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# The Contribution of Phonological Overlap to the Cognate Effect: An Event-Related Potential Study of Persian-English Bilinguals

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# The Contribution of Phonological Overlap to the Cognate Effect: An Event-Related Potential Study of Persian-English Bilinguals

by

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## Abstract

The purpose of this dissertation was to examine the contribution of phonological overlap to visual word recognition. More specifically, this study aimed at testing the phonological account of the cognate effect (i.e., faster and more accurate mental processing of cognates than noncognates) in visual word recognition in Persian and English, which are languages with different scripts. The phonological account attributes the cognate effect to the phonological similarity of cognates (form and semantically related words) in addition to the conceptual similarity that cognates and noncognates (semantically related words) have and to the degree of phonological similarity between cognates in two languages. Thus, the phonological account predicts that the size of the cognate effect correlates with the phonological similarity of cognates and the lack of this feature in noncognates. Another objective of this study was to examine and confirm the nonselectivity view of bilingual word recognition in late but proficient Persian-English bilinguals, which holds that bilinguals cannot avoid the nontarget language when reading in one language. Also, this study aimed to investigate whether the effect of the nontarget language, if any, would start earlier when the languages have different rather than similar scripts. This dissertation comprises three studies. In the first study (Chapter 2) a database was created that included the stimuli used in subsequent studies. Lexico-semantic features of the stimuli in the database were examined to determine the importance of these features in Persian and English. The second (Chapter 3) and third (Chapter 4) studies used a masked priming lexical decision task to collect response time (RT), accuracy, and event-related potentials (ERPs) to assess whether the Persian-English (Chapter 3) and English-Persian (Chapter 4) direction affected the processing of cognates and noncognates. A within-subjects analysis of variance supported the importance of high phonological similarity in visual word recognition in Persian-English bilinguals who know two different-script languages, as cognates with lower phonological similarity showed inconsistent effects and noncognates failed to show any priming effects in either direction in the experiments. Cognates with high phonological similarity were processed faster in both Persian and English and produced more correct responses in English. Finally, the event-related potential (ERP) analysis showed that high phonological similarity elicited a P100 in English and a smaller N150 in Persian. A better understanding of bilingual word recognition has theoretical implications for models of bilingual word processing and practical implications for language teaching, especially when the words have similarities in the first and second language.

*Keywords:* cognates and noncognates, the phonological account, visual word recognition, ERPs, Persian-English bilinguals

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## List of Abbreviations

ANOVA - Analysis of variance

AoA - Age of acquisition

ASL - American Sign Language

BIA+ - Bilingual interactive activation plus

CLT - Cross-linguistic transfer

EEG - Electroencephalography

ERP - Event-related potential

fMRI - Functional magnetic resonance imaging

HPS - High-phonological similarity

ICA - Independent component analysis

IELTS - International English language testing system

L1 - First language

L2 - Second language

LA - Right anterior

LP - Left posterior

LPS - Low-phonological similarity

M - Mean

MA – Master of Arts

MANOVA - Multivariate analysis of variance

MSc – Masters of Science

O - Orthographic

P - Phonological

Ph.D. - Doctor of Philosophy

RA - Left anterior

RHM - Revised hierarchical model

RP - Right posterior

RP - Vertical midline

RT - Response time

SD - Standard deviation

SEM - Standard error of measurement

TEFL - Teaching English as a foreign language

VM - Vertical midline

β - Slope of the line of regression

ηp2 - Eta-squared

λ - Lambd

# Chapter 1. Introduction

## 1.1. Significance of Research on Bilingualism

Bilingualism is the ability to understand and speak two languages (Grosjean & Li, 2013). It is hard to determine the actual number of people who speak more than one language, but estimates indicate that more than half of the world's population are bilingual (Grosjean, 2010). The rise in bilingualism results from the requirements of living in the modern world, making it a norm for people to learn another language for business, academic, and other endeavors. Alternatively, it is usual to grow up bilingual in countries like Canada. Not only has bilingualism improved communication between people, but it also offers cognitive and cultural advantages to those who have learned more than one language (Bialystok, 1999, 2008). Undoubtedly, bilingualism leads to better career opportunities in all sectors of modern societies.

Bilingual research focuses on linguistic, sociolinguistic, psycholinguistic, and neurolinguistics aspects of the phenomenon. A common issue in all these fields is how bilinguals differ from monolinguals regarding the language systems they have acquired and how they use their acquired languages. More specific to psycholinguistics and neurolinguistics, however, are how bilinguals manage two languages simultaneously and how they comprehend and produce each language. In fact, one of the critical questions regarding language comprehension and production is how bilinguals process words and access their lexico-semantic features.

A lexicon is the set of all the words and idioms of any language that language speaker knows (Richards, Platt, & Platt, 1992a). Lexicons have a central role in language comprehension and production, as the quantity and quality of words that speakers of a language know, and the way they process these words, are the factors that distinguish native from nonnative speakers of a language (Levelt, 1989). A large body of research has investigated speakers' first language (L1) and second language (L2) systems and their influences on one another.

Research on the connection between L1 and L2 and their mutual influence when bilinguals perform a task in one language has theoretical and practical implications (Dijkstra & van Heuven, 2002). On the theoretical level, these findings contribute to the models of visual word recognition and word access in bilinguals. When bilinguals read words in one language, they face issues that are absent in monolinguals. Because bilinguals have two language systems, they must direct their word processing towards the language they are reading and decrease the influence of the other language in the task. Hence, the main question is whether one language system accounts for word recognition without the influence of the specific knowledge of another language or both systems. An understanding of word recognition, thus, reveals the nature of this process and the way bilinguals differ from or resemble monolinguals. The more researchers understand bilingual word recognition, the better they understand the underlying principles of this process.

On the practical side, the findings of these studies improve foreign language teaching and provide educators with insights into language comprehension and production, as words are the building blocks of sentences, and sentences, in turn, are the building blocks of larger pieces of discourse. Any improvement in the teaching and learning of an L2 is not achievable unless one learns more about the nature of language representation and processing in bilinguals. Realizing that L2 learners rely on their L1 knowledge helps syllabus designers, textbook writers, and language teachers to make better pedagogical decisions.

## 1.2. Bilingual Mental Organization and Word Access

A look into the literature reveals two contrasting views on the mental organization of the lexicon (word knowledge) and word access in a bilingual brain. The language selective activation view postulates separate mental lexicons with no mutual interlingual interactions (Macnamara & Kushnir, 1971; Scarborough, Gerard, & Cortese, 1984), while the nonselective activation view assumes an integrated lexicon (a combined lexicon) with shared interlingual interactions between two language systems (Dijkstra, Grainger, & van Heuven, 1999; Dijkstra & van Heuven, 2002) to describe the architecture of word knowledge and access. According to the language selectivity view, bilinguals have two mental lexicons which are organized independently and kept apart. This means that when a bilingual speaker processes one language, only words and features specific to that language are activated (Gerard & Scarborough, 1989; Rodriguez-Fornells, Rotte, Heinze, Nösselt, & Münte, 2002). According to the nonselectivity view, bilinguals possess a shared lexicon that includes words belonging to both languages. Therefore, when a bilingual speaker uses one language, word features in that language and related word features in the other language will automatically be activated (de Bruijn, Schriefers, & Brinke 2000; de Groot, Delmaar, & Lupker, 2000; Dijkstra, Timmermans, & Schriefers, 2000; Dijkstra & van Heuven, 2002; Lagrou, Hartsuiker, & Duyck, 2011; Spalek, Hoshino, Wu, Damian, & Thierry, 2014). According to the nonselectivity view, for example, when English-French speakers read the word *attend*, they cannot avoid access to the meaning and pronunciation of the French word *attendre* along with those of *attend*.

Most studies have provided evidence for nonselective access to the mental lexicon (de Bruijn et al., 2000; de Groot et al., 2000; Dijkstra & van Heuven, 2002; Lagrou et al., 2011; Spalek et al., 2014) even when languages were profoundly different (Zhou, Chen, Yang, & Dunlap, 2010). Zhou, et al. (2010) collected performances on homophones and their control words using a masked-priming word naming and a lexical decision task in a group of Chinese-

English speakers in L1-L2 and L2-L1. These researchers suggested that phonologically related words were named faster than phonologically unrelated words in Chinese and English, one being a logographic and the other an alphabetic language, respectively. The researchers found similar results in the lexical decision task, although phonology was indirectly related to the task.

Interestingly, nonselective access was found in bilingual word recognition when the language modality of the L1 and L2 varied, and when two languages had no phonological and orthographic overlap like American Sign Language (ASL) and English (Morford, 2014). Cross-language activation was observed in deaf ASL dominant speakers with moderate English proficiency and hearing English-dominant ASL learners. Participants performed a semantic relatedness judgment task in English with semantically related or unrelated pairs. Semantically related words in English were either phonologically related in ASL (sharing features such as handshape, location, and movement) or unrelated. Both groups made a slower judgment on the semantically unrelated condition when the ASL translations of the target words were phonologically related than when the translation equivalents were phonologically unrelated in the ASL. The results, however, were more pronounced for the deaf group. Moreover, the deaf group judged the English words to be semantically related faster when their ASL translations were phonologically related.

Models like the bilingual interactive model plus (BIA+, Dijkstra & Van Heuven, 2002) postulate that bilingual word processing benefits from nonselective and selective access. The processing is nonselective when a string is encountered and the incoming linguistic information contacts representations in both languages. Next, language selectivity operates in a top-down processing format, inhibiting the representations in the nontarget language. This inhibition cannot completely block the nontarget language representations, but it aims at minimizing the cross-language interference.

## 1.3. Cognate and Noncognate Words

Researchers who study word processing and word access in bilinguals use words that display different degrees of overlap between form and meaning across languages, such as homophones, homographs, cognates, and noncognates. These words share specific features with their translation equivalents in another language. Homophones are "words which sound alike but are written differently and often have different meanings," while homographs are "words that are written in the same way and sound alike but which have different meanings"(Richards, Platt, & Platt, 1992b). Cognates are words "that are similar in form and in meaning" in different languages (Lado, 1956, p.32). They are translation equivalents that are conceptually and phonologically similar in two languages, although they might be similar orthographically (same-script languages) or not (different-script languages). Conversely, noncognates are translation equivalents that share conceptual features without any phonological or orthographic similarity in two languages (Nakayama, Verdonschot, Sears, & Lupker, 2014). For example, the words *Appel* and *Apple* are cognates in Dutch and English due to their similarity in spelling, pronunciation, and meaning. To provide more examples, *analytique* (*analytic*), *tomate* (*tomato*), *créatif* (*creative*), and *banque* (*bank*) are cognates in French and English. Examples for cognates in English and Spanish are *academic* (*académico*), *alcoholic* (*alcohólico*), *domestic* (*doméstico*), *organic* (*orgánico*), and *panic* (*pánico*). Urdu and English have cognates such as college ( کالج ), name ( نام ) , chutney ( چٹنی), and shah (شاہ).

Cognates have historical origins when they belong to the same language family, or they are borrowed from other languages (Friel & Kennison, 2001). To illustrate, *filter* and *pyramid* are historically related in Hebrew and English (Gollan, Forster, and Frost, as cited in Friel &

Kennison, 2001) while *baseball* and *ice cream* were lent to Japanese (Hatta and Ogawa, 1983, as cited in Friel & Kennison, 2001). Some of the Persian and English cognates have the same historical origin, as Persian and English have a shared ancestral Proto-Indo-European language family while a few others result from borrowing ("List of English words of Persian origin," n.d.). Examples of the first type include *mother (*مادر /mɑːˈdœr/) *, father (*پدر /peˈdœr/), *daughter* (دختر /dʊkhˈtœr/), brother (برادر /bœrɑːˈdœr/), and *name* (نام /ˈnɑːm/). The following words have Persian origins: *Bazaar (بازار /ba'zar/*), *bronze*( *برنج/be'rendʒ/), caviar (خاویار* /khɑviˈɑr/), and *paradise(* بهشت*/be'hesht/*). Conversely, the Persian language has loan words with English and French origins, such as *ampule* (*آمپول* /ɑːmˈpuːl/), *mobile (موبایل* /mu'bail/) , *hamburger* (همبرگر /*'hæm'ber'ger/), hacker (هکر*/*'hæker*/), and *schizophrenia (اسکیزوفرنیا/'eskizu'fernia:/*).

Cognates have a special status in cross-language studies in bilingualism, second language teaching, and psycholinguistics. Cognates are a part of L1 knowledge that is transferable to L2 and can improve language comprehension when learners have limited L2 knowledge (Vandergrift, 1997). Cognates are retrieved faster from memory, easier to learn in L2, and faster and more accurate to translate into L1 and L2 (Otwinowska & Szewczyk, 2019). Hence, they are essential in studying word recognition, word processing, and the architecture of the bilingual lexicon.

Two tasks help to determine whether and to what extent words of two languages resemble one another: similarity-rating (de-Groot & Nas, 1991) and translation-elicitation (Kroll & Stewart, 1994). In the similarity-rating task, a group of bilinguals who speak both languages rate the similarity of a list of words and their translation equivalents in another language on a *7*-scale continuum with *very high similarity* at one end and *very low similarity* at the other end. Words rated as *highly similar* are identified as identical cognates, and words rated as *highly* *dissimilar* as noncognates. In the translation-elicitation task, a word is provided in one language, and raters provide a translation equivalent in the other language. Both tasks produce similar results (Friel & Kennison, 2001).

Cognates can also be defined according to the number of letters they share in two languages. For example, Willis and Ohashi (2012) considered cognateness the proportion of letters that words share in two languages. They used this criterion to put cognates on a continuum while they applied a binary classification to divide words into cognates and noncognates in languages like Japanese and English, which do not share scripts and borrowed words are written in a different script (Katakana) than other words (Kanji).

Likewise, cognates enjoy a special status in the lexicon because they provide a "foothold" into the L2 lexicon (Midgley, Holcomb, & Grainger, 2011, p. 1634); they are words that bilinguals have learned and used in their L1. Thus, they are a part of the L1 knowledge. Cognates, therefore, are appropriate stimuli to use to understand at which level of phonology and orthography the two lexical systems are connected and which levels bilinguals use to access the lexicon. These aims are achievable by manipulating formal and semantic features of words when selecting bilinguals with similar-script or different-script languages.

## 1.4. Representation of Cognates in the Bilingual Lexicon

To explain the faster processing of cognates, the following models are postulated.

### 1.4.1. Shared-morpheme view.

According to the shared-morpheme view (Figure 1.1), there exists a language-independent level that includes the root of morphologically-related words and cognates in languages with similar scripts (Cristoffanini, Kirsner, & Milech, 1986; Davis et al., 2010; Kirsner, Lalor, & Hird, 1993; Peeters, Dijkstra, & Grainger, 2013; Sáchez-Casas, García-Albea, & Davis, 1992). This level exists between form and lemma (an abstract conceptual form of a word) levels. Bilinguals encounter cognates in both languages, and so their cumulative frequency increases more than that of noncognates that occur in one language. Thus, the shared representation of cognates is activated twice as much compared to the representation of noncognates and strengthened more than noncognates, accordingly. This shared representation leads to the faster and more accurate recognition of identical cognates observed in most studies.

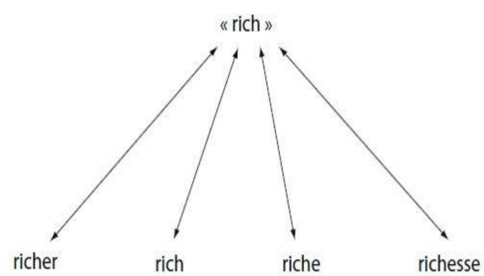



*Figure 1.1*. Morphologically-based organization of cognates adopted from Voga and Grainger (2007)

**1.4.2. Form-overlap view.**

The form-overlap view states that orthographically identical cognates have one shared orthographic representation, two phonological representations (one in each language), and one semantic representation (Midgley et al., 2011). Noncognates, on the other hand, have one orthographic and one phonological representation. Thus, two phonological representations activate one semantic representation in cognates, while only one phonological representation activates noncognates. As bilinguals use cognates in both languages, the semantic representation of cognates is activated more strongly than that of noncognates and results in the cognate effect in word recognition and word processing studies.

