | | | | | |
| Nonword | 608 | 14 | 7.7 | 4.8 | 620 | 24* | 7.7 | -4.2 |
| 2LD NW | 604 | 18 | 6.7 | 3.4 | ---- | ---- | ---- | ---- |
| Word | ---- | ---- | ---- | ---- | 632 | 12 | 9.6 | -8.1 |
| Unrelated | 622 | | 6.7 | | 644 | | 11.9 | |
| Nonword Targets | | | | | | | | |
| Nonword | 715 | 3 | 15.4 | 1.6 | 734 | -1 | 12.8 | 0.7 |
| Word | 716 | 2 | 17.3 | -0.3 | 704 | 29* | 16.7 | -3.2* |
| Unrelated | 718 | | 17.0 | | 733 | | 13.5 | |

*Note*: *= p < .05

The data from the eleven previously rejected participants was reintroduced for the individual differences analysis. The Low Error Group (error rate < 15%) contained 18 participants and the High Error Group (20%<error rate<35%) contained 11 participants. Table 11 presents the data from these analyses. For the Low Error Group, the only significant reaction time comparison was with the facilitation observed for nonword primes for Block 2 long word targets, $t$= 2.042, $p$ < .05. This group also demonstrated significant inhibitory error rate effects for word primes with nonword targets in Block 2, $z$= 2.881, $p$ < .01, and a trend towards inhibitory error rate effects for word primes with Block 1 nonword targets, $z$= 1.876, $p$ = .06. No other error rate comparisons approached significance for this group. No reaction time differences were significant for the High Error Group. The only significant error rate results for this group were for nonword primes, $z$= 2.847, $p$ < .01, and word primes, $z$= 3.069, $p$ < .01, with Block 2 word targets.

Table 11

*Reanalysis of reaction times (ms) and percent error rates (in parentheses) for word and nonword targets as a function of stimuli type for participants in Experiment 5, classified according to error rates.*

| | Group Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | High Error Group | | | | Low Error Group | | | |
| Prime Type | RT | Priming | %ER | Priming | RT | Priming | %ER | Priming |
| Filler Word Targets (Block1) | | | | | | | | |
| Nonword | 568 | -24 | 17.4 | 3.1 | 604 | 19 | 7.4 | -0.5 |
| 2LD NW | 561 | -17 | 18.2 | 2.3 | 601 | 22 | 4.2 | 2.7 |
| Unrelated | 544 | | 20.5 | | 623 | | 6.9 | |
| Long Word Targets (Block 2) | | | | | | | | |
| Nonword | 599 | -2 | 12.9 | 10.6** | 625 | 24* | 7.4 | 3.2 |
| Word | 598 | -1 | 13.6 | 9.9** | 638 | 11 | 7.4 | 3.2 |
| Unrelated | 597 | | 23.5 | | 649 | | 10.6 | |
| Filler Nonword Targets (Block1) | | | | | | | | |
| Nonword | 597 | -18 | 31.1 | 2.2 | 721 | -4 | 11.1 | -0.5 |
| Word | 605 | -26 | 41.7 | -8.4 | 718 | -1 | 13.0 | -1.4! |
| Unrelated | 579 | | 33.3 | | 717 | | 11.6 | |
| Long Nonword Targets (Block 2) | | | | | | | | |
| Nonword | 682 | -33 | 34.9 | -4.6 | 725 | -5 | 11.1 | -0.9 |
| Word | 686 | -37 | 36.4 | -6.1 | 707 | 13 | 15.3 | -5.1** |
| Unrelated | 649 | | 30.3 | | 720 | | 10.2 | |

*Note*: *= p < .05, **= p < .01, ***= p < .001, != trend

*Discussion*

Experiment 5 exhibited significant nonword priming and no effect for word primes in the second block containing long items. The presence of this Type 1 prime lexicality effect argues against the idea that simple fatigue is responsible for the order effects observed in Chapter 3. This experiment also provided a somewhat surprising result for Block 1 filler items. Here, no nonword prime facilitation was observed. This was unexpected given the results established by Forster and Veres (1998) and Veres (1986), where nonword priming was consistently found using similar items. A key difference here, however, was that word primes for word targets were replaced with two-letters-different nonword primes. This had the effect of reducing the proportion of related word pairings within that block. The lack of nonword priming might not be that surprising, then, given previous work that has shown less facilitation when reduced related word pairing proportions were used (Bodner & Masson, 2003; Tweedy, Lapinski, & Schvaneveldt, 1977).

Participants classified according to error rate performed as expected given Forster and Veres's predictions for risky versus cautious responders. Reaction times were consistently higher for those in the Low Error Group. This group was also the one to demonstrate a strong prime lexicality effect with word targets in Block 2. These observations, coupled with the lack of any significant inhibition in this experiment, are more consistent with the search model view than they are with the interactive activation stance on visual word recognition. Still, a lingering question remains. Namely, what are the circumstances that can account for the disruption that prime lexicality patterns encounter when occurring in the second half of an experiment? The current experiment did not produce a Type 3 prime lexicality effect for Block 2 long items when following a block of long filler items. This filler block, however, did not contain word primes for word targets. If it had, habituation to the error signal proposed by Forster and Veres might have resulted in the same Type 3 effects observed in Experiment 2. Experiment 6 was conducted to explore this possibility.

