PROCESSING L2 SCRIPTS IN HIGHLY-PROFICIENT BILINGUALS

by

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ABSTRACT

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This dissertation explores second language (L2) word recognition in different-script bilinguals (i.e., bilinguals whose first language (L1) is written in a different script than their L2). Previous examinations of L2 word recognition in different-script bilinguals have indicated that these bilinguals may deal with L2 orthographic similarities differently compared to L1 speakers and same-script bilinguals. Masked form priming studies testing L1 speakers (e.g., Davis & Lupker, 2006) and same-script L2 speakers (Bijeljac-Babic et al., 1997) have found evidence for a lexical competition mechanism during word recognition, through which formally-similar lexical representations compete for selection by inhibiting each other's activation. Consistent with this lexical competition assumption, these studies have found inhibitory priming effects (slowed recognition of a target word) with formally-similar masked word primes. On the other hand, recognition of L2 words by different-script bilinguals is found to be facilitated, rather than inhibited, by formally-similar masked word primes (Nakayama & Lupker, 2018; Qiao & Forster, 2017). The experiments detailed in this dissertation explore the reason behind this unexpected pattern of L2 form priming effects in different-script bilinguals. Based on the results of highly-proficient Persian-English bilinguals in a series of form priming and translation priming experiments, we propose that, due to being slow at attaining detailed orthographic information from L2 words, different-script bilinguals may need extended exposure to an L2 word in order to differentiate it from formally-similar competitors. However, even with extended time for gathering and processing orthographic information from an L2 word, inhibitory priming does not arise, though facilitation is eliminated. This leads to the conclusion that the operation of lexical competition in L2 word recognition by different-script bilinguals is not identical to L1 word recognition.

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DEDICATION

There is something mysteriously difficult about completing a dissertation. I was lucky to have friends who listened to my complaints and advised me to stop nagging and get back to work. I would like to dedicate this work to all my great friends who made it possible, and who made the value of their friendship obvious to me. I would mention just a few names: Dayi (Reza Rokni), Parham Asgari, Bahar Momeni, Sharmin Afshar, Sama Gharaei, Iya Khelm Price, Mr. (Daniel) Amy, Juliet Huynh, Mr. Chao Chao (Rongchao Tang), and certainly Bargh-o-Baad. Thank you!

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CHAPTER ONE

INTRODUCTION

Delineating the factors that contribute to fluent reading in a second language (L2) is a subject of ongoing inquiry among bilingual language processing and second language acquisition researchers, as well as second language teachers. While early accounts of L2 reading development usually did not differentiate between general L2 proficiency and L2 reading ability, recent research has identified a variety of subskills that interact with one another to determine overall reading abilities in L2 readers (see Koda, 2007 for a review). Importantly, while some fundamental processes related to reading are universal and relevant to any reading experience (Perfetti, 2003, Perfetti & Liu, 2005), other components of reading are language-specific and therefore necessitate developing skills that may not be transferable from one language to the other. In this study, we look at one of the crucial skills involved in L2 reading, namely the ability to recognize individual L2 words. Specifically, we will investigate how dealing with an L2 script (i.e., a script that is different from the first language) may affect L2 word recognition abilities.

The attempt to identify the role of specific processing abilities in L2 reading has been driven by a componential view of reading put forward by Carr and Levy (1990). In contrast to the holistic approaches which treat reading as an indivisible whole (e.g., Goodman, 1967; 1969), the componential view considers reading skill to be a collection of distinct but interrelated capabilities. These two stances lead to opposing views about L2 reading development. Based on a holistic view of reading, the difficulties of reading in an L2 are mainly related to higher-level, top-down processing skills, such as conceptual abilities, utilization of background knowledge and forming processing strategies (e.g., Coady, 1979). Lower-level processing skills (i.e., the ability to extract linguistic information directly from the text without strategic manipulation) were considered to be simply a by-product of general L2 proficiency. A componential approach to reading, on the other hand, emphasizes the importance of building reliable and automatized lower-level L2 processing skills, which would free up cognitive and attentional resources for higher-level comprehension processes (Perfetti & Lesgold, 1977; Shiffrin & Schneider, 1977). In accordance with this view, L2 reading researchers have extensively studied the role of lower-level processing on L2 reading performance (see Nassaji, 2014 for a review).

A foundational lower-level processing skill involved in reading is word recognition -- i.e., the ability to decode the orthographic forms of words in order to retrieve their meanings (Perfetti & Hart, 2001). Research in first language (L1) reading has found a positive correlation between word recognition and reading comprehension abilities (e.g., Perfetti, 1999; Stanovich, 1980), especially when reading is performed in time-constrained settings (e.g., Walczyk, 1995; 2000). Similar correlations between word recognition and reading comprehension have been found in L2 readers (e.g., Inutsuka, 2009; Jeon, 2009; Koda, 1992). Crucially, the important role of word recognition abilities in L2 reading is not limited to lower levels of proficiency -- even when L2 readers are highly proficient, their L2 word recognition abilities can reliably predict their general L2 reading comprehension (Akamatsu, 2003; Favreau & Segalowitz, 1983; Koda, 1992; Nassaji 2003; Nassaji & Geva, 1999; Shiotsu, 2009). Therefore, studying the factors that may contribute to good or poor word recognition skills in L2 readers can have important theoretical implications and methodological applications for L2 reading.

At the core of the cognitive processes required for word recognition is orthographic processing, defined as the ability to form, store and access orthographic representations (Stanovich & West, 1989). Good orthographic processing skills have been shown to make a unique contribution to reading abilities in L1, even when the contribution of related factors such as phonological processing skills is controlled (Barker, Torgesen & Wagner 1992; Cunningham & Stanovich 1990; Cunningham, Perry & Stanovich 2001; Stanovich & West 1989;). The same positive correlation between orthographic processing skills and reading abilities have been found in L2 readers (Chikamatsu, 2006; Haynes & Carr, 1990; Muter & Diethelm, 2001; Nassaji, 2003; Verhoeven, 2000). Therefore, researchers have shown great interest in the factors that may contribute to the development of good or poor L2 orthographic processing skills.

Orthographic processing abilities are believed to develop through extended exposure to the orthographic symbols and their configurations in a certain script (Berninger, 1995). Correspondingly, one factor that appears to affect the development of orthographic processing abilities in the L2 is the extent to which L1 and L2 scripts share the same characteristics. This topic has been addressed mainly by examining L2 orthographic processing skills in different-script bilinguals -- i.e., L2 readers whose L1 uses a different script than their L2 (e.g., Akamatsu, 1999, 2003; Hamada & Koda, 2008; Koda, 2000; Muljani, Koda & Moates, 1998; Wang & Koda, 2005; Wang, Koda, & Perfetti, 2003). Besides their graphic dissimilarity, different scripts may also differ in terms of writing systems -- i.e., what linguistic element each of their orthographic units represents. In an alphabetical writing system (such as the Roman alphabet used in writing English), each orthographic unit represents a phoneme. In logographic systems (such as Chinese and Japanese Kanji) and syllabic systems (such as Japanese Kana), the representational units are, respectively, morphemes and syllables. Neuroimaging studies have shown that reading in different writing systems involves activation of distinct brain networks (Nelson, Liu, Fiez, & Perfetti, 2009; Perfetti & Liu, 2005; Perfetti et al., 2007). Interestingly, the differential patterns of brain activation in L2 readers with a different L1 writing system are maintained even when they reach a high level of reading fluency (e.g., Liu & Perfetti, 2003).

Consistently, different L1 writing system backgrounds are shown to affect the cognitive procedures involved in L2 word recognition in different ways. For example, L2 English readers with an alphabetic L1 background (i.e., the same type of writing system as English) are found to put their main emphasis on phonological decoding of English words, whereas L2 readers with a logographic L1 background pay more attention to the visual forms of English words (Akamatsu, 1999, 2003; Wang et al., 2003). An alphabetic background is also associated with faster and more accurate performance in certain tasks involving English word recognition compared to a logographic L1 background (e.g., Hamada & Koda, 2008; Koda, 2000; Muljani et al., 1998; Wang & Koda, 2005). Also, while certain word recognition components can be transferred from the L1 to facilitate L2 reading in same-script bilinguals, L1 skills are less likely to transfer across different writing systems (e.g., Chikamatsu, 1996, 2006; Fender, 2003; Koda, 1998; Wang, Koda, & Perfetti, 2003).

While the effects of dealing with an L2 script on L2 word recognition abilities have been mainly addressed in terms of the difference between the nature of the orthographic codes in different writing systems, one may wonder if the graphic dissimilarity of L1 and L2 scripts has consequences for L2 word recognition that are independent of the effects of differences in writing systems. Although this topic has received little attention, there is some evidence that even when L1 and L2 use the same type of writing systems, differences in scripts may lead to certain disadvantages in L2 word recognition (Koda, 1990; Holm & Dodd 1996; Fender, 2008).

In order to investigate the consequences of graphic dissimilarity between L1 and L2 scripts, this dissertation examines L2 word recognition in highly-proficient Persian-English bilinguals. Persian is written in the Perso-Arabic script, which, like Roman, is an alphabetic script. However, the alphabet letters in the two scripts are visually distinct (Figure 1), which provides a desirable situation for examining the effects of graphic distance between L1 and L2 scripts without the confounding influence of writing system differences.

Roman and Perso-Arabic scripts are visually distinct.

خط رومی و خط فارسی-عربی از نظر دیداری متفاوت‌اند.

Figure 1. The Graphic Distance between the Roman Script (Used in Writing English) and the Perso-Arabic Script (Used in Writing Persian).

In this dissertation, we focus on a specific aspect of L2 word recognition skills in different-script bilinguals -- i.e., the ability to select the correct lexical representation for a visually presented L2 word from among a set of formally-similar lexical candidates. We will address this topic mainly in the context of psycholinguistic studies that use form priming techniques (to be reviewed in Chapter Two) to investigate how L1 and L2 orthographic forms are represented and processed. Recent research in this area has revealed a different pattern of results in the L2 of different-script bilinguals (Nakayama & Lupker, 2018; Qiao & Forster, 2017) compared to both native speakers (e.g., Davis & Lupker, 2006) and same-script bilinguals (Bijeljac-Babic, Biardeau & Grainger, 1997). Specifically, while evidence has been found that word recognition in native speakers and same-script bilinguals involves a competition between formally-similar lexical representations for selection, different-script bilinguals have shown a different pattern of results in L2 from priming experiments. We will investigate the reason behind this difference between form priming results in different-script bilinguals on the one hand and native speakers and same-script bilinguals on the other.

Chapter Two provides a review of the research on form priming in L1 and L2. In Chapter Three, we present the results of three L2 form priming experiments testing highly-proficient Persian-English bilinguals. Experiment 1 shows that Persian-English bilinguals' recognition of an L2 word (e.g., *beard*) is facilitated by a brief (i.e., 50-ms) presentation of a formally-similar prime (e.g., *bread*). Moreover, this facilitation is not significantly different from a condition where the same target word is preceded by an identical prime (i.e., *beard*). This is while, in the same experiment, native English speakers' recognition of the target words is slowed down by formally-similar primes. These results replicate the findings of previous form priming experiments testing different-script bilinguals – unlike native speakers, and these bilinguals do not show evidence for lexical competition with brief form primes.

Experiment 2 demonstrates that adding a 450-ms processing time after presentation of the 50-ms primes does not change the pattern of results in Experiment 1 – form primes still facilitate recognition of L2 target words as strongly as identical primes. When the duration of the primes is increased to 500-ms in Experiment 3, the facilitatory effect of the form primes is eliminated, although these primes still do not slow down recognition of their targets. Based on these findings, we propose that different-script bilinguals may be slow at gathering orthographic information from L2 words, and therefore may need extended exposure time to an L2 word in order to decode its exact orthographic form.

In Chapter Four, we present the results of two cross-linguistic priming experiments, in which L2 word primes precede their L1 semantic equivalents as target words. Consistent with our conclusions based on Experiments 1-3 (i.e., that different-script bilinguals may not be able to decode briefly-presented L2 words), Persian-English bilinguals do not show any priming effects with masked L2 primes in Experiment 4. When the prime duration is increased to 500 ms in Experiment 5, L2 primes facilitate recognition of their L1 equivalents.

The implications of these findings for development of L2 word recognition skills in different-script bilinguals is explored in Chapter Five. In short, we argue that due to their poor L2 orthographic processing abilities, lexical competition in the L2 of different-script bilinguals may not be as automatic and strong as in the L1.

CHAPTER TWO

FORM PRIMING AND LEXICAL COMPETITION: A LITERATURE REVIEW OF L1 AND L2 STUDIES

Much research in psycholinguistics has been dedicated to visual lexical processing in bilinguals. One area of ongoing debate is whether first language (L1) and second language (L2) word recognition involve the same mechanisms for selecting a word's unique lexical representation. In addition, the consequences of dealing with an L2 script (i.e., a script that is different from the L1, such as the Roman script for L1 Chinese speakers) for representing and processing of L2 words are not fully clear. For instance, some studies have found evidence that accessing the unique lexical representation for a word in the L1 is made possible by a lexical competition mechanism, through which formally-similar lexical representations compete for being selected by inhibiting the activation of one another (e.g., Davis & Lupker, 2006). However, while similar findings have been reported for L2 word recognition in same-script L2 speakers (Bijeljac-Babic et al., 1997), evidence supporting a lexical competition mechanism in the L2 of different-script bilinguals has been nonexistent or weak (Nakayama & Lupker, 2018; Qiao & Forster, 2017). This pattern of findings leaves it unclear whether lexical competition is a mechanism available to both L1 and L2 lexicons, and how differences between L1 and L2 scripts may influence this particular aspect of L2 word recognition.

The studies that have looked into lexical competition in the L2 of different-script bilinguals have tested Chinese-English bilinguals (Qiao & Forster, 2017) and Japanese-English bilinguals (Nakayama & Lupker, 2018). A notable point about these groups of bilinguals is that besides differences in the visual features of their L1 and L2 scripts, they also use different writing systems in their L1 and L2. Chinese uses a logographic writing system, in which each orthographic unit represents a morpheme. Japanese also uses a logographic system (Kanji), as well as a syllabic system (Kana), in which the orthographic units represent syllables. By contrast, English uses the Roman alphabetic system, in which the orthographic units stand for phonemes. Importantly, an L1 writing system background that is different from the L2 is shown to affect L2 word recognition in a number of ways (e.g., Akamatsu, 1999, 2003; Wang et al., 2003). Therefore, it is necessary to test whether the lack of evidence for L2 lexical competition in different-script bilinguals is a consequence of dealing with different L1 and L2 writing systems. Hence, in this dissertation we will investigate whether different-script bilinguals whose L1 and L2 are both alphabetic (in this case, Persian-English bilinguals) would yield the same pattern of L2 lexical competition as Chinese-English and Japanese-English bilinguals previously studied. In particular, we will examine whether any deficiencies of orthographic processing in a less familiar L2 script may be responsible for different-script bilinguals' unexpected performance in the experimental settings commonly used for testing lexical competition.

The idea that word recognition involves a competition between lexical representations is a common assumption in activation-based models of word recognition (e.g., Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981). Such models maintain that the visual word recognition system consists of three levels of orthographic representations, namely a feature level, a letter level and a word level. The representational units or nodes at the feature and letter levels (i.e., the so-called sublexical levels) are, respectively, visual features constituting letter shapes (such as [|], [_] and [/]), and abstract letter forms as well as their relative positions in words. Each node at the word level (i.e., the lexical level) stands for the whole-word orthographic representation of a particular lexical item. The nodes at each level have excitatory and inhibitory connections to the level above them. An excitatory signal to a certain node increases the activation level of that node and hence aids its recognition. Conversely, an inhibitory signal hinders recognition of a certain node by suppressing its activation. When a certain feature node is activated, it sends excitatory signals to the letter nodes that contain that feature, and inhibitory signals to the letter nodes that do not contain that feature. Similarly, an activated letter node excites the words that contain that letter in the same relative letter position and inhibits the words that do not (see Figures 2 and 3). Notably, as postulated in more recent activation-based models (e.g., Davis, 2010), there is some flexibility in encoding letter positions, such that letters may activate the words that contain them, but not necessarily in the exact position that the letters appear.

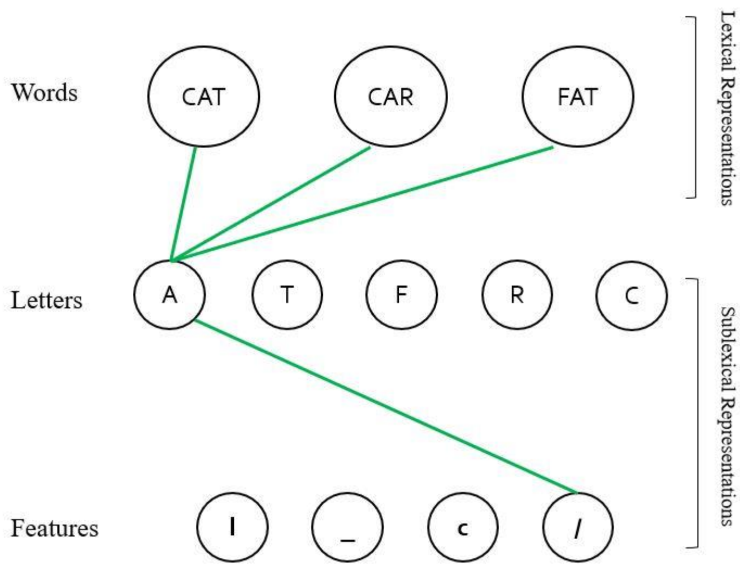

Figure 2. Excitatory Connections (Solid Green Lines) across Orthographic Representational Levels.

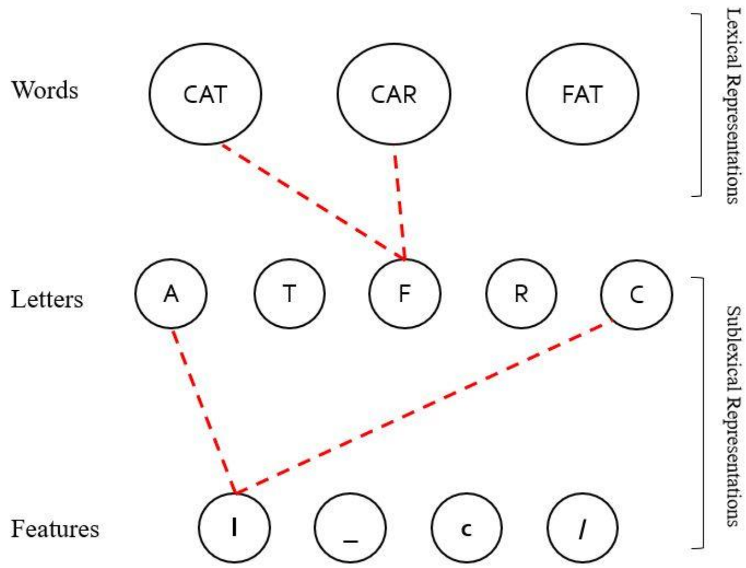

Figure 3. Inhibitory Connections (Broken Red Lines) across Orthographic Representational Levels.

The connections within the letter level as well as the word level are assumed to be inhibitory, such that each activated node at these levels suppresses the activation of other nodes at the same level. The inhibitory process at the word level, by which each activated lexical representation suppresses the activation of its competitors, is referred to as lexical competition (Figure 4). Word recognition takes place when one of the competitors reaches a threshold level of activation.