### 1.4.3. Two-morpheme view.

The two-morpheme view is similar to the form-overlap view, proposing that identical cognates have one single orthographic representation and two phonological representations activating one semantic representation (Dijkstra & van Heuven, 2002; Peeters et al., 2013). Nonetheless, each cognate has a specific morphological representation in each language, to which the morphemic markers, such as plural markers and past-tense markers, are attached. Upon reading a cognate, the reader activates the orthographic, phonological, and morphological representations in both languages. However, one of the representations receives priority depending on the nature of the task, items on the list, and task language. Hence, the activated representation affects the response time and accuracy of responses to cognates.

### 1.4.4. The BIA+ model.

The BIA+ model was developed to show the interactive nature of bilingual representation and processing (Figure 1.2, Dijkstra & Van Heuven, 2002). The BIA+ model assumes that orthographic, phonological, and semantic representations of words are interactive; when words in one language are processed, the information about the associated words in the other language is also activated.

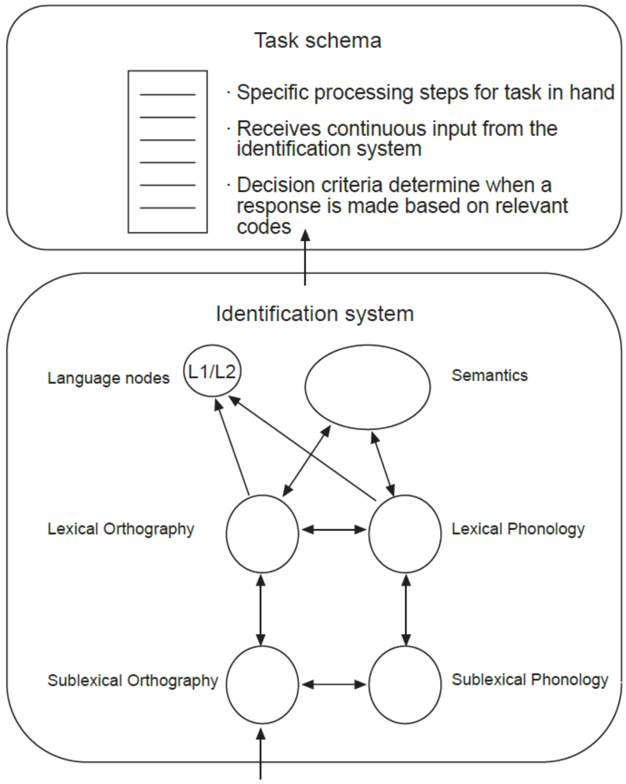



*Figure 1.2.* The BIA+ model of bilingual word recognition (Dijkstra & Van Heuven, 2002)

The BIA+ model (Figure 1.2) has two components that function independently: the word identification and the task schema systems. The word identification system includes sublexical and lexical orthography that are hierarchically ordered and are connected to their corresponding phonological components. Upon reading a word, these components interact and allow the word to be processed in a bottom-up manner. Language nodes in the model represent language membership, and they hold relevant information about each word in the form of language tags. The word identification system uses the linguistic information that a word or word context provides while the task or decision system uses nonlinguistic information, such as the reader's expectations, strategies a reader uses, and task requirements.

Visual word processing begins with an input letter string that activates lexical orthographic candidates in both languages in parallel. The criteria for the selection and activation of word candidates are their orthographic similarity to the input string and their threshold level that depends on factors such as word frequency (the number of times a word appear in a corpus), recency of use, word neighborhood density (the number of words made by changing, adding, or deleting one phoneme), and language proficiency in each language, but not to which language the word belongs. Stated otherwise, the visual word identification system initially activates the words that are orthographically similar to the stimulus and have a lower threshold for the mentioned lexical features, irrespective of the language to which the word candidate belongs.

According to the model, the linguistic context, such as the sentence context, affects the threshold level of word candidates and restricts the number of word candidates that are to be activated. In other words, contextual information decreases or increases the threshold level of the word candidates and, consequently, influences their initial activation. The orthographic similarity is advantageous for homographs and cognates over other word types because it limits the initial list of activated word candidates. After the word candidates are activated, the activation spreads to the associated phonological and semantic representations. The sequence of the activation stage and the spread of the initial orthographic activation to other levels result in a temporal delay between the orthographic activation and the activation of other representational levels. However, the model assumes that interactions between orthographic, phonological, and semantic codes are ongoing and dynamic, as shown by two-way arrows in the model. After a word is recognized, other word candidates are suppressed.

The task scheme system functions based on nonlinguistic information, such as the reader's expectations and task requirements, but it does not influence visual word processing directly. This system adapts the temporal deadlines between the activation of the orthographical, phonological, and semantic representations and decision parameter settings to produce the most optimized performance. The task scheme functions independently of the identification system; it is possible to make a decision without word recognition or delay it until more information arrives. The following situations clarify how the task system works. If, for example, the task is a language decision, the task system uses the information that the language codes provide. Alternatively, if the task is a lexical decision, the task system uses the activation threshold of the target item and temporal deadlines. In the lexical decision task, the task system binds the “yes” response to a sufficient activation of a word at a particular moment in time while the system binds the “no” answer to the lack of lexical information (i.e., for nonwords) after a temporal deadline is reached.

As Figure 1.2 shows, the model uses one-way arrows to connect language nodes to lexical orthographic and phonological representations. It means that language membership works on the output of the word identification process, and it does not influence word activation and the rejection of nontarget words. Language nodes retrieve language membership using lexical codes (i.e., orthographic, phonological, and lemma representations). However, lemma representation is excluded from the model for simplicity. Language nodes fail to affect the word identification process, possibly because language identification occurs too late to affect the word recognition process, and feedback that a language node sends to a word unit is much smaller than the activation that it receives from the word. The reason the activation from the language node to the word identification process is so small is because a language node is attached to a large group of words, and activation is a constant. Placing language nodes in the word identification system shows its independence of nonlinguistic information. This model has provided a detailed account of activation and representation of orthographic codes. However, as Dijkstra and Van Heuven (2002) have asserted, there is insufficient data regarding the relationship between orthographic, phonological, and semantic codes of cognates in order to implement these in the BIA+ model. Studies have provided facilitatory, inhibitory or null effects of cognates in different-script languages (Dijkstra et al., 1999; Khan, 2012; Lemhöfer, Dijkstra, & Michel, 2004), which originates from their phonological overlap. This issue complicates the whole picture and necessitates investigating the role of phonology further.

**1.4.5. The Multilik model.**

The Multilink model (Dijkstra et al., 2019) has hold the basic assumptions of the BIA+ model while including a localist connectionist network (Figure 1.3).

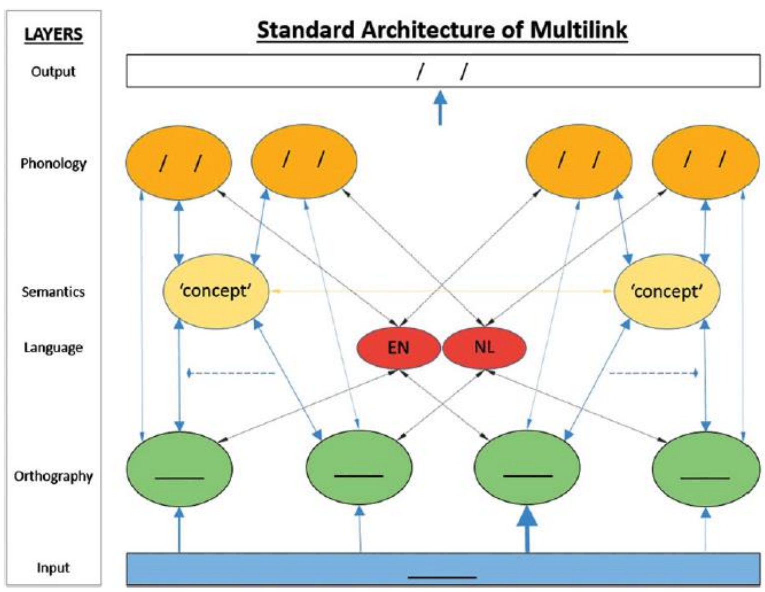



*Figure 1.3.* (Color online) Standard network architecture of Multilink. Note: Input is indicated by blue underscore, orthographic (O) representations by green underscore, phonological (P) representations by slashes. EN = English, NL = Dutch. The dashed line between two connections from O to S (semantics) indicates that their activation is summed after taking half of the second node's activation input (see text). Output is task-dependent. Here slashes indicate a phonological output in the same or a different language (for word naming or translation).Adopted from Dijkstra et al. (2019).

Similar to the BIA+ model, the Multilink model proposes an integrated lexicon for the L1 and L2 words, language nonselective word access, separation of the word recognition and ask/decision systems, and the activation of lexical representations of word competitors depending on their orthographic similarity with the word input and also the subjective frequency of word usage. What makes the Multilink model different from the BIA+ is its layered network architecture, which better shows interactions between the orthographic, semantic, and phonological representations of words and the role of the language membership nodes in word recognition. This model can also explain the effect of word frequency and L2 proficiency better through the resting level activation of word forms and the strength of the links among the semantics, orthographic and phonological features.

A localist model such as the Multilink can explain the activation, the spread of activation and managing the competition of the activated representations more efficiently. Because bilinguals use two language systems simultaneously, they need to "attend to two representations, ignore interference from the nontarget language, and switch appropriately between representations" (Bialystok, 2011, p. 466). Most models of visual language processing posit that when bilingual speakers use one language, both target and nontarget language words are activated automatically (Dijkstra & Van Heuven, 2002; Jared & Kroll, 2001), and this activation spreads within and between both languages, leading to competition among the activated lexical candidates. This competition must be managed, and the most activated word candidates should be selected in the target language. An inhibitory control (IC) system can play a role in managing this competition using selection through inhibition i.e., the IC system impedes contextually irrelevant lexical competitors (D. W. Green, 1998). The IC system also uses the language tags to ensure that relevant outputs are in the target language.

The IC system is hypothesized to function in conjunction with working memory and attention systems (Hughes, 1998), as well as conflict monitoring and search strategies (Maier, Liepelt, & Steinhauser, 2023), enabling individuals to exhibit adaptive, flexible, and complex goal-directed behavior (Olson & Luciana, 2008). These distinct yet interconnected components constitute the executive functioning system, which is enhanced through cognitively demanding experiences for individuals (C. S. Green & Bavelier, 2003) and by engaging in the daily use of two languages for bilinguals. Various types of research support the IC system hypothesis, such as experiments on language switching costs (Liu, et al., 2020), bilingual advantages in cognitive control (Bialystok, Craik, Klein, & Viswanathan, 2004), and bilingual Stroop effect (Costa, Albareda, & Santesteban, 2008). In these models (and other theories of bilingual language control), the IC system is considered an essential component of the broader executive control system, which also includes attentional and working memory processes. These executive control processes are thought to interact with the language processing system to enable bilinguals to efficiently manage their two languages and avoid interference from the nontarget language.

#### 1.4.6. The phonological account.

The theoretical views and the BIA+ model discussed above explain bilingual word recognition mainly in languages with similar scripts, such as English, French, German, and Dutch. Nonetheless, the phonological account discusses visual word recognition in different-script languages like Japanese, English, Chinese, Korean, and Persian. According to the phonological account, cognates show an advantage over noncognates in visual word recognition due to cognates' phonological and conceptual overlaps (Voga & Grainger, 2007). In fact, the phonological account attributes the cognate effect in different-script languages to their phonological in addition to their conceptual similarity, as the latter has also produced the facilitative effect of noncognates. Also, consistent with the phonological account, the phonological overlap functions independently of the conceptual overlap in cognates. Evidence is provided by Nakayama, Sears, Hino, and Lupker (2013), who have shown that conceptual overlap functions similarly in cognates and noncognates, as both word-types were modulated by word frequency and proficiency in L2; masked related primes improved performance on low-frequent words and helped low-proficient participants more than high-frequent words and high-proficient participants for cognates and noncognates. Nakayama, et al. also observed that the size of the cognate effect did not significantly differ across the levels of word frequency and proficiency in the L2 when the prime was in the L1 and the target in the L2. However, when the prime was in the L2, only cognates showed a facilitated effect for low and high proficient participants. Conversely, noncognates showed a facilitative effect for high-proficient participants. The researchers concluded that the nature of the cognate effect in the L2-L1 direction was the phonological similarity of cognates.

## 1.5. The Masked Priming Lexical Decision Task

Research studies on bilingual lexical processing have used various tasks, such as word naming, semantic go/no go, and masked-priming lexical decision (Forster & Davis, 1984). In the masked-priming lexical decision task, participants give a timed response to a rapidly presented prime (i.e., 50 ms for an L1 prime) which is hidden by number signs (#####). They indicate whether the target is a word or nonword. The prime and target are related or unrelated in terms of meaning, phonology, and orthography. The mask hides the prime and makes it invisible and unidentifiable. Thus, the prime fails to receive conscious attention and the use of conscious strategies that result from nonautomatic or strategic processing (Forster & Davis, 1984). Stated differently, a mask prevents participants from strategically connecting one word in a language with its translation equivalent in another language (Kirsner, Smith, Lockhart, King, & Jain, 1984). The RT between the pairs is measured and compared across the experimental conditions to determine whether semantic, orthographic, or phonological relationships between the prime and target facilitates the task. A faster RT to a related prime and target across two languages supports the proposal that lexico-semantic features of the prime and target are connected in a bilingual mental lexicon. Thus, the prime influences the recognition of the target in the other language. Overall, using a prime makes the task bilingual without participants consciously knowing it.

Two issues are critical in a lexical decision paradigm when using words as stimuli: matching the lexico-semantic features of words and the duration of the prime in L2. Researchers tend to measure and control lexico-sematic features of stimuli in studies on visual word recognition to match them across the experimental conditions because these features can interact with the variables of the study and decrease its internal validity. These features are word frequency, word length, age of acquisition (AoA), neighborhood density, familiarity, imageability, and concreteness (D. A. Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004). Online databases have provided information about these features for words in English, French, German, etc. However, this information does not exist for less frequently studied languages like Persian. Thus, the first step in conducting similar studies in Persian is to measure these word features. Regarding the prime duration, it is almost consensus that a prime of 50 ms for L1 keeps the processing of the word under the level of consciousness while making it effective in processing the target (Forster & Davis, 1984). However, the best duration of the prime in L2 is debated because researchers believe that L2 primes require more processing time to produce significant effects in L1 (Lee, Jang, & Choi, 2018). Given the importance of these two issues, cross-language researchers must measure and control lexico-semantic features of words and decide the duration of the L2 prime in a new linguistic context.

Lexical decisions and tasks similar to it are product- rather than process-oriented. These tasks elicit responses that are recorded after participants have accomplished the tasks. Such measures do not provide any information about the brain processes that underlie the task. Thus, researchers record brain activities like an electroencephalogram (EEG) or functional magnetic resonance imaging (fMRI) to understand how the brain functions while participants are engaged in the task. EEG data are averaged across participants and experimental conditions to create event-related potentials (ERPs, Luck, 2004).