# Experiment 6

The strong Type 1 prime lexicality effect observed in Block 2 of the previous experiment suggests that the order effects obtained in Experiments 2 through 4 cannot be attributed to simple fatigue. The results from Experiment 5, however, were obtained with stimuli in Block 1 that did not contain word primes for word targets. This variation might account for why a Type 3 prime lexicality effect was not observed with Block 2 long items as it had been in Experiment 2. This might be the case because, according to Forster and Veres, word primes paired with word targets produce error signals within the lexical processor. These error signals trigger a system restart that nullifies the form priming advantages that the word primes would have contributed to reaction times. It's possible that the lexical processor might become temporarily desensitized to this signal if it has been repeatedly triggered in rapid succession throughout the course of a long experiment that taxes this error correction mechanism. Thus, word primes for word targets occurring in the first block would be a necessary component of the order effects observed in Chapter 3.

Experiment six was designed to test this *error signal adaptation hypothesis*. This was accomplished by restoring the word primes that had been created (and subsequently replaced with two-letters-different nonwords) during the construction of the Block 1 long filler items used in Experiment 5. With the word prime component restored, it was hypothesized that Block 1 filler items would produce the standard Type 1 prime lexicality effect that occurred for Block 1 items in Experiments 3 and 4. If the error signal adaptation hypothesis is correct, habituation to the error signal should produce a Type 3 prime lexicality effect for long items in Block 2 via enhanced word prime facilitation. Otherwise, a Type 1 pattern would be produced in Block 2 as it was in Experiment 5.

## *Method*

### *Participants*

Twenty-six students at the University of Arizona took part in this experiment and received partial course credit for participating.

### *Materials and Design*

The conditions and design were the same as Experiment 5 except that the Block 1 filler long items were re- adjusted so that they had corresponding shared neighbor word primes for word targets.

### *Procedure*

The instructions and mode of presentation were the same as Experiment 5, except that Block 1 now consisted of long filler items in which word targets were accompanied by word primes in the same way that the Block 2 long items were.

### *Results*

Once again, the modeling and trimming procedures were the same as with Experiment 2. Seven participants were rejected for having overall error rates above 20%. Less than 0.95% of the observations for word target data and less than 1.8% of the observations for nonword target data was lost as a result of the data trimming procedures. The results of these analyses are presented in Table 12. For Block 1 filler items, no reaction time comparisons were significant. Significant error rate effects for these items were seen only for nonword primes with word targets, *z*= 2.106, *p* < .05, and word primes with nonword targets, *z*= 2.418, *p* < .05. For Block 2 long items, only nonword prime reaction times produced a significant effect, *t*= 2.278, *p* < .05. Nonword primes with word targets produced a trend towards significance, *z*= 1.743, *p*= .08.

Table 12
*Mean reaction times (ms) and percent error rates (in parentheses) for word and nonword targets as a function of stimuli type for Experiment 6.*

| | Target Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Filler Words (Block1) | | | | Long Words (Block 2) | | | |
| Prime Type | RT | Priming | %ER | Priming | RT | Priming | %ER | Priming |
| Word Targets | | | | | | | | |
| Nonword | 605 | 13 | 7.9 | 4.8* | 622 | 30* | 7.9 | -4.2! |
| Word | 605 | 13 | 7.5 | 3.4 | 644 | 8 | 9.2 | -8.1 |
| Unrelated | 618 | | 5.7 | | 652 | | 7.5 | |
| Nonword Targets | | | | | | | | |
| Nonword | 708 | 28 | 14.0 | 5.3 | 705 | 13 | 16.2 | -1.7 |
| Word | 720 | 16 | 14.9 | 4.4* | 713 | 5 | 13.2 | 1.3 |
| Unrelated | 736 | | 19.3 | | 718 | | 14.5 | |

*Note*: *= p < .05

The previously rejected participants were reincorporated into the data pool for the individual differences analyses. Sixteen participants were included in the Low Error Group (error rate<15%) and six other participants were included in the High Error Group (20%<error rate<35%). Results for these analyses are presented in Table 13. The only significant reaction time comparison for the Low Error Group was with nonword primes for Block 2 long items with word targets, *t*= 2.46, *p* < .05. Evaluation of error rates for this group revealed significant effects for nonword primes, *z*= 2.457, *p* < .05, and word primes, *z*= 1.999, *p* < .05, for Block 1 filler items. There were also trends for significance for nonword primes with Block 1 nonword targets, $z$= 1.714, $p$ = .09, nonword primes with Block 2 long nonword targets, $z$= 1.788, $p$ = .07, and word primes with Block 2 long nonword targets, $z$= 1.713, $p$ = .09.