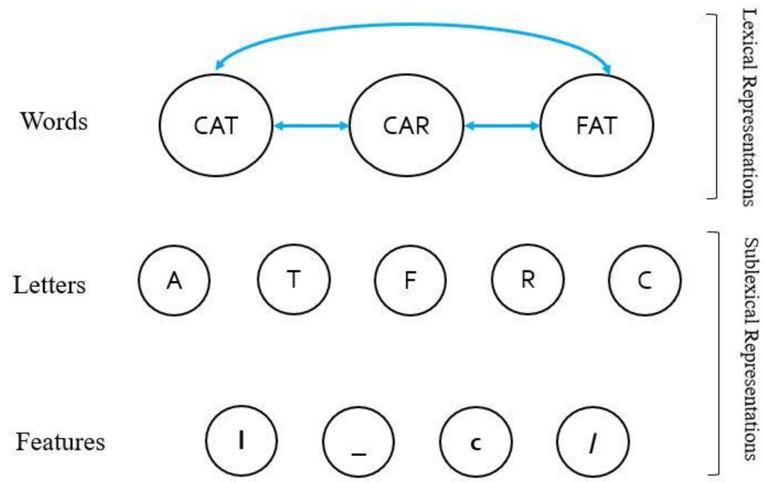

Figure 4. Inhibitory Connections (Blue Arrows) between Lexical Representations.

Consider, for example, when the word recognition system receives the word *cat* as input. At the lowest level, this input activates the feature nodes that constitute the letter shapes in the word. Each activated feature sends excitatory signals to the relevant letter nodes and inhibitory signals to the irrelevant letter nodes. At the letter level, activation of the letter *c* excites the word representations containing this letter (e.g., *cat*, *car*, etc.) while inhibiting activation of the words that do not (e.g., *fat*, *net*, etc.), and these processes continue for the rest of the letters. Finally, at the word level, the lexical representation for *cat* and other partially activated candidates (e.g., words that differ from the stimulus by only one letter, such as *car* or *fat*) compete by inhibiting the activation of one another, until the best candidate reaches its threshold activation level and is selected as the match.

Lexical competition plays a critical role in activation-based models of word recognition (e.g., Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981). As outlined above, a visually presented word initially activates a number of formally-similar lexical representations as candidates for selection. These candidates are activated due to the excitatory signals they receive from the sublexical components they share with the presented word. So, in order for a word (e.g., *cat*) to be correctly identified, its lexical representation needs to be selected from among a set of activated lexical competitors (e.g., *car*, *fat*, etc.). This is made possible through the inhibitory connections between word form representations – since one lexical representation (i.e., *cat*) fully matches the orthographic form of the stimulus, it sends a strong inhibitory signal to its competitors. This lexical competition mechanism allows the correct lexical representation (e.g., *cat* rather than *car*) to reach its threshold activation level by suppressing the activation of other partially activated lexical representations (Davis & Lupker, 2006). Therefore, accurate word recognition requires differentiating the sublexical from of a word from that of closely similar competitors.

The assumption that word recognition involves a lexical competition mechanism is commonly tested through priming experiments. In these experiments, the participants are asked to read the stimuli presented to them, known as targets, when these targets are preceded by other stimuli, known as primes. The primes may be either related, where the prime shares certain features with the target, or unrelated, with prime and target not sharing those features. In repetition priming, the related prime is identical to the target (e.g., *spear-SPEAR*), while in form priming, the related prime may be a word or a nonword with partial form overlap with the prime (e.g., *speak-SPEAR* or *speam-SPEAR*). The participants' performance in each of these related conditions, such as the speed or accuracy of making lexical decisions (i.e., deciding whether the target is a real word or not), is usually compared to an unrelated control condition, where the prime may be a word or nonword unrelated to the target. Depending on the nature of the relationship between the primes and the targets, priming effects may be facilitatory (i.e., speeding up reaction times in related compared to unrelated priming conditions) or inhibitory (i.e., slowing down reaction times in related compared to unrelated priming conditions).

Priming experiments may also differ in terms of visibility of the primes. In unmasked priming, the primes are displayed long enough to be consciously perceived. By contrast, in masked priming (Forster & Davis, 1984), the primes are presented very briefly (e.g., for 50 ms), such that the participants are not consciously aware of seeing any stimulus other than the target. Since the relationship between the masked primes and the targets is not consciously perceived, masked priming effects can be attributed to automatic processing of the masked primes rather than higher-level decision-making strategies (Gomez, Perea & Ratcliff, 2013; but see Bodner Masson, 2001 for an argument regarding the possibility of strategic effects in masked priming).

Research on masked priming generally shows facilitatory effects in word recognition in repetition priming (Bar & Biederman, 1999; Bodner & Masson, 1997; Forster & Davis, 1984; Grainger, Diependaele, Spinelli, Ferrand, & Farioli, 2003; Karayanidis, Andrews, Ward, & McConaghy, 1993), as well as in form priming with nonword primes (Forster, et al., 1987). However, when the prime and the target are formally-similar words such as orthographic neighbors (commonly defined as words that are one letter different from one another, such as *speak-SPEAR*: Coltheart, Davelaar, Jonasson, & Besner, 1977), facilitatory priming effects are commonly absent, both in masked priming (e.g. Davis & Lupker, 2006; Forster & Veres, 1998; Nakayama, Sears, & Lupker, 2008; Qiao & Forster, 2013; Segui & Grainger, 1990) and unmasked priming settings (e.g., Burt, 2009; Colombo, 1986; Massol, Molinaro, & Carreiras, 2015; Segui & Grainger, 1990). Indeed, form priming effects with word primes may even be inhibitory -- i.e., a word prime may slow down recognition of a formally-similar target word. Such inhibitory form priming effects are more likely to emerge in certain priming settings, such as when the prime is higher in frequency than the target, the prime and the target have a large number of shared orthographic neighbors, and the stimuli are relatively short in length (e.g., Davis & Lupker, 2006; Segui & Grainger, 1990). Inhibitory priming effects are usually taken as strong evidence that during word recognition, lexical representations may compete for recognition through inhibiting each other’s activation. When the prime is a real word (e.g., *speak*), it activates a number of lexical candidates (e.g., *speak*, *spear*, *steak*, etc.) as possible matches. But since one lexical representation (namely, *speak*) fully matches the prime, it acts as a strong competitor for the other candidates and pushes down their activation levels. As a result, recognition of a target word that is an orthographic neighbor of the prime (e.g., *SPEAR*) would not be facilitated, and may even be inhibited. Conversely, a nonword prime (e.g., *speam*) is more likely to facilitate recognition of a formally-similar target – since a nonword does not have a lexical representation, it activates a number of lexical candidates due to partial sublexical overlap. But since none of these candidates is a better match for the prime, the target word will not receive strong inhibition from a particular competitor. This account explains why form priming effects are commonly facilitatory with nonword primes, but not with word primes. In other words, the ability of a prime to facilitate recognition of a formally-similar target word can be said to depend on whether its sublexical form is perceived as an exact match to one of the target's lexical competitors.

Recent research in word recognition has focused on whether lexical competition, as outlined above, is a shared property of both L1 and L2 word recognition. Qiao and Forster (2017) propose that L1 and L2 lexicons may work differently in terms of how words are recognized, specifically regarding lexical competition mechanisms. In a masked priming experiment testing native English speakers, these authors found null priming effects with orthographic neighbor primes (e.g., *protect-PROJECT*) (Qiao & Forster, 2013). However, testing Chinese-English bilinguals with the same set of orthographic neighbors, Qiao and Forster (2017) found facilitatory priming effects. This finding sharply contrasts with the assumption that lexical representations compete for being recognized by inhibiting the activation of other lexical candidates. Based on this assumption, a word prime (e.g., *protect*) is expected to activate a strong competitor for its orthographic neighbors and significantly suppress their activation, including activation of the target word (e.g., *PROJECT*). Therefore, contrary to Qiao and Forster's (2017) finding with Chinese-English bilinguals, the priming effects with orthographic neighbors are expected to be inhibitory or null, rather than facilitatory. Qiao and Forster (2017) argue that this difference between the patterns of lexical competition in Chinese-English bilinguals and native English speakers is consistent with the idea that L1 and L2 words may be stored in two distinct memory systems (Jiang & Forster, 2001; Witzel & Forster, 2013). Specifically, these authors suggest that lexical competition mechanisms may be limited to the memory system that L1 words are stored in, and therefore, competition between lexical representations may not occur during recognition of L2 words.

Contrary to Qiao and Forster (2017), Nakayama and Lupker (2018) suggest that lexical competition is a shared property of L1 and L2 word recognition. They point out that Bijeljac-Babic et al. (1997) found evidence for L2 lexical competition in French-English bilinguals, similar to lexical competition effects found in native speakers. Nakayama and Lupker (2018) argue that different-script bilinguals (e.g., Japanese-English or Chinese-English speakers) may simply deal with L2 orthographic similarities differently than L1 speakers and same-script bilinguals (e.g., French-English speakers). Testing highly-proficient Japanese-English bilinguals in a number of L2 orthographic neighbor priming experiments, these authors found evidence for L2 lexical competition, but only when they increased prime durations. When the primes were presented for 67 ms, native English speakers yielded inhibitory priming effects with orthographic neighbor primes (e.g., *city-PITY*), while Japanese-English bilinguals showed facilitatory effects with the same set of orthographic neighbors. These facilitatory priming effects in the Japanese-English bilinguals were observed despite the fact that Nakayama and Lupker (2018) always used higher-frequency neighbors as the primes. Crucially, high-frequency primes are expected to act as strong competitors for their lower-frequency orthographic neighbors, and therefore, inhibitory priming effects are expected to be particularly strong when the prime is more frequent than the target (Davis & Lupker, 2006).

While Nakayama and Lupker (2018) found facilitatory, rather than inhibitory, priming effects with masked L2 orthographic neighbors in Japanese-English bilinguals, they found that the facilitatory L2 neighbor priming effects in Japanese-English bilinguals were eliminated when the prime duration was increased to 175 ms. Interestingly, these authors also found that the same group of Japanese-English bilinguals who did not show any evidence of lexical competition in masked L2 neighbor priming settings yielded significant masked L2-L1 translation priming – i.e., L2 words presented as masked primes significantly facilitated recognition of their L1 semantic equivalents. This finding suggests that these bilinguals were able to select a unique lexical representation as the exact match for a masked L2 prime and access its meaning, which in turn activates the lexical representation for the prime's L1 semantic equivalent. Based on these findings, Nakayama and Lupker (2018) suggest that even though different-script bilinguals can correctly identify masked L2 primes, they may need additional prime processing time and/or conscious appreciation of a formally-similar competitor in order to yield any evidence of lexical competition in their L2.

In summary, results of orthographic neighbor priming experiments with L2 speakers indicate that, unlike L1 speakers and same-script bilinguals, different-script bilinguals' recognition of L2 words is facilitated by masked neighbor primes. These results raise a number of questions about the nature of lexical competition effects in L2 word recognition by different-script bilinguals. First, it remains to be determined what causes the divergent pattern of neighbor priming effects in different-script L2 speakers compared to L1 speakers and same-script bilinguals. Nakayama and Lupker (2018) propose that different-script bilinguals may process L2 orthographic similarities differently than L1 speakers and same-script bilinguals. However, the distinctive characteristic in different-script bilinguals' processing of L2 orthographic similarities that distinguishes these bilinguals from L1 speakers and same-script bilinguals remains to be determined. An important issue to consider is whether the pattern of form priming in different-script bilinguals previously studied (i.e., Chinese-English and Japanese-English bilinguals) results from differences between L1 and L2 writing systems, rather than the fact that the L1 and L2 scripts in these bilinguals are graphically distinct.

Second, it is not clear how the distinctive manner of dealing with L2 orthographic similarities in different-script bilinguals may result in facilitatory masked L2 neighbor priming effects, and how increasing the prime duration leads to elimination of these facilitatory effects (Nakayama & Lupker, 2018: Experiment 6). As mentioned above, Nakayama and Lupker (2018) point out that increased prime processing time and/or conscious awareness of the prime may be needed for different-script bilinguals to show any lexical competition effects in L2 form priming settings. Therefore, further investigation is necessary to determine whether these bilinguals simply need additional processing time to inhibit activation of a masked L2 prime's competitors, or whether conscious awareness of the prime is crucial for any inhibitory effects to emerge.

Finally, Nakayama and Lupker's (2018) unexpected finding regarding masked translation priming needs to be revisited for possible replication. This finding showed that different-script bilinguals may be able to identify a masked L2 prime (as demonstrated by significant L2-L1 translation priming effects) despite the fact that they yield no evidence for lexical competition in masked form priming settings. In terms of activation-based models of word recognition, selecting a unique lexical match for a visually-presented word is only made possible through inhibiting the activation of formally-similar competitors (Davis & Lupker, 2006). Therefore, it is not clear how different-script bilinguals may recognize masked L2 primes even though these primes do not seem to inhibit the activation of their competitors. Hence, in order to better understand the L2 word recognition procedures in different-script bilinguals, we attempt to replicate Nakayama and Lupker's (2018) findings with a different group of bilinguals.

In short, this dissertation explores lexical competition during L2 word recognition in different-script bilinguals in an effort to replicate and provide a better understanding of Qiao and Forster (2017) and Nakayama and Lupker's (2018) results. Specifically, we examine whether the patterns of L2 form priming previously found in different-script bilinguals (i.e., facilitatory priming effects with L2 word primes) can be replicated with highly-proficient Persian-English bilinguals. Crucially, both the L1 and L2 of these bilinguals use alphabetic writing systems, which eliminates the possible role of writing system differences. Furthermore, we implement an alternate form priming design using anagrams rather than orthographic neighbors. In the next chapter, Experiment 1 tests this novel design on native English speakers and Persian-English bilinguals. Since the results essentially replicate the findings of Nakayama and Lupker (2018) and Qiao and Forster (2017), Experiments 2 and 3 then increase processing time and duration of the primes to determine how these factors affect the pattern of L2 form priming effects in different-script bilinguals.

CHAPTER THREE

FORM PRIMING IN AN L2 SCRIPT:

EVIDENCE FROM HIGHLY-PROFICIENT PERSIAN-ENGLISH BILINGUALS

Orthographic neighbor priming experiments have revealed an unexpected pattern of results in different-script bilinguals in comparison with both native speakers and same-script bilinguals. Masked orthographic neighbor priming (e.g., *speak-SPEAR*) with native speakers usually yields null effects (e.g., Forster & Veres, 1998) or, in some cases, inhibitory effects (e.g., Davis & Lupker, 2006), but no facilitatory effects. The same pattern has been found in L2 word recognition by same-script bilinguals (Bijeljac-Babic et al., 1997). The results found with both native speakers and same-script bilinguals are consistent with the idea that, during word recognition, lexical representations compete with one another for selection.

In contrast to native speakers and same-script bilinguals, facilitatory effects have been found in L2 masked orthographic neighbor priming for Chinese-English bilinguals (Qiao & Forster, 2017) and Japanese-English bilinguals (Nakayama & Lupker, 2018). These results have been interpreted in terms of lexical competition in L2 word recognition. Qiao and Forster (2017) suggest that lexical competition may be limited to the L1 lexicon, while Nakayama and Lupker (2018) contend that lexical competition operates in both L1 and L2, but it may not be an automatic mechanism in different-script bilinguals as it is in L1 speakers and different-script bilinguals. With regards to the results of masked form priming experiments, Nakayama and Lupker (2018) suggest that these bilinguals may need additional prime processing time and/or conscious awareness of the prime to show any effects of lexical competition.

The first experiment presented in this chapter examines whether previous findings (i.e., facilitatory L2 form priming in different-script bilinguals) are replicable in bilinguals whose L1 and L2 scripts use the same type of writing system, and when the form priming design uses anagrams rather than orthographic neighbors. Experiments 2 and 3 aim to clarify the role of processing time and consciousness of the prime in the pattern of lexical competition effects in different-script bilinguals by testing whether emergence of these effects simply requires extended time for processing a masked prime (Experiment 2), or whether unmasking the prime (Experiment 3) is necessary for any competition effects to occur.

As reviewed in Chapter Two, previous findings regarding L2 lexical competition in different-script bilinguals have been limited to Chinese-English (Qiao & Forster, 2017) and Japanese-English (Nakayama & Lupker, 2018) speakers. Chinese and Japanese scripts are not only formally dissimilar to English, but also use different types of writing systems than English – unlike English, which uses an alphabetic writing system (i.e., Roman), the Chinese script is logographic, and the Japanese script uses logographic (Kanji) and syllabic (Kana) systems. This raises the question of whether the pattern of results found by Qiao and Forster (2017) and Nakayama and Lupker (2018) were somehow affected by the difference in types of L1 and L2 writing systems in the bilinguals they tested. In order to rule out this possibility, we tested Persian-English bilinguals. Persian is written in Perso-Arabic script, which, like Roman, is an alphabetic writing system. Therefore, if the pattern of masked L2 form priming found in Chinese-English and Japanese-English bilinguals (i.e., facilitatory priming effects with word primes) is generalizable to other types of different-script bilinguals, the same pattern of results would be expected to emerge in Persian-English bilinguals. In order to make sure that possible absence of lexical competition effects does not result from a lack of basic L2 reading proficiency, the participants in the experiments were recruited from a population of highly-proficient L2 speakers.

Besides testing different-script bilinguals whose L1 and L2 both use alphabetic writing systems, we also use a different form priming design than what is commonly used in the literature, in order to increase the chance of witnessing lexical competition effects. This alternate design uses only real words as primes, and anagrams rather than orthographic neighbors as formally-similar words. As mentioned in Chapter Two, lexical competition mechanisms are commonly examined in form priming settings, where orthographic neighbors (i.e. words differing in one letter) are used as formally-similar prime-target pairs. In such experiments, the target words are usually presented in two types of priming conditions: word prime and nonword prime. In the word condition, the related prime is the target's orthographic neighbor (e.g., *protect-PROJECT*), while in the nonword condition, the related prime is a nonword that is one letter different from the target (e.g., *propect-PROJECT*). The idea behind such experimental designs is that while the nonword primes should facilitate recognition of the target by activating its form properties, the word primes are expected to yield no facilitatory priming effects, and even possibly yield inhibitory effects, due to strong competition between the prime and the target's lexical representations (e.g., Davis & Lupker, 2006). However, the pattern of results with word vs. nonword form priming experiments has not always been reliable, as in some cases no facilitatory form priming effects have been found even with nonword primes (e.g., Forster et al., 1987). If nonword primes fail to facilitate recognition of formally-similar target words, the possible absence of facilitatory effects with word primes cannot be straightforwardly attributed to a lexical competition mechanism.

Due to this potential issue with nonword primes, in this study we implement a different method of testing lexical competition, in which anagrams (words made of the same letters, but in different positions) serve as formally-similar prime-target pairs. Priming effects are compared between a repetition condition (e.g., *beard-BEARD*) and an anagram condition (e.g., *bread-BEARD*). The reason for choosing this design is that while repetition priming regularly shows robust facilitatory effects, priming with formally-similar word primes commonly shows no facilitatory effect. Moreover, inhibitory form priming effects have been found to be stronger with transposed-letter words (e.g., *calm-CLAM*) compared to orthographic neighbors (Andrews & Lo, 2012). Strong inhibitory effects have also been found with reversed anagram pairs, such as *paws-SWAP* (Morris & Still, 2012). These findings show that words that share all letters but in different positions act as strong competitors during word recognition. Furthermore, in order to maximize the possibility of getting lexical competition effects, we always used the higher-frequency word of the anagram pair as the prime, since lexical inhibition in form priming is shown to be stronger when the prime is more frequent than the target (e.g., Davis & Lupker, 2006). Hence, a consistent difference is expected between repetition and anagram primes in terms of the magnitude or direction of priming effects.

EXPERIMENT 1

This experiment investigates lexical competition in highly-proficient Persian-English bilinguals' recognition of L2 words. Specifically, this experiment was designed to confirm the findings of previous form priming studies that observed no evidence for L2 lexical competition in masked form priming experiments testing different-script bilinguals. Highly-proficient Persian-English bilinguals, as well as a group of L1 English speakers, were tested in a masked priming experiment using a repetition priming condition (e.g., *beard-BEARD*) and an anagram priming condition (e.g., *bread-BEARD*). The native English speakers were included to verify the basic assumptions of the experiment. Specifically, consistent with the reported effects of form priming with word primes (e.g., Davis & Lupker, 2006), it was predicted that the native English speakers would yield facilitatory priming effects only for the repetition primes, but no such effects (or possibly inhibitory effects) for the anagram primes.