## 1.6. Electrophysiological Measures

EEG helps researchers take a multi-dimensional approach to bilingual research by adding EEG measures to traditional behavioral data collection tasks. This approach allows researchers to access more informative data including final responses and the online measure of the brain processes that lead to those responses. EEG recordings are continuous signals that show online brain activity. These signals are time-locked to a stimulus and averaged across participants and trials to produce ERPs (Luck, 2014). ERPs provide a temporal representation of the electrochemical communication of neurons. Many bilingual studies have used ERPs to examine language comprehension and production (Jackson, Swainson, Mullin, Cunnington, & Jackson, 2004; Khateb A et al., 2007; Männel & Friederici, 2008; Phillips, Kazanina, & Abada, 2005; Proverbio, Leoni, & Zani, 2004).

A few ERP components have been identified in language processing research (Luck, 2014). One component is the N400, which is a negative-going component reflecting the ease with which the conceptual knowledge associated with a meaningful stimulus is retrieved, or the meaning of a stimulus integrates into the previous discourse (Kutas & Federmeier, 2000, as cited in Luck). A more negative N400 shows more neural activity for either process. The process of finding and activating the meaning of a stimulus varies with the status of the stored knowledge representation and the retrieval cues provided by the preceding context. Generally, the N400 is larger over the central and parietal electrodes and in the right compared to the left hemisphere where it is generated (Hagoort, Brown, & Swaab, 1996); the generator dipole tends to point upward and to the right instead of straight upward. The generation of the N400 has been attributed to the left anterior medial temporal lobe (McCarthy, Nobre, Bentin, & Spencer, 1995). The N400 is related to the activity in the left prefrontal cortex (Halgren, Boujon, Clarke, Wang, & Chauvel, 2002). Two more ERP components related to language processing are the P600, which is positive going and reflects syntactic violations, and the left frontal negativity, which varies between 300 and 500 ms (Luck, 2004).

As EEG fails to have adequate spatial resolution, researchers divide electrodes into clusters to analyze all scalp channels (Holcomb, Reder, Misra, & Grainger, 2005; Hoshino, Midgley, Holcomb, & Grainger, 2010; Midgley, Holcomb, & Grainger, 2009; Midgley et al., 2011; Peeters et al., 2013). Also, they divide each epoch into time windows to capture the intended ERP components in smaller time segments. Midgley et al. (2009, 2011) used 200-300 ms, 300-500 ms, and 500-800 ms time windows in seven columns: three pairs of lateral columns in the left and right hemispheres and one midline column. They selected these time windows to capture the pre N400 activity (e.g., the N250), the N400 activity, and late effects. Peeters et al. (2013) divided the head surface into five clusters: two anterior, two posterior, and one midline. Each epoch was averaged from 100 ms pre-stimulus onset until 900 ms after the stimulus onset and was divided into time windows of 100 ms long.

## 1.7. Studies on Cognates and Noncognates

### 1.7.1. Cross-language studies on cognates and noncognates.

Researchers study cognates and noncognates to understand the architecture of the bilingual lexicon and word recognition because these words have shared features in L1 and L2.

Comparing these words shows the importance of phonological, orthographic, and semantic features of words in each language and possible interactions between the two language systems. More specifically, comparing the cognate translation effect with the noncognate translation effect can reflect the impact of shared formal similarities (phonology and/or orthography) on the recognition of cognates, which is not available in noncognate translation equivalents. Also, using different-script bilinguals can isolate the effect of phonological similarity on the visual word recognition of cognates.

Researchers have collected behavioral measures such as RT and accuracy when cognates and noncognates were preceded by related or unrelated primes using a masked lexical decision task in same-and different-script languages. Facilitative priming effects were mainly observed for cognates over noncognates and more in L2 than in L1. To illustrate, related primes facilitated the processing of cognates and noncognates in Dutch-English (de-Groot & Nas, 1991), Hebrew-English and English-Hebrew (Gollan, Forster, & Frost, 1997), Korean-English (Kim & Davis, 2003), Greek-French (Voga & Grainger, 2007), and Spanish-English (Davis et al., 2010) bilinguals. The findings of these studies supported that the similarity or lack of similarity of scripts did not prevent the appearance of priming effects for both types of words and the advantage that cognates showed over noncognates in terms of faster and more accurate responses in L2.

The facilitative effect of related primes did not appear in L1, except in studies where the languages involved had similar scripts and participants were advanced or near-native speakers. Cognates showed priming effects in Dutch-English (de-Groot & Nas, 1991), and noncognates showed priming effects in Spanish-English (Basnight-Brown & Altarriba, 2007), Greek-French (Voga & Grainger, 2007), and Dutch-French (Duyck & Warlop, 2009), but not for cognates in

Hebrew-English and English-Hebrew (Gollan et al., 1997) and noncognates in most studies (Finkbeiner, Forster, Nicol, & Nakamura, 2004; Grainger, 1998) in L1.

Khan (2012) studied the lexical representation and access of cognates and noncognates in Urdu-English bilinguals, examining the role of the frequency of primes and targets in a primed lexical decision task. Participants acquired Urdu as L1 and English as L2. They, however, reported higher fluency in English than in Urdu. Cognates and noncognates were divided into balanced (LU-LE, HU-HE) and unbalanced (LU-HE, HU-LE) word-frequency lists. The results were: (a) a cognate effect for LU-LE but no cognate effect for LU-HE, (b) a reverse cognate effect for high-frequent Urdu primes with either high- or low-frequent English targets, and (c) no cognate effect in the E-U direction. Some of the findings did not match those of previous studies. For example, Peeters et al. (2013) found that the frequency of cognates in the task language influenced the cognate effect in French and English rather than which language was dominant. Thus, both HU-HE and LU-HE lists were expected to show the cognate effect. Also, previous studies showed the appearance of the cognate effect in the nondominant language, but no effect was observed in Urdu in this study. Khan attributed the discrepancies to the high variance of participants' proficiency levels in Urdu, although participants reported higher fluency in English. This conclusion was supported by greater variance that participants showed on a reading test in Urdu than in English.

Khan's study (2012) reported both facilitation and inhibition effects for cognates, thereby complicating the role and interaction of formal features of cognates. An important issue that differs in this study from studies on different-script languages is that Urdu reads from right to left. Only a few languages with this feature have been the subject of cross-language studies. Also, Urdu and English are used interchangeably by this specific population and in different contexts, resulting in different proficiency levels in auditory and visual modalities. Using another pair of languages that read in opposite directions and a different bilingual population that allows better control of the proficiency of L1 and L2 will provide a better picture of how two languages with these specificities are represented and processed in the brain.

Attempting to explain the cognate effect, Voga and Grainger (2007) studied the importance of morphological relatedness of cognates in Greek-French bilinguals (i.e., the morphological account of the cognate effect). Cognates are related etymologically in European languages because these languages have common ancestral roots like Latin. Thus, they show morphological similarity, which was predicted to create the cognate effect in different studies. In their first experiment, Voga and Grainger tested this hypothesis in a masked priming lexical decision task where cognates were primed by their translation equivalent (τύπος –type; prime meaning type in English), morphologically related (τυπικό-type; prime meaning typical in English), and phonologically related but conceptually unrelated (ρύπος-type; prime meaning dirt in English) Greek words. Researchers displayed primes for 50 ms and 67 ms. According to the morphological account of the cognate effect, they predicted a similar pattern for cognate translating equivalents and morphologically related words in Greek and French because cognates and morphologically related words in either language are assumed to have the same language independent root (Figure 1.1). However, results did not support the morphological view for Greek and French, as cognates and morphologically related words showed different patterns of processing. Cognates primed by their translation equivalents were processed faster than the other word types with both prime durations, but morphologically related words showed a priming effect only when the prime duration was 67 ms. Researchers concluded that the cognate effect did not originate from either the phonological or morphological relationship between cognates in

Greek and French. They dismissed the hypothesis that considers one root for cognates and morphologically related words in L1 and L2 in different-script languages like Greek and French.

In their second experiment, Voga and Grainger (2007) used phonologically high-overlap cognate, phonologically low-overlap cognate, and noncognate French word targets primed by translation equivalent, phonologically related, or phonologically and conceptually unrelated Greek words. Generally, translation equivalents produced faster responses than phonologically related, and phonologically and conceptually unrelated primes. Moreover, cognates produced faster and more accurate responses than noncognates. Besides, significant interactions between target and prime types for noncognates, high-overlap cognates, and low-overlap cognates showed that translation equivalent primes produced faster responses for cognates than phonologically related and unrelated primes. In high-overlap cognates, the net priming effect when translation equivalents were compared with the phonological and unrelated conditions were 38 ms and 55 ms respectively. In other words, high-overlap cognates showed a larger cognate effect when compared with the unrelated condition than the phonologically related condition. The net priming effects for low-cognates and noncognates were 46 ms and 45 ms, and 36 ms vs. 23 ms respectively.

Voga and Grainger (2007) used findings to conclude that cognates do not have different mental representations from noncognates. Instead, cognates have phonological and conceptual overlaps, while noncognates have only conceptual overlaps. The additional phonological overlap of cognates produced faster and more accurate responses in various studies. This conclusion was further supported by the observation that cognates showed a typical advantage over noncognates when they were measured against an unrelated baseline and not phonologically related primes. All in all, the second experiment showed that the cognate effect resulted from a combination of phonological and conceptual similarities in Greek and French instead of either feature alone. Based on these findings, they introduced the phonological account of the cognate effect that attributes the cognate advantage to the phonological overlap of cognate translation equivalents in different-script languages, which is absent in noncognate translation equivalents.

The cognate advantage observed in languages with similar scripts can be supported by orthographic, phonological, and conceptual similarities across two languages. However, manipulating formal features of stimuli might show the importance of phonological features and its interplay with the orthographic information. Hence researchers have tested the phonological account in similar-script languages. In one study, researchers manipulated the orthographic and phonological overlap of a group of cognates and presented them with noncognates to Portuguese-English bilinguals using masked-priming silent reading to study the N100, the P200, and the N400 components (Comesana et al., 2012). Cognates were assigned to four experimental conditions for their orthographic (O) and phonological (P) overlap: O+P+ (bomba-BOMB), O+P− (cometa-COMET), O−P+ (danca-DANCE), and O−P−(laco-LACE). Comesana et al. (2012) observed different patterns of processing for cognates depending on the degree of orthographic similarity. Cognates with higher orthographic similarity (O+P+ & O+P−) showed less negative N400 while cognates with less orthographic similarity (O-P+, O-P-) showed more negative N400. The results were more pronounced for O-P+ than O-P- cognates. For noncognates, related primes showed less negative N400 than unrelated noncognates. Also, cognates with less orthographic similarity showed modulations of the N100 component regardless of their level of phonological similarity. These researchers concluded that sharing orthographic and phonological features eased the sublexical processing of cognates and made them distinct from noncognates in their study. Stated differently, they concluded that these features create a combined effect for cognates; the less orthographical similarity and the more phonological similarity of cognates, the greater the inhibitory effect. This inhibitory effect originated from the orthographic representation of cognates in either language competing for one phonological representation. No inhibitory effect was observed for noncognates, as noncognates have two orthographic, two phonological, and one conceptual representation. A logical follow-up to study the importance of the phonological component of cognates is selecting languages with completely different written characters rather than manipulating the degree of orthographic overlap.

Voga and Grainger's proposal (2007) was tested in a study using a similar design and task to that of Nakayama, et al. (2012). More specifically, Nakayama et al. (2012) examined the phonological account by comparing the processing of cognates with words that had phonological overlaps in Japanese and English, which are languages with completely different writing systems than Greek and French. The phonological account attributes the cognate effect to the phonological and conceptual overlap and not to phonological similarity alone. Nakayama et al. primed English targets by cognate translation equivalent, phonologically similar but conceptually unrelated, and phonologically and conceptually unrelated words in Japanese. They manipulated the frequency of English targets and the participant's proficiency in L2, predicting that only cognates would show interactions of these factors because of their conceptual overlap across these languages and not because the words were only phonologically related. Findings showed that related primes facilitated the processing of cognates and phonologically related words in the other language, confirming the integration of phonological features of the two language systems. However, researchers observed that only cognates showed interactions of these variables. In other words, they observed that frequency and proficiency had little impact on the phonological priming, but they influenced cognate priming in L2. The cognate effect was larger for low- than high-frequency words and low- than high-proficient participants. These effects are due to a shared conceptual component between cognates across two languages. These findings supported the phonological account and the hypothesis that interactional effects of cognates were due to their conceptual overlap in Japanese and English, which was absent in phonologically related words in these languages.

To further examine the phonological account of the cognate effect, (Nakayama et al., 2013) conducted a similar experiment to their 2012 study, but they added noncognates to the list of stimuli. First, they replicated the priming advantage for cognates over noncognates in Japanese and English. Second, they showed that similar to cognates, the noncognate effect was modulated by word frequency and language proficiency in L2; the noncognate effect was larger for low-frequent English targets and low-proficient participants. Third, they showed that the size of the effects of the two variables was similar across cognates and noncognates. Finally, they found that the cognate advantage occurred in low and high proficient groups in the L1 and L2 while they failed to observe the noncognate advantage in the L2-L1 direction. Overall, their results confirmed the phonological account. The researchers also attributed the cognate effect in the L2-L1 direction in both proficiency groups to the shared phonology in cognates, while related the absence of the priming effect for noncognates in L2-L1 to a lack of phonological similarity.

Nakayama et al.'s studies (2012, 2013) demonstrated that the cognate effect originated from the phonological and conceptual overlap that cognates benefited from in two languages with different scripts. They further studied the phonological account by examining whether the size of the cognate priming effect correlated with the degree of phonological similarity of cognate translation equivalents in Japanese-English bilinguals (Nakayama et al., 2014). Voga and Grainger (2007) studied a similar topic with Greek-French bilinguals. However, they did not compare the priming differences between cognates with more and less phonological similarity. Also, Greek and French have more orthographic similarities than Japanese and English. Hence, Nakayama et al. (2014) selected cognates with varying levels of phonological similarity, namely high-phonological similarity (HPS) and low-phonological similarity (LPS) cognates, and collected RT and the accuracy of responses in a masked priming lexical decision task. The phonological overlap of cognate translation equivalents produced 47 ms faster responses in HPS than in LPS cognates. However, researchers could not compare LPS cognates with noncognates to observe whether the LPS cognates would produce faster and more correct responses than noncognates because cognates are written in Katakana and noncognates are written in Kanji. Katakana is used to represent words borrowed from other languages (e.g., ラップトップ meaning laptop), but Kanji is an adaptation of Chinese picture characters in Japanese (e.g., 鳥 meaning bird). This difference in characters creates an issue when comparing the effect of cognates with noncognates in priming studies. Nakayama et al. (2014) predicted that the facilitative effect of LPS cognates over noncognates would occur if the degree of phonological similarity in cognates and noncognates correlates with the magnitude of the priming effect and if the phonological account correctly explains the cognate effect. No study has addressed this issue in different-script languages.

Electrophysiological studies on cognates and noncognates have had various objectives and used various tasks. Peeters et al. (2010) and Midgley et al. (2011) compared cognates with noncognates in bilinguals who knew English and French. In Peeters et al.'s study, French-English bilinguals, who learned English in adulthood, made a lexical decision in the L2 while the word frequency of orthographically identical cognates and noncognates was manipulated in the L1 and L2. Cognates were processed faster than noncognates, but it was generally the frequency of words in the task language that determined which type of words was faster and produced smaller N400 amplitudes rather than whether the task language was the participant's dominant or nondominant language. That is, when the task was in the L2, words with higher frequency in English were faster and produced smaller N400 amplitudes and vice versa. Midgley et al. compared orthographically identical, orthographically nonidentical, and noncognates in English-French bilinguals in a semantic go/no go task to examine the effect of the degree of orthographic overlap in L1 and L2. Cognates produced less negative N400 amplitudes than noncognates in the L1 and L2. However, ERP effects started earlier in the L1 (around 200 ms stimulus onset) and continued until 500 ms stimulus onset. Nonetheless, ERP effects started later (around 300 ms stimulus onset) and continued after 550 ms in the L2.