Table 13

*Reanalysis of reaction times (ms) and percent error rates (in parentheses) for word and nonword targets as a function of stimuli type for participants in Experiment 6, classified according to error rates.*

| | Group Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | High Error Group | | | | Low Error Group | | | |
| Prime Type | RT | Priming | %ER | Priming | RT | Priming | %ER | Priming |
| Filler Word Targets (Block1) | | | | | | | | |
| Nonword | 500 | 13 | 13.9 | 12.8 | 626 | 15 | 6.8 | -1.6* |
| Word | 501 | 12 | 12.5 | -1.4 | 634 | 7 | 7.3 | -2.1* |
| Unrelated | 513 | | 11.1 | | 641 | | 5.2 | |
| Long Word Targets (Block 2) | | | | | | | | |
| Nonword | 536 | 41 | 13.9 | -1.4 | 634 | 40* | 6.3 | 0.5 |
| Word | 552 | 25 | 19.4 | -6.9 | 661 | 13 | 10.4 | -3.6 |
| Unrelated | 577 | | 12.5 | | 674 | | 6.8 | |
| Filler Nonword Targets (Block1) | | | | | | | | |
| Nonword | 601 | 16 | 40.3 | -2.8 | 724 | 29 | 10.9 | 4.7! |
| Word | 627 | -10 | 40.3 | -2.8 | 734 | 19 | 12.0 | 3.6 |
| Unrelated | 617 | | 37.5 | | 753 | | 15.6 | |
| Long Nonword Targets (Block 2) | | | | | | | | |
| Nonword | 642 | -13 | 34.7 | -5.5 | 726 | 12 | 14.1 | -1.1! |
| Word | 631 | -2 | 37.5 | -8.3 | 724 | 14 | 11.5 | 1.5! |
| Unrelated | 629 | | 29.2 | | 738 | | 13.0 | |

*Note*: *= p < .05, != trend

*Discussion*

The second presentation block of Experiment 6 produced a strong Type 1 prime lexicality effect. This result is inconsistent with the predictions from the error rate adaptation hypothesis. It was thought that continued responding to the error signal generated by word primes with word targets in the first block would result in facilitation by word primes in the second block due to the lexical processor beginning to attenuate its responses to that signal. The lack of word priming in Block 1 is evidence that the exact match error signal was indeed produced in Block 1 (if Forster and Veres's account of word recognition is correct). The subsequent lack of word priming in Block 2, then, suggests that some mechanism other than error signal adaptation is responsible for the order effects obtained in Chapter 3.

One concern is that the lack of a prime lexicality effect in Block 1 may have somehow disrupted the proposed habituation process. Recall that a strong Type 1 prime lexicality effect was predicted for Block 1given that the word length and priming conditions were designed to be identical to that of the Block 2 long items. Surprisingly, no nonword priming was observed for Block1 word targets. In fact, nonword and word primes showed identical (nonsignificant) effects whereas the original long items produced a Type 1 pattern when they were presented first. It's possible, then, that there was something different about this set of long filler items such that they were not functioning in a manner that would be conducive to error signal habituation.

Recall that the long filler items were derived from a mixture of items taken from Forster and Veres and additional items that were constructed for these experiments. Note that this experiment required the use of 144 long word and nonword targets, each with three sets of primes that needed to be associated to the target in the right way (i.e. one-letter-different or two-letters-different that the target for related prime conditions). This meant that the pool of potential items that could be used to supplement the original Forster and Veres stimuli was limited at best. Thus, it may be the case that the additional items that were chosen varied in some relevant way. To evaluate this possibility, average frequency and neighborhood density for the long filler items was compared with those values for the Block 2 long items (See Table 14). Additionally, the number and types of affixes for each items set were compared. No appreciable differences were detected.

Table 14
*Comparison of the average frequency and neighborhood density for long versus filler items from Experiment 6.*

Word Targets:

| | Long items: | | Filler items: | |
|---|---|---|---|---|
| | Freq | N | Freq | N |
| TARGET: | 16.0475 | 1.277778 | 19.55333 | 1.527778 |
| NW PRIME: | 0 | 1.111111 | 0 | 2.111111 |
| WORD PRIME: | 13.28611 | 1.611111 | 37.89722 | 1.805556 |
| UNREL PRIME: | 29.13 | 0.083333 | 17.29861 | 0.305556 |

Nonword Targets:

| | Long items: | | Filler items: | |
|---|---|---|---|---|
| | Freq | N | Freq | N |
| NWTARGET: | 0 | 1.055556 | 0 | 1.055556 |
| NW PRIME: | 0 | 0.111111 | 0 | 0.055556 |
| WORD PRIME: | 22.72194 | 0 | 8.868333 | 0.305556 |
| UNREL PRIME: | 10.15028 | 0.111111 | 10.97 | 0.222222 |

It is still unclear why the nonword primes for filler items failed to produce facilitation in Block 1 of this experiment (and Experiment 5). However, a number of themes have remained consistent across the experiments presented in Chapters 3 and 4. Once again, evaluations of individual differences revealed that reaction times for the Low Error Group were higher than for the Higher Error Group in this experiment. Again, the only significant prime lexicality effect came from the Low Error Group. Further, long words never lead to significant inhibitory priming. It also remains apparent that what happens in the first block of these experiments can have an impact on the pattern of priming that emerges in the second block.