On the other hand, Persian-English bilinguals were tested to add to the body of literature on lexical competition in different-script bilinguals. Experiment 1 thus examines whether previous form priming results testing different-script bilinguals (Nakayama & Lupker, 2018; Qiao & Forster, 2017) can be replicated in bilinguals whose L1 and L2 use the same type of writing system. If L2 recognition in these bilinguals involves the same lexical competition mechanism as L1 word recognition, it was expected that the Persian-English bilinguals would yield the same pattern of results as the native speakers, i.e., no facilitatory priming effects for the anagram primes. This is because in this case the lexical representation of an L2 prime would inhibit activation of the anagram target. Finally, if different-script bilinguals can recognize the accurate form of a masked L2 prime but their L2 word recognition involves no lexical competition, priming effects were expected to be facilitatory for both prime types. This is because in the absence of strong lexical inhibition, the activation of the anagram targets due to partial sublexical overlap with the primes would persist.

<u>Method</u>

Participants. Twenty-eight native speakers of English and 36 highly-proficient Persian-English speakers participated in this experiment. The native speakers were undergraduate students at the University of Texas at Arlington and participated in the experiment for course credit. The Persian-English bilinguals were all graduate students at the University of Texas at Arlington and were compensated US$5 for their participation. Based on the university's English proficiency requirements for entering graduate programs (a minimum score of 6.5 on the IELTS, or a minimum TOEFL iBT total score of 79), these participants were considered to be highly proficient in English. Of the TOEFL scores reported, the average scores were 22 for reading, 21.6 for writing, 22.3 for listening and 22 for speaking. Of the IELTS scores reported, the average scores were 6.8 for reading, 7.2 for writing, 7.3 for listening and 7 for speaking. The average age of acquisition of English in these bilinguals was 10.7 (range = 8 to 13) and the average age when they started to read English was 11.1 (range = 9 to 13). The average length of residence in the US for these participants was 4.4 years. The Persian-English bilinguals also self-reported their English proficiency on a scale of zero to ten. The average self-ratings were 7.6 for speaking, 7.8 for understanding and 8.7 for reading.

Materials and design. One hundred pairs of formally-similar English words were chosen as the experimental items. Several criteria were considered for the anagrams included. First, an attempt was made to ensure that all the experimental items would be familiar to non-native speakers. This was done by choosing relatively shorter words (4 to 6 letters, mean = 4.73) with relatively high frequencies (mean = 94.76) in the CELEX database (Baayen, Piepenbrock, & van Rijn, 1993), as well as by relying on the author's intuition as an unbalanced Persian-English bilingual.

Second, anagrams were chosen with an adequate degree of form similarity, which was calculated by using the normalized Levenshtein distance (Schepens, Dijkstra & Grootjen, 2012). The Levenshtein distance (Levenshtein, 1966) provides a measure of form similarity between pairs of letter strings by calculating the number of editing operations (i.e., insertions, deletions and substitutions) necessary to change one sequence into the other. A potential problem with using the Levenshtein distance is that it gives each editing operation an equal weight no matter the word length. Therefore, word pairs such as *cat-car* and *infection-injection* would have an equal distance of 1, although the second pair has a larger number of overlapping letters. To account for length variations, the normalized Levenshtein distance (Schepens et al., 2012) takes the lengths of the two letter sequences into consideration when determining their degree of similarity, with higher normalized Levenshtein distance values indicating greater similarity. Since anagrams with varying lengths were used in this experiment, the normalized Levenshtein distance was deemed a more accurate measure for controlling the visual similarity of anagrams across the experimental items. A normalized Levenshtein distance of 0.5 or higher was used as the criterion for including anagram pairs as experimental items (mean = 0.56, range = 0.5 to 0.71).

The third and final criterion for choosing anagrams was to avoid including anagram pairs that involved replacement of the first letter. This was because the effects of replacing the initial letter on word recognition is shown to be significantly different from replacing letters at any other position (Scaltritti & Balota, 2013).

From each pair of anagrams, the lower-frequency word was used as the target. The higher-frequency word of the anagram pair was used as the prime to better ensure that the Persian-English bilinguals knew the prime word and did not perceive it as a nonword. Furthermore, the effects of prime lexicality have been shown to be stronger when the prime is higher in frequency than the target (Davis & Lupker, 2006).

Each selected target word was paired with a repetition prime and an anagram prime. For each of these priming conditions, an unrelated word was also chosen to serve as the control prime. These control primes matched their corresponding related primes in length and frequency (mean length = 4.73, mean frequency = 93.68, mean Levenshtein normalized distance from the targets = 0.09). This design resulted in four priming conditions -- a related repetition (e.g., *beard-BEARD*) and its control condition (e.g., *three-BEARD*), as well as a related anagram (e.g., *bread-BEARD*) and its control condition (e.g., *chair-BEARD*). The prime type (anagram vs. repetition) and the relatedness (related vs. control) factors were counterbalanced into four files with 25 items in each condition.

In order to create items for "no" responses in a lexical decision task, 100 orthotactically legal nonwords (mean length = 4.73) were created. First, a random set of 4 to 6 letter words was generated from the MRC Psycholinguistics Database (Coltheart, 1981). Then one letter was changed in each of these words to create a nonword. Care was taken to maintain orthotactic legality of these nonwords in English, and each nonword was checked in the Google dictionary to ensure that it was not a real word. Each nonword target was paired with a repetition prime and a nonword anagram prime. The same similarity criterion (normalized Levenshtein distance of 0.5 or higher and no replacement of initial letters) was used to create these nonword anagrams. The mean normalized Levenshtein distance between these nonword anagrams was 5.5. For each prime, a length-matched unrelated nonword was used as the control prime. The nonword items were also counterbalanced into the four lists. In addition to these word and nonword experimental items, 4 word and 4 nonword trials were developed with a similar design to be used as practice items.

Procedure. Participants were tested individually. The native speakers took the experiment in the Psycholinguistics Lab at The University of Texas at Arlington, while the bilingual participants were tested at other convenient locations on a personal computer. The experiment was programmed using the DMDX software (Forster & Forster, 2003). The sessions began with 8 practice items. Each trial began with a forward mask of 6 hash marks (######) for 500 ms, followed by a 50 ms presentation of the prime in lowercase letters. Immediately following the prime, the target was presented in uppercase letters for 500 ms (Figure 5). All the stimuli were presented in 12-point Courier New font. The participants were asked to indicate whether each target letter string was a real English word or not by pressing buttons on a game controller. They were asked to respond as quickly as possible, but not so quickly that they make errors.

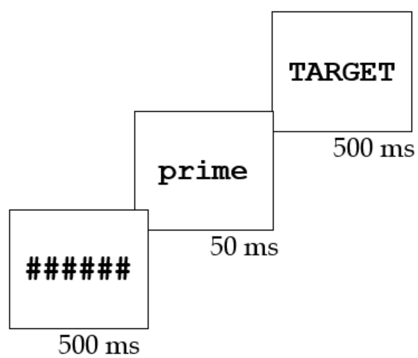

Figure 5. Presentation of the Stimuli in Each Trial in Experiment 1.

Results

All participants with error rates greater than 20% for responses to word and nonword items combined were removed and replaced with different participants to maintain nine subjects in each of the four experimental lists. The 20% error rate criterion was held for the native

English speakers as well as the Persian-English bilinguals. For analysis of the reaction times, all responses faster than 300 ms or slower than 2000 ms were excluded from the analysis, which resulted in discarding 0.39% of the native speaker's data and 0.27% of the Persian-English bilinguals' data. Outlier data points were modified to two standard deviation units above or below each participant's mean reaction time to the word items. This procedure resulted in modification of approximately 3.62% of the native English speakers' data and 4.09% of the Persian-English speakers' data. Separate subject- and item-based ANOVA analyses were conducted on correct responses, one for native English speakers and one for Persian-English bilinguals. For each group, responses to word and nonword items were analyzed separately. Each analysis followed a 2 x 2 x 4 design, with prime type (Repetition vs. Anagram) and relatedness (Related vs. Control) as repeated measures and list (for subject analysis) / item group (for item analysis) as a non-repeated measure. Table 1 shows mean reaction time and error rates for each condition.

Table 1

Mean Reaction Times in Milliseconds and Percentage of Errors (in Parenthesis) for Native and Persian-English Speakers in Experiment 1

	Condition	Repetition	Anagram
Native Speakers	Related	658 (6)	710 (9)
	Control	695 (7.7)	694 (8.9)
	Priming	37***	-16*
Persian-English Speakers	Related	714 (12)	724 (10.4)
	Control	747 (13.2)	746 (12.2)
	Priming	33***	22***

$* p < .05$ $** p < .01$ $*** p < .001$

For the native English speakers, mean reaction times to word targets showed a significant main effect of prime type, $F1$ (1, 24) = 16.44, $p < .001$; $F2$ (1, 96) = 18.00, $p < .001$, with responses to the repetition condition faster than responses to the anagram condition. The main effect of relatedness was approaching significance in both subject analysis and item analysis $F1$ (1, 24) = 3.11, $p = .09$; $F2$ (1, 96) = 3.54, $p = .06$, indicating a trend toward faster reaction times to related compared to control primes for repetition and anagram priming conditions combined. Furthermore, a significant interaction between prime type and relatedness was also found, $F1$ (1, 24) = 17.26, $p < .001$; $F2$ (1, 96) = 16.43, $p < .001$, suggesting a difference between priming effects for repetition and anagram primes. Simple comparisons showed significant facilitatory priming effects for the repetition primes, $F1$ (1, 24) = 14.71, $p < .001$; $F2$ (1, 96) = 20.09, $p < .001$, while the anagram primes showed an inhibitory effect that was significant in subject analysis, $F1$ (1, 24) = 4.43, $p < .05$ and approaching significance in item analysis $F2$ (1, 96) = 3.47, $p = .66$. Error rate analysis revealed a significant effect of prime type, $F1$ (1, 24) = 5.99, $p < 0.5$; $F2$ (1, 96) = 5.2, $p < 0.5$, indicating higher error rates in the anagram priming condition. The error rates did not show a significant main effect of relatedness, both F's < 1, and no interaction between prime type and relatedness, both F's < 1.

Mean reaction time data for the Persian-English bilinguals showed a significant main effect of relatedness, $F1$ (1, 32) = 30.63, $p < .001$; $F2$ (1, 96) = 33.52, $p < .001$, with the related condition responded to faster than the control condition. There was no significant main effect of prime type, $F1 < 1$; $F2$ (1, 96) = 1.72, $p = .19$, and crucially, the interaction between prime type and relatedness was not significant, $F1$ (1, 32) = 1.64, $p = .21$; $F2$ (1, 96) = 1.01, $p = .32$, indicating the same magnitude of priming for anagram and repetition primes. The error rate analysis revealed no significant effect of relatedness, $F1$ (1, 32) = 2.16, $p = .15$; $F2$ (1, 96) =

2.28, p = .13, or prime type, $F1$ (1, 32) = 1.57, p = .22; $F2$ (1, 96) = 1.35, p = .25, and no significant interaction between relatedness and prime type, both F's < 1.

Discussion

The results of this experiment reveal that the patterns of masked priming effects with English repetition vs. anagram primes for highly-proficient Persian-English bilinguals are markedly different from those for native English speakers. The native English speakers yielded facilitatory priming for repetition primes, while the priming effects for anagram primes were inhibitory. In contrast, the Persian-English speakers showed comparable facilitatory priming for repetition and anagram primes. These results confirm the findings of previous studies regarding lexical competition effects for L1 speakers and different-script L2 bilinguals in form priming settings. The inhibitory priming effects with anagram primes in the native English speakers are consistent with previous studies that have found no facilitatory form priming with word primes in the L1 (e.g., Davis & Lupker, 2006; Forster & Veres, 1998; Qiao & Forster, 2013). Furthermore, the results of this experiment confirm that the set of anagram pairs we used as formally-similar words can function as strong competitors during L1 word recognition, just as orthographic neighbors (e.g., Davis & Lupker, 2006), transposed-letter word pairs (Andrews & Lo, 2012) and reverse anagrams (Morris & Still, 2012) do. On the other hand, the facilitatory effect of L2 anagram priming in Persian-English bilinguals is consistent with the results of previous masked form priming studies that have found no evidence for lexical inhibition in the L2 of different-script bilinguals (Qiao & Forster, 2017; Nakayama & Lupker, 2018).

The results of Experiment 1 add to the previous findings by showing that these findings can be extended to different-script bilinguals whose L2 uses the same type of writing system as their L1. Qiao and Lupker (2017) and Nakayama and Lupker (2018) found the absence of evidence for lexical competition in the L2 of bilinguals whose L2 uses a different script than their L1, such as Chinese-English or Japanese-English bilinguals. However, the L2 writing system of those bilinguals (i.e., the alphabetic system of Roman script) was also of a different type than their L1 (i.e., the logographic system of Chinese and Japanese Kanji, and the syllabic system of Japanese Kana). The results of this first experiment indicate that, as far as L2 lexical competition is concerned, the difference between L1 and L2 writing systems may not matter as much as the visual dissimilarity of L1 and L2 scripts. Despite the fact that Persian and English both use alphabetic writing systems, Persian-English bilinguals behave similarly to Chinese-English or Japanese-English bilinguals in L2 form priming experiments (and differently from the pattern of form priming effects in the L1) in that processing a masked L2 word prime facilitates these bilinguals' recognition of a formally-similar L2 target. Since we also used anagrams as formally-similar words instead of orthographic neighbors, our findings suggest that the lack of lexical competition effects in masked L2 form priming settings is a reliable phenomenon in different-script bilinguals.

Since the results of Experiment 1 confirm that the pattern of form priming in the L2 of different-script bilinguals is different from form priming in the L1, the question we next address is what the source of this discrepancy in these bilinguals' processing of L2 word forms may be. Of course, one possibility is that lexical competition does not operate in different-script bilinguals' L2 word recognition. This assumption would be consistent with Qiao and Forster's (2017) proposal that lexical competition may not be involved in the memory system where L2 words are stored. However, Nakayama and Lupker's (2018) finding with increased prime duration in L2 orthographic neighbor priming settings leads these authors to provide an alternative proposal. While Nakayama and Lupker (2018) found facilitatory L2 neighbor priming effects with masked primes in Japanese-English bilinguals, these facilitatory priming effects went away when the prime duration was increased to 175 ms, with an insignificant trend towards inhibitory effects. Based on this finding, these authors suggest that additional prime processing time and/or conscious appreciation of the prime may be needed for different-script bilinguals to yield any indication of lexical competition effects in an L2 neighbor priming experiment, although even in these conditions lexical competition effects may be weak. Therefore, a closer look into how increasing the prime duration may alter the L2 form priming effects in different-script bilinguals can help clarify how lexical competition functions in the L2 of these bilinguals.

Crucially, increasing the display duration provides at least two advantages for processing a prime. First, a longer prime duration extends the processing time, such that the participant has a longer time to figure out what word they see. Specifically, after decoding the orthographic form of a word, this extended processing time provides additional time for activation at the lower, sublexical levels to spread to the level of word representations, and for the prime's lexical representation to accumulate strong activation and inhibit the activation of its competitors. Second, increased prime duration also extends the time available for gathering orthographic information, since the participant gets to look at the prime for a longer period of time. This extended input continuously activates the orthographic features constituting the prime, which in turn continues to feed activation to the relevant letter representations. As such, increased prime duration may enhance the reader's ability to accurately decode the sublexical orthographic components of the prime.

In view of these factors, the elimination of facilitatory L2 neighbor priming effects in different-script bilinguals by increasing prime duration (Nakayama & Lupker, 2018) can be interpreted in two ways. It may be the case that different-script bilinguals simply need additional processing time to activate the prime's lexical representation as the best match and inhibit the activation of its competitors. In this case, additional processing time after displaying a masked L2 prime would be expected to result in inhibitory form priming effects. This is because the lexical representation of a formally-similar prime would suppress the activation of the target word, and consistent with the results found in Experiment 1 for L1 speakers, this process should result in inhibitory priming effects.

Alternatively, or perhaps in addition to needing more processing time to initiate lexical competition, different-script bilinguals may have difficulties with decoding the sublexical orthographic components of L2 word forms. Specifically, gathering sufficient orthographic information from an L2 word to decode its unique sublexical orthographic form may take longer in these bilinguals than the duration of a masked prime (e.g., 50 ms) provides. If it is the case that different-script bilinguals are slow at gathering orthographic information from L2 words, simply increasing the time for processing a masked L2 prime would not be expected to change the pattern of results we found in Experiment 1 for Persian-English bilinguals. In other words, even with increased processing time, no lexical competition effects would be expected to emerge with masked L2 primes. This is because, if 50 ms is too short for different-script bilinguals to gather sufficient orthographic information from L2 words, these bilinguals may not be able to decode the precise sublexical form of a masked L2 prime. Therefore, regardless of subsequent processing time, a unique lexical representation may not be activated as the exact match to the prime, and thus, the competitors may not receive strong inhibition. Consequently, masked L2 primes would be expected to facilitate recognition of a formally-similar target word.

To clarify the nature of L2 lexical competition in different-script bilinguals, Experiments 2 and 3 examine whether these bilinguals simply need additional processing time to yield any lexical competition effects with masked L2 primes, or if they need extended exposure to an L2 word in order to decode its unique orthographic form and inhibit activation of the formally-similar competitors. Specifically, we ask whether additional prime processing time and/or additional time for conscious appreciation of the prime may alter the pattern of results we found for Persian-English bilinguals in Experiment 1. Experiment 2 specifically asks whether increasing the time to process masked L2 primes before presentation of the target words results in any evidence for lexical competition in Persian-English bilinguals. Experiment 3 examines the effect of extended prime duration.

EXPERIMENT 2

The purpose of Experiment 2 was to test whether a brief time for gathering sublexical information from an L2 word prime followed by extended time for lexical selection would result in any lexical competition effects arising on different-script bilinguals' recognition of a formally-similar target word. This question was addressed by testing highly-proficient Persian-English bilinguals in a masked priming experiment with L2 repetition and anagram priming conditions. Importantly, while the primes were masked and presented very briefly (50 ms), the stimulus onset asynchrony (SOA) between the prime and the target was increased to 500 ms. This extended SOA was assumed to provide sufficient time following accumulation of orthographic information from a masked word prime to activate the prime's appropriate lexical representation and inhibit the activation of formally-similar lexical competitors.

The following predictions were made for this experiment. If different-script bilinguals are efficient at gathering orthographic information from an L2 prime but slow at finding an exact lexical match and inhibiting activation of the competitors, priming effects were anticipated to be facilitatory for repetition primes, but inhibitory for anagram primes, since an anagram prime is expected to inhibit activation of its target word (as observed in native English speakers in Experiment 1). This is because the 500-ms SOA would give these bilinguals extended time for mapping the sublexical information they have gathered from a masked L2 prime to a fully matching lexical representation and inhibiting activation of its competitors. Alternatively, if different-script bilinguals are slow at obtaining orthographic information from L2 words, facilitatory priming effects were expected for both repetition and anagram primes, because a 50-ms exposure to an L2 prime would likely be insufficient for these bilinguals to decode the prime's exact form and activate its unique lexical representation.

Method

Participants. Thirty-six highly-proficient Persian-English speaking graduate students at the University of Texas at Arlington were recruited for this experiment and were compensated US$5 for their participation. The average age of acquisition of English in these participants was 10.4 (range = 5 to 17), and the average age they started to read English was 11 (range = 5 to 17). The average length of residence in the US for these participants was 4 years. The average TOEFL scores reported (N = 17) were 23.3 for reading, 23.2 for writing, 23.1 for listening and 22.8 for speaking. The average IELTS scores reported (N = 7) were 7.5 for reading, 6.9 for writing, 7 for listening and 7.1 for speaking. The average self-rating of English proficiency on a scale of zero to ten were 7.5 for speaking, 8.1 for understanding and 8.5 for reading.

Materials and design. The materials and design were identical to those in Experiment 1.

Procedure. The procedures were identical to those in Experiment 1, with one exception: the SOA was increased to 500 ms by adding a 450-ms backward mask (######) after presenting the 50-ms prime (Figure 6).