Midgley et al. (2009) and Hoshino et al. (2010) compared repetition (L1-L1, L2-L2) with cross-language priming (L1-L2, L2-L1) in a semantic go/no go task in the L1 and L2 with French-English and Japanese-English bilinguals, respectively. Researchers used the stimulus onset asynchrony (SOA, amount of time between the start of one stimulus and the start of another stimulus) of 67 (50 ms prime duration and 17 ms blank interval) in the former and 80 ms (50 ms prime duration and 30 ms blank interval) in the latter study to give the L2 prime enough processing time. They studied the contribution of form- and meaning-based representations in similar-script and different-script languages using noncognate translation equivalents. Hoshino et al. used different-script languages to control for the inhibitory effects that a target word presumably sends to the prime to suppress its processing after the target is recognized in a situation when the prime and target have similar scripts (Friesen & Jared, 2012). Also, Hoshino et al. aimed to understand whether using different-script languages would accelerate the effect of the prime due to script differences, which can direct the word processing system to look for the prime and target in a specific lexicon where either one belongs. Briefly, Hoshino et al. conducted a similar study to Midgley et al.'s to provide a better ground to examine the effect of the prime and the possibility of mapping prelexical information onto whole word representations of translation equivalents to determine if any effect was to be observed.

Hoshino et al. (2010) and Midgley et al (2009) showed that repetition priming affected the N250 and N400 components due to the similarity of form and meaning respectively in L1 and L2. Also, related primes modulated the N400 and the N250 components in all four conditions, except the L2-L1 condition, where no priming effect was observed on the N250 component. In all conditions, related primes produced less negative N400 and N250 components. In both studies, primes were processed faster in the L1 than in the L2. However, in Hoshino's study, the effect of L1 primes was observed about 100 ms earlier than the same effect in Midgley's (2009), and L1 primes were processed faster in the L1-L2 than the L1-L1 direction due to script differences, confirming their predictions. The facilitative effect of the L1 prime on the N250 and the absence of the effect of the L2 prime on the same component supported the role of the feedback that the L1 prime received from meaning and not from the prime activating whole word representations of the target for two reasons: (a) no priming effect was observed in the L2-L1 direction and (b) noncognate translation equivalents did not share any formal overlap in L1 and L2. Researchers used these findings to support the BIA+ model and reject the revised hierarchical model (RHM). According to the RHM, L2 words establish stronger lexical links to L1 words than vice versa. Thus, the priming effect should have been from L2-L1 rather than in the opposite direction. The L1-L2 feedback effect supported the BIA+ model because this model asserts that translation priming is always semantically mediated, and no excitatory connections between lexical form representations of translation equivalents exist.

These studies used semantic categorization as a task that focuses on meaning more than form. Using a lexical decision task might lead to a different pattern of processing for noncognates because this task focuses on formal properties of words (form-level) like phonology when languages have different scripts. Although noncognates have no shared formal properties in two languages that a bilingual has, noncognates receive feedback from meaning to the processing of form (Hoshino et al., 2010).

**1.7.2. Studies on cognates and noncognates in Persian and English.**

Research studies that examined cognates in Persian as an L1 and English as an L2 have adopted various orientations (Fotovatnia & Taleb, 2012; Gholami, Alavinia, & Izadpanah, 2015; Karami-Fard & Sayadian, 2014; Marzban & Chahardahcherik, 2015; Pirooz, 2003; Taleb & Fotovatnia, 2013; Talebinejad & Nazari-Sarmazeh, 2012). One group of studies examined cognates linguistically. For example, Marzban and Chahardahcherik (2015) aimed to identify false cognates, which are words with the same form but different meanings, in Persian and English by tracing them historically back to their shared Proto-Indo-European language family. Pirooz (2003) studied false cognates with a similar intention. These researchers produced a list of false cognates in Persian and English. Another group of studies was pedagogically oriented. To illustrate, Talebinezhad et al. (2012), Karami-Fard et al. (2014), and Gholami et al. (2015) studied false and true cognates by analyzing Persian-English learners’ interlanguage, looking for errors that false cognates produced. These researchers concluded that false cognates caused misunderstanding and miscommunication in this group of learners. Ghomali et al. taught a list of true and false cognates to Persian-English learners and observed that participants learned true cognates better than false cognates. These researchers concluded that cognate-based instruction is effective for Persian-English learners.

Three studies have examined the processing of cognates and noncognates in Persian and another language (Fotovatnia & Taleb, 2012; Ghazi-Saidi, 2012; Taleb & Fotovatnia, 2013). Ghazi-Saidi (2012) manipulated word type and language distance to examine the behavioral and neural correlates of cross-linguistic transfer (CLT) effects in L2 learning. They studied cognates, clangs (words with different meanings but similar phonology), and non-cognate-non-clangs (conceptually similar words) in a picture-naming task in Persian-French (distant languages) and Spanish-French (close languages) bilinguals. RT, accuracy rates, event-related fMRI BOLD responses, and functional connectivity analysis showed an interaction between the word type and language distance. In close-language bilinguals, shared neural areas processed cognates and clangs, while the same areas together with the working memory and the attentional and cognitive control networks processed non-clang-non-cognates. For distant-language bilinguals, shared L1-L2 areas and the cognitive networks processed all the word types.

Fotovatnia and Taleb (2012) compared the processing of cognates with noncognates in lower-intermediate Persian speakers studying in an undergraduate teaching English as a foreign language (TEFL) program, once with a masked L1 prime and L2 target and another time with a masked L2 prime and L1 target in a lexical decision task. Only cognates with an L1 prime showed priming effects. Taleb and Fotovatnia (2013) tested the existence and strength of the lexical links that connect L2 to L1 translation equivalents (noncognates) in elementary and higher proficiency TEFL learners of English whose first language was Persian in a masked-priming lexical decision episodic task. Elementary learners showed priming effects in the L2-L1 direction, but no priming effects were observed in the other conditions of the study. This priming effect supported the existence of direct lexical links between L2 and L1 translation equivalents as the RHM (Kroll & Stewart, 1994; Kroll & Tokowicz, 2001) predicts. However, lack of priming effects in the other three conditions was not in line with the RHM. Taken together, Fotovatnia and Taleb and Taleb and Fotovatnia suffered from a few shortcomings: first, only twelve learners participated in each language direction. Second, Persian stimuli were controlled only for length and frequency. Finally, participants were elementary and lower-intermediate English learners who had merely used English for course requirements in formal settings of a language institute and university rather than as a means of communication in their daily activities as they did in Persian.

## 1.8. Presentation of the Dissertation Project

Literature on visual word recognition asserts that cognates are recognized faster and more accurately than noncognates in languages written in similar and different characters (i.e., the cognate effect). Also, there is evidence that the phonological similarity of cognates facilitates the activation of relevant features of words in another language and their recognition (i.e., the phonological account of the cognate effect). Nevertheless, the role of the degree of the phonological similarity of cognates in visual word recognition and its interplay with the semantic overlap in languages with different scripts in the L2 and L1 are not clear and require further investigation. Thus, the present series of dissertation studies investigated the phonological account of the cognate effect in Persian-English bilinguals using behavioral and ERP measures when bilinguals performed a masked-priming lexical decision task in the L2 and L1. Furthermore, this study examined whether the effect of another language showed up earlier in different- than similar-script languages due to the absence of orthographic overlap between the scripts, and accordingly lack of interference due to the orthographic overlap.

No previous study has pursued this study's objectives in Persian-English speakers. Using a new group of bilingual speakers provided a different linguistic context to study the connection between the L1 and L2 and the effect of the phonological and conceptual similarity of cognates and noncognates in these two languages. In addition, Persian and English lack any orthographic overlap. Thus, it was possible to isolate the phonological overlap and observe the effect of the degree of the overlap in cognates in these languages. Moreover, this study overcame the limitations of Fotovatnia and Taleb (2012) and Taleb and Fotovatnia (2013) by recruiting higher proficient participants and measuring the lexico-semantic features of Persian cognates and noncognates to control these features across the experimental conditions. Studies have shown that language proficiency changes the demand for cognitive resources in the L2 (Ghazi-Saidi, 2012), and the daily use of language in a natural setting affects L2 processing (Friesen & Jared, 2012). Thus, different outcomes were expected by selecting advanced Persian-English speakers who used English to fulfil their routines in Canada, and controlling the features of stimuli to ensure that priming effects or their lack would not result from these features. Fourth, this study used ERPs to add complementary online measures to RT and accuracy to extend findings of previous studies. Responding to a need for a more comprehensive investigation, we designed three studies and included them in this dissertation.

Three manuscripts have provided information about the creation of stimuli and testing the phonological account in the Persian-English, and the English-Persian directions. The manuscripts are included in separate chapters in this dissertation. The following paragraphs summarize the objectives of these studies and provide justifications for them.

The first manuscript, included in Chapter 2, contains information about a Persian-English cross-linguistic database created to provide stimuli for data collection. Language studies that use words and pictures as stimuli should control the variables that have confounding effects on the experimental manipulations of the study (D. A. Balota et al., 2004). One source of such variables is the lexico-semantic features of words such as word frequency, word length, age of acquisition, neighborhood density, familiarity, imageability, and concreteness (Balota et al., 2004). Researchers use language databases in English and other languages to match the experimental conditions for these features. Databases for English and other languages are available. Examples of such databases are the MRC Psycholinguistic Database (Max Coltheart, 1981), WordNet (Fellbaum, 1998), the English Lexicon Project (D.A. Balota et al., 2007), and the CLEAR POND (Marian, Bartolotti, Chabal, & Shook, 2012). No such database was available in the Persian language until 2022, when Nemati, Westbury, Hollis, and Haghbin (2020) created a dataset containing frequencies, orthographic neighbors, and word type information for 62,114 Persian words and 1800 plausible nonwords. Therefore, the first step in this dissertation study was to create a list of cognates and noncognates and measure the lexico-semantic features of those words in Persian. These features interact with the task and the language of the task (Boukadi, Zouaidi, & Wilson, 2016; De-Groot, Borgwaldt, Bos, & Van Den Eijnden, 2002). Thus, it seemed necessary to understand which lexico-semantic features to control in a Persian-English linguistic context. This objective was pursued in a study on cognates and noncognates using a sample of Persian-English bilinguals and a masked-priming lexical decision task. This study showed which lexico-semantic features should be controlled in studies in Persian and English. Overall, this study aimed at the selection of stimuli, creation of word lists, and controlling word features across the experimental conditions. This database is also a resource for studies in Persian-English bilinguals.

The second manuscript, included in Chapter 3, reports on a study in the Persian (prime)-

English (target) direction that collected the RT, accuracy of responses, and ERPs to understand the effect of the dominant L1 on the visual word recognition in the nondominant L2. Research in visual word recognition uses words with varying degrees of orthographic, phonological, and semantic overlap in two languages to determine how words are represented and processed in the brain. Following this logic, this study isolated the phonological overlap by selecting two languages with different scripts and including cognates with higher and lower phonological overlap and noncognates in the study to examine the effect of the degree of phonological overlap on visual word recognition. The effect of the variables on the speed, accuracy, and ERP components in the bilingual group was examined and compared with a monolingual English group. Overall, this study tested the phonological account of the cognate effect and nonselectivity view of bilingual word recognition in the L1-L2 direction and compared the results with those of monolingual English speakers.

The third manuscript, included in Chapter 4, reports on a study with the same objectives, stimuli, and procedures as the second study but in a different direction. In this study, primes were English and targets were Persian words. Previous studies have investigated English-Hebrew (Gollan et al., 1997), Korean-English (Kim & Davis, 2003), Japanese-English (Hoshino et al., 2010), and Chinese-English (Jiang, 1999; Jiang & Forster, 2001) bilinguals to study the influence of L2 on L1. These studies examined whether cognates would show an advantage over noncognates due to the phonological overlap they have across two languages. These studies have produced mixed results, especially for noncognates. Also, no study has investigated the effect of the degree of phonological overlap of cognates on visual word recognition in L1. This study included two experiments. In Experiment 1, two prime durations, namely 50 ms and 70 ms, in the English-Persian direction were compared with the prime duration of 50 ms in the English-

English direction to adjust the prime duration in Experiment 2. In Experiment 2, cognates with varying degrees of phonological overlap and noncognates were examined in the L2-L1 direction to determine whether cognates show graded effects following their degree of phonological overlap in the dominant Persian language. Overall, the third study aimed at finding an effective prime duration in L2-L1 and using it to examine the predictions of the phonological account in L1.

# Chapter 2. A Persian-English Cross-Linguistic Dataset for Research in Visual Processing of Cognates and Noncognates[1]


## Abstract

Finding out which lexico-semantic features of cognates and noncognates are critical in cross language studies and comparing these features across cognates and noncognates helps researchers to decide which features to control in these studies. Normative databases provide necessary information for this purpose. Such resources are lacking in the Persian language. We created a dataset and determined norms for the essential lexico-semantic features of 288 cognates and noncognates and matched them across the experimental conditions. Furthermore, we examined the relationship between these features and the response time (RT) and accuracy of responses in a masked-priming lexical decision task. This task was performed in English by Persian-English speakers in conditions where the prime and target words were related or unrelated in terms of meaning and/or form. Overall, familiarity with English words and English frequency were the best predictors of RT in related and unrelated priming conditions. Pronunciation similarity also predicted RT in the related condition for cognates, while the number of phonemes in the prime predicted RT for the unrelated condition. For both related and unrelated conditions, English frequency was the best predictor for noncognates. This bilingual dataset can be used in bilingual word processing and recognition studies of cognates and noncognates.


[1] Fotovatnia, Z., Scheerer, N.E., & Jones, J. A. (2019). A Persian-English (cross-linguistic) dataset for research on the visual processing of cognates and noncognates. *Iranian Journal of Applied Linguistics*, 22, 36-70.

## 2.1. Introduction

An important issue for language researchers is how formal and semantic properties of words in two languages are represented and recognized by bilinguals. Of particular interest is whether the words in each language are stored in a language-specific lexicon or a shared lexicon, and whether a relationship exists between phonology, orthography, and meaning (the three main features of a word) in L1 and L2. Manipulation of phonological and semantic word features in languages with similar scripts (for example, French and English) and phonological, semantic, and orthographic word features in languages with different scripts (for example, Persian and English) provide an ideal situation for investigating these topics.

In such studies, cognates and noncognates play an important role and need to be matched on important lexico-semantic features such as frequency, length, phonological neighborhood density, orthographic neighborhood density, imageability, concreteness, and familiarity. Cognates are translation equivalents that have an overlap between formal and semantic features across two languages (Kondrak, Marcu, & Knight, 2003). Noncognates, on the other hand, are translation equivalents that display semantic but not formal overlap. Furthermore, different degrees of overlap in terms of phonology and/or orthography result in two kinds of cognates, based on a maximum to minimum formal overlap, identical and close, respectively (Bultena, Dijkstra, & van Hell, 2014). Despite the importance of such lexico-semantic features in bilingual language processing research, few studies have collected bilingual measures and made them available in Persian as the native and English as the nonnative language.