The results of Experiment 6 do not appear to confirm the error signal adaptation hypothesis. Given that both fatigue and habituation have been ruled out as possible accounts of the order effects observed in Chapter 3, then only one of the previously discussed potential explanations of order effects still remains. Namely, it is possible that the decision-making procedures that work for one type of stimuli may not be as effective for other types of stimuli. Thus, this lack of transferability may explain why prime lexicality effect patterns vary as a function of the type of stimuli that are presented in earlier blocks within a given experiment. This notion is discussed further in Chapter 5.

# CHAPTER 5. LENGTH AND MIXED STIMULI PRESENTATION

The order effects observed in Experiments 2 through 4 present themselves as an additional factor that needs to be explained when attempting to characterize the nature of prime lexicality effects. Experiments 5 and 6 were attempts at accounting for those order effects by evaluating fatigue and error signal habituation as potential explanations. These hypotheses were disconfirmed by the data that was obtained in those experiments. There was, however, one other potential explanation for the order effects that were exhibited when long and short items were blocked and presented in the same experiment. Namely, it may be the case that participants begin using a type of nonconscious decision making strategy that works well for the stimuli in the first block, but that is not effective in the same way when the stimulus type changes during the second block. This might explain why the same sets of stimuli produce theory-predicted results when they are presented in the first block, but then produce theory-inconsistent result patterns when they occur in Block 2 following items of a different length.

This account of the order effects suggests the question: which nonconscious strategies might the participants be using such that they exhibit differential effectiveness for long versus short items? In answering this question, it may be beneficial to recall some of the insights gleaned from Experiment 1. There, the misspelling decision results confirmed that distinguishing between correctly spelled words and nonwords was more difficult for short items than for long ones. It may therefore be the case that participants adjust their discrimination criteria depending upon the type of stimuli being presented.

This proposed difference in discrimination criteria might even help account for the why Davis and Lupker (2006) found word prime inhibition with their short items while Forster and Veres (1998) found no word prime effect with their long items. Restated, it may not only be lexical feature differences between short and long items that lead to disparate result patterns. The different decision-making criteria that they provoke might also be contributing to the PLE patterns observed.

Forster and Veres already established that differences in discrimination difficulty can disrupt prime lexicality effects patterns (1998). In their studies, word primes produced no effects when “close distractors” (i.e. one-letter-different nonwords) were used. In contrast, word primes produced significant facilitation when more “distant” distractors (i.e. two-letters-different nonwords) were used during lexical decision. If, as Forster and Veres propose, the shift from distant to close distractors increases nonconscious emphasis on post-orthographic checking, a similar sort of shift in emphasis may be occurring when long versus short items are being used. If distinct discrimination criteria are being used when participants are presented with disparate stimulus types in isolation, this may create a situation where transfer effects become relevant when items of varying word length are presented during the same experiment.

One possibility is that participants begin using one type of discrimination criteria in the first block and inadvertently carry over that same approach when a new stimulus type is presented in the second block. For example, if short items are presented first, the greater discrimination difficulty associated with these items may provoke the use of a more strict discrimination criterion than would have been employed for long items. If this stricter criterion is carried over when long items are presented in Block 2, the subsequent discriminations would appear to be much easier by comparison. This might be why the long items that followed Block 1 short items in Experiment 2 showed a result pattern that matches the effects demonstrated when Forster and Veres used distant distractors (i.e. an easier discrimination task).

The existence of variable discrimination criteria for different stimulus conditions also allows for another potential explanation of the order effects observed. In contrast to the notion of carry-over effects, participants may be adjusting their discrimination criteria to accommodate the new stimulus type. That is, rather than using the same criterion from Block 1 or switching to a different stimulus-specific criterion in Block 2, participants may (nonconsiously) be employing a more all-encompassing criterion once an additional stimulus type is introduced into the experiment. Thus, the variant Block 2 result patterns observed in Experiments 2 through 4 may be a consequence of this new, adaptive discrimination criterion. To further investigate these different types of potential context effects, an additional experiment was conducted in which long and short stimuli were presented in a mixed fashion such that both stimulus types occurred in each block.