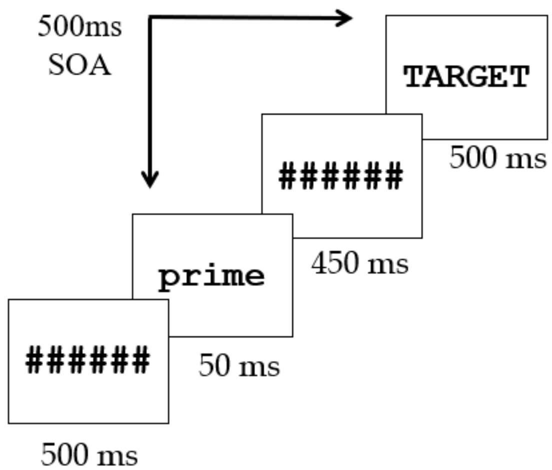

Figure 6. Presentation of the Stimuli in Each Trial in Experiment 2.

Results

The participants with error rates greater than 20% were replaced, maintaining 9 subjects in each of the four experimental lists. The trimming procedures were the same as Experiment 1, and resulted in excluding 2.8% of the data (i.e., responses faster than 300 ms or slower than 2000 ms) and adjusting 6.8% of the remaining data to two standard deviations below or above each participant's average reaction time to the word targets. The same design of subject- and item-based ANOVA analyses conducted for Experiment 1 was used to analyze the results of this experiment. Mean reaction times and error rates for responses to the word items are presented in Table 2.

Table 2

Mean Reaction Times in Milliseconds and Percentage of Errors (in Parenthesis) in Experiment 2

Condition	Repetition	Anagram
Related	928 (12.6)	941 (14.9)
Control	952 (13.7)	966 (15.4)
Priming	24**	25†

† p < .1 * p < .05 ** p < .01 *** p < .001

Analyzing mean reaction times to word items revealed a significant main effect of relatedness, *F*1 (1, 32) = 8.47, $p < .01$; *F*2 (1, 96) = 11.23, $p < .01$, showing faster responses to the related condition than the control condition. The main effect of prime type was significant in subject-based analysis, *F*1 (1, 32) = 4.17, $p < .05$, indicating that the repetition condition was responded to faster than the anagram condition, but this effect was not significant in item-based analysis, *F*2 (1, 96) = 5.37, $p < .05$. The interaction between prime type and relatedness was not significant, both *F*s < 1, demonstrating that the anagram and the repetition primes had comparable contributions to the overall effect of relatedness. Simple comparisons revealed a significant effect of relatedness for the repetition primes, *F*1 (1, 32) = 8.09, $p < .01$; *F*2 (1, 96) = 5.27, $p < .05$. For the anagram primes, the main effect of relatedness was marginally significant in subject-based analysis, *F*1 (1, 32) = 3.11, $p = .09$, and significant in item-based analysis, *F*2 (1, 96) = 5.56, $p < .05$

Analyzing error rates revealed no significant effect of relatedness, both *F*'s < 1. There was an indication of higher error rates for anagram condition than repetition condition, but the main effect of prime type was only approaching significance, *F*1 (1, 32) = 3.52, $p = .07$; *F*2 (1,

96) = 3.19, $p = .8$. The interaction between relatedness and prime type was not significant, both F's < 1.

Discussion

The results of Experiment 1 revealed lexical competition effects (in the form of inhibitory anagram priming) in L1 speakers, but no such effects in the L2 of different-script bilinguals. Experiment 2 was thus conducted to investigate the reason behind the absence of any lexical competition effect in masked form priming experiments testing different-script bilinguals (Qiao & Forster, 2017; Nakayama & Lupker, 2018; as well as Experiment 1 in this study). Specifically, we asked whether these bilinguals need additional processing time to activate a masked L2 prime's representation as a strong competitor for formally-similar lexical candidates.

The results of Experiment 2 indicate that merely increasing the time available for lexical selection after displaying a masked L2 word prime does not result in observing any lexical competition effects in different-script bilinguals' recognition of a formally-similar target word. Even with the SOA between masked L2 primes and their targets increased to 500 ms, Persian-English bilinguals yielded an overall facilitatory priming effect across repetition priming (*beard-BEARD*) and anagram priming (*bread-BEARD*) conditions. Indeed, as indicated by the lack of interaction between prime type and relatedness factors, the magnitude of facilitatory priming effects for anagram primes in this experiment was not different from repetition priming effects. Crucially, this is the same pattern of priming effects demonstrated by Persian-English bilinguals in Experiment 1, where the SOA between the masked primes and their targets was kept at 50 ms. That is, increasing the SOA in Experiment 2 did not result in the emergence of any lexical competition effects, nor did it reduce the facilitatory effect of the anagram primes relative to the repetition primes. This finding suggests that, regardless of the length of time available for processing the orthographic information gathered from a masked L2 prime, an anagram prime and a repetition prime facilitate recognition of a target word to the same degree. This finding provides strong evidence that masked L2 primes may not initiate competition with formally-similar lexical competitors.

Since masked L2 primes do not seem to be perceived by different-script bilinguals as potential competitors for formally-similar L2 targets, the question that needs to be addressed is whether these bilinguals would yield any lexical competition effects in L2 form priming settings when the primes are unmasked. It should be noted that inhibitory form priming effects with unmasked word primes have been found in L1 readers (e.g., Burt, 2009; Massol, Molinaro, & Carreiras, 2015), which shows that conscious awareness of the prime may still give rise to lexical competition effects. As discussed earlier, Nakayama and Lupker (2018) found some evidence for lexical competition effects with unmasked L2 neighbor primes in different-script bilinguals. When the prime duration was increased from 67 ms (Experiments 1 and 4) to 175 ms (Experiment 6), the facilitatory effect of L2 neighbor primes in their Japanese-English bilinguals were eliminated. However, even with unmasked L2 primes, the evidence for a lexical competition mechanism in these bilinguals was not as compelling as what these authors found with masked neighbor primes in native English speakers. Specifically, while the native English speakers yielded significant inhibitory priming effects with masked neighbor primes, the inhibitory effects of unmasked L2 neighbors in Japanese-English bilinguals was only significant in the error data (i.e., more errors were made in the neighbor priming condition compared to the control condition). Based on these results, Nakayama and Lupker (2018) propose that lexical competition may operate too slowly/weakly in the L2 of different-script bilinguals, such that the effects of lexical competition may not show up in a typical masked priming experiment.

Importantly, the results of Experiment 2 suggest that the lack of lexical competition effects with masked L2 primes in different-script bilinguals cannot be explained merely in terms of slow operation of the lexical competition mechanism in these bilinguals. If lexical competition was simply a slow process in these bilinguals (i.e., if it took some additional time for an activated lexical representation to inhibit activation of its competitors), the long (500-ms) SOA in Experiment 2 should have resulted in inhibition of the L2 target words by the anagram primes. However, even with the increased SOA, Persian-English bilinguals showed no evidence for lexical competition with masked L2 anagram primes. Indeed, as discussed above, masked L2 anagram and repetition primes equally facilitated recognition of a target word.

As discussed previously, Nakayama and Lupker's (2018) results with 175-ms primes (i.e., elimination of facilitatory form priming effects) could be due to one or both of two distinct factors associated with increased prime duration: more processing time and/or extended exposure to the prime. Experiment 2 indicates that simply providing more processing time is not enough to induce any lexical competition effects in different-script bilinguals. Comparable facilitatory effects still persisted with both repetition and anagram primes even with an SOA of 500 ms. Therefore, we now move to the question of extended exposure time. As reviewed above, when Nakayama and Lupker (2018: Experiment 6) increased the prime duration to 175 ms, the facilitatory L2 form priming effects in Japanese-English bilinguals were eliminated, but no significant inhibitory effects were found. However, it is possible that 175 ms of exposure to an L2 prime is still not quite long enough to lead to inhibition of lexical competitors in different-script bilinguals. Specifically, these bilinguals may need even more time to gather sufficient orthographic information from an L2 word in order to decode its unique orthographic form. Therefore, in Experiment 3 we increase the prime duration to 500 ms, which should provide sufficient time for gathering and processing orthographic information from the primes.

EXPERIMENT 3

The purpose of Experiment 3 was to examine whether extended exposure to an L2 word's orthographic form would result in emergence of lexical competition effects on recognition of a formally-similar word in different-script bilinguals. In order to address this question, we tested highly-proficient Persian-English bilinguals in an unmasked L2 priming experiment with a repetition priming condition (e.g., *beard-BEARD*) and an anagram priming condition (e.g., *bread-BEARD*). The primes were unmasked and were displayed for 500 ms. We expected that if different-script bilinguals simply require extended exposure to an L2 word prime's orthographic form to inhibit the activation of its lexical competitors, anagram primes should yield inhibitory rather than facilitatory effects. Assuming, based on the results of Experiments 1 and 2, that 50 ms of exposure to an L2 prime is too short to initiate lexical competition in these bilinguals, a 500-ms prime duration should be long enough to activate an L2 anagram prime as a strong competitor for its target word. Therefore, similar to what we found for anagram primes in native English speakers in Experiment 1, these primes are expected to suppress the activation of their targets, resulting in inhibitory priming effects.

Method

Participants. Thirty-six highly-proficient Persian-English speakers participated in this experiment. As in Experiments 1 and 2, these bilingual speakers were graduate students at The University of Texas at Arlington and were compensated $5 for their participation. The average

age of acquisition of English in these participants was 10.8 (range = 7 to 18) and their average age of starting to read English was 11.8 (range = 7 to 18). The average length of residence in the US for these participants was 4.2 years. The average TOEFL scores reported (N = 23) were 23 for reading, 23 for writing, 23.3 for listening and 23 for speaking. The average IELTS scores reported (N = 3) were 6.7 for reading, 6.5 for writing, 6.5 for listening and 6.8 for speaking. The average self-rate English proficiency scores on a scale of zero to ten were 7.8 for speaking, 8.2 for understanding and 8.4 for reading.

Materials and design. The materials and design were the same as Experiments 1 and 2.

Procedure. The procedures were identical to those in Experiment 1, with two exceptions. First, as in Experiment 2, the SOA between displaying the prime and the target was increased to 500 ms. However, while in Experiment 2 the SOA was increased by displaying a backward mask between the 50-ms prime and the target, in Experiment 3 the prime duration was extended from 50 ms to 500 ms, and the prime was immediately replaced by the target (Figure 7). Also, since both the prime (presented in lowercase) and the target (presented in uppercase) were visible, the participants were asked to read the two words in each trial and decide whether the word displayed in uppercase is a real English word or not.

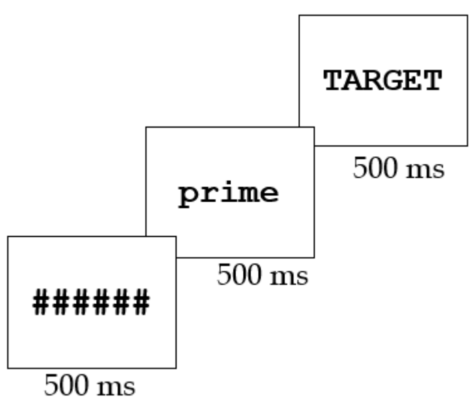

Figure 7. Presentation of the Stimuli in Each Trial in Experiment 3.

Results

As in Experiments 1 and 2, the participants whose overall error rates were higher than 20% were replaced. The responses that were faster than 300 ms or slower than 200 ms were excluded, which resulted in discarding 1.75% of the data. The outlier data points were adjusted to two standard deviation units above and below each participant's mean reaction time to the word items, resulting in modification of approximately 5.96% of the remaining data. Subject- and item-based ANOVA analyses were conducted based on the same design as in Experiments 1 and 2. Table 3 shows mean reaction time and error rates for responses to the word items in each priming condition.

Table 3

Mean Reaction Times in Milliseconds and Percentage of Errors (in Parenthesis) in Experiment 3

Condition	Repetition	Anagram
Related	843 (8.6)	933 (11.3)
Control	954 (14)	949 (12.8)
Priming	111***	16

* p < .05 ** p < .01 *** p < .001

Analyzing the reaction times for the correct responses to the word items revealed a significant main effect of prime type, $F1\ (1, 32) = 14.09$, $p < .001$; $F2\ (1, 96) = 16.20$, $p < .001$, revealing faster reactions in the repetition priming conditions. The main effect of relatedness was also highly significant, $F1\ (1, 32) = 42.95$, $p < .001$; $F2\ (1, 96) = 49.66$, $p < .001$, indicating faster reaction times to related primes compared to control primes. There was also a significant interaction between prime type and relatedness, $F1\ (1, 32) = 18.07$, $p < .001$; $F2\ (1, 96) = 25.12$, $p < .001$. Simple comparisons showed significant priming for repetition primes, $F1\ (1, 32) =$

56.35, $p < .001$; $F2$ (1, 96) = 69.79, $p < .001$, but not for anagram primes, $F1$ (1, 32) = 1.14, p = .29; $F2$ (1, 96) = 1.95, p = .17. The analysis of error rates revealed a significant main effect of relatedness, $F1$ (1, 32) = 6.5, $p < .05$; $F2$ (1, 96) = 11.02, $p < .01$, which showed that more errors were made in the control priming conditions. The main effect of prime type was not significant, both F's < 1. Finally, the interaction between prime type and relatedness was significant only in item analysis, $F1$ (1, 32) = 3.16, p = .08; $F2$ (1, 96) = 4.71, $p < .05$.

Discussion

The results of Experiment 3 demonstrate that when L2 primes were unmasked and displayed for an extended amount of time (in this case, 500 ms), Persian-English bilinguals yielded a significant difference between the priming effects for L2 repetition primes (*beard-BEARD*) and anagram primes (*bread-BEARD*). To be more specific, there was significant facilitatory priming only for repetition primes, while anagram primes yielded a non-significant (16 ms) priming effect. Importantly, these results contrast with what was found in Experiments 1 and 2, where the L2 primes were masked and presented only for 50 ms. In both of those experiments, Persian-English bilinguals showed significant and comparable facilitatory priming for L2 repetition and anagram primes, even when additional time was provided for processing the masked primes by adding a backwards mask of 450 ms (Experiment 2). Therefore, the significant difference between repetition and anagram priming effects with unmasked primes in Experiment 3 suggests that different-script bilinguals need extended exposure to an L2 word, and not just extended processing time, in order to eliminate activation of the word's competitors.

However, while an extended prime duration did eliminate facilitatory anagram priming effects, still no inhibitory effects were seen. This raises the question of whether elimination of the facilitatory anagram priming effects with unmasked L2 primes in Experiment 3 results from operation of a lexical competition mechanism. The results do not provide a straightforward answer to this question. On the one hand, the lack of facilitatory anagram priming effects can be interpreted as evidence for an inhibitory connection between formally-similar lexical representations (see Nakayama, Sears & Lupker, 2010 for a similar interpretation of null form priming effects in L1 readers). As discussed in Chapter Two, according to activation-based models of word recognition, form priming consists of two opposite effects – a facilitatory effect due to form overlap between the prime and the target, and an inhibitory effect due to activation of the target's formally-similar lexical competitors (Perry, Lupker & Davis, 2008; Nakayama et al., 2010). Therefore, it is possible that the null anagram priming effect in Experiment 3 is due to the facilitatory and inhibitory effects of anagram primes cancelling one another out. It should be noted that, even in the L1, form priming effects with word primes may be null, rather than inhibitory (e.g., Nakayama et al., 2010; Qiao & Forster, 2013). Therefore, one may take the results of Experiment 3 to indicate that, if different-script bilinguals have sufficient time for processing the orthographic forms of L2 words, they exhibit evidence for lexical competition.

But, on the other hand, the pattern of anagram priming effects found in Experiment 3 for different-script bilinguals is not the same pattern found in L1 speakers in Experiment 1. In that experiment, native English speakers showed significant inhibitory priming effects with the same set of anagram pairs in masked priming settings. However, increasing the prime duration to 500 ms in Experiment 3 only resulted in elimination of facilitatory priming effects for L2 anagram primes in Persian-English bilinguals, with no indication of an overall inhibitory priming effect. Importantly, this is the same pattern of results that Nakayama and Lupker (2018) found in Japanese-English bilinguals, who also yielded null priming effects (with an insignificant indication of inhibitory effects) with unmasked L2 neighbor primes displayed for 175 ms. Thus, a general conclusion from these findings is that extended exposure to an L2 word by different-script bilinguals may result in some inhibition of that word's competitors, but this inhibition is weak compared to the L1.

In summary, the results of Experiment 3 show that with extended prime duration, the facilitatory effect of formally-similar L2 word primes in different-script bilinguals goes away. Moreover, even an extended (500ms) prime duration does not result in inhibitory effects for L2 word primes in these bilinguals. The implications of these findings for the nature of lexical competition mechanisms in different-script bilinguals' L2 word recognition will be discussed in the following General Discussion section.

GENERAL DISCUSSION OF EXPERIMENTS 1-3

Previous form priming studies examining lexical competition in the L2 of different-script bilinguals have revealed a puzzling pattern of results -- contrary to the assumption that lexical representations compete for recognition through an inhibitory process (e.g., Davis & Lupker; 2006), different-script bilinguals' recognition of an L2 word such as *spear* has been shown to be facilitated, rather than inhibited, by a masked neighbor prime such as *speak* (Qiao & Forster, 2017; Nakayama & Lupker, 2018). This finding has been interpreted to suggest that L2 lexical processing may not involve a lexical competition mechanism (Qiao & Forster, 2017), or that automatic lexical competition may not have developed in the L2 of different-script bilinguals, such that any evidence for lexical competition in these bilinguals may require longer processing time and/or conscious appreciation of a competitor (Nakayama & Lupker, 2018). While previous studies have tested different-script bilinguals whose L1 and L2 use different writing systems (i.e., Chinese-English and Japanese-English bilinguals), in this chapter we investigated lexical competition in the L2 of Persian-English bilinguals, whose L1 and L2 use different scripts, but are both written in alphabetic systems. In order to examine the assumptions of lexical competition in these bilinguals, we tested them in three form priming experiments which used anagrams as formally-similar lexical competitors.

In Experiment 1, we found no evidence for lexical competition when we tested highly-proficient Persian-English bilinguals in a form priming experiment with masked (50-ms) L2 anagram primes (e.g., *bread-BEARD*) and repetition primes (*beard-BEARD*) – both these prime types equally facilitated recognition of their target words in these bilinguals. In the same experiment, native English speakers yielded inhibitory priming effects with masked anagram primes. In Experiment 2, increasing the SOA between the masked primes and their targets to 500 ms by adding a 450-ms backward mask after the 50-ms primes did not change the pattern of results we found in Experiment 1 in the Persian-English bilinguals – these bilinguals still yielded comparable facilitatory priming effects with L2 anagram and repetition primes. In Experiment 3, increasing the duration of the L2 primes to 500 ms led to elimination of facilitatory anagram priming effects in Persian-English bilinguals, although there was still no inhibitory priming effect.

In short, our findings suggest that the absence of inhibitory priming effects with L2 orthographic neighbors in different-script bilinguals (Nakayama & Lupker, 2018; Qiao & Forster, 2018) is not restricted to bilinguals with different L1 and L2 writing systems, and can be replicated with a different type of formally-similar L2 words (i.e., anagrams instead of orthographic neighbors). Furthermore, even with additional processing time, different-script bilinguals do not show a significant difference between L2 repetition and anagram priming effects when the primes are masked. In order for the facilitatory effects of formally-similar L2 word primes to go away, these bilinguals need extended exposure time to the L2 primes. However, even with extended prime duration, these bilinguals do not yield inhibitory priming effects with formally-similar L2 word primes.