Research studies have investigated bilingual word representation and processing for languages with the same (Bice & Kroll, 2015; Comesana et al., 2014; Grainger, 1998; Jacobs, Fricke, & Kroll, 2016; Midgley et al., 2009, 2011; J.G. van Hell & T.  Dijkstra, 2002) and different scripts (Gollan et al., 1997; Hoshino et al., 2010; Nakayama, Sears, Hino, & Lupker, 2012; Nakayama et al., 2013; Nakayama et al., 2014; Voga & Grainger, 2004; Zhou et al., 2010; Zhu & Mok, 2020). As most of these studies are conducted to compare bilinguals with English as an L2, or less frequently as an L1, and another similar script language such as French, German, Spanish, and Dutch, online databases are available to use as resources for measuring the essential lexical and semantic features of words and creating nonwords to be used as stimuli. Examples of such databases in English are the MRC Psycholinguistic Database (Max Coltheart, 1981) and the CLEARPOND Database (Marian et al., 2012). In relatively few studies, different-script languages such as Hebrew (Gollan et al., 1997), Japanese (Nakayama et al., 2014), and Chinese (Zhou et al., 2010) were used. Few attempts have been made to pursue these topics with Persian-English bilinguals (Fotovatnia & Taleb, 2012; Taleb & Fotovatnia, 2013). This issue could explain the lack of resources available for determining the lexico-semantic features of words in Persian. Given the importance of this type of research to determine how bilinguals represent and process words in various languages, we created a dataset for bilingual Persian-English word research and teaching. Investigating bilinguals with languages that have been less studied should increase the generalizability of the findings on the processing and representation of words in a bilingual brain.

#### 2.1.1. Lexico-semantic features of words.

A review of the literature on visual word recognition research shows that researchers control variables such as word frequency, word length, age of acquisition (AoA), neighborhood density, familiarity, imageability, and concreteness (D. A. Balota et al., 2004) for their potentially contaminating effects on the main variables of the study. These effects differ based on the specific requirements of the task, the language used for the task, the orthographic depth of the L1 and L2, and the participants' language proficiency in either language. The existence of an interaction between acquired languages and task type is a critical issue that requires further investigation in bilingual studies. Indeed, few studies have pursued these topics in Persian-English speakers to understand which lexico-semantic features of the stimuli to control in cross-language studies. Furthermore, creating a dataset and establishing the normative bases of the stimuli will provide a foundation for any research on word representations and word processing of Persian-English speakers, a neglected population.

Word frequency is defined as the number of times a word appears in a corpus. In general, low-frequency words are processed more slowly than high-frequency words in both L1 (Brysbaert, Lagrou, & Stevens, 2016) and L2 (Peeters et al., 2013), although the slower processing is more evident in the latter group of words. This pattern is the result of the level of exposure to words in a language. The more one is exposed to words, the richer their vocabulary knowledge becomes, and the more proficient that person will be in that language (the lexical entrenchment hypothesis, Diependaele, Lemhöfer, & Brysbaert, 2013).

Words differ in the number of letters or phonemes they include. These two variables are highly related. However, each feature seems to interact with the task type, task language, and word frequency in either L1 or L2. For example, the number of phonemes has been found to affect reading latencies in Tunisian Arabic (Boukadi et al., 2016). However, when both the number of phonemes and letters were entered into a regression (other variables controlled), orthographic length remained a better predictor of word-naming performance. Word length and the task language showed an interaction in a study where the number of letters affected the performance of Dutch-English speakers in lexical decision and word naming in English, but not word naming in Dutch. Furthermore, an interaction between the orthographic length and the frequency of words was observed in research studies (Bakhtiar & Weekes, 2015). Bakhtiar and Weekes (2015) found that orthographic length was a better predictor of word naming performance for low-frequency words than for high-frequency words. Overall, investigating the interactions between word length in terms of the number of phonemes and letters, and task type with different language speakers should further contribute to the existing literature and help to control the lexico-semantic features of the stimuli required to collect data.

AoA is defined as the age at which a word is first acquired in L1. Research shows that words learned early in life are processed and remembered more efficiently than words learned later (Brysbaert et al., 2016). AoA is not a strong predictor of lexical processing performance in the L2, due to learning the language at different ages in life, and mainly after mastering the L1. Furthermore, AoA measures correlate with a range of other word features such as concreteness ($r = -.50$), imageability ($r = .72$), and rated familiarity ($r = -.72$), as shown by Gilhooly and Logie (1980), as well as word frequency (Juhasz, 2005). Therefore, it seems reasonable to use these measures instead of AoA.

A word's orthographic neighbors are defined as a set of words that exist in the L1 or L2 and that differ from the target word in one letter position. Neighbors can be created by changing one letter of the word while preserving letter positions. For example, the words *pike*, *pine*, *pole*, and *tile* are all orthographic neighbors of the word *pile* (Coltheart, Davelaar, Jonasson & Besner, 1977). Theoretically, a word with a large number of orthographic neighbors would activate a large search set (search models of word recognition, Forster, 1976), or would create more within-level inhibition resulting from greater orthographic overlap with its neighbors (interactive activation models of word recognition, McClelland & Rumelhart, 1981). Therefore, for words with a greater number of orthographic neighbors, people should take more time and have more difficulty searching through the set, or suppressing the inhibition to perform a task. The empirical results, however, are not straightforward. For example, Grainger and Jacobs (1996) reported inhibitory influences of neighborhood frequency (i.e., a word with higher frequency neighbors produced slower lexical decision times). Other studies reported no main effect of neighborhood density, but an interaction between the neighborhood density and word frequency (D. A. Balota et al., 2004; Sears, Hino, & Lupker, 1995). Neighborhood density facilitated the processing of low-frequency words, but inhibited that of high-frequency words.

Familiarity is a subjective measure based on the number of times individuals have experienced a word. Therefore, it is highly related to culturally specific experiences, which vary from one language community to another (Boukadi et al., 2016). This is called subjective frequency and is highly related to the objective frequency, which reflects the number of times a word occurs in a language corpus. However, these two measures are independent of each other (Connine, Mullennix, Shernoff, & Yelen, 1990; Kreuz, 1987). The reason seems to be that familiarity affects the level of semantic activation, whereas frequency affects the level of phonological encoding in word naming and lexical decision tasks (Boukadi et al., 2016). Connine et al. (1990) reported faster reaction times for high-familiarity words in visual and auditory lexical decision tasks, as well as for word naming. Familiarity effects are also observed for pictures in picture naming studies, with faster naming for familiar objects and slower naming for uncommon objects (Cuetos, Ellis, & Alvarez, 1999). Familiarity is considered an important possible predictor of naming latencies when conducting these studies (Boukadi et al., 2016). Subjective frequency estimates were found to be a better predictor of object frequency counts in some visual and auditory word processing studies (Connine et al., 1990).

Imageability and concreteness (Paivio, Yuille, & Madigan, 1968) are examples of the semantic features of a word. Imageability is defined as the ease with which a word arouses a sensory mental image of something, while concreteness involves the extent to which a word is experienced by the senses. Imageability is confounded with concreteness in the sense that words high in imageability are more concrete than words low in imageability (the so-called abstract words). However, these two features seem to exploit partially different components. Imageability is related to the number of semantic features that develop a concept. Consequently, the concepts of high-imageability words are connected to many more semantic features than the concepts of low-imageability words (Plaut & Shallice, 1993). An imageability rating is based on the graded amounts of sensory (mainly visual) information associated with words. The concreteness rating is spatiotemporally based, where concrete words are more spatiotemporally based than abstract words (Kousta, Vigliocco, Vinson, Andrews, & Del Campo, 2011) meaning that concrete words have spatial and temporal qualities that are absent in abstract words.

Most studies have shown faster responses to concrete words than abstract words (Kanske & Kotz, 2007; Kounios & Holcomb, 1994). Indeed, concrete words are represented in a verbal as well as a nonverbal code, while abstract words are represented only in a verbal code (dual-coding theory, Paivio et al., 1968). This means that concrete words activate verbal and image-based systems through referential connections to these systems. On the other hand, abstract words activate representations in the verbal or linguistic semantic system. To illustrate, the word *table* has images associated with it, while the word *kindness* creates no mental images. Furthermore, concrete words have stronger and denser associative links than abstract words (the context availability hypothesis, Schwanenflugel, 1991).

Studies that have examined the effect of lexico-semantic features of stimuli on the RT and accuracy across different tasks have mainly been in English and another language, though not English and Persian. De Groot et al. (2002) examined 18 variables in Dutch (L1) and English (L2) lexical decision and word naming when the stimuli were 3, 4, and 5 letter words (Table 2.1).

Table 2.1. *Lexico-Semantic Variables Affecting Lexical Decision (LD) and Word Naming (WN) in Dutch (L1) and English (L2)*

| | **Dutch** | | **English** | |
|---|---|---|---|---|
| Variables | LD | WN | LD | WN |
| Frequency | major | + | Major | + |
| Orthographic length | | + | + | + |
| Semantic variables | + | | + | + |
| Onset variables | | + | | + |
| Neighborhood words | | + | | + |
| Cognate effect | | + | + | + |
| Reaction time | Flow | Fast | Long | Long |

As Table 2.1 shows, frequency highly affected Dutch and English word recognition. The effect of frequency, however, was found to be exaggerated in the lexical decision and word naming tasks, as frequency showed interactions with familiarity in the former and the length of words in the latter task, in English. Considering the RT, lexical decision in Dutch was slower than word naming in the same language but took the same amount of time as word naming in English. De Groot et al. (2002) used the differences in the grapheme-to-phoneme relationship in each language to interpret their findings, which is consistent with the orthographic depth hypothesis (Katz & Frost, 1992) and the dual-route model of reading (M. Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). Dutch is a shallower language than English, meaning that it is easier to predict the pronunciation of words from spelling in Dutch than in English. Thus, word access uses the more effective indirect grapheme-to-phoneme route, and not the direct lexical route. This explanation seems plausible due to the importance of onset variables (e.g., the number of consonants in the onset of the first syllable of the spoken word and the preferred onset structure) in Dutch and not in English word naming. Furthermore, as Table 2.1 shows, these tasks seem to have more commonalities in English L2 than in Dutch L1, showing that they probably captured similar components more in L2 than L1. From their findings, the authors concluded that familiarity is used to discriminate words from nonwords in a lexical decision task. This conclusion is further supported by an interaction between frequency and familiarity. In another study, Boukadi et al. (2016) investigated the effect of familiarity, subjective frequency, imageability, and word length in terms of the number of phonemes on word naming in Tunisian Arabic word naming. Word length and frequency were found to be the best predictors of word naming latencies in Tunisian Arabic. An interesting finding was that imageability and familiarity significantly predicted word reading latencies, indicating that semantic features play an important role in this task.

Only a few studies have investigated the effect of lexico-semantic features of words on visual word processing in Persian, and these studies have not specifically examined cognates and noncognates using a lexical decision task (Bakhtiar & Weekes, 2015; Nemati, Westbury, Hollis, & Haghbin, 2022). For example, Bakhtiar and Weeks (2015) studied the effect of AoA and spelling transparency of Persian words on word naming. The Persian writing system allows the omission of vowels, which makes the mapping of orthographic to phonological information difficult. Thus, words can be easier or more difficult to pronounce based on their spelling (transparent vs. opaque respectively). Bakhtiar and Weeks found that spoken and writing frequency, familiarity, and imageability significantly predicted word-naming latencies in Persian. They also found a significant interaction effect between AoA and transparency such that AoA affected low-imageability opaque words more than high-imageability opaque words. Nemati et al. (2022) compiled the frequency and orthographic density of a number of words and nonwords in Persian. They also collected the RT for the words and nonwords in a visual lexical decision task. From the results, they concluded that word length and neighborhood density reflect the structure of a language more than a universal feature of word processing.

### 2.1.2. This study

The purpose of the current study was twofold. On the one hand, we created a dataset including cognates and noncognates in Persian and English and determined the lexico-semantic features that have been shown to be important in priming studies. This is an important step because no databases are available for cross-language studies including these two languages. On the other hand, we investigated the relationship between the lexico-semantic features of Persian primes and English targets with the RT and accuracy of responses in a cross-linguistic masked lexical decision task on cognates and noncognates. The prime was masked to prevent it from reaching conscious attention (Forster & Davis, 1984). To our knowledge, no such study has focused on cognates and noncognates to determine which features of the stimuli are relevant to the RT and accuracy of responses and which features could best predict these measures in a masked-priming lexical decision task. Learning about this relationship could prevent the confounding effects of word features on the main variables in cross-language studies.

## 2.2. Method

### 2.2.1. Participants.

Three groups of Persian-English speakers were recruited for this study. Two groups were involved in determining the lexico-semantic features of the words, while the third group participated in a lexical decision task. The first group completed questions about the phonological similarity of cognates in Persian and English, and familiarity with the English words. The second group included students, either graduated or studying, in the English program at the Islamic Azad University, Najafabad Branch, Iran. This group completed questions about the concreteness and imageability of the Persian words. Table 2.2 provides detailed information about these two groups. The third group included 32 Persian-English speakers residing in Waterloo and London, Canada, either graduated from or studying at university. They had received a minimum of eight years of formal English instruction in Iran before immigration to Canada, and they all obtained a score of 5.5 - 8 ($M$=6.96, $SD$=.69) on the IELTS Academic module. This group made a lexical decision task with Persian primes and English targets to understand the relationship between the lexico-semantic features of the prime and target and the RT and accuracy of responses. Furthermore, six more proficient speakers, who were different from those who received the questionnaires, translated the words from Persian to English, and vice versa.

Table 2.2 *Detailed Information About Group One (G1) and Group Two (G2), M(male), F (female), BA (Bachelor's Degree), Ms (Master's Degree), LI (Lower Intermediate), UI (Upper Intermediate), Adv. (Advanced)*

| | Gender | | Age range | | Degree | | | Self-rated proficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | M | F | 20-39 | 40-50 | BA | MA | PhD | LI | UI | Adv. |
| **G1 (52)** | 16 | 36 | 46 | 6 | 7 | 34 | 11 | 4 | 19 | 29 |
| **G2 (46)** | 17 | 29 | 41 | 5 | 8 | 36 | 2 | 10 | 18 | 18 |

### 2.2.2. Materials.

The stimuli included only nouns, as some studies have shown larger cognate effects for nouns than verbs (Bultena et al., 2014). The stimuli were prepared following the steps below. Appendix 1 includes word targets and their matched related and unrelated primes.

1. A random list (N=150) of cognates (e.g., taxi, star) and noncognates (e.g., sparrow, ring) was created in English to use as targets in the lexical decision task in the L1

(prime) - L2 (target) direction. The words were then translated into Persian to use as related primes. Another list was created to use as unrelated primes. The related and unrelated primes were matched for the number of phonemes and letters in each word. Different from most studies, where the number of letters was primarily used for matching the related to unrelated primes, we used the number of letters and phonemes due to the specific characteristics of the Persian script. In Persian, only consonants are represented by letters in the written form. This selection allowed us to see whether word length, defined in terms of phonemes versus letters, would have a different effect. Cognate primes (e.g., تیفوس/ti:ˈfu:s/) and their corresponding targets (e.g., typhus) shared semantic and phonological similarity, while noncognate primes and their corresponding targets shared only semantic features, (e.g., خطا,/khæˈta/, meaning error). Unrelated primes did not have any phonological or semantic relationship with the targets. Related and unrelated prime words were selected from the same category insofar as their semantic features, such as imageability and concreteness were concerned (e.g., living/nonliving things, animals, food, events).

2. To ensure that the translation equivalents in both languages had the same meaning, the words were presented in two random lists. The lists were given to six proficient Persian-English speakers to translate from Persian into English and vice versa. Only the words that were translated similarly in both directions by all people were included in the list, and the others were removed. For example, the word *scholar* was replaced with the word *researcher*, as the former was translated as محقق/mʊhæˈghɛgh/ in Persian, but the same Persian word (محقق) was translated as *researcher* in English. Similarly, the word مسافر/mʊsaˈfɛr/ was not included, because it was translated as

*traveler* by one translator, and as *passenger* by another translator. Likewise, the word زمین/zæˈmin/ was not included because it was translated as *earth* by one, and *land* by another translator. Related primes and targets had to be translation equivalents. In fact, each prime had to activate the corresponding target and no other word. Furthermore, unrelated primes and their corresponding targets did not share any onset phoneme or letter.