## Experiment 7

Experiment 7 was conducted to explore the extent to which the simultaneous presentation of long and short items would affect the types of prime lexicality effect patterns that were exhibited by these disparate item types. An assumption that underlies this investigation is that short items will provoke a more strict discrimination criterion than long items given the greater discrimination difficulty associated with those times. If the transfer hypothesis is correct, then the more stringent short item criterion should be used throughout the experiment. If this is the case, short items should manifest the same Block 1 pattern that was seen in Experiment 2. This pattern should be consistent across both blocks. In contrast, long items should exhibit the Type 3 PLE that they exhibited in Block 2 of Experiment 2 given the relative ease of the discrimination of these items in this context. If, however, context effects are best explained by the use of a more all encompassing adaptive discrimination criterion, then both short and long items should exhibit their variant Block 2 patterns (i.e. Type 1 and Type 3, respectively) throughout an experiment using mixed presentation.

## *Method*

### *Participants*

Thirty-four students at the University of Arizona took part in this experiment. The participants were enrolled in an introductory psychology course and received partial course credit for participation.

### *Materials, Design, and Procedure*

The materials, design, and procedure was identical to that of Experiment 2 with the following exception. Long and short items were each divided in half and equally distributed between Blocks 1 and 2. Thus, Block 1 consisted of half of the short items and half of the long items used in Experiment 2. The remaining long and short items were presented in Block 2.

### *Results*

The modeling equations and trimming procedures used were the same as those for Experiment 2. Nine participants had error rates over 20% which resulted in their data being rejected. Data trimming procedures resulted in a loss of less than 1.3% of the observations for word targets and less than 3.8% of the observations for nonword targets. The results of these analyses are presented in Table 15. Evaluation of the long items revealed significant reaction time facilitation for nonword primes, $t$= 2.542, $p < .05$, and word primes, $t$= 2.574, $p < .05$, for word targets. No other long items effects were significant. Analysis of short item comparisons only showed significant effects for reactions for nonword primes with word targets, $t$= 2.437, $p < .05$, and reaction times for nonword primes with nonword targets, $t$= 3.00, $p < .01$.

Table 15
*Mean reaction times (ms) and percent error rates (in parentheses) for word and nonword targets as a function of stimuli type for Experiment 7.*

| | Length Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Long Items (Block 1&2) | | | | Short Items (Block 1&2) | | | |
| Prime Type | RT | Priming | %ER | Priming | RT | Priming | %ER | Priming |
| Word Targets | | | | | | | | |
| Nonword | 623 | 34* | 7.6 | 0.1 | 614 | 24* | 13.0 | 3.7 |
| Word | 635 | 22* | 8.0 | -0.3 | 639 | -1 | 16.3 | 0.4 |
| Unrelated | 657 | | 7.7 | | 638 | | 16.7 | |
| Nonword Targets | | | | | | | | |
| Nonword | 748 | 25 | 21.0 | -1.0 | 695 | 38** | 15.3 | -2.3 |
| Word | 751 | 22 | 23.0 | -3.0 | 728 | 5 | 12.7 | 0.3 |
| Unrelated | 773 | | 20.0 | | 733 | | 13.0 | |

*Note*: *= p < .05, **= p < .01

Rejected participants were reincorporated for the individual differences analyses. This created a Low Error group (error rate<15%) with 16 participants and a High Error Group (20%<error rate<35%) with 8 participants. The results from these analyses are presented in Table 16. The Low Error Group showed significant reaction time facilitation for nonword primes with long word targets, $t$= 2.255, $p < .05$, word primes with long word targets, $t$= 1.974, $p < .05$, and nonword primes with short nonword targets, $t$= 3.11, $p < .01$. A trend was detected in the reaction times for nonword primes with short word targets, $t$= 1.852, $p < .07$. Evaluation of the error rates for the Low Error Group revealed significant word prime effects for long word targets, $z$= 2.783, $p < .01$, and a trend for word primes with short nonword targets, $z$= 1.877, $p = .06$. Analysis of the High Error Group only showed significant reaction time effects for nonword primes with long word targets, $t$= 2.609, $p < .01$, and a trend towards significance for word primes with long word targets, $t= 1.833$, $p < .07$. No other reaction time or error rate effects were significant for this group.

Table 16
*Reanalysis of reaction times (ms) and percent error rates (in parentheses) for word and nonword targets as a function of stimuli type for participants in Experiment 7, classified according to error rates.*