The fact that Persian-English bilinguals demonstrate similar results as Chinese-English and Japanese-English bilinguals rules out the role of L1 and L2 writing system differences in the pattern of masked L2 form priming in the L2 of different-script bilinguals previously studied. In other words, while a different L1 writing system may have certain effects on processing L2 words (e.g., Akamatsu, 1999, 2003; Wang et al., 2003), it may not be responsible for the absence of lexical competition effects in an L2 script. Instead, it is possible that this pattern results from dealing with an L2 script with different visual features than the L1 script. The fact that inhibitory form priming effects with masked word primes have been found in the L2 of same-script bilinguals (i.e., French-English speakers: Bijeljac-Babic et al., 1997) supports the idea that the emergence of such effects in the L2 may depend on the similarity of L1 and L2 scripts.

A comprehensive explanation of the pattern of L2 form priming effects in different-script bilinguals must account for several points. First, it should explain why different-script bilinguals show an unexpected pattern of form priming effects in their L2, i.e., facilitatory priming effects with formally-similar masked word primes, while these effects are null or inhibitory in L1 speakers and same-script bilinguals. Second, it should describe the mechanism by which increasing the prime duration results in elimination of form priming effects with word primes. As found in Experiment 3 in the current study as well as in Nakayama and Lupker (2018: Experiment 6), the facilitatory effect of formally-similar L2 word primes goes away when the primes are unmasked. Finally, a third question that needs to be addressed is whether different-script bilinguals' L2 word recognition is different from L1 word recognition in terms of lexical competition. Evidence for lexical competition has been found both in L1 speakers (e.g., Davis & Lupker, 2006; Segui & Grainger, 1990) and same-script bilinguals (Bijeljac-Babic et al., 1997) in the form of inhibitory priming effects with formally-similar word primes. Notably, inhibitory form priming effects in the L1 have been found not only with masked primes, but also with unmasked primes (e.g., Burt 2009, Massol et al., 2015). However, no significant inhibitory form priming effects have been found in the L2 of different-script bilinguals, neither in masked priming (Nakayama & Lupker, 2018, Experiments 1, 4 and 5; Qiao & Forster, 2017; as well as Experiments 1 and 2 in the current study) nor in unmasked priming settings (Nakayama & Lupker, 2018, Experiment 6; as well as Experiment 3 in the current study).

In order to provide an explanation for the points outline above, it is necessary to take a closer look at how an activation-based account of form priming (e.g., Davis & Lupker, 2006) predicts the emergence of inhibitory priming effects in orthographic neighbor priming. As reviewed in Chapter Two, such models consider form priming effects to be a combination of facilitatory and inhibitory effects. The lexical representation of a target word (e.g., *beard*) receives some activation due to partial sublexical overlap with a formally-similar prime, while, in parallel, its activation is inhibited by the lexical competitors that also receive activation from the prime. Crucially, this inhibition is particularly strong when the prime is a real word (e.g., *bread*), since one lexical representation fully matches the prime and therefore sends strong inhibitory signals to its competitors, including the target word. This activation of a strong competitor by the prime would be expected to significantly reduce activation of the target word, resulting in null or even inhibitory priming effects. Based on this account, observing strong competition effects in orthographic neighbor priming settings would depend on whether or not a fully matching lexical representation can be found for the prime, so that it strongly inhibits activation of the target word.

It should be emphasized that in masked priming settings, the primes are displayed for a very short amount of time (e.g., 50 ms), and therefore, they are normally processed only subconsciously. Therefore, the reader may need to have sufficiently advanced and automatized orthographic processing skills in order to accurately decode the unique orthographic form of a masked prime and activate the appropriate lexical representation for it from among a set of formally-similar candidates. Hence, one possible explanation for the finding that masked L2 neighbor priming effects in different-script bilinguals are facilitatory rather than inhibitory (as reported by Qiao & Forster, 2017; Nakayama & Lupker, 2018) is that these bilinguals are inefficient at processing L2 orthographic forms, and therefore, unable to distinguish the orthographic form of a masked L2 word prime from formally-similar words. If these bilinguals cannot accurately decode the orthographic form of a masked L2 prime (e.g., *bread*), the prime's lexical representation may not receive sufficient activation to act as a strong competitor for a neighbor target (e.g., *beard*). Consequently, while the target word would receive activation due to sublexical overlap with the prime, it would not receive strong inhibition from the prime's lexical representation, resulting in facilitatory priming effects.

The idea that different-script bilinguals may be unable to decode the precise orthographic form of a masked L2 prime is indeed supported by the fact that Persian-English bilinguals yielded equal facilitatory priming effects for masked L2 anagram and repetition primes in Experiments 1 and 2. In terms of the interactive-activation account of word recognition outlined above, this finding suggests that an L2 lexical representation such as *beard* may not receive more activation from a masked repetition prime (*beard-BEARD*) than a formally-similar masked word prime (*bread-BEARD*) in different-script bilinguals. Notably, our results also suggest that different-script bilinguals' inability to distinguish formally-similar masked L2 word primes may not be fully explicable in terms of needing additional time for lexical selection. This was seen in Experiment 2, where even a considerable extension of processing time by increasing the SOA between the masked primes and the targets to 500 ms yielded the same pattern of results found in Experiment 1, i.e., comparable facilitatory priming with masked L2 anagram and repetition primes. On the other hand, increasing the prime duration to 500 ms in Experiment 3 resulted in elimination of facilitatory priming effects with L2 anagram primes in Persian-English bilinguals. Taken together, these results suggest that a brief (e.g., 50-ms) exposure to an L2 word may not give different-script bilinguals enough sublexical orthographic information to differentiate that word from a formally-similar competitor. Specifically, these bilinguals may be slow at gathering orthographic information from L2 words, such that a brief display duration would not be sufficient for them to decode the precise orthographic form of an L2 word.

The mechanism by which slow gathering of L2 orthographic information leads to facilitatory form priming effects with masked L2 word primes in different-script bilinguals can be explained as follows. When an L2 prime (e.g., *bread*) is presented for a very short time (e.g., for 50 ms in a typical masked priming setting), these bilinguals may not be able to decode the precise sublexical properties of the prime in terms of features, letters and/or letter positions. In the absence of detailed sublexical information, while a number of close lexical matches (e.g., *bread*, *beard*, *break*, etc.) may receive activation due to excitation of their sublexical components, the input from the sublexical to the lexical level may not be sufficient for discriminating between these formally-similar lexical representations as candidates for lexical selection. As a result, the prime's lexical representation (i.e., *bread*) may receive essentially the same amount of activation as the other candidates (i.e., *beard*, *break*, etc.). In such conditions, since none of the lexical candidates is recognized as a better match compared to the others, no strong lexical inhibition would be expected. Thus, by the time the target word (e.g., *BEARD*) is being processed, its lexical representation still sustains the activation it received due to sublexical form overlap with the prime, resulting in facilitatory priming effects.

While the lack of inhibitory priming effects with masked L2 primes in Experiments 1 and 2 can be attributed to different-script bilinguals' inability to decode the accurate orthographic forms of masked L2 primes, the results of Experiment 3 with unmasked primes may provide insight into the nature of L2 lexical competition in different-script bilinguals. Increasing the prime duration to 500 ms in Experiment 3 led to elimination of priming effects for L2 anagram primes, while repetition priming effects remained strongly facilitatory. The differential priming effects of anagram and repetition primes in this experiment indicates that with extended time for gathering and processing orthographic information, different-script bilinguals can differentiate L2 word primes from formally-similar words. Therefore, the 500-ms prime duration created the necessary setting for emergence of lexical inhibition between the prime and the target words. However, anagram priming effects were still not inhibitory -- these primes yielded a nonsignificant 16-ms priming effect.

It is important to note that Nakayama and Lupker (2018) found similar results for unmasked L2 neighbor primes in Japanese-English bilinguals. While these authors found significant facilitatory priming with masked L2 neighbor primes in Japanese-English bilinguals, these facilitatory effects went away when the prime duration was increased to 175 ms. This finding led Nakayama and Lupker (2018) to propose that different-script bilinguals may need additional time for processing an L2 prime and/or conscious awareness of the prime to yield any lexical competition effects. The results of Experiment 2 in the current study rule out the possibility that additional processing time alone may result in inhibition of an L2 target word by a masked formally-similar word prime – even when we provided plenty of time for processing masked L2 primes by delaying presentation of the targets for 450 ms, masked anagram primes still facilitated recognition of their targets. Also, despite the fact that in Experiment 3 we used a considerably longer prime duration (500 ms) compared to the 175-ms prime duration used in Nakayama and Lupker's (2018) unmasked priming experiment, our results were not qualitatively different from Nakayama and Lupker's – in both experiments, the facilitatory priming effects of L2 word primes went away by increasing the prime duration, but there was still no significant inhibitory priming effect.

Considering the findings outlined above, one may ask whether L2 word recognition in these bilinguals works differently in terms of lexical competition compared to L1 word recognition. Importantly, in Experiment 1, native English speakers showed significant inhibitory priming effects with anagram primes. This is while, regardless of processing time and prime duration, Persian-English bilinguals did not yield any inhibitory effects with the same set of anagram pairs. The same was the case in Nakayama & Lupker (2018), who found significant inhibitory effects with masked English orthographic neighbor primes in native speakers, but not in Japanese-English bilinguals – although these bilinguals showed an indication of inhibitory effects when the primes were unmasked, these effects were not statistically significant. The absence of significant inhibitory priming effects even with unmasked L2 primes in different-script bilinguals suggests that, additional time for processing of an L2 word prime is unlikely to result in strong inhibition of the activation of a formally-similar target word. In other words, while inhibitory form priming effects provide strong support for a lexical competition mechanism during L1 word recognition, different-script bilinguals do not yield such strong evidence for lexical competition in their L2.

One may argue that the difference in the patterns of form priming in L1 speakers (in Experiment 1) and Persian-English bilinguals (in Experiment 3) may not be due to differences in lexical competition, but due to the fact that in Experiment 3, the primes were unmasked. Indeed, at least according to some accounts of priming, the nature of priming effects in masked and unmasked priming settings is not exactly the same. Specifically, in unmasked priming, the memory traces formed due to conscious awareness of the prime may influence decision-making (Forster & Davis, 1984). This is while masked priming is believed to have a time saving effect, such that the prime initiates the process of recognizing the target before the target is presented (Forster, Mohan & Hector, 2003; Gomez et al., 2013; but see Bodner & Masson, 2001; Kinoshita & Norris, 2010 for alternative accounts of masked priming). However, it should be noted that inhibitory priming effects with formally-similar word pairs are frequently found in unmasked priming settings (e.g., e.g., Burt, 2009; Colombo, 1986; Massol et al., 2015; Segui & Grainger, 1990). As a matter of fact, inhibitory priming effects are shown to get stronger when the prime duration is increased (Gobin & Mathey, 2010). Therefore, the fact that Persian-English bilinguals did not show any inhibitory priming effects even with a 500-ms prime duration supports the idea that even if lexical competition operates in the L2 of different-script bilinguals, it may not have exactly the same characteristics as lexical competition in the L1.

Indeed, it is possible to interpret the elimination of facilitatory L2 form priming effects with unmasked primes in different-script bilinguals (as found in Experiment 3, as well as in Nakayama & Lupker, 2018) as evidence for lexical competition between the prime and the target. Specifically, one may argue that while an L2 prime (e.g., *bread*) initially activates a formally-similar lexical representation (e.g., *beard*) due to excitation of its sublexical components, extended exposure to the prime would enable different-script bilinguals to find the prime's exact lexical match, which would in turn inhibit activation of its competitors. It may be further argued that this inhibitory signal from the prime's lexical representation may cancel out the activation of the competitors, but the inhibition may not be strong enough to delay recognition of these competitors. Hence, the overall priming effects on recognition of a formally-similar target word (e.g., *beard*) will be null, rather than inhibitory. This analysis will be consistent with Nakayama and Lupker's (2018) proposal that lexical competition may operate at a reduced level in different-script bilinguals.

However, it should be noted that presence of a lexical competition mechanism, even at a reduced level, is not necessary in order to account for absence of facilitatory form priming effects with words primes. Null priming effects with formally-similar words can be explained in terms of an account of word recognition that does not incorporate lexical competition as an essential mechanism for identifying a word, such as the entry-opening model (Forster, 1999; Forster & Davis, 1984). According to this model, word recognition is a two-stage process. The first stage involves opening a number of lexical entries (i.e., selecting a number of lexical candidates) that closely match the orthographic form of the presented word. The second stage involves a verification process, during which detailed orthographic information is retrieved from the opened lexical entries to find the closest matching candidate. Once one candidate is verified as an exact match, the other lexical entries are closed down.

In terms of the entry-opening model (Forster, 1999; Forster & Davis, 1984), facilitatory form priming effects emerge when prior to presentation of a target word, its lexical entry is opened by the prime, which reduces the amount of time necessary for recognizing the target. For example, when a target word is preceded by a formally-similar prime (e.g., *speam-SPEAR*), the prime opens the entry for the target word as a candidate for verification. Therefore, when the target word is presented, its entry is already open, and therefore, its recognition is facilitated. Importantly, if the formally-similar prime is also a word (e.g., *speak-SPEAR*), there is a chance that it is verified as an exact match, which would result in closing down the entries that have been selected as candidates, including that of the target word. Since the entry for the target would have to be re-opened, the priming effects will be null, or they may be slightly inhibitory (Qiao & Forster, 2017).

Based on this account, the patterns of from priming with L2 word primes in different-script bilinguals in this study (as well as in Qiao & Forster, 2017; Nakayama & Lupker, 2018) can be explained in terms of these bilinguals' ability to verify a lexical entry as an exact match to an L2 prime. Since these bilinguals may be slow at gathering L2 orthographic information, they may not be able to decode the detailed orthographic form of a masked L2 word prime. As a result, although the prime opens a number of lexical entries as candidates, it is unlikely that one of these candidates is verified as a closer match to the prime than the other entries. Since the search for the best lexical match is not resolved, the entries for the selected candidates (including the target word) will remain open, resulting in facilitatory priming effects (current study: Experiments 1 and 2; Qiao & Forster, 2017; Nakayama & Lupker, 2018: Experiment 1, 4 and 5). On the other hand, extending the prime duration may allow different-script bilinguals to verify and exact match for the prime, hence closing down the entry for the target and eliminating any facilitatory effects (current study: Experiment 1; Nakayama & Lupker, 2018: Experiment 6).

In short, the results of Experiments 1-3 do not provide a definitive answer as to whether L2 word recognition in different-script bilinguals involves a lexical competition mechanism. On the one hand, we found that masked form priming experiments with L2 word primes may not provide a reliable method of testing lexical competition in different-script bilinguals, because these bilinguals may be too slow at gathering L2 orthographic information to decode the sublexical orthographic form of a masked L2 prime. On the other hand, when these bilinguals are given extended time for gathering and processing L2 orthographic information from L2 primes by increasing the prime duration, they yield only null priming effects, but no inhibitory effects. Crucially, while null form priming effects with L2 word primes can be interpreted as evidence for some lexical competition, these effects can also be accounted for without assuming a lexical competition mechanism in different-script bilinguals' L2 word recognition. Thus, we would propose that lexical competition in the L2 of different-script bilinguals may be a significantly different process compared to the L1 in terms of automaticity and strength.

An interesting finding in this chapter is the differing results in Experiments 2 and 3, which indicate that different-script bilinguals are unable to correctly decode masked L2 primes, even when given additional processing time. However, recall that Nakayama and Lupker (2018: Experiment 3) found masked translation priming effects with the same Japanese-English bilinguals who showed facilitatory masked L2 neighbor priming. In other words, processing a masked L2 word prime by these bilinguals facilitated recognition of an L1 semantic equivalent which was not formally related to the L2 prime. This finding implies that Japanese-English bilinguals were able to identify a masked L2 prime and access its meaning, which in turn activated the L1 equivalent. This finding is problematic for our account, which argues that different-script bilinguals cannot fully decode the sublexical orthographic form of a masked L2 prime. In Chapter Four, we examine this issue, attempting to replicate the translation priming results of Nakayama and Lupker with Persian-English bilinguals.

CHAPTER FOUR

IDENTIFYING WORDS IN AN L2 SCRIPT: EVIDENCE FROM MASKED AND UNMASKED TRANSLATION PRIMING

In the previous chapter, we examined lexical competition in L2 word recognition in different-script bilinguals. We tested highly-proficient Persian-English bilinguals in three L2 form priming experiments using anagram and repetition primes in different prime display settings. The results of these experiments replicated the findings of previous studies that reported facilitatory rather than inhibitory form priming effects with masked L2 word primes (and hence, no evidence for lexical competition) in Chinese-English bilinguals (Qiao & Forster, 2017) and Japanese-English bilinguals (Nakayama & Lupker, 2018). Furthermore, we found that in masked priming settings the magnitude of anagram and repetition priming effects were not significantly different, even when the time available to process the masked primes was increased. The facilitatory effect of anagram primes was eliminated only when the prime duration was extended, although still no inhibitory effects emerged. Based on these findings we proposed that different-script bilinguals may be slow at gathering orthographic information from L2 words, such that they may not be able to decode the precise orthographic form of a masked L2 prime and distinguish it from a competitor.

In this chapter, we will further investigate the proposal that different-script bilinguals may be inefficient at decoding L2 orthographic forms and, therefore, unable to identify masked L2 primes. Using the translation priming technique, we examine Persian-English bilinguals' ability to process masked and unmasked L2 primes. In translation priming (specifically when the translation equivalents are non-cognates, i.e., orthographically and phonologically unrelated semantic equivalents) the prime and the target do not have any systematic sublexical overlap, but they share the same meaning. Therefore, any priming effects can be attributed to the activation of the target word's meaning by the prime. Crucially, accessing the meaning of a prime requires that the prime's lexical representation be selected as the exact match. Therefore, translation priming effects can be taken as strong evidence that the primes are uniquely identified.

Notably, the prediction that different-script bilinguals may not be able to identify masked L2 primes is challenged by a number of studies that have found significant masked L2-L1 translation priming effects with non-cognates in highly-proficient Japanese-English bilinguals (Nakayama, Ida & Lupker, 2016; Nakayama, Lupker & Itaguchi, 2017; Nakayama & Lupker, 2018) and balanced Chinese-English bilinguals (Wang, 2013). Nakayama and Lupker's (2018) translation priming results are particularly interesting, since these authors found significant masked L2-L1 priming in the same group of Japanese-English participants who yielded no evidence for lexical competition in masked L2 neighbor priming settings. It is important to note that lexical competition is defined as a mechanism that is crucial for selecting the correct lexical match for a visually presented word (Davis & Lupker, 2006). Hence, Japanese-English bilinguals' ability to identify masked L2 primes while yielding no evidence for lexical competition in masked L2 form priming (Nakayama & Lupker, 2018) raises the question of whether lexical competition has the same critical function in different-script bilinguals' recognition of L2 words as it does in L1 word recognition. Specifically, can different-script bilinguals identify an L2 word without strong inhibition of its lexical competitors?

Experiment 4 tests whether Nakayama & Lupker's (2018) findings (i.e., significant masked L2-L1 translation priming effects) can be replicated in highly-proficient Persian-English bilinguals. Experiment 5 tests Persian-English bilinguals with the same materials used in Experiment 4, but with unmasked (500-ms) primes. Based on our proposed interpretation of

Experiments 1-3 in the previous chapter (i.e., that Persian-English bilinguals may not be able to decode the precise orthographic forms of masked L2 primes), we expect to find L2-L1 translation priming effects only with unmasked primes.

EXPERIMENT 4

Nakayama and Lupker (2018), as well as the experiments presented in Chapter Three of this dissertation, found no inhibitory priming effects, and therefore no evidence for lexical competition, in masked L2 form priming settings with word primes in highly-proficient different-script bilinguals. However, Nakayama and Lupker (2018) found significant masked L2-L1 translation priming effects in the same group of bilinguals, suggesting that different-script bilinguals may be able to identify masked L2 primes. The purpose of Experiment 4 is to test whether Nakayama and Lupker's (2018) findings could be replicated with Persian-English bilinguals. Specifically, we test whether highly-proficient Persian-English bilinguals yield evidence for identifying masked L2 primes in L2-L1 translation priming settings.