3. The number of letters and phonemes, word frequency, and orthographic neighborhood density of the English stimuli were determined using the CLEARPOND database (Marian et al., 2012).
4. Nonwords were generated using the English Project Website (at elexicon.wustl.edu) and were matched with the corresponding words for the number of letters and neighborhood density (n=230).
5. The frequency of the Persian primes was manually determined using the MAHAK (means "measure" in English) corpus (Sheykh Esmaili, et al., 2007). MAHAK is the largest Persian test collection containing 3007 documents and 216 queries on various topics.
6. Cognate phonological similarity, familiarity with English words, and concreteness and imageability of the Persian words were determined through two *5*-point Likert scale questionnaires presented to participants using Qualtrics (http://www.qualtrics.com). The first questionnaire included two sections: (a) 125 English and Persian cognate pairs selected in the previous stage and a number of noncognates used as fillers (n=17), and (b) all cognates and noncognates (N=250). The former section elicited the degree of similarity in the pronunciation of cognates

and the latter asked for the level of familiarity with the English words. For phonological similarity, each cognate in Persian was presented with its English equivalent and participants were asked to pronounce both words, determine how similar in the pronunciation they were, and then select one point along a *5*-point Likert scale ranging from *completely different* to *completely similar*. For familiarity, the question was "how frequently do you encounter these words in listening, reading, speaking, and writing?" (Bakhtiar & Weekes, 2015). The scales ranged from *never* (completely unfamiliar) to *daily* (completely familiar). The second questionnaire included only Persian words presented in two sections. These words were rated for concreteness and imageability. For concreteness, participants selected one point on the scale ranging from *completely abstract* to *completely concrete*. For imageability, participants determined how easily a word evoked a mental image in the form of a picture, sound, taste, or smell (*very difficult* to *very easy*). Instructions and examples were provided in Persian to ensure that participants understood the task.

7. The neighborhood density of Persian words was determined based on the MAHAK corpus using calculations made in Microsoft Office Excel 2013 (Bakhtiar & Weeks, 2015).
8. Forty-eight words with similar features to the main stimuli were used as fillers in the lexical decision task.

**2.2.3. Procedure.**

All participants signed an online consent form to participate in the study, which was approved by the Wilfrid Laurier University Research Ethics Board (Research Ethics Board approval number, 4585). Participants in the first and second groups received the invitation to the survey, a URL to access the questionnaire, and general instructions via email. Upon accessing the questionnaire, participants read specific instructions for the first feature to rate. Each page included 25 words, and each word was immediately followed by a *5*-point scale. After they rated all the words for one feature, they received instructions for the next feature rating. The order of features and words in each list varied randomly for each participant.

To collect the reaction time (RT) and accuracy of the responses to the stimuli, participants in the third group were seated in front of a computer in the Center for Cognitive Neuroscience at Wilfrid Laurier University. The stimuli (n=144 target words, n= 230 nonwords) were presented in black at the center of a white background on a Dell P170S monitor with a refresh rate of 60 Hz and the resolution of 1280 × 1024. Two lists of stimuli were counterbalanced across participants. Stimuli were presented using STIM2 software in the following order: a fixation sign (+) for 500 ms, number signs to mask the prime (#######) for 500 ms, a Persian prime in 14 pt Nazanin font for 50 ms, and an English target word or nonword in 16pt New Times Roman font in lowercase letters, which remained on the screen until a response was recorded (Figure 3.1). Participants pressed different keys on a response box (Neuro Scan, INC. STIM system switch response pad P/N 1141) for words and nonwords they saw on the screen as quickly and accurately as possible. Each participant performed a 30-item practice block similar to the main task. Participants were compensated for their time.

## 2.3. Results

Only the questionnaires that were more than 75% filled out were analyzed. The words with no response were treated as missing data. The mean of each feature was calculated by averaging the ratings across all participants. RTs that were between 300-1800 ms and within 2 standard deviations of the mean for the correct answers were analyzed. The data from one participant was removed because more than 25% of their responses were incorrect. RTs and correct responses to each word were then averaged for each condition. The first section below presents the analysis of all words, and the second section presents the analysis of cognates and noncognates separately.

### 2.3.1. Analysis of all words.

To understand which word features correlated with one another, and with the RTs and accuracy of responses, a Pearson product-moment correlation was run. A significant relationship was observed between the number of phonemes and the number of letters, $r(288) = .79$, $p < .001$, concreteness and familiarity with the English words, $r\ (240) = .216$, $p$=.001, imageability and English frequency, $r\ (247) = .147$, $p$ =.021, concreteness and Persian frequency, $r\ (249) = -.228$, $p < .001$, concreteness and imageability, $r\ (249) = .855$, $p < .001$, and familiarity and English frequency, $r\ (248) = .402$, $p < .001$. Correlation coefficients for RT and accuracy and the lexico-semantic features of the stimuli are shown in Table 2.3.

**Table 2.3.** *Correlation Coefficients Showing the Relationship Between the Lexico-Semantic Features of Words and RT and Accuracy of Responses*

| | English | English letters | English frequency | Familiarity with English words | English Neighborhood density | Farsi phoneme | Farsi letters | Farsineighborhood density | Farsi frequency | Image ability | Concreteness |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RT | .360** | .416** | -.453** | -.506** | -.354** | .200** | .224** | -.235** | -.232** | -.109 | .002 |
| Sig | .000 | .000 | .000 | .000 | .000 | .001 | .000 | .000 | .000 | .087 | .974 |
| Number | 286 | 286 | 286 | 240 | 262 | 288 | 288 | 249 | 250 | 249 | 249 |
| Accuracy | -.020 | -.650 | .257** | .512** | .195** | .003 | -.066 | .010 | .110 | .009 | -.038 |
| Sig | .739 | .273 | .000 | .000 | .001 | .953 | .261 | .870 | .083 | .883 | .550 |
| Number | 286 | 286 | 286 | 240 | 262 | 288 | 288 | 249 | 250 | 249 | 249 |

**Correlation is significant at the 0.05 level (2-tailed)*
***Correlation is significant at the 0.01 level (2-tailed)*

As shown in Table 2.3, words with more phonemes and letters were processed more slowly than shorter words. On the other hand, higher word frequency and word neighborhood density in English and Persian, and familiarity with English words were associated with faster responses. For response accuracy, increased English frequency, English neighborhood density and familiarity with English words were associated with a higher number of correct responses.

To find the best predictors of RT and accuracy, multiple regression analyses were run. Assumptions of normality, linearity, multicollinearity, and homoscedasticity were met. For RT, the total variance explained by the model as a whole was 46.5 %, $F(6,151) = 21.84$, $p < .001$. Significant contributions to the model were the following in descending order: English word familiarity, $t(239) = 6.32$, $p < .001$, $\beta = .42$; the number of letters of English targets, $t(287) = 3.28$, $p = .001$, $\beta = .41$; and English frequency, $t(285) = -2.65$, $p = .009$, $\beta = -.19$. Pronunciation similarity and neighborhood density did not significantly contribute to the model.

For accuracy, the total variance explained by the model as a whole was 28.4 %, $F(6,151) = 9.98$, $p < .001$. The only significant unique contribution to the model was familiarity with English words, $t(158) = -6.32$, $p < .001$, $\beta = -6.1$. No other variables contributed significantly to the model.

To determine how much variance in RT and accuracy was explained by the number of phonemes, number of letters, frequency per million, and concreteness and imageability of the Persian primes, a multiple regression analysis was run. For RT, the total variance explained by the model as a whole was 15.3%, $F(6,236\ ) = 7.09$, $p < .001$. Significant contributions to the model were the following in descending order: frequency of Persian primes, $t(238) = -\ 2.88$, $p = .03$, $\beta = -.2.$; imageability of Persian primes, $t(238) = -2.84$, $p$ , $\beta = -.3$; neighborhood density, *t*(263) = -2.52, *p* =.01 , β = -.2.; and the number of phonemes, *t*(277) = -2.22, *p* =.02, β = -.13. The model was not significant for accuracy. None of the features of Persian primes contributed significantly to the model.

**2.3.2. Analysis of Cognates and Noncognates**

Similar steps were followed to investigate the relationship between length, frequency, familiarity, pronunciation similarity, and the RT and accuracy of related and unrelated cognates and noncognates (Table 2.4).

Table 2.4. *Correlation Coefficients Showing the Relationship Between Length, Frequency, Familiarity, Pronunciation Similarity, and RT and Accuracy of Responses for Related and Unrelated Cognates and Noncognates*

| | | Related | | | | Unrelated | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Cognate | | Noncognate | | Cognate | | Noncognate | |
| | | RT | Accuracy | RT | accuracy | RT | Accuracy | RT | Accuracy |
| English Phoneme | Pearson correlation | .301** | -.154 | .309* | .036 | .483** | .093 | 387** | .097 |
| | Sig. (2-tailed) | .005 | .157 | .018 | .788 | .000 | .397 | .003 | .470 |
| | N | 86 | 86 | 58 | 58 | 86 | 86 | 58 | 58 |
| English Letter | Pearson correlation | .333** | -.220* | .415** | .030 | .535** | .005 | .428** | .053 |
| | Sig. (2-tailed) | .001 | .041 | .001 | .824 | .000 | .962 | .001 | .693 |
| | N | 91 | 86 | 58 | 58 | 86 | 86 | 58 | 58 |
| English Frequency | Pearson correlation | -.464** | .258* | -.495** | .341** | -.497** | .255* | -.419** | .195 |
| | Sig. (2-tailed) | 000 | .017 | .000 | .009 | .000 | .018 | .001 | .142 |
| | N | 90 | 85 | 58 | 58 | 85 | 85 | 58 | 58 |
| English Familiarity | Pearson correlation | -.556 | .457 | -352** | .466** | - .604** | 583** | -.264 | .484** |
| | Sig. (2-tailed) | .000 | .000 | .019 | .001 | .000 | .000 | .083 | .001 |
| | N | 81 | 81 | 44 | 44 | 81 | 81 | 44 | 44 |
| Persian Frequency | Pearson correlation | -257* | .054 | -.275* | .360** | -.123 | .055 | -.325* | .039 |
| | Sig. (2-tailed) | .018 | .626 | .044 | .008 | .271 | .624 | .016 | .782 |
| | N | 84 | 84 | 54 | 54 | 82 | 82 | 54 | 54 |
| Pronunciation Similarity | Pearson correlation | -.221* | .140 | - | - | -.098 | .112 | - | - |

Table 2.4 illustrates the results of running Pearson product-moment correlations on the data. As shown, the length of the related and unrelated targets correlated positively with RT in all four conditions, such that longer words were processed more slowly. For accuracy, the length of targets was not an important factor, as it did not correlate significantly with accuracy in almost all of the conditions. Nevertheless, the number of letters of cognates correlated negatively with accuracy in the related prime condition; longer cognates elicited more incorrect responses. More frequent English targets elicited faster responses for both related and unrelated cognates and noncognates, and more correct responses in all conditions, except in the unrelated noncognate condition. Familiarity with English words was positively related to RT and accuracy in all conditions, except for RT for unrelated noncognates. Familiar English words were processed faster and more accurately. Persian frequency was negatively related to RT for cognates and noncognates and positively related to accuracy in all conditions, except for RT in the unrelated cognate and the related noncognate conditions. Indeed, more frequent primes were processed faster and more accurately. Besides, pronunciation similarity was negatively related to the RT for the related cognates. Cognates that were similar in pronunciation in Persian and English were processed faster. Overall, the frequency of the prime correlated negatively with RT in most the conditions, and the length of the prime correlated positively with RT in only two conditions. Also, similar features of the targets (the number of phonemes and letters, frequency, and familiarity) significantly correlated with RT in nearly all of the conditions. On the other hand, fewer features of the prime correlated with accuracy than with RT.

Word features that correlated with RT and accuracy were entered into a multiple regression analysis for each condition. For related cognates, English and Persian frequency, pronunciation similarity, and Familiarity with English words were considered. The total variance in RT explained by the model as a whole was 63.4%, $F(4,75) = 12.59$, $p < .001$. Significant contributions to the model were the following in descending order: familiarity with English words, $t(80) = -4.01$, $p<.001$ , β = -.41; English frequency, $t(83) = -2.76$, $p = .007$, β = -.28; and pronunciation similarity, $t(79) = -2.03$, $p = .04$, β = -.19. For related cognates, the total variance of accuracy explained by the model as a whole was 46.1%, $F(2,77) = 10.36$, $p <.001$. The only significant unique contribution to the model was familiarity with English words, *t*() = 3.77, $p < .001$, β = .43.

For unrelated cognates, English frequency, familiarity with English words, and the number of Persian phonemes and letters were considered. The total variance in RT explained by the model as a whole was 72%, $F(4,75) = 20.16$, $p < .001$. Significant contributions to the model were the following in descending order: familiarity with English words, $t(80) = -5.79$, $p = .002$, β = -.53; Persian phonemes, $t(85) = 2.76$, $p =.007$, β = .43; and English frequency, $t(84) = -2.28$, $p = .025$, β = -.21. For unrelated cognates, the same four variables as those for RT were entered into the model. The total variance in accuracy explained by the model as a whole was 63.9%, $F(4,75) = 12.93$, $p < .001$. The only significant unique contribution to the model was familiarity with English words, $t(80) = 5.67$, $p <.001$, β = .57.

For related noncognates, English and Persian frequency, familiarity with English words, and the number of Persian letters were entered into the model. The total variance of RT explained by the model as a whole was 59.3%, $F(4,39) = 5.30$, $p = .002$. The strongest significant unique contribution to the model was English frequency, $t(43) = -1.53$, $p =.015$, β = -.36. For accuracy, English and Persian frequency, and the number of Persian letters were entered into the model. The total variance in accuracy explained by the model as a whole was 61.4%, $F(4,39) = 5.9$, $p = .001$. The strongest significant unique contribution to the model was familiarity with English words, *t*(43) = 2.72, *p* =.01, β = .38. The next significant unique contribution to the model was the number of Persian letters, *t*(57) = -2.18, *p* =.04, β = -.31.

For unrelated noncognates, English and Persian frequency were entered into the model. The total variance in RT explained by the model as a whole was 48.3%, *F* (2, 51) = 7.76, *p*= .001. The strongest significant unique contribution to the model was English frequency, *t*(48) = -3.22, *p* =.003, β = -.37. For accuracy, Familiarity with English words, and the number of Persian letters were used in the model. The total variance in accuracy explained by the model as a whole was 52%, *F*(2,41) = 7.59, *p*= .002. The only significant unique contribution to the model was familiarity with English words, *t*(43) = 3.22, *p* =.003, β = .44.

Comparing the semantic features of cognates with noncognates (Table 2.5) showed that cognate means were larger than the corresponding noncognate means for imageability, concreteness, and familiarity. Independent samples *t*-tests showed that cognates were rated as more imageable and concrete than noncognates, *t*(243) = 1.989, *p* =.048, and *t*(243) = 2.95, *p*=.003, respectively.

Table 2.5. *Descriptive Statistics of Imageability and Concreteness of Persian Words and Familiarity of English Words*

| | Type | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Imageability | Cognate | 89 | 3.90 | .72 | .08 |
| | Noncognate | 156 | 3.71 | .67 | .05 |
| Concreteness | Cognate | 89 | 3.77 | .75 | .08 |
| | Noncognate | 156 | 3.45 | .85 | .07 |
| Familiarity | Cognate | 78 | 2.68 | .80 | .09 |
| | Noncognate | 40 | 2.61 | .74 | .12 |

## 2.4. Discussion

Models of visual word recognition have primarily been developed using the outcomes of experiments with English as the L1 or L2. The existence of dependencies between orthography and word-recognition procedures (e.g., Katz & Feldman, 1983; Katz & Frost, 1992) makes it appropriate to use languages with different phonological and/or orthographic features to evaluate the validity of the findings observed in previous studies. We created a dataset in Persian and investigated the relationship between word lexico-semantic features that had been found critical in studies on visual word recognition in a masked-priming lexical decision task. We further investigated the relationship between these features and the RT and accuracy of responses to cognates and noncognates to determine which features were essential to control for each word type and whether we could generalize the findings of other languages to Persian and English.