| | Group Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | High Error Group | | | | Low Error Group | | | |
| Prime Type | RT | Priming | %ER | Priming | RT | Priming | %ER | Priming |
| Long Word Targets (Block 1&2) | | | | | | | | |
| Nonword | 516 | 49** | 12.5 | -2.1 | 624 | 41* | 3.7 | 2.6 |
| Word | 527 | 38! | 12.5 | -2.1 | 641 | 24* | 4.7 | 1.6** |
| Unrelated | 565 | | 10.4 | | 665 | | 6.3 | |
| Short Word Targets (Block 1&2) | | | | | | | | |
| Nonword | 523 | 6 | 31.3 | -2.1 | 618 | 24! | 12.5 | 2.6 |
| Word | 545 | -16 | 22.9 | 6.3 | 647 | -5 | 16.7 | -1.6 |
| Unrelated | 529 | | 29.2 | | 642 | | 15.1 | |
| Long Nonword Targets (Block 1&2) | | | | | | | | |
| Nonword | 680 | 28 | 39.6 | -11.5 | 759 | 34 | 16.5 | 0.7 |
| Word | 673 | 15 | 44.8 | -16.7 | 759 | 34 | 16.7 | -4.5 |
| Unrelated | 668 | | 28.1 | | 793 | | 17.2 | |
| Short Nonword Targets (Block 1&2) | | | | | | | | |
| Nonword | 609 | 37 | 17.7 | 5.2 | 702 | 40** | 14.1 | -4.2 |
| Word | 628 | 20 | 30.2 | -7.3 | 729 | 13 | 8.9 | 1.0! |
| Unrelated | 648 | | 22.9 | | 742 | | 9.9 | |

*Note*: *= p < .05, **= p < .01, != trend

The data from Experiment 7 was separated so that a comparison could be made between the results from the first and second presentation blocks. It should be noted that these analyses have less statistical power than the original analysis given that each block has half the number of stimuli. The results of these analyses are presented in Table 17. For Block1, evaluation of the reaction times only revealed significant effects for nonword primes with short nonword targets, $t= 2.187$, $p < .05$, and a trend for nonword primes with short word targets, $t= 1.663$, $p = .09$. Error rate effects for this block were only significant for word primes with long word targets, $z= 2.762$, $p < .01$, and word primes with short nonword targets, $z= 2.304$, $p < .05$. For Block 2, reaction time comparisons were significant for nonword primes with long word targets, $t= 2.486$, $p < .05$, word primes with long word targets, $t= 2.028$, $p < .05$, nonword primes with short word targets, $t= 2.157$, $p < .05$, and nonword primes with short nonword targets, $t= 2.041$, $p < .05$. Error rate comparisons for this block produced only trends towards significance for nonword primes with short word targets, $z= 1.858$, $p < .07$, and nonword primes with short nonword targets, $z= 1.784$, $p < .08$.

Table 17
*Reanalysis of reaction times (ms) and percent error rates for word and nonword targets as a function of stimuli type for participants in Experiment 7, classified according to presentation block.*

| | Block Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Block 1 | | | | Block 2 | | | |
| Prime Type | RT | Priming | %ER | Priming | RT | Priming | %ER | Priming |
| Long Word Targets | | | | | | | | |
| Nonword | 625 | 20 | 5.3 | 4.0 | 621 | 49* | 9.1 | -3.1 |
| Word | 628 | 17 | 6.0 | 3.3** | 641 | 29* | 10.0 | -4.0 |
| Unrelated | 645 | | 9.3 | | 670 | | 6.0 | |
| Short Word Targets | | | | | | | | |
| Nonword | 599 | 28! | 11.3 | 2.0 | 631 | 19* | 14.7 | 5.3! |
| Word | 645 | -18 | 15.3 | -2.0 | 634 | 16 | 17.3 | 2.7 |
| Unrelated | 627 | | 13.3 | | 650 | | 20.0 | |
| Long Nonword Targets | | | | | | | | |
| Nonword | 743 | 28 | 20.7 | -1.4 | 752 | 24 | 21.3 | -1.2 |
| Word | 758 | 13 | 22.0 | -2.7 | 744 | 32 | 24.0 | -3.9 |
| Unrelated | 771 | | 19.3 | | 776 | | 20.1 | |
| Short Nonword Targets | | | | | | | | |
| Nonword | 691 | 34* | 15.3 | -2.6 | 698 | 43* | 15.3 | -2.0! |
| Word | 720 | 5 | 10.7 | -2.0* | 736 | 5 | 14.7 | -1.4 |
| Unrelated | 725 | | 12.7 | | 741 | | 13.3 | |

*Note*: *= p < .05, **= p < .01, != trend

*Discussion*

When collapsing across both blocks of mixed presentation, long items produced facilitation for both word and nonword primes while short items only showed priming with nonword primes. These patterns are identical to the Block 2 patterns observed in Experiments 2 and 4. The story becomes more complicated, however, after evaluation of the effects shown in each block. In Block1, short items exhibit a (nonsignificant) numerical pattern that matches up with the Type 2 PLE predicted by the interactive activation model. These results shift, however, into the Type 1 PLE that was observed for short items in Block 2 of Experiment 4. In contrast, long items here demonstrate a Type 3 PLE in both blocks despite only having demonstrated this pattern in the second block beforehand.