This question is addressed by testing highly-proficient Persian-English speakers in a masked translation and repetition priming experiment. Translation priming effects were measured for both the L2-L1 priming direction (where L1 targets were primed by their L2 equivalents) and the L1-L2 priming direction (where L2 targets were primed by their L1 equivalents). The L1-L2 translation priming condition was included as a baseline for interpreting the L2-L1 translation priming results. It was assumed that Persian-English bilinguals could process masked L1 primes to the lexical level, and that they could get cross-language priming with semantic equivalents. Based on this assumption, we expected to find significant translation priming effects in the L1-L2 direction. Furthermore, based on the hypothesis that masked L2 primes may not be accurately decoded by different-script bilinguals (as indicated by the results of Experiments 1 and 2 in Chapter Three), we predicted that these bilinguals would not be able to identify masked L2 primes and access their meanings, and therefore, no masked L2-L1 translation priming effects were expected. If, however, we find masked L2-L1 translation priming effects like those in Nakayama and Lupker (2018), this would provide strong evidence that these bilinguals are able to identify masked L2 primes. This finding would demonstrate that different-script bilinguals may be able to identify masked L2 primes in L2-L1 translation priming experiments, even though they do not show any evidence for lexical competition with these primes in form priming settings.

It should be noted that while masked L2-L1 translation priming effects would provide compelling evidence for identification of the masked L2 primes, these effects are generally uncommon in lexical decision experiments. Therefore, in order to help interpret the possible absence of L2-L1 translation priming effects, masked L2-L2 and L1-L1 repetition priming conditions were also included and the magnitude of priming effects in these conditions was compared to ensure that the participants could process masked L2 primes at least beyond the level of sublexical form. Masked repetition priming effects in L1 lexical decision experiments are commonly believed to involve not only activation of sublexical form properties, but also activation at the level of lexical representations (see Forster, 1998 and Forster, 1999 for an overview). Therefore, we assumed that the magnitude of L2-L2 repetition priming effects in comparison to L1-L1 repetition priming effects would provide an additional clue to the participants' ability to process masked L2 primes. Specifically, comparable L2-L2 and L1-L1 repetition priming effects were taken as evidence that a possible lack of L2-L1 translation priming in this experiment was not simply due to the masked L2 primes' failing to activate their lexical representations.

Method

Participants. The participants were 36 highly-proficient Persian-English bilinguals. They were all graduate students at the University of Texas at Arlington, and were compensated US$5 for their participation. These bilinguals' average age of acquisition of English was 11 (range = 6 to 15), and the average age they started to read English was 11.9 (range = 6 to 15). The average length of residence in the US for these participants was 2.8 years. The average TOEFL scores reported (N = 23) were 24 for reading, 22.7 for writing, 23.1 for listening and 22.4 for speaking. The average IELTS scores reported (N = 6) were 7.3 for reading, 6.6 for writing, 7.3 for listening and 7.1 for speaking. The average self-rate English proficiency scores on a scale of zero to ten were 7.4 for speaking, 8.1 for understanding and 8.5 for reading.

Materials and design. The experiment consisted of two randomly presented blocks of items -- an L1 target block and an L2 target block. The L1 target block included L2-L1 translation and L1-L1 repetition conditions. The L2 target block included L1-L2 translation and L2-L2 repetition conditions. One hundred English words and their Persian equivalents were chosen to serve as targets in L1-L2 and L2-L1 translation conditions. These words were selected based on a norming study. For the purpose of this norming study, 200 pairs of Persian-English equivalents were used to create two lists, each consisting of 200 words. One list included the English equivalents of the first 100 pairs and the Persian equivalents of the second 100 pairs. The second list consisted of the opposite equivalents. Each list was given to 5 Persian-English speakers, who were asked to provide the English (or Persian) equivalents of the words on the list.

The 100 pairs of Persian-English equivalents that were used as targets in L2-L1 and L1-L2 translation conditions were selected from among the words that were given the same English and Persian translations by each of the 5 individuals.

L1 target block. This block included 100 Persian words and 100 Persian nonwords as targets. The first 50 word targets (mean length = 4.48, range = 3 to 7) were paired with two types of L2 primes -- a related L2 prime (the English equivalent of the Persian word), and an unrelated L2 prime (a phonologically and semantically unrelated L2 word). The related and unrelated L2 primes were matched based on length, and as much as possible based on frequency, N size, and concreteness ratings. The related L2 primes had a mean length of 5.72 (range = 4 to 10), a mean N size of 2.84 (range = 0 to 15), a mean CELEX frequency (Baayen et al., 1993) of 83.13 (range = 4.24 to 557.12) and a mean concreteness rating (Brysbaert et al., 2013) of 4.42 (range = 1.48 to 5). The unrelated L2 primes had a mean length of 5.72 (range = 4 to 10), a mean N size of 3.1 (range = 1 to 17), a mean frequency of 85.9 (range = 0.67 to 640.76) and a mean concreteness rating of 4.44 (range = 3.1 to 5). T-tests showed no significant difference between the related and the unrelated L2 primes for any of these measures (all *t*s < 1).

The second 50 word targets (mean length =5.62, range = 5 to 7) were paired with two types of L1 primes -- a related L1 prime (repetition of the target word) and an unrelated L1 prime (an unrelated Persian word). The related and unrelated L1 primes for each target were matched for length, and as much as possible for frequency (based on the absolute number of occurrences in Bijankhan Persian corpus: Bijankhan, 2004). The mean frequency values were 901.86 for the related primes (range = 740 to 1123) and 891.88 for the unrelated primes (range = 738 to 1131). The difference between these means was not significant ($t < 1$).

The 100 nonword targets requiring a “No” response in the lexical decision task were orthotactically legal Persian nonwords created by substituting one letter in real Persian words. The first 50 nonword targets (mean length = 4.72, range = 3 to 7) were matched with related and unrelated primes, which were orthotactically legal English nonwords. The related prime for each of these nonword targets was an English nonword created by substituting one letter in the English equivalent of the Persian word that the target was one letter different from. For example, the nonword target کوغ was created by changing one letter from the Persian word کوه, which means “mountain”, and the related prime for this nonword target was *mounsain*. The related primes had a mean length of 6.32 (range = 4 to 10) and a mean N size of 2.42 (range = 0 to 10). The unrelated primes were unrelated English nonwords matching the related primes for length and as much as possible for N size (mean = 2.5, range = 0 to 11). The second 50 nonword targets were paired with length-matched related (repetition) and unrelated Persian nonwords.

Four word and four nonword Persian targets were similarly matched with related and unrelated L1 and L2 primes to serve as practice items.

L2 target block. This block consisted of 100 English words and 100 English nonwords as targets. The first 50 word targets (mean length = 5.62, range = 3 to 9) were paired with a related L1 prime (the Persian equivalent of the English word), and a phonologically and semantically unrelated L1 prime. The related L1 primes had a mean length of 4.52 (range = 3 to 9), and a mean absolute frequency (based on Bijankhan Persian corpus: Bijankhan, 2004) of 484.56 (range = 5 to 6899). The unrelated L1 primes matched the related L1 primes for length, and as much as possible for frequency (mean = 454.96, range = 5 to 4653). The difference between the mean frequency values for related and unrelated L1 primes was not significant ($t < 1$).

The second 50 word targets (mean length = 6.22, range = 4 to 10) were paired with a related L2 prime (repetition of the target word) and an unrelated L2 prime, which was an unrelated L2 word. The related and unrelated L2 primes for each target were matched for length, and as much as possible for frequency and N size. The related L2 primes had a mean frequency of 81.88 (range = 1.96 to 439) and a mean N size of 2 (range = 0 to 11). The unrelated L2 primes had a mean frequency of 82.69 and a mean N size of 2.22 (range = 0 to 12). T-tests showed no significant difference between related and unrelated primes for any of these measures (all *t*s < 1).

One hundred orthotactically legal English nonwords were used as the targets requiring a "No" response. These nonwords were created by changing one letter from real English words. The first 50 nonword targets (mean length = 5.92, range = 4 to 8) were paired with related and unrelated L1 primes. The related L1 prime for each of these nonword targets was an orthotactically legal Persian nonword created by changing one letter from the Persian equivalent of the English word that the nonword target was one letter different from. For example, the nonword target *STALUE* was created by changing one letter from the English word *statue*. The related prime for this nonword target (مبسمه) was created by changing one letter from the Persian word for *statue*, i.e., مجسمه. The unrelated prime for each of the first 50 nonword targets was an unrelated orthotactically legal Persian nonword that matched in length with its corresponding related prime. The second 50 nonwords were paired with length-matched related (repetition) and unrelated English nonword primes.

Eight practice items were also created by matching 4 word and 4 nonword English targets with related and unrelated L1 and L2 primes.

For each of the L1 target and L2 target blocks, two counterbalanced lists of word and nonword items were created, so that the targets primed by related primes in List A were primed by unrelated primes in List B and vice versa. Each participant was randomly assigned to list A or B for both L1 target and L2 target blocks.

Procedure. The experiment was programmed using the DMDX software (Forster & Forster, 2003). Each participant was presented with both the L1 and the L2 blocks of the experiment, in a random order. Each trial began with displaying a forward mask (###########) for 500 ms, followed by a 50-ms presentation of the prime. Immediately following the prime, the target was presented for 500 ms. All the stimuli were displayed in Courier New font. To prevent perceiving the prime and the target as one continuous stimulus, the English primes were presented in lowercase, and the English targets were presented in uppercase. However, since a distinction similar to lowercase and uppercase letter forms does not exist in the Persian script, the primes also differed from the targets in font sizes -- across all the items, the font sizes were 14 for the primes and 18 for the targets. The participants were asked to decide as quickly but as accurately as possible whether the target word in each trial is a real Persian (or English) word by pressing buttons on a game controller. They were not told about the presence of masked primes.

Results

All the participants had overall error rates smaller than 20% in both L1 target and L2 target blocks. Responses that were faster than 300 ms or slower than 2000 ms were removed, which resulted in discarding about 0.28% of the L1 target data and 0.69% of the L2 target data. The outlier reaction time data points were modified to two standard deviation units above and below each participant’s mean reaction time to the word items. This procedure resulted in modification of 4.75% of the L1 target data and 4.87% of the L2 target data. For the L1 and the L2 target blocks, separate subject- and item-based ANOVA analyses were conducted on responses to the word items in the translation and the repetition priming conditions. The analyses for each of these item sets followed a 2 x 2 design, with relatedness (Related vs. Control) as a repeated measure and list (for subject analysis) / item group (for item analysis) as a non-repeated measure. Mean reaction times and error rates for related and unrelated primes in the translation and repetition conditions are provided in Table 4.

Table 4

Mean Reaction Times in Milliseconds and Percentage of Errors (in Parenthesis) for Translation and Repetition Priming Conditions in Experiment 4

	Translation Priming		Repetition Priming	
Primes	L2-L1	L1-L2	L1-L1	L2-L2
Related	615 (1.8)	774 (4.9)	589 (3.1)	777 (6.4)
Unrelated	612 (2.4)	839 (7.4)	623 (4.3)	811 (9.7)
Priming	-3	65***	34***	34***

* p < .05 ** p < .01 *** p < .001

Analyzing the reaction time data for the L1 targets in the L1-L1 condition revealed a significant main effect of relatedness, $F1\ (1, 34) = 27.59$, $p < .001$; $F2\ (1, 48) = 41.86$, $p < .001$, demonstrating strong repetition priming effects. The main effect of relatedness in the L2-L1 condition was not significant, both *F*s < 1, indicating no significant L2-L1 translation priming. Analyzing the error rates showed no significant effect of relatedness in L1-L1 condition, *F*1 (1,

34) = 2.19, $p = .15$; $F2$ (1, 48) = 1.69, $p = .2$ or the L2-L1 condition, $F1$ (1, 34) < 1; $F2$ (1, 48) = 1.65, $p = .2$.

For the L2 targets, the analysis showed a significant main effect of prime type in L2-L2 condition, $F1$ (1, 34) = 15.44, $p < .001$; $F2$ (1, 48) = 15.94, $p < .001$, as well as in L1-L2 condition, $F1$ (1, 34) = 34.76, $p < .001$; $F2$ (1, 48) = 36.11, $p < .001$, demonstrating facilitatory priming effects for both L2-L2 repetition and L1-L2 translation conditions. Analyzing error rate data also revealed a main effect of relatedness both in L2-L2 repetition condition, $F1$ (1, 34) = 5.62, $p < .05$; $F2$ (1, 48) = 6.84, $p < .05$, and in L1-L2 condition, $F1$ (1, 34) = 5.38, $p < .05$; $F2$ (1, 48) = 6.63, $p < .05$, indicating more errors for the unrelated primes in both L2-L2 and L1-L2 conditions.

The magnitude of L1-L1 and L2-L2 repetition priming effects were compared using subject- and item-based ANOVA analyses. These analyses followed a 2x2x2 design. In the subject analysis, relatedness (Related vs. Control) and language (L1-L1 vs. L2-L2) were treated as repeated measures, and list was included as a non-repeated measure. In the item analysis, relatedness was treated as a repeated measure, while language and item group were included as non-repeated measures. The analyses revealed a main effect of relatedness, $F1$ (1, 34) = 35.53, $p < .001$; $F2$ (1, 48) = 39.22, $p < .001$, and a main effect of language, $F1$ (1, 34) = 105.46, $p < .001$; $F2$ (1, 48) = 397, $p < .001$. The interaction between relatedness and language was not significant, both Fs < 1, showing that L1-L1 and L2-L2 repetition priming effects were not significantly different in magnitude.

Discussion

The results of Experiment 4 are straightforward – with a 50-ms prime duration, highly-proficient Persian-English bilinguals yielded translation priming only in the L1-L2 direction, while the L2-L1 translation priming effects were null. Therefore, this experiment does not replicate Nakayama and Lupker's (2018) results, who found significant masked L2-L1 translation priming effects in different-script (Japanese-English) bilinguals. On the other hand, L2-L2 repetition priming effects were significant and comparable in magnitude to L1-L1 repetition priming effects. Taken together, these results suggest that the effects of the masked L2 primes are unlikely to be merely sublexical, as the strong L2-L2 repetition priming effects indicate. In other words, these primes were probably processed beyond their sublexical orthographic forms. Nevertheless, there was no evidence that Persian-English bilinguals could correctly identify and activate the meaning of masked L2 primes, as no L2-L1 translation priming effects were found.

The translation priming results in this experiment are consistent with our findings in Chapter Three regarding lexical competition with masked L2 primes in Persian-English bilinguals. In Experiments 1 and 2, we found no evidence that processing masked L2 primes by these bilinguals involves resolution of the competition between formally-similar lexical competitors. In those experiments, Persian-English bilinguals' recognition of L2 words (e.g., *beard*) was facilitated by processing formally-similar masked L2 word primes (e.g., *bread*), showing that the lexical representation of a masked L2 prime may not inhibit activation of its competitors. Furthermore, we found evidence that the lack of lexical competition effects in masked L2 form priming in Persian-English bilinguals may be due to an inability to distinguish the orthographic form of a masked L2 word prime from its formally-similar competitors.

Therefore, the fact that these bilinguals did not yield L2-L1 masked translation priming is not unexpected.

However, recall that Nakayama and Lupker (2018) did not find the same pattern of correspondence between masked L2 form priming and masked L2-L1 translation priming in Japanese-English bilinguals. These authors found significant L2-L1 masked translation priming effects in Japanese-English bilinguals, while the same group of bilinguals did not show any evidence for lexical competition in masked L2 form priming experiments. The fact that we could not replicate Nakayama and Lupker's (2018) findings in highly-proficient Persian-English bilinguals indicates that although different-script bilinguals with varying L1 backgrounds may not be different in terms of whether/how lexical competition operates in their L2, the ability to get masked L2-L1 translation priming in these bilinguals may depend on specific properties of their L1 scripts. We propose that L1 writing system background may play a significant role in emergence of masked L2-L1 translation priming effects in these bilinguals. A more detailed discussion of this possibility will be provided in the General Discussion of this chapter.

It is important to note that masked L2-L1 translation priming effects have rarely been found in lexical decision experiments. Previous studies testing unbalanced bilinguals in masked translation priming experiments have frequently reported significant priming effects only in the L1-L2 direction, but not in the L2-L1 direction. Importantly, this asymmetry between L1-L2 and L2-L1 translation priming effects has been observed not only in different-script bilinguals (e.g., Chen, Liang, Cui, & Dunlap, 2014; Finkbeiner, Forster, Nicol, & Nakayama, 2004; Gollan, Forster, & Frost, 1997; Wang, 2013; Wang & Forster, 2015; Witzel & Forster, 2013), but also in same-script bilinguals (e.g., Dimitropoulou, Duñabeitia, & Carreiras, 2011a; Ferré, Sánchez-Casas, Comesaña, & Demestre, 2017; Grainger & Frenck-Mestre, 1998). The infrequency of L2-

L1 translation priming effects in lexical decision experiments has been attributed to a number of factors, such as generally lower activation levels of L2 words compared to L1 words due to lower L2 proficiency (Voga & Grainger, 2007), differences in meaning between L1 and L2 equivalents (Finkbeiner et al., 2004; van Hell & de Groot, 1998; Wang & Forster, 2010) and differences between the memory systems in which L1 and L2 words are stored (Jiang & Forster, 2001; Witzel & Forster, 2013). Thus, although the absence of masked L2-L1 translation priming effects in Persian-English bilinguals is consistent with our conclusion in Chapter Three that these bilinguals may not be able to distinguish masked L2 word primes from their competitors, these results may also be explicable without assuming a failure at lexical selection. In other words, one may argue that Persian-English bilinguals were able to identify masked L2 primes, but identifying these primes still did not facilitate recognition of their L1 equivalents.

In order to understand to what extent the lack of any L2-L1 translation priming effects in this experiment can be attributed to Persian-English bilinguals' inability to identify masked L2 primes, it is necessary to examine these bilinguals in an L2-L1 translation priming setting in which they are more likely to identify L2 primes. In Chapter Three, we found evidence that Persian-English bilinguals may need extended exposure to an L2 word in order to differentiate its orthographic form from formally-similar competitors. Specifically, while masked L2 anagram primes facilitated recognition of target words as strongly as repetition primes, increasing the prime duration to 500 ms eliminated the facilitatory anagram priming effects. We interpreted this finding by suggesting that extended time for gathering and processing L2 orthographic information would enable different-script bilinguals to distinguish an L2 word from its competitors. Therefore, in the next experiment we test whether giving Persian-English bilinguals

500 ms of exposure to L2 primes results in any L2-L1 translation priming effects with the same set of items used in Experiment 4.

EXPERIMENT 5

In Experiment 4, we found no L2-L1 translation priming effects with masked primes in highly-proficient Persian-English bilinguals. The purpose of Experiment 5 was to determine the extent to which the null effect of masked L2 primes on recognition of their L1 equivalents can be attributed to Persian-English bilinguals' inability to select a unique lexical match for masked L2 primes. This topic was investigated by testing highly-proficient Persian-English bilinguals in the same translation and repetition priming conditions as Experiment 4, but increasing the prime duration to 500 ms. This prime duration was chosen because in Experiment 3 in the previous chapter Persian-English bilinguals showed evidence for distinguishing the orthographic forms of 500-ms L2 primes from formally-similar lexical competitors. Therefore, it was assumed that these bilinguals would likely be able to identify 500-ms L2 primes and access their meanings, which would create the necessary conditions for obtaining L2-L1 translation priming effects. Similar to Experiment 4, an L2-L2 repetition priming condition was also included in this experiment as an additional measure of the ability of Persian-English bilinguals to process L2 primes. L1-L2 translation priming and L1-L1 repetition priming conditions were also included to provide references for interpreting the performance of these bilinguals in L2-L1 translation and L2-L2 repetition conditions.