With regard to the word features investigated in this study, concreteness was found to be correlated positively with familiarity with English words and imageability of Persian words, and negatively with Persian frequency. The positive relationship between concreteness, imageability, and familiarity supports the idea that concrete words are more imageable, and these two features together can create a feeling of familiarity for the L2 words. The positive relationship between concreteness and imageability, where concrete words are more imageable than abstract words, supports the dual-code theory (Paivio et al., 1968), which attributes the concreteness effect (i.e., concrete words are processed faster and more accurately than abstract words) to qualitative differences between concrete and abstract words. This might be an indication that when participants were evaluating their familiarity with the English words, they could not ignore word concreteness, which was measured using Persian words. The negative relationship between concreteness and Persian frequency may be the result of the Persian language frequency being calculated using the MAHAK database, which is based on written sources. The relationship might have been different if the frequency had been determined using a speech-based database. Unfortunately, there is no speech-based database available in Persian. This finding might further confirm that concreteness and frequency are two different, but related components. Interestingly, cognates were rated as more imageable and concrete than noncognates. Cognates and noncognates were randomly selected in this study. However, this finding might confirm that cognates have a special status for bilinguals, as they are encountered in both languages. Engaging with cognates in either language might result in more familiarity with this type of word.

RT was related to the word length, frequency, and neighborhood density of both primes and targets, and familiarity with the English targets. However, the best predictors of RT (for the English targets) were familiarity with English words, number of letters, and frequency of English targets, while the best predictors of RT (for the Persian primes) were Persian frequency, imageability, neighborhood density, and the number of phonemes. We found that the number of phonemes and letters of the English targets were highly correlated with each other, as well as with RT, while the number of letters was a better predictor of RT. This is similar to what Boukadi et al. (2016) found in a word-naming task in Tunisian Arabic. Conversely, the number of phonemes of the Persian primes, but not the number of letters, was a significant predictor of RT. This finding might be related to a specific feature of the Persian language, as the written script does not display all vowels in Persian. It remains to be investigated whether the number of phonemes could be a better predictor of RT with Persian words as targets in a lexical decision task.

Another interesting finding is the negative relationship that was found between the neighborhood density of primes and RT. Almost all previous studies that used a priming paradigm only controlled for the neighborhood density of the targets. The results of the present study show that the neighborhood density of primes should also be controlled, as the prime ultimately influences the processing of target words. Furthermore, given the importance of the number of phonemes and not the number of letters of the Persian primes, researchers might consider controlling the phonological neighborhood density of the primes in addition to their orthographic neighborhood density in future studies. The phonological neighborhood density of primes might be a better predictor of RT in Persian. More research on this topic is necessary.

Another issue we could infer from the findings of the first study is the relationship between English frequency and familiarity with English words. The results clearly show that these two components are highly related, but different, and Familiarity with English words was a more influential feature than English frequency. Familiarity is presumably a more realistic measure of frequency for L2 speakers than the number of times that a word appears in written and spoken discourse and is included in L1 databases. For accuracy, familiarity with English words was a critical feature. No features of the Persian primes predicted the accuracy of responses. Once more, this finding emphasizes the importance of familiarity with L2 words.

The present study further investigated the relationship between features of cognate and noncognate targets and the RT and accuracy of responses when the targets were preceded by the related and unrelated primes. For cognates in all conditions, RT was positively related to the length of English targets (the number of phonemes and letters), and familiarity with English words was the best predictor of RT. On trials involving related and unrelated noncognates, though, English frequency was the best predictor of RT. English frequency, however, was the second-best predictor of RT for related and unrelated cognates. While the third significant predictor for the related cognates was the pronunciation similarity, it was instead the number of Persian phonemes for unrelated cognates. This finding shows that cognates are special words because they share not only meaning but also a degree of formal features in both languages. This finding supports the phonological account of the cognate advantage (Voga & Grainger, 2007) reported in many experiments, where related primes were processed faster and more accurately than unrelated primes. Persian frequency was not a significant predictor of RT and accuracy, although it correlated negatively. This finding, therefore, casts doubt on the idea that frequency in L1 results in a cognate advantage (Peeters et al., 2013), at least for languages with different scripts. Peeters and colleagues (2013) reported that the best situation for observing the cognate advantage is when frequency in both L1 and L2 is high. Such findings support the idea that cognate and noncognate representations are quantitatively different, meaning that a positive cognate effect results from differing exposure to cognates and noncognates. Cognates are available in both languages. Therefore, they have an exposure frequency advantage over noncognates, which are merely available in one language.

The results of this study are consistent with those reported by De Groot and colleagues (2002) in that familiarity with English words was found to be the best predictor of RT and accuracy in most conditions. In other words, participants seemed to use their familiarity with the English words, especially familiarity with cognates, to perform the lexical decision. This is further supported by the fact that increasing the neighborhood density of targets helped participants make faster decisions.

These findings have implications for L2 teaching. Cognates were shown to be more familiar than noncognates in this study. This feature was even more important than the frequency of English words. Thus, cognates are a part of the knowledge base of L1 that is transferable to

L2. This transferability gives cognates an advantage over noncognates in vocabulary learning. Furthermore, learners can rely on this knowledge when they have limited L2 vocabulary knowledge (Vandergrift, 1997). Thus, it would be advantageous for language teachers to include cognates in their curriculums and also raise learners' awareness of their existence in L1 and L2 (Agnieszka Otwinowska-Kasztelanic, 2009), especially at early stages of L2 learning. Raising awareness is essential, as the proportion of the similarity of form in Persian and English influenced RT in this study. Otherwise stated, if teachers aim to help learners improve their language skills in L2, they can help L2 learners identify L2 words more quickly by purposively teaching their students to identify cognates and their similarity in the two languages. Improving processing speed can increase the amount of information that learners attend to and encode at one time (Sival et al. 2021).

## 2.5. Conclusion

The present study produced a dataset that can be used by researchers who would like to conduct cross-language studies in Persian and English. This dataset provides 288 cognates and noncognates whose features such as frequency, orthographic and phonological length, familiarity, orthographic neighborhood size, imageability, and concreteness were determined and matched across experimental conditions. Nevertheless, as item selection is observed to bring about inconsistencies in the literature, more comprehensive datasets in Persian-English are needed to provide generalizability of findings observed in studies on languages other than Persian.

# Chapter 3. The Role of Phonological Overlap of Cognates in Cross-Language Visual Word Recognition in Languages with Different Scripts

## Abstract

Words that are similar in meaning and form across two languages (cognates) may be processed differently by bilinguals than words that are similar in meaning in both their languages (noncognates). This study examined the effect of phonological similarity of cognates in a second language (L2) when the primes in a first language (L1) were presented to determine whether phonological priming was more readily observable in languages that are written in different characters (different-script languages), such as Persian and English, and whether it can explain the size of the priming effect in bilinguals who speak these languages. Participants made a lexical decision to English targets that were primed by visually presenting related or unrelated masked Persian (or English for an English monolingual control group) words while participants' response times (RTs), accuracy, and event-related potentials (ERPs) were recorded. English targets were cognates with varying degrees of phonological similarity and noncognates in Persian and English and nonwords. Overall, related primes decreased RTs and increased accuracy for all stimuli, supporting the hypothesis that word representations in Persian and English are connected in a bilingual brain. Furthermore, phonological similarity decreased RTs for HPS and LPS cognates, while cognates with lower phonological similarity produced fewer accurate decisions, substantiating the role of L1 knowledge. Also, high phonological similarity modulated the amplitudes of event-related potential (ERP) components at 0-100 ms prime onset in the bilingual group (P100), supporting the hypothesis that a change of script provides an ideal

condition for L1 phonology to affect the processing of L2 cognates. However, the size of the effects did not correlate with the degree of phonological overlap between the Persian prime and the English target. Overall, the findings provide partial support for the effect of L1 phonology on the processing of L2 cognates in Persian-English bilinguals.

## 3.1. Introduction

Understanding how bilinguals store and process words in either language is essential for developing models that describe these phenomena. Researchers manipulate the phonological, orthographic, and semantic features of words in both languages that bilinguals know to reveal how bilinguals organize and access their mental lexicon, which is defined as the set of words an individual uses or recognizes when used by others regularly ("APA Dictionary of Psychology," n.d.; Richards et al., 1992b). The Bilingual Interactive Activation plus (BIA+) model (Dijkstra & Van Heuven, 2002) states that when bilinguals read a word in one language, the orthographic and/or phonological features of the word are activated and that these features automatically activate the features of the words that are similar in the other language. Consequently, bilinguals cannot ignore the nontarget language system when reading in one language. This is known as the nonselectivity view in bilingual language processing (de Bruijn et al., 2000; de Groot et al., 2000; Dijkstra, De Bruijn, Schriefers, & Ten Brinke, 2000; Dijkstra & van Heuven, 2002; Lagrou et al., 2011; Spalek et al., 2014; Xiong, Verdonschotb, & Tamaoka, 2020).

There has been debate regarding the language nonselectivity view under conditions where a bilingual reader’s languages are written in different scripts. One hypothesis is that early processing of script differences might guide the incoming sensory information towards the lexical system of the language in which the text is written so that no contact with the nontarget language representations will be established (Rodriguez-Fornells et al., 2002). This selectivity view, therefore, postulates a complete separation of the two language systems. One way to examine access to the mental lexicon is to use words that are shared in the two languages a bilingual knows and manipulate the orthographic, phonological, and semantic features of those words. Cognates and noncognates have frequently been used for these purposes in research studies. Cognates are words that display similar semantic and phonological, and sometimes orthographic features across languages. For example, *door* and در */ dær /* are cognates in English and Persian. These words are phonologically and semantically similar but orthographically different. Noncognates, conversely, are translation equivalents that share semantic features across languages. *Table* and میز */mɪ:z /* are noncognates in Persian and English.

Most studies have shown that cognates are processed faster and more accurately than noncognates and control words (i.e., the cognate effect). Cognates were recognized faster in lexical-decision tasks (Lemhöfer et al., 2004) and were translated more rapidly (Sáchez-Casas et al., 1992) than noncognates. Similar results were obtained in priming (Cristoffanini et al., 1986; Lalor & Kirsner, 2001; Nakayama et al., 2013) and masked priming experiments (de-Groot & Nas, 1991; Gollan et al., 1997; Sáchez-Casas et al., 1992) with similar-script languages such as Dutch and English (de-Groot & Nas, 1991), Chinese and Japanese (Xiong et al., 2020), and different-script languages such as Hebrew and English (Gollan et al., 1997) and Korean and English (Kim & Davis, 2003).

Insofar as the cognate effect has been established in the literature, studies investigating the processing of noncognates have produced mixed results in languages with similar and different scripts and in using different tasks. Gollan et al. (1997, Exp. 1 & Exp. 2) had Hebrew-English and English-Hebrew bilinguals perform a primed lexical-decision task in the L1-L2 (prime-target) direction. They found prime effects for cognates and noncognates, although the effects were stronger for cognates. Similarly, Kim and Davis (2003) found priming effects for cognates and noncognates in a lexical decision and semantic categorization task in Korean-English bilinguals. Grainger and Frenck-Mestre (1998) obtained significant noncognate priming effects with English-French bilinguals in a semantic categorization task but not in a lexical decision task. Fotovatnia and Taleb (2012) found cognate facilitation effects but no effects for noncognates in Persian-English bilinguals in a masked-priming lexical decision task. Comparing cognates and noncognates in a new linguistic context would develop insights into the bilingual visual recognition of words.

More recently, researchers have employed techniques such as EEG and ERPs to complement behavioral measures in their studies. ERPs are “small voltage fluctuations in the EEG that are correlated in time with sensory or motor events” (Federmeier, Wlotko, & Meyer, 2008, p.3), and studies have shown them to be markers of cognitive processes (Federmeier et al., 2008). Due to the high temporal resolution of ERPs (within milliseconds), they can be used to assess rapid and temporally overlapping processes used in language comprehension (WlotkoKara & Federmeier, 2013). ERPs are multidimensional; they show both time-course information and scalp distribution patterns (Midgley et al., 2011).

To explain the cognate effect observed in single-script languages in electrophysiological terms, Midgley et al. (2011) compared the performance of English-French bilinguals on identical cognates (e.g., *table* in English is *table* in French), close cognates (e.g., *victim*, *victime*), and noncognates using a semantic categorization task in L1 and L2. Participants observed words on a screen one at a time and pressed a button whenever they saw the name of an animal. These nontarget words comprised 12% of the total words presented. Noncognates showed larger N400 amplitudes (increased negativity) than cognates in both languages. Cognate effects (reduced negativity in the N400) were observed in L1 and L2, but the timing and distribution across the scalp of these effects were different. These effects started around 200 ms in L1 and were widespread across the scalp through the 300-500 ms time window but did not continue to the 500-800 ms time window. For L2, the cognate effect did not start until around 300 ms and was widespread after 550 msec. Peeters, Dijkstra, and Grainger (2013) studied the representation and processing of identical cognates and noncognates by late French-English bilinguals in a lexical decision task, manipulating the frequency in French and English. Both Midgley et al. (2011) and Peeters et al. found cognate effects in the N400 time window. However, Peeters and colleagues found an additional P600 effect, which they attributed to the lexical decision task used in their study. They concluded that identical cognates are represented twice in the mental lexicon although they are orthographically the same, and depending on the task language, one of these orthographic representations receives priority.

Several studies have demonstrated that the cognate effect is partly due to the orthographic similarity of the words across languages (Dijkstra &Van Heuven, 2002, the BIA+ model). However, the role of phonology and its interaction with other features of cognates in languages with different scripts are not yet fully understood (Comesana et al., 2014). Studying the facilitative effect of cognates in Greek-French bilinguals, Voga and Grainger (2007) found priming effects for cognates when they compared cognate translation equivalents with phonologically related primes in Greek in a lexical decision task (Exp. 1). In Experiment 2, the researchers primed cognates with translation equivalents, phonologically similar words, and phonologically and semantically unrelated words in Greek and French to examine whether the cognate effect resulted from the addition of phonological overlap to the semantic overlap in this word type. Voga and Grainger used cognates with high-phonological overlap, cognates with low-phonological overlap, and noncognates. They observed that cognates showed no advantage in the degree of phonological overlap when compared with phonologically related primes. However, when compared with unrelated primes, cognates with higher phonological overlap showed larger priming effects than cognates with lower phonological overlap. The researchers attributed the size of the cognate effect to the degree of phonological overlap between the prime and target and concluded that cognates showed facilitative effects because they possess both phonological and semantic overlap, rather than only semantic overlap possessed by other translation equivalents in different-script languages. If this conclusion is correct, we would expect cross-language cognates with higher phonological overlap to show more priming effects than cross-language cognates with lower phonological overlap because the former group shares more phonological features than the latter group. We would also expect cognates with lower phonological similarity to show smaller priming effects than noncognates. Although Greek and French were considered different-script languages by Voga and Grainger, we believe these languages show sufficient script similarities (e.g., French and Greek translation equivalents, *kilo*, *κιλό*; *taxi*, *τάξη*; and *café*, *καφές*) to warrant testing the phonological account in studies with different groups of bilinguals to clarify the issue further.