These results aren't consistent with either the transfer or the adaptive criterion hypotheses that were considered at the onset of this experiment. Instead, they seem to support a hybrid theory that is intermediate between the two. In Block 1, participants seem to be using a more stringent discrimination criterion to accommodate short words, making the long item discrimination easier by comparison. Thus, as the transfer hypothesis predicted, short items perform as they would in isolation and long items seem to show the facilitation patterns that they show when easier discrimination tasks are used. In Block 2, however, responses to short items seem to adapt such that inhibitory word priming effects are diminished while long items continue to benefit from the contrast provided by the short items. From a search model perspective, these might be the conditions under which reduced responding to the error signal takes place. Hence, Block 2 results are consistent with the adaptive criterion hypotheses.

The conjunction of these two proposed context effects may help explain all of the results observed in this study. First, the Block 1 trend towards significant nonword priming with short items suggests that the failure to obtain nonword facilitation with short items in Experiment 2 was simply an anomalous result. In addition, the emergence of word priming for the long items in Block 2 of Experiment 2 can now be explained by considering that the discrimination task for these items was made easier once the short item context had been established. The Type 1 PLE exhibited by short items in Block 2 of Experiment 4 can be thought of as the result of a more adaptive criterion being used once it became clear that two different types of stimuli were being presented during that experiment. Additionally, Experiments 5 and 6 may have failed to account for order effects simply because there were no order effects to explain. Rather, context effects were responsible for the disparate prime lexicality effect patterns observed, a fact that was confounded with order of presentation until mixed presentation of stimuli was utilized.

The results of Experiment 7 also confirm some of the themes that have presented themselves throughout this study. Once again, the Low Error Group had longer reaction times than the Higher Error Group and again the Low Error Group was more likely to produce a prime lexicality effect. In addition, it was once again the case that any inhibitory effects observed got weaker as the experiment progressed and that long items never exhibited any significant inhibitory effects at all. Finally, Experiment 7 confirms that the evaluation of differences between the results obtained in distinct presentation blocks is beneficial when assessing prime lexicality effect patterns.

# CHAPTER 6- GENERAL DISCUSSION:

The goal of this study was to investigate conflicting claims about the nature of the prime lexicality effect and to explore the extent to which various models of word recognition can account for the data that has been observed. In particular, clarity was sought regarding the reliability of contradictory claims in the literature about the existence of word prime inhibition with this effect. In Experiment 1, a misspelling decision task was used to assess potential differences in wordlikeness between short stimuli of the sort used by Davis and Lupker (2006) and long stimuli of the sort used by Forster and Veres (1998). The results of that experiment demonstrated that discriminating between short words and nonwords was more difficult than it was for long items, lending credence to the viability of Davis and Lupker’s claims about observing word prime inhibition. Experiment 2 was an attempt to verify the facts in evidence by seeing if the Forster and Veres and the Davis and Lupker results could be replicated when the same method of presentation was used. The results here confirmed the presence of word prime inhibition for short word target items, but they also raised questions about the role of order effects and the impact they may have on prime lexicality effect patterns. Experiments 3 and 4 used a different order of stimulus presentation and confirmed that different PLE patterns are observed depending on which type of stimuli is being used and the order in which different stimulus types are presented. Experiments 5 and 6, which were restricted to long item stimuli, ruled out simple participant fatigue and error signal habituation as potential accounts of the order effects that had been observed. Finally, Experiment 7 utilized mixed stimulus presentation and indicated that context effects, rather than simple order effects, provided a better account of the different PLE patterns that have been reported.

The results collected above illustrate several important points regarding features of the prime lexicality effect. First, though the results patterns shown with short items was more variable than that of long ones, there was evidence of inhibitory word priming for those items. This effect is problematic for search model approaches to word recognition. However, contrary to the predictions of the competition-based models, long items never exhibited significant inhibitory effects with word primes. In addition, whenever inhibition was shown by short items, the inhibitory effects always lessened as the experiment in question progressed. More generally, increases in facilitation were seen in each word target condition in the latter half of the lexical decision experiments. This could be due, in part, to the fact that participants got feedback after each trial as they did in the Forster and Veres work (a feature that was not a part of the Davis and Lupker design). Another reliable finding from this study is that word primes for long word targets never show significant effects when long items are presented first or in isolation, but they always exhibit significant facilitation when they are presented in conjunction with, or are preceded by, short items. This pattern is consistent with the idea that when long items are presented in the context of short items, the more difficult discrimination provided by the latter makes the discrimination of long word stimuli easier by comparison. Finally, analyses of individual differences showed that prime lexicality effects are far more consistent for cautious participants who are slower with their responses and thus make fewer errors.

The insights provided by these results are in large part compatible with Forster and Veres's view that discrimination difficulty is a key factor in the generation of the prime lexicality effect. Difficulty in a discrimination task like lexical decision can be manipulated in many ways. In the Forster and Veres work, close versus distant nonword distractors produced differences in difficulty that affected whether or not a PLE was exhibited. Earlier work by Veres (1986) and Humphreys et al. (1988) has shown that conscious awareness of the prime can disrupt the generation of a PLE. The results of the current study indicate that differences in the word length of the stimuli being used can also alter the difficulty of the discrimination task in ways that affect the type of PLE pattern that is observed. The results here also imply that the stimulus context (e.g. order of stimulus presentation) can create differences in discrimination difficulty that affect PLE patterns.