The following predictions were made for the results of this experiment. If the lack of masked L2-L1 translation priming effects in Persian-English bilinguals is due to factors that are independent of these bilinguals' ability to identify L2 primes, we expected to find no L2-L1 translation priming effects. This is because, even though Persian-English bilinguals are likely to access the unique lexical match for the 500-ms L2 primes (as suggested by the results of Experiment 3), these primes would not facilitate recognition of their L1 equivalents. Conversely, if the null L2-L1 translation priming effects with masked L2 primes in Persian-English bilinguals are due to these bilinguals' inability to identify masked L2 primes, we expected to find significant L2-L1 translation priming in this experiment, because a 500-ms prime duration was assumed to allow these bilinguals to identify the L2 primes.

Method

Participants. As in the previous experiments, the participants in this experiment were 36 highly-proficient Persian-English bilinguals who were graduate students at the University of Texas at Arlington and were paid US$5 for their participation. The average age of acquisition of English in these participants was 10.3 (range = 6 to 15), and the average age they started to read English was 11.2 (range = 6 to 18). The average length of residence in the US for these participants was 3.1 years. The average TOEFL scores reported (N = 23) were 24.9 for reading, 23.3 for writing, 23.1 for listening and 24 for speaking. The average IELTS scores reported (N = 3) were 6.5 for reading, 6.8 for writing, 6.8 for listening and 6.8 for speaking. The average self-rating of English proficiency on a scale of zero to ten were 7.3 for speaking, 8.3 for understanding and 8.7 for reading.

Materials and design. The materials and design in this experiment were identical to Experiment 4.

Procedure. The procedures were the same as Experiment 4, except that the primes were presented for 500 ms. Also, the participants were told that in each trial they would see two letter strings in succession. They were asked to read the first letter string, and then decide whether the second letter string is a real Persian (or English) word.

Results

All the participants had overall error rates smaller than 20% in both L1 target and L2 target blocks. Response times smaller than 300 ms or greater than 2000 ms (2.55% of the L1 target data and 3.5% of the L2 target data) were discarded. From the remaining data, outlier data points (6.8% of the L1 target data and 7.66% of the L2 target data) were adjusted to two standard deviations above or below each participant's mean reaction times to word items. Separate subject- and item-based ANOVA analyses were conducted for the L1 and the L2 target blocks on responses to the word items in the repetition and the translation priming conditions. The analyses followed the same design as Experiment 4. Table 5 provides mean reaction times and error rates for related and unrelated primes in the translation and repetition conditions.

Table 5

Mean Reaction Times in Milliseconds and Percentage of Errors (in Parenthesis) for Translation and Repetition Priming Conditions in Experiment 5

	Translation Priming		Repetition Priming	
Primes	L2-L1	L1-L2	L1-L1	L2-L2
Related	620 (1.4)	741 (1.8)	543 (2.2)	699 (2.7)
Unrelated	661 (3.8)	854 (9.2)	641 (5.1)	837 (6.9)
Priming	41***	113***	98***	138***

* p < .05 ** p < .01 *** p < .001

Analysis of the reaction times to the L1 targets showed a significant main effect of relatedness both in the L1-L1 condition, $F1\ (1, 34) = 107.92$, $p < .001$; $F2\ (1, 48) = 182.48$, $p < .001$, and in the L2-L1 condition, $F1\ (1, 34) = 33.93$, $p < .001$; $F2\ (1, 48) = 46.66$, $p < .001$, showing that the L1-L1 repetition and L2-L1 translation priming effects were both significant. Analyzing the error rates showed a main effect of relatedness in the L1-L1 condition, but this effect was significant only in item-analysis, $F1\ (1, 34) = 2.52$, $p = .12$; $F2\ (1, 48) = 4.09$, $p > .05$, indicating more errors for the unrelated primes. In the L2-L1 condition, the main effect of relatedness was significant, $F1\ (1, 34) = 8.67$, $p < .01$; $F2\ (1, 48) = 10.16$, $p < .01$, showing that there were more errors in the unrelated priming condition.

Analyzing the reaction time data for the L2 targets also showed a significant main effect of prime type in the L2-L2 condition, $F1\ (1, 34) = 51.73$, $p < .001$; $F2\ (1, 48) = 159.8$, $p < .001$, as well as in the L1-L2 condition, $F1\ (1, 34) = 36.11$, $p < .001$; $F2\ (1, 48) = 152.4$, $p < .001$, demonstrating significant L2-L2 repetition and L1-L2 translation priming effects. The error rate data also showed a main effect of relatedness both in the L2-L2 repetition condition, $F1\ (1, 34) = 24.58$, $p < .001$; $F2\ (1, 48) = 16.29$, $p < .001$, and in the L1-L2 translation condition, $F1\ (1, 34) = 30.8$, $p < .001$; $F2\ (1, 48) = 28.92$, $p < .001$, revealing more errors for the unrelated primes in both the L2-L2 and L1-L2 conditions.

The L1-L2 and L2-L1 translation priming effects, as well as the L1-L1 and L2-L2 repetition priming effects were compared by conducting separate ANOVA analyses. These analyses followed a 2x2x2 design. The subject analyses included relatedness (Related vs. Control) and target language (L1 vs. L2) as repeated measures, and list as a non-repeated measure. In the item analyses, relatedness was treated as a repeated measure, while language and item group were included as non-repeated measures. Analyzing the repetition priming data revealed a main effect of relatedness, $F1\ (1, 34) = 75.48$, $p < .001$; $F2\ (1, 48) = 296.9$, $p < .001$, a main effect of target language, $F1\ (1, 34) = 37.06$, $p < .001$; $F2\ (1, 48) = 447.67$, $p < .001$, and a significant interaction between relatedness and target language, $F1\ (1, 34) = 9.02$, $p < .01$; $F2\ (1, 48) = 4.37$, $p < .05$. These results demonstrate significantly stronger repetition priming effects in the L2-L2 compared to the L1-L1 condition. Analyzing the translation priming data also showed a main effect of relatedness, $F1\ (1, 34) = 48.98$, $p < .001$; $F2\ (1, 48) = 145.6$, $p < .001$, a main effect of target language, $F1\ (1, 34) = 40.32$, $p < .001$; $F2\ (1, 48) = 605.83$, $p < .001$, and a significant interaction between relatedness and target language, $F1\ (1, 34) = 15.88$, $p < .001$; $F2\ (1, 48) = 29.16$, $p < .001$, revealing significantly greater translation priming effects in L1-L2 than L2-L1 direction.

Discussion

The results of Experiment 5 provide clear evidence that increasing prime duration enables highly-proficient Persian-English bilinguals to identify L2 primes, and that identifying the L2 primes facilitates recognition of their L1 translation equivalents. When the primes were unmasked and presented for 500 ms, Persian-English bilinguals yielded significant priming effects not only in the L2-L2 and L1-L1 repetition priming conditions, but also in both L1-L2 and L2-L1 translation priming conditions. This is while in Experiment 4 masked translation priming effects in these bilinguals were significant only in the L1-L2 translation direction, but not in the L2-L1 direction. The distinct patterns of masked and unmasked L2-L1 translation priming effects in Experiments 4 and 5 is consistent with the conclusion driven from Experiments 1-3 in the previous chapter -- i.e., that due to being slow at gathering L2 orthographic information, different-script bilinguals may need extended exposure to L2 word forms in order to differentiate these words from formally-similar competitors. While different-script bilinguals may not be able to select a unique lexical match for a briefly presented L2 word (e.g., a 50-ms masked L2 prime), increasing the display duration (in this case, to 500 ms) enables these bilinguals to identify an L2 word and activate its meaning.

In short, the results of this experiment help interpret the results of masked L2-L1 translation priming in Experiment 4. While we proposed that the absence of any L2-L1 translation priming effects with masked primes in Experiment 4 is likely due to Persian-English bilinguals' inability to identify masked L2 primes, this conclusion would not be valid without ensuring that L2-L1 translation priming is indeed possible in these bilinguals and with the particular set of translation equivalents that we used. Emergence of L2-L1 translation priming effects in this experiment shows that, once uniquely identified, L2 word primes can facilitate recognition of their L1 equivalents in Persian-English bilinguals. This finding in turn supports the idea that inefficient processing of L2 word forms may be a critical factor contributing to the fact that Persian-English bilinguals did not yield any L2-L1 translation priming effects with masked primes.

It should be noted that although we take the contrast between the results of Experiments 4 and 5 as evidence for Persian-English bilinguals' inability to identify masked L2 primes, we are not suggesting that failing to identify masked L2 primes is the only factor responsible for the lack of masked L2-L1 translation priming effects in these bilinguals. Indeed, even in same-script bilinguals, masked L2-L1 translation priming effects are not frequently obtained -- although these effects are less common in different-script bilinguals, several studies testing same-script bilinguals have also reported null or weak masked L2-L1 translation priming (e.g., Dimitropoulou et al., 2011a; Ferré et al., 2017; Grainger & Frenck-Mestre, 1998). Also, while increasing the prime duration in Experiment 5 resulted in significant translation priming effects in both L1-L2 and L2-L1 directions, the effects were much weaker in the L2-L1 condition compared to the L1-L2 condition. These relatively weak L2-L1 translation priming effects indicate that even when an L2 prime is identified, its facilitatory effect on recognition of its L1 equivalent may be small.

What is important for our purpose, however, is that the form priming experiments in Chapter Three and the translation priming experiments in Chapter Four reveal a consistent pattern of results. When the prime duration is too short (e.g., 50 ms) for Persian-English bilinguals to decode the orthographic form of L2 word primes and suppress the activation of formally-similar lexical competitors, these bilinguals do not show any evidence of being able to uniquely identify such primes in an L2-L1 translation priming experiment. Only when the prime durations are sufficiently long (e.g., 500 ms) do Persian-English bilinguals demonstrate an ability to distinguish the orthographic forms of L2 word primes from formally-similar lexical competitors, as well as evidence (although disputable) for suppressing the activation of these competitors. Correspondingly, in L2-L1 translation priming settings, these bilinguals yield strong evidence for identifying L2 primes displayed for 500 ms.

GENERAL DISCUSSION OF EXPERIMENTS 4 AND 5

In Chapter Three of this dissertation, based on Persian-English bilinguals' performance in L2 form priming experiments, we proposed that gathering and processing of L2 orthographic information may be markedly slow in different-script bilinguals, such that these bilinguals may not be able to decode the precise sublexical orthographic form of a briefly-presented L2 word, such as a masked L2 prime. We further discussed that due to this inefficiency at orthographic processing, it may not be possible for different-script bilinguals to differentiate the orthographic form of a masked L2 word prime from formally-similar lexical competitors, and therefore, the competition between lexical candidates to be selected as the exact match to a masked L2 prime may not be resolved. The purpose of the experiments presented and discussed in Chapter Four was to further examine the proposal that different-script bilinguals may be unable to uniquely identify masked L2 primes. For this purpose, we tested highly-proficient Persian-English bilinguals in translation priming experiments with masked and unmasked primes.

The results of testing highly-proficient Persian-English bilinguals in masked translation priming settings in Experiment 4 did not suggest that the masked L2 primes could be uniquely identified. While these bilinguals yielded significant masked L1-L2 translation priming effects, they showed no significant priming effects in the opposite, L2-L1 translation priming direction. This is while L2-L2 repetition priming effects were comparable in magnitude to L1-L1 repetition priming effects, which suggested that processing the masked L2 primes by Persian-English bilinguals probably involved some activation of the prime's lexical representation – i.e., that the activation induced by these primes was not purely sublexical. Furthermore, when the prime duration was increased to 500 ms in Experiment 5, significant L2-L1 translation priming effects were obtained with the same set of translation equivalents. Taken together, these results suggest that although masked L2 primes induce activation at the level of lexical representations in Persian-English bilinguals, selecting the unique lexical match for an L2 word in these bilinguals may be possible only with extended time for orthographic processing and lexical selection. Importantly, as indicated by the outcome of Experiments 1 and 2 in the previous chapter, a 50 ms exposure to an L2 word may not give these bilinguals sufficient orthographic information to discriminate between a set of formally-similar lexical candidates and activate one as a stronger candidate for selection. By contrast, a 500 ms prime duration in Experiment 3 allowed Persian-English bilinguals to activate the lexical representation of masked L2 primes to a greater degree than their competitors. Therefore, the fact that L2-L1 translation priming effects were observed only with 500-ms primes and not with 50-ms primes is in line with the proposal that different-script bilinguals may need extended exposure to an L2 word in order to differentiate that word from its formally-similar competitors.

Thus, the question that needs to be addressed is how the results of Nakayama and Lupker’s (2018) L2-L1 translation priming experiment with Japanese-English bilinguals can be accounted for. As noted above, these authors found masked L2-L1 translation priming effects in the same group of Japanese-English bilinguals who showed no lexical competition effects in masked form priming experiments with L2 words.

Of course, a comprehensive explanation of Nakayama and Lypker’s (2018) findings would require a closer examination of L2 lexical access in Japanese-English bilinguals. But it is possible that the different masked L2-L1 translation priming outcomes in Japanese-English bilinguals compared to Persian-English bilinguals tested in this study is related to the nature of L1 writing systems in these two groups of different-script bilinguals. It is important to note that processing of a masked prime is not completed within the very brief amount of time that it is displayed (e.g., 50 ms). In other words, processing of the masked primes has to continue after subsequent presentation of the targets, and therefore, masked priming effects involve simultaneous processing of the prime and the target stimuli (Forster, 2013). Hence, one possible explanation of masked L2-L1 translation priming effects in Japanese-English bilinguals (Nakayama & Lupker, 2018) would be that simultaneous processing of a masked L2 prime and an L1 target is easier when the L1 and L2 are written in two different writing systems (e.g., a logographic L1 and an alphabetic L2 and). This proposal is indeed supported by the fact that the rare cases of masked L2-L1 translation priming in different-script bilinguals have been mainly found in highly-proficient or balanced bilinguals with a logographic L1 and an alphabetic L2, namely Japanese-English bilinguals (Nakayama & Lupker, 2018; Nakayama et al., 2015; Nakayama et al., 2017) and Chinese-English bilinguals (Wang, 2013; but see Dimitropoulou et al., 2011b, which found masked L2-L1 translation priming in Greek-English bilinguals). Therefore, it is possible that continuous processing of masked L2 primes along with L1 targets allows Japanese-English bilinguals to suppress activation of the prime's competitors and identify the prime.

Also, a logographic L1 writing system background may, in and of itself, give Japanese-English bilinguals some advantage regarding identification of briefly-presented L2 words compared to different-script bilinguals with an alphabetic L1 background, such as Persian-English bilinguals. Alphabetic systems, in which the characters correspond to phonemes, code more detailed phonological information than logographic systems, in which each character represents a morpheme. Hence, while reading in an alphabetic system relies more on segmentation of the words' internal components to retrieve phonological information, reading in logographic systems relies more on holistic visual information (Inutsuka, 2009; Koda, 2005, 2007). Importantly, there is evidence that these word recognition strategies may be transferred from L1 to L2 (Akamatsu, 1999, 2003; Wang et al., 2003). Therefore, it is possible that when an L2 word is presented very briefly, Japanese-English bilinguals' holistic approach to decoding the word's visual form is more likely to lead to successful identification of the word than Persian-English bilinguals' analytical approach.

In short, the results of Experiments 4 and 5 are consistent with the results of the form priming experiments in the previous chapter and the account provided for the absence of any indication of lexical competition in Persian-English bilinguals in L2 masked form priming settings. Specifically, the experiments detailed in this chapter indicate that different-script bilinguals may not be able to correctly identify briefly-presented L2 words. In order for an L2 word to be distinguished from its lexical competitors and correctly identified, the display duration of the word may need to be extended (e.g., to 500 ms), so that different-script bilinguals can decode its precise orthographic form.

CHAPTER FIVE

CONCLUSIONS

Research on L2 reading suggests that the development of orthographic processing skills necessary for fast and accurate L2 word recognition may be affected by the L2 readers' L1 orthographic background (e.g., Hamada & Koda, 2008; Koda, 2000; Muljani et al., 1998; Wang & Koda, 2005). The experiments in this dissertation tested how the graphic dissimilarity of L1 and L2 scripts in different-script bilinguals may affect these bilinguals' ability to efficiently process the orthographic forms of L2 words, and how possible shortcomings of L2 orthographic processing may influence these bilinguals' L2 word recognition. We specifically focused on the effects of poor L2 orthographic processing skills on different-script bilinguals' ability to distinguish the orthographic form of an L2 word from formally-similar words. We addressed this topic by testing highly-proficient Persian-English bilinguals in form priming and translation priming experiments.

The results of the experiments reported in Chapter Three indicated that Persian-English bilinguals may be slow at gathering orthographic information from L2 words. In Experiment 1, these bilinguals showed a different pattern of form priming effects with masked (50-ms) English word primes than native English speakers did. Specifically, native speakers showed facilitatory priming effects with repetition primes (e.g., *beard-BEARD*) and inhibitory masked priming effects with anagram primes (e.g., *bread-BEARD*), indicating a competition for recognition between formally-similar lexical candidates. Persian-English bilinguals, on the other hand, yielded comparable facilitatory priming effects with L2 anagram primes and repetition primes, which suggested that they could not differentiate between the orthographic form of a masked L2 prime and a formally-similar competitor. In Experiment 2, increasing the SOA between the masked primes and their targets to 500 ms, but keeping the prime duration at 50 ms, did not change the pattern of priming effects in Persian-English bilinguals – these bilinguals still showed equal facilitatory priming effects with masked L2 anagram and repetition primes. This finding suggests that mere increasing of processing time did not help Persian-English bilinguals to find the exact lexical match for a masked L2 prime.

In Experiment 3, when the prime duration was increased to 500 ms, the L2 anagram priming effects in these bilinguals were eliminated. We concluded that Persian-English bilinguals may need extended time to gather detailed orthographic information from an L2 word in order to decode its precise sublexical form. Consistent with this conclusion, in Chapter Four we found differential L2-L1 translation priming effects with masked and unmasked primes in these bilinguals – while L2-L1 translation priming effects with masked primes in Experiment 4 were null, increasing the prime duration to 500 ms in Experiment 5 resulted in significant L2-L1 translation priming effects.

The distinct patterns of form priming effects with masked English primes in Persian-English bilinguals compared to native English speakers in Experiment 1 are consistent with previous findings regarding L2 form priming in different-script bilinguals. While masked form priming effects with orthographic neighbors (e.g., *speak-SPEAR*) are usually not facilitatory in L1 speakers (Davis & Lupker, 2006; Forster & Veres, 1998; Nakayama et al., 2008; Qiao & Forster, 2013; Segui & Grainger, 1990) and same-script bilinguals (Bijeljac-Babic et al., 1997), different-script bilinguals with Chinese and Japanese L1 backgrounds have shown significant facilitation with these primes (Nakayama & Lupker, 2018, Qiao & Forster, 2017). The findings of the current study add to this literature in several significant ways. First, our study shows that the pattern of L2 form priming previously found in different-script bilinguals (i.e., facilitatory effects with masked word primes) is not restricted to bilinguals whose L1 and L2 use different writing systems. The writing systems used in Chinese (logographic) and Japanese (logographic and syllabic) differ from English, which uses an alphabetic writing system. L2 readers dealing with a different L2 writing system than their L1 have been shown to adopt distinct L2 word recognition strategies compared to L1 speakers and same-script bilinguals (e.g., Koda, 1999) or even different-script bilinguals whose L1 and L2 use the same type of writing system (e.g., Wang & Koda, 2007; Wang et al., 2003). This raised the question of whether the uncommon pattern of form priming effects in the L2 of Chinese-English bilinguals (Qiao & Forster, 2017) and Japanese-English bilinguals (Nakayama & Lupker, 2018) is somehow related to these bilinguals' L1 backgrounds. Finding facilitatory L2 form priming effects with masked word primes in Persian-English bilinguals shows that this particular pattern of results may not be a direct consequence of differences in L1 and L2 writing systems, but probably due to the graphic distance between L1 and L2 scripts.