Factors other than discrimination difficulty can also affect prime lexicality effects. For example, Davis and Lupker (2006) argue that manipulating lexical features such as the relative frequency of the prime-target pairing can influence the magnitude of word prime inhibition shown with short items. The current study verifies Forster and Veres's claim that differences in participants' decision-making characteristics (i.e. whether they are "risky" or "cautious" responders) can affect whether or not prime lexicality effects are observed. Recent work by Andrews and Hersch (2010) has also shown individual differences in the PLE patterns that are detected. Their study found that those who were better spellers exhibited larger inhibitory effects than poor spellers. Those researchers, however, only used stimuli that were 4 to 5 letters long. Thus, it remains the case that inhibitory prime lexicality effects have only been demonstrated when short items were used.

The variable patterns in observed prime lexicality effects present problems for both views of word recognition. For example, in order for the search model to account for inhibitory effects, it would have to stipulate that lexical entries that have been closed down after the restart of the verification process are difficult to reopen for some period of time. This would enable a delay in the benefit from the prime and might account for delayed recognition of the target. The search model does allow for the existence of this type of a refractory period. A refractory period like this, however, should work the same way for both long and short items alike. As mentioned above, long items never demonstrated word prime inhibition. Thus, the addition of a refractory period to the search model can only accommodate the results obtained here if an additional mechanism is proposed that would account for differences between long and short items. For example, it may be the case that closing down and subsequently reopening a large number of lexical entry candidates is more difficult than doing the same for a smaller number of candidates. If so, stimuli with high neighborhood densities, like short items, might take longer to rebound from the system restart and thus show inhibition whereas low-N long stimuli might not. This is just one potential explanation. What is clear is that amendments need to be made to the search model in order to account for the existence of short word prime inhibition.

In the same way that short word prime inhibition is problematic for search models, the lack of long word prime inhibition is problematic for competition-based approaches. Recall that the SOLAR model, which was derived from the interactive activation model, clearly predicts strong word prime inhibition for both long and short items (see Table 2). Those predictions are incommensurate with the long item results obtained in Experiments 2 through 7. Davis and Lupker conceded that they "might indeed have been able to eliminate the inhibition effect entirely" (2006, p. 679) if they had used nonword targets with neighborhood densities as low as those used by Forster and Veres. This concession, however, does not enable their competition-based model to account for the existence of the significant long word prime facilitation that was observed in Experiments 2 and 7. Thus, activation-based accounts also appear to need revision if they are to explain the results obtained in this study.

An additional finding from the current studies is problematic for both of the dominant views on visual word recognition. Namely, it is not clear how either perspective can fully account for the context effects observed in this report. For those adhering to activation-based accounts, it doesn't seem to be the case that competition should able to be turned on and off depending on the type of stimuli being used. It is possible that modeling parameters like activation thresholds can be adjusted, but it is not obvious how such a system would be able to make those adjustment from block to block simply based on the type of stimuli being used. Forster and Veres may be able to account for context effects by appeal to issues related discrimination difficulty. Indeed, initial attempts were made here during the explanation of the results of Experiment 7. For example, an “adaptive discrimination criterion” was suggested to account for the Type 1 PLE found for short items when they follow a block of long item stimuli. This account needs further examination and, even if accurate, more theoretical work needs to be done to describe how such a mechanism might work.

As with most empirical work, this study seems to have answered some questions while raising others. Though context effects clearly seem to be having an effect on PLE patterns, more work needs to be done in clarifying the mechanisms that underlie them. For example, how pronounced do the differences between word length need to be? Would using stimuli with midrange word lengths (e.g. 5-6 letters long) generate different PLE patterns in the presence of long or short items? Other lexical features might affect prime lexicality effect patterns. For instance, it may be informative to investigate the extent to which manipulating factors like the average frequency of neighbors or the neighborhood density of the prime might affect response patterns. Additionally, it is not clear why inhibitory effects diminish (and facilitory effects increase) as the experiments progress in time. One possibility may be that participants are somehow (nonconciously) learning to more effectively use information provided by the prime. This might not be too surprising given that participants were given feedback during these tasks. The result patterns might change if the feedback were not provided (as was the case in the Davis and Lupker studies). The loss of feedback might be particularly disruptive for “cautious” responders who might be taking advantage of that information. Finally, it may be useful to investigate the extent to which “cautious” responding covaries with spelling ability given the work of Andrews and Hersch. It may be the case that poor readers underperform simply because they have underdeveloped lexical representations, or it may be that their poor spelling ability leads them to embark on more "risky" response strategies during a difficult lexical decision task. Though much has been learned about the various conditions that are relevant for prime lexicality effects, future work will be beneficial in clarifying the multifaceted nature of this phenomenon.

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