Besides clarifying the role of L1 writing system background, our findings also demonstrate that previous findings regarding facilitatory L2 form priming effects with masked word primes in different-script bilinguals can be replicated using anagrams, rather than orthographic neighbors, as formally-similar word pairs. Inhibitory form priming effects in the L1 have been found to be stronger with words that involve letter transpositions than with orthographic neighbors (Andrews & Lo, 2012). Such effects have been found even with reversed anagrams, i.e., pairs of words that contain the same letters, but in reverse orders, such as *paws* and *swap* (Morris & Still, 2012). These findings suggest that words that share all their letters act as strong competitors for recognition. This assumption was confirmed by the results of native speakers in Experiment 1, who showed significant inhibitory priming effects with anagram primes. Therefore, the fact that we found strong facilitatory effects, rather than inhibitory effects, with L2 anagram primes in Persian-English bilinguals indicates that the lack of lexical competition effects in masked L2 form priming experiments testing different-script bilinguals is a reliable phenomenon.

A third implication of our findings is that the absence of inhibitory priming effects in L2 masked form priming settings in different-script bilinguals may not be solely due to slow operation of lexical competition in the L2 of different-script bilinguals, nor may it be due to requiring additional time to process the masked L2 primes. The results of Experiment 2 provide insight into this topic. In that experiment, increasing the SOA between the masked prime and the target by inserting a 450-ms backward mask after the 50-ms primes did not result in any inhibitory effects for the anagram primes. In fact, the results of this experiment were not different from Experiment 1, in which the masked 50-ms primes were immediately followed by the targets -- in both experiments, the anagram primes facilitated recognition of their targets as strongly as the repetition primes. Notably, the facilitatory effect of anagram primes was eliminated only when the duration of the primes was increased to 500 ms in Experiment 3. Comparing the results of these experiments indicates that if the L2 prime duration (i.e., the amount of time available for attaining orthographic information from the prime) is very short, additional processing time may not lead to inhibition of the prime's lexical competitors. In fact, in the absence of extended time for gathering orthographic information, additional processing time may not even enable different-script bilinguals to decode the precise sublexical form of an L2 prime in order to discriminate between formally-similar lexical representations as possible matches.

Overall, the most important contribution of our findings to the study of lexical competition in different-script bilinguals' L2 word recognition is that interpreting the results of L2 masked form priming in these bilinguals should take into account their inefficiency at processing low-level orthographic information. As reviewed in detail in Chapter Two, inhibitory or null priming effects with masked orthographic neighbor primes (e.g., *speak*-*SPEAR*) have been taken as evidence for inhibition of a target word's activation by the neighbor prime (e.g., Davis & Lupker, 2006). The same interpretation has been given based on masked neighbor priming in the L2 of same-script bilinguals (Bijeljac-Babic et al., 1997). In the same manner, the fact that different-script bilinguals show facilitatory form priming effects with masked L2 word primes (Nakayama & Lupker, 2018; Qiao & Forster, 2017, as well as Experiments 1 and 2 in this dissertation) may be taken as evidence that, as far as lexical competition is concerned, L2 word recognition in different-script bilinguals works differently than both L1 and same-script bilinguals' L2. However, it should be noted that expecting the emergence of lexical competition effects in a form priming setting requires assuming that the orthographic form of the prime is accurately decoded, so that it activates a strong competitor for the target word. Importantly, this assumption cannot be confidently made about different-script bilinguals' processing of masked L2 primes. As the results of Experiments 1 and 2 indicate, a brief presentation of an L2 prime (e.g., for 50 ms) may be too short for these bilinguals to differentiate between two formally-similar lexical representations as the best match to the prime, even when additional processing time is provided after the prime is briefly displayed. In other words, the absence of any lexical competition effects in L2 masked form priming in different-script bilinguals may be due to a shortcoming at processing the sublexical orthographic forms of L2 words, rather than an indication of L2 word recognition procedures at the lexical level that are unique to different-script bilinguals.

It should be noted that proposing poor orthographic processing abilities in different-script bilinguals is not without precedence. Nakayama et al. (2017) have proposed that L2 readers' ability to process L2 word forms may depend on the similarity of the L1 and L2 scripts, such that L2 form processing skills may be weak when the L1 and L2 use different scripts. In an L2-L1 masked translation priming experiment with highly-proficient Japanese-English bilinguals, Nakayama et al. (2017) found overall slower responses when the L2 primes were low-frequency words, and that the largest priming effects occurred when low-frequency L1 targets followed high-frequency L2 primes. To interpret these findings, Nakayama et al. (2017) refer to the idea that in masked priming, processing of the prime's form information is reset by presentation of the target, but processing of the conceptual information can progress even after the target is displayed (Forster, 2013; Grainger, Lopez, Eddy, Dufau & Holcomb, 2012). They propose that even at higher levels of proficiency, different-script bilinguals may have weak L2 form processing skills, and therefore they may not be able to finish processing all masked L2 primes at the form level. Specifically, if the masked L2 prime is a low-frequency word, these bilinguals may be unable to process its form sufficiently well before the target is displayed -- since low-frequency words have a lower resting activation level, these bilinguals would need more time to process them. As a result, when a low-frequency word is presented as a masked L2 prime, processing its form may still be ongoing by the time the L1 target is displayed, hence slowing down processing of the target. Nakayama et al. (2017) also argue that the combination of a high-frequency L2 prime and a low-frequency L1 target provides more time for different-script bilinguals to process an L2 prime's form information before the L1 target is recognized. In such conditions, it is more likely that processing of the L2 prime continues to the conceptual level, which explains why these authors found the largest L2-L1 translation priming effects when high-frequency L2 primes followed low-frequency L1 targets.

Moreover, even in L1 readers, masked form priming effects have been shown to correspond to the level of orthographic processing skills (Andrews & Hersch, 2010; Andrews & Lo, 2012). Andrews and Hersch (2010) found that individual differences in spelling abilities among a group of native English speakers were associated with different patterns of masked orthographic neighbor priming. While neighbor priming effects with high-N primes (i.e., word primes with many orthographic neighbors) were inhibitory in better spellers, poorer spellers showed facilitatory effects with these primes. Andrews and Lo (2012) reported similar results in a study examining transposed-letter priming and substituted-letter priming (e.g., *calm-CLAM* and *clay-CLAM*) in native English speakers, where better spelling skills were associated with stronger inhibitory effects for both prime types. These findings suggest that observing lexical competition effects in form priming experiments (as indexed by inhibitory rather than facilitatory priming effects) may depend on the reader's level of orthographic processing abilities. Hence, considering that different-script bilinguals have to deal with a less familiar L2 script, our finding that L2 form priming in these bilinguals may be impacted by their poor L2 orthographic processing skills is not entirely surprising.

It should be noted that although we used a different test of lexical competition than previous studies (i.e., anagram priming rather than orthographic neighbor priming), we propose that our findings could be extended to account for the general pattern of lexical competition effects found in masked L2 form priming experiments testing different-script bilinguals. Specifically, if (as the results of Experiments 1 and 2 suggest) different-script bilinguals are unable to distinguish a masked L2 word prime from an anagram competitor, it is very likely that they would have the same issue with orthographic neighbors, which have a great degree of orthographic overlap. Nevertheless, further investigation is required to determine whether different-script bilinguals are particularly inefficient at decoding relative letter positions in L2 words, which is directly related to the ability to differentiate anagrams.

While our findings indicate caution in assuming the lack of a lexical competition mechanism in the L2 of different-script bilinguals based on the results of masked L2 form priming experiments, it is still possible (as pointed out in Nakayama & Lupker, 2018) that lexical competition effects operate, albeit weakly, in the L2 of these bilinguals. Recall that in Experiment 3, where the L2 primes were displayed for 500 ms, the facilitatory effect of anagram priming was fully eliminated. In line with this finding, it is possible that when different-script bilinguals are given enough exposure to an L2 word prime to decode its unique form, the lexical representation of the target word receives an inhibitory signal from that of the prime, but this inhibitory signal is only strong enough to neutralize the activation that the target word has received due to sublexical overlap with the prime.

However, the null form priming effects with unmasked L2 word primes may also be explained without relying on an inhibitory competition mechanism. For example, it is possible that, considering the long SOA between the prime and the target in unmasked priming settings, activation of the prime's lexical competitors simply returns to the resting level after the prime is identified. In other words, it may be the case that elimination of the target word's activation in an unmasked anagram priming condition (as indexed by null priming effects) is due to resolution of the lexical selection process for the prime, rather than an inhibitory signal from the prime's lexical representation. A closer look into the effects of prime duration (e.g., by an incremental increase of prime duration, possibly even beyond 500 ms) can clarify how much exposure time different-script bilinguals may need to decode the orthographic form of an L2 prime, and whether any lexical competition effects would start to emerge at that point.

To conclude, while operation of a lexical competition mechanism or lack thereof in different-script bilinguals' recognition of L2 words remains an open question, it seems safe to assume that even if such a mechanism operates in these bilinguals, it may not be as strong and automatic as in L1 word recognition. Specifically, due to being slow at decoding L2 orthographic forms, selecting the appropriate lexical match for an L2 word from among a number of formally-similar lexical candidates may require extended exposure to the word, and possibly, conscious analysis of its orthographic properties.

APPENDIX A

EXPERIMENTAL ITEMS FOR EXPERIMENTS 1-3

Primes				**Targets**
Anagram Condition		Repetition Condition		
Related	**Unrelated**	**Related**	**Unrelated**	
diary	charm	dairy	bride	DAIRY
calm	fool	clam	axle	CLAM
carve	foggy	crave	proxy	CRAVE
sacred	powder	scared	polite	SCARED
field	lives	filed	alley	FILED
fired	devil	fried	drill	FRIED
coast	enter	coats	imply	COATS
boats	knock	boast	maker	BOAST
beast	alien	beats	greet	BEATS
busy	pale	buys	mint	BUYS
stored	option	sorted	dismay	SORTED
east	bank	eats	fold	EATS
plane	raise	panel	alike	PANEL
quite	house	quiet	radio	QUIET
saint	quote	stain	eagle	STAIN
south	close	shout	brave	SHOUT
angle	eager	angel	curse	ANGEL
coal	bird	cola	null	COLA
sign	milk	sing	fund	SING
alert	blown	alter	blank	ALTER
break	eight	brake	polar	BRAKE
cater	graph	crate	idiom	CRATE
cosmic	liquor	comics	rating	COMICS
spare	burst	spear	booth	SPEAR
meal	hurt	male	rise	MALE
trial	faith	trail	belly	TRAIL
unite	forum	untie	repel	UNTIE
bread	claim	beard	gross	BEARD
barely	editor	barley	oppose	BARLEY
horse	grass	heros	bloat	HEROS
shares	defeat	shears	helper	SHEARS

tries	flour	tires	glaze	TIRES
stops	panel	spots	elbow	SPOTS
waist	flash	waits	paste	WAITS
exist	alive	exits	guise	EXITS
chased	rocket	cashed	overly	CASHED
hates	cheer	haste	quest	HASTE
sale	joke	seal	lazy	SEAL
lake	bent	leak	fake	LEAK
lane	pace	lean	plot	LEAN
being	right	begin	drink	BEGIN
steal	porch	stale	motel	STALE
meat	rain	mate	leaf	MATE
team	rock	tame	oily	TAME
risen	aloud	rinse	ninth	RINSE
bear	grew	bare	harm	BARE
skin	born	sink	pack	SINK
blow	aged	bowl	goal	BOWL
knee	rage	keen	pile	KEEN
snake	index	sneak	merge	SNEAK
singer	derive	signer	alumni	SIGNER
stake	mayor	skate	murky	SKATE
weird	prose	wired	brace	WIRED
there	about	three	great	THREE
except	period	expect	animal	EXPECT
tied	cope	tide	corn	TIDE
ears	lift	eras	anew	ERAS
nest	mist	nets	lens	NETS
post	nose	pots	clue	POTS
pets	comb	pest	lush	PEST
lost	road	lots	copy	LOTS
fires	harsh	fries	latin	FRIES
fast	bill	fats	pulp	FATS
rare	gate	rear	chin	REAR
crude	layer	cured	onion	CURED
burden	lonely	burned	column	BURNED
never	going	nerve	penny	NERVE
boots	crazy	boost	rebel	BOOST
intend	relate	indent	hereby	INDENT
drive	peace	diver	quill	DIVER
dear	paid	dare	load	DARE

stop	care	spot	cook	SPOT
mean	kind	mane	cite	MANE
bake	dive	beak	idol	BEAK
beat	cool	beta	disk	BETA
abroad	golden	aboard	export	ABOARD
casual	behave	causal	corpus	CAUSAL
from	have	form	hard	FORM
cellar	expose	caller	joyous	CALLER
fear	easy	fare	beam	FARE
fist	doll	fits	poem	FITS
framed	agenda	farmed	entail	FARMED
cast	feed	cats	bull	CATS
crude	lodge	cured	purse	CURED
admits	banker	amidst	faulty	AMIDST
gaps	junk	gasp	papa	GASP
best	keep	bets	itch	BETS
dome	heap	demo	gram	DEMO
same	away	seam	chef	SEAM
snow	draw	sown	monk	SOWN
tire	deed	tier	cute	TIER
moon	diet	mono	dill	MONO
none	hall	neon	feat	NEON
heat	rich	hate	pair	HATE
feel	help	flee	loop	FLEE
vein	cork	vine	blot	VINE
vote	bath	veto	pear	VETO
weak	data	wake	gift	WAKE
finger	detail	fringe	legend	FRINGE
great	might	grate	berry	GRATE

APPENDIX B

EXPERIMENTAL ITEMS FOR EXPERIMENTS 4 AND 5

L1-L2 Translation Condition

Primes		Targets
Related	**Unrelated**	
ملکه	آگهی	QUEEN
تصادف	محتوا	ACCIDENT
فرودگاه	پیشگیری	AIRPORT
فصل	گاز	SEASON
حشره	نقاب	INSECT
خواهر	سانحه	SISTER
الماس	تعمیر	DIAMOND
غریبه	مغازه	STRANGER
جراحی	پنجاه	SURGERY
شغل	حرم	JOB
راهنما	شاهکار	GUIDE
باغ	قلب	GARDEN
اجاره	عکاسی	RENT
سرعت	سقوط	SPEED
خلاصه	انسان	SUMMARY
آتش	مهر	FIRE
فلز	جبر	METAL
سیاه	بنده	BLACK
دکمه	طاقت	BUTTON
کاسه	غبار	BOWL
عقاب	متمم	EAGLE
قفل	آهک	LOCK
وزن	دهه	WEIGHT
ماهیچه	مادیات	MUSCLE
موج	جشن	WAVE
زاویه	تعدیل	ANGLE
صبحانه	مبالغه	BREAKFAST
خامه	سفره	CREAM
تقویم	آواره	CALENDAR
سوراخ	درگاه	HOLE
اشتباه	تولیدی	MISTAKE
شراب	صدمه	WINE
عادت	وکیل	HABIT
چاقو	چرخش	KNIFE

نقره	رقیب	SILVER
دستکش	آسیاب	GLOVE
پرستار	پرتقال	NURSE
دوچرخه	میانجی	BICYCLE
زانو	لهجه	KNEE
بشقاب	تعرفه	PLATE
دامن	مغرب	SKIRT
طناب	خفاش	ROPE
نرم‌افزار	تخته‌سیاه	SOFTWARE
کشور	مردم	COUNTRY
دست	نظر	HAND
صورت	وجود	FACE
هزار	توجه	THOUSAND
فرهنگ	وزارت	CULTURE
جامعه	گذشته	SOCIETY
زندگی	اشاره	LIFE

L2-L2 Repetition Condition

Primes		**Targets**
Related	**Unrelated**	
minute	artist	MINUTE
sheep	scale	SHEEP
marriage	platform	MARRIAGE
change	weapon	CHANGE
walnut	raisin	WALNUT
freedom	brother	FREEDOM
word	coal	WORD
week	cash	WEEK
skin	soil	SKIN
mushroom	mattress	MUSHROOM
page	bomb	PAGE
industry	military	INDUSTRY
enemy	trail	ENEMY
writer	device	WRITER
pencil	signal	PENCIL
morning	journal	MORNING
fish	gift	FISH
twenty	temple	TWENTY
north	night	NORTH
branch	street	BRANCH
research	material	RESEARCH
shrimp	stereo	SHRIMP

explosion	afternoon	EXPLOSION
hospital	composer	HOSPITAL
yard	four	YARD
triangle	schedule	TRIANGLE
knowledge	furniture	KNOWLEDGE
chair	cover	CHAIR
soap	food	SOAP
university	restaurant	UNIVERSITY
summer	engine	SUMMER
engineer	darkness	ENGINEER
olive	shelf	OLIVE
leader	square	LEADER
teacher	gesture	TEACHER
music	human	MUSIC
pressure	entrance	PRESSURE
price	grave	PRICE
factory	article	FACTORY
family	object	FAMILY
spoon	cheek	SPOON
forest	friend	FOREST
camp	mind	CAMP
blood	color	BLOOD
young	heart	YOUNG
activity	audience	ACTIVITY
spring	symbol	SPRING
problem	citizen	PROBLEM
growth	member	GROWTH
airplane	minister	AIRPLANE

L2-L1 Translation Condition

Primes		**Targets**
Related	**Unrelated**	
sword	whale	شمشیر
question	children	سوال
salt	pipe	نمک
government	conference	حکومت
soldier	bedroom	سرباز
cancer	jungle	سرطان
guest	lodge	میهمان
honey	phone	عسل
novel	nanny	رمان

bone	wire	استخوان
interview	chocolate	مصاحبه
basket	cookie	سبد
plant	slave	گیاه
window	record	پنجره
horse	stick	اسب
onion	dryer	پیاز
smile	joint	لبخند
school	doctor	مدرسه
paper	state	کاغذ
girl	baby	دختر
kitchen	address	آشپزخانه
experience	foundation	تجربه
lunch	sound	ناهار
wall	jail	دیوار
nature	prince	طبیعت
camera	notice	دوربین
mayor	award	شهردار
mirror	valley	آینه
driver	shower	راننده
snow	farm	برف
bird	desk	پرنده
brain	porch	مغز
neighbor	elephant	همسایه
flag	hood	پرچم
tomato	jersey	گوجه
wheel	money	چرخ
candle	inmate	شمع
coffee	dinner	قهوه
church	lawyer	کلیسا
customer	follower	مشتري
manager	monster	مدیر
bride	yeast	عروس
future	throat	آینده
husband	captain	شوهر
bread	radio	نان
death	smoke	مرگ
finger	pocket	انگشت
group	field	گروه
body	lady	بدن
game	deal	بازی

<u>L1-L1 Repetition Condition</u>

Primes: Related	Primes: Unrelated	Targets
اصلاحات	جشنواره	اصلاحات
اظهار	حكومت	اظهار
امر	غرب	امر
امروز	خارجي	امروز
امنيت	مانند	امنيت
انسان	موضوع	انسان
آزاد	ساير	آزاد
آينده	مربوط	آينده
باعث	مصرف	باعث
بالا	علمي	بالا
بدون	خارج	بدون
بسياري	فوتبال	بسياري
بيان	ممكن	بيان
پيدا	طريق	پيدا
پيروزي	ارتباط	پيروزي
تاكيد	گسترش	تاكيد
تعداد	نتيجه	تعداد
تغيير	مقابل	تغيير
چهار	ساخت	چهار
حاضر	هنوز	حاضر
حركت	بازي	حركت
حضرت	جنوب	حضرت
خانه	قابل	خانه
دور	كمك	دور
ديروز	منابع	ديروز
رسيد	زنان	رسيد
رشد	تحت	رشد
روابط	اساسي	روابط
زمين	اخير	زمين
زيادي	جمعيت	زيادي
سفر	مدت	سفر
سوم	شكل	سوم
شبكه	دلار	شبكه
شرايط	البته	شرايط
شمال	بودن	شمال
شهرستان	مطبوعات	شهرستان
طول	ملت	طول
علت	طرف	علت

غربي	موجب	غربي
غير	نفت	غير
قوه	جنگ	قوه
كاهش	تمام	كاهش
گونه	قدرت	گونه
لازم	شامل	لازم
مرحله	اولين	مرحله
مشكلات	تاريخي	مشكلات
مطرح	واقع	مطرح
مقام	تلاش	مقام
مناطق	طبيعي	مناطق
مهم	محل	مهم

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