Investigating the phonological account with Japanese-English bilinguals, Nakayama, Verdonschot, Sears, and Lupker (2014) found that HPS cognates produced more cognate effects than LPS cognates. As predicted by the phonological account, the researchers found 47 ms faster response times for HPS than LPS cognates. However, the researchers could not examine the prediction of the phonological account that LPS cognates should produce larger priming effects than noncognates for two reasons: (a) the researchers did not counterbalance the noncognates in their study, and (b) the cognates and noncognates were written in Katakana and Kanji respectively in Japanese. Katakana are syllabic characters that correspond to sounds or syllables, while Kanji are logographic characters equivalent to whole words or phrases. To adequately test the hypothesis, the primes for cognates and noncognates should be written in the same script. Unlike Japanese, Persian uses the same scripts for cognates and noncognates. Consequently, using Persian would allow researchers to better test the predictions of the phonological model when cognates are compared with noncognates. No study has used behavioral and ERP measures to examine the phonological account in Persian and English. When the scripts of L1 and L2 are different, cognates benefit only from shared phonology. Thus, one can measure the effects of shared phonology more accurately. Consequently, differences between cognate priming effects can be attributed to phonological and semantic similarities.

This study aimed to examine the processing of cognates and noncognates in English and to test the predictions of the phonological account of the cognate effect by focusing on the degree of phonological overlap between cognates in Persian and English in a lexical decision task. This theoretical view has been supported in Greek-French bilinguals (Voga & Grainger, 2007) and Japanese-English bilinguals (Nakayama et al., 2014). Voga and Grainger (2007) showed that the size of cognate priming effects in French varied with the phonological similarity of cognates in Greek and French when cognates were compared with primes that were phonologically and semantically unrelated to the targets. No such effect was observed when cognates were compared with phonologically related primes. Furthermore, Greek and French are Indo-European languages with similar etymological roots and similarities in orthography. Nakayama, et al. (2012) observed larger priming effects for HPS cognates than LPS cognates. However, they did not compare the LPS cognates with noncognates, as primes for cognates and noncognates are necessarily written in different scripts in Japanese. Persian and English are written in completely different characters and Persian reads from right to left. In addition, unlike the Japanese language, which uses Katakana for writing loan words (i.e., words adopted from another language), the Persian language does not use different scripts for loan words. Thus, because of these issues, we believe that Persian-English bilinguals may provide a better test of the phonological account of the cognate effect. We also anticipated that the additional measurement of ERPs would complement the behavioral data.

We used the following time windows to analyze the ERP components: a) four time windows before 300 ms post-target onset to investigate form-related processing, (b) a window from 300 to 500 ms post-target-onset that contains the N400 component, and c) a window that shows late processing of meaning (Midgley et al., 2009). The N400 is a negative potential sensitive to semantic processing with a peak around 400 ms after word onset. Smaller N400 amplitudes show easier processing of the meaning of a word (Kutas & Federmeier, 2000). The form-related time windows were the 0-100 ms post-prime onset, 100-150 ms post-prime onset, 100-200 ms post-target onset, and 200-300 ms post-target onset. The late processing window was the 500-850 ms post-target onset. We also collected data from a group of monolingual English speakers to ensure that the observed effects in the bilingual group were not ascribed to uncontrolled characteristics of the stimuli. We further compared the monolingual group with the bilingual Persian-English speakers to detect the earliest time after the presentation of the prime that the priming effect appears in each group. Additionally, we hypothesized that if word features in Persian and English are connected in the brain, we should observe the main effect of the prime in this study. That is, primes in Persian should automatically activate relevant word features of English targets. Consequently, we expected to find faster and more accurate processing of related (translation equivalents of targets) than unrelated primes in the behavioral analysis and more-positive going N400 over the central and parietal electrodes in the ERP analysis for cognates and noncognates. This observation would replicate previous studies that support the nonselectivity view of bilingual word processing and word access.

Second, we expected to replicate the advantages of cognate processing over noncognate processing observed in previous cross-language studies. As discussed, cognates share phonological and semantic features, while noncognates share only semantic features across Persian and English. This observation supports one of the claims of the phonological account of the cognate effect that attributes the facilitative effects of cognates to the addition of phonological features to the semantic features of this word group across these languages. In line with another prediction of the phonological account of the cognate effect, we also expected the size of this effect to show a direct relationship to the phonological similarity of the prime and target. That is, we expected HPS cognates to be faster and more accurately identified than LPS cognates. We also predicted that HPS cognates would show earlier form-related amplitude effects than LPS cognates in the ERP analysis. Following this line of reasoning, we expected LPS cognates to show more advantages in RTs, accuracy, and ERP form-related measures than noncognates. To put it differently, we predicted that HPS cognates would show more cognate effects than LPS cognates, and in turn, LPS cognates would show more facilitative effects than noncognates in all measures.

Third, we expected to find an effect of phonological similarity of cognates, in terms of interactions between the prime type and word type in earlier time windows in the current study than the same effect reported previously in similar-script languages in the ERP analysis (e.g., Midgley et al., 2009). We also predicted that similar interactions would occur earlier in the bilingual than in the monolingual group. Gollan et al. (1997) attributed this issue to the difference between the language of the prime and the target that directs the language processor to look for the prime in the relevant lexical system.

Finally, regarding our monolingual group, we expected them to show facilitative priming effects for related primes, as these primes are more related orthographically, phonologically, and semantically to the targets (repetition priming, e.g., prime & target being *ambulance*) than unrelated primes (e.g., prime being *newspaper* & target being *ambulance*). However, we expected the priming effect for this group to occur equally for cognates and noncognates because monolinguals access only one language system. Observing a different pattern of results for cognates than noncognates in this group would have called into question the cognate effect we predicted to find in the bilingual group, as the differences would reflect that the features of stimuli had not been adequately controlled. In addition, we expected to see the effects of related primes earlier than unrelated primes in bilinguals than monolinguals. Early effects are claimed to occur because changing the script between the prime and target removes the competition between the orthographic representations of the prime and target in different-script languages. The competition arises when similar-script languages are involved. That is, after recognition, the target word sends inhibitory effects to all the words that share features with the target, including the prime, to prevent the prime's further processing (Dimitropoulou, Dunabeitia, & Carreiras, 2011). The prime can be processed further in similar-script languages if its effects are stronger and faster than the target's inhibitory effect. This never happens in different-script languages because the prime does not share the script with the target, and so it does not receive these inhibitory effects. We expected the monolingual group to show this inhibitory effect of processing of the prime later than the bilingual group.

## 3.2. Method

### 3.2.1. Participants.

Forty-one native male (n=26) and female (n=15) Persian-English speakers with normal or corrected to normal vision, residing in Waterloo and London, Canada, either graduated or studying in an MA/MSc (n=24), or a Ph.D. (n=17) graduate program at the time of testing (*M* age= 32.47, *SD*=5.21) were recruited for this study. Participants had received a minimum of eight years of formal English instruction in Iran before immigrating to Canada. All participants obtained a score of 5.5 to 8 (*M*=6.96, *SD*=.69) in the IELTS Academic module. Participants rated the mean frequency at which they used English daily as 6.14 (*SD*=1.4), 6.29 (*SD*=.89), 5.6 (*SD*=1.42), and 5.17(*SD*= 1.61) on a *7*-point Likert scale in reading, listening, speaking, and writing, respectively. Based on these criteria, we considered the Persian-speaking group to be advanced L2 English speakers. Participants were recruited through flyers, posters, and Facebook advertisements. Thirty-two English monolingual speakers (13 males & 19 females) studying at Wilfrid Laurier University, with a mean age of 18.5, were also recruited through Wilfrid Laurier University's Psychology Research Experience Program as the control group. These participants rated the mean frequency at which they read and write English daily as 4.18 (*SD*=.99) and 4.57 (*SD*=.50) on a *7*-point Likert scale. The Wilfrid Laurier University Research Ethics Board approved all procedures (REB approval number, 4585).

### 3.2.2. Stimuli.

All the stimuli used in the current study were generated by Fotovatnia, Jones, and Scheerer (2019). Four types of nouns were used in the lexical decision task: HPS cognates (e.g., tire), LPS cognates (e.g., lemon), noncognates (e.g., prize), and word fillers in the L1 (Persian prime) - L2 (English target) direction. For the bilingual group, English targets were preceded by either related or unrelated Persian primes. Related primes were related in meaning (noncognates) and meaning and form (HPS & LPS cognates) to the English targets. For example, related and unrelated primes for were تایر /*taːˈjer* / and, چکمه / *ʧækˈme* / for HPS cognates (target word being *tire*), لیمو/ *liːˈmuː*/, and روضه /*rɔʊˈze*/ for LPS cognates (target word being *lemon*), and جایزه/*dʒajeˈze* / and زندان/*zenˈdɔn* / for noncognates (target word being *reward*), respectively.

Unlike other studies that defined word length in terms of the number of letters (Ando, Matsuki, Sheridan, & Jared, 2014; Hoshino et al., 2010; Midgley et al., 2011), this study matched the related and unrelated primes for both the number of letters and phonemes. In the Persian language, letters mainly represent consonants and not vowels. For example, the word ثمر /*sæ'mær*/ has three letters but five phonemes. Also, Fotovatnia et al. (2019) showed that the number of phonemes of the Persian prime significantly affected the RT in the lexical decision task. The CLEARPOND database (Marian, Spivey, & Hirsch, 2003; Shook & Marian, 2012) was used to determine the number of phonemes and letters, word frequency, and orthographic neighborhood density of the English targets. The English Project Website (at elexicon.wustl.edu) generated 230 English nonwords, matched with the corresponding words for the number of letters and neighborhood density. The MAHAK (means "measure" in English) corpus (Sheykh-Esmaili et al., 2007) was used to determine the frequency of Persian words and their neighborhood density. Two questionnaires were developed to determine the phonological similarity of cognates, familiarity with English words, and concreteness and imageability of the Persian words (Fotovatnia et al., 2019). Fotovatnia et al. have provided further details on the selection of the stimuli and determining their semantic features. The features of primes and targets matched across the experimental conditions are shown in Appendix 2. A one-way ANOVA did not show significant differences across the experimental conditions. Lexico–

semantic features of words have confounding effects on lexical decision performance and should thus be controlled (Appendix 3 & Appendix 4).

Cognates were divided into two types according to the phonological similarity ratings performed by 55 Persian-English speakers in Fotovatnia et al.'s study (2019, HPS, $M$=4.23, $SD$= .38, & LPS, $M$ = 2.61, $SD$= .33). HPS and LPS cognates significantly differed from each other on phonological similarity, $t(60)$ =18.87, $p$<.001. The stimuli included 32 HPS cognates, 32 LPS cognates, 32 noncognates, 48 fillers, and 230 nonwords. A complete list of the stimuli is provided in Fotovatnia et al. (2019).

**3.2.3. Apparatus and procedure.**

Participants wore a 32 channel NeuroScan Quik-Cap (Compumedics, Charlotte, SC, USA) and were tested in a sound-attenuated, electrically shielded booth (Raymond EMC, Ottawa, ON, Canada) after completing the consent form and the demographic questionnaire. EEG signals were amplified via two NeuroScan SynAmp 2 amplifiers (Compumedics NeuroScan, Charotte, NC). The signals were digitized with 12-bit precision at 1000 samples per second. Additional electrodes were used to monitor for eye-related artifacts (blinks and vertical and horizontal eye movements); one below and one above the left eye (VE), and two horizontally next to the right and left eye (HE). Electrode impedances were maintained below 5 kΩ throughout the duration of the experiment.

The stimuli were displayed on the center of a white background on a 16-inch Dell P170S monitor with a refresh rate of 60 Hz and a resolution of 1280 × 1024, located approximately 50 cm in front of participants using STIM2 software. Each trial began with a fixation sign (+) displayed for 500 ms, followed by the presentation of a forward mask (#######) for 500 ms (Figure 3.1). The Persian prime was displayed in 14 pt Nazanin font for 50 ms. To select the font size in each language, we consulted with three participants, who took part in the pilot study. Our goal was to select a font size, that participants felt comfortable viewing while keeping the height of the characters approximately the same in Persian and English. The prime was immediately replaced by the English target word or nonword in 16pt New Times Roman font in lower case letters, and it remained on the screen until the participant responded. The next trial started 2000 ms after each response.

Participants received instructions in English printed on paper. They were instructed to make a lexical decision to the English targets as quickly and accurately as possible by pressing a button for “word” and another for “nonword” on a response box (Neuro Scan, INC. STIM system switch response pad P/N 1141). The researchers used Persian to verbally clarify the instructions during the experiment. We attempted to match the size of the prime with the target. However, there were situations where unavoidable differences in the number of letters appeared between translation equivalents in the two languages. To ensure that these differences did not make the primes visible, we flanked targets by brackets (>>>> item <<<<).

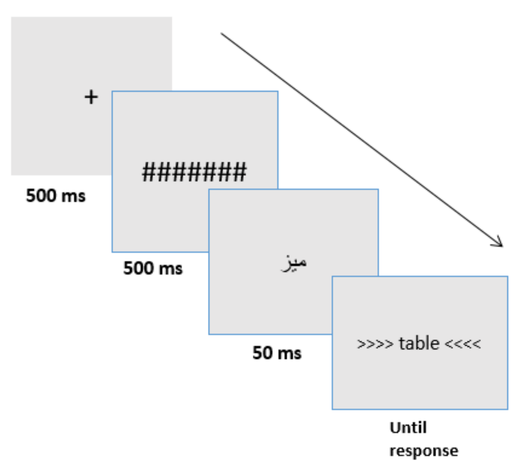



*Figure 3.1.*The masked prime lexical decision task

Using masks in a lexical decision task engages automatic processing of the prime (Forster & Davis, 1984) and prevents the prime from reaching conscious attention. Participants, therefore, do not use conscious strategies that result from nonautomatic or strategic processing. Thus, the masked primes prevented the bilinguals from strategically connecting one language with their other language (Kirsner et al., 1984).

Two counterbalanced lists of stimuli were presented such that each target word was preceded by a related prime in one list and by an unrelated prime in the other list. Each list included 144 words and 230 nonwords. No target word was repeated on each list. Put differently, half of the targets in each condition were preceded by related primes and the other half were preceded by unrelated primes in one list. This order was reversed in the other list. Consequently, each target was preceded by both the related prime and unrelated prime, but not in the same list.

The stimuli were presented in four blocks of equal length. Participants were given a break of their desired length between each block. Each participant performed a 30-item practice trial similar to the main task. Participants were asked to blink only when the fixation sign was on the screen, after a response, or between the trials. After the experiment, participants were asked about their experience during the task to determine whether they noticed the prime. No participant reported seeing any Persian word during the experiment. Each block lasted from 13 to 15 minutes. In total, the experimental session lasted less than 2 hours (including the cap-set-up time). Monolingual speakers received the same set of words and followed the same procedures in English.

## 3.3. Data Analysis

RT, accuracy, and ERP data were analyzed by conducting a within-subjects analysis of variance on the mean values with an alpha level of .05, using IBM SPSS version 25. We interpreted the output of a Multivariate Analysis of Variance (MANOVA) for all analyses because the MANOVA does not require the assumption of sphericity (Pallant, 2016). Following Pallant (2016), we used the value of Wilk's Lambda in all analyses. The Bonferroni hoc test was run when significant main effects were compared. When the initial analysis revealed a significant interaction, follow-up investigation proceeded with the computation of simple effect tests that reveal the degree to which one factor is differentially effective at each level of a second factor. Syntax was written to conduct the post-hoc investigation of interaction effects (Field, 2017), as IBM SPSS Statistics does not perform this analysis by default.

### 3.3.1. Behavioral analysis.

The study used a 3 (Word Type: HPS cognates, LPS cognates, noncognates) x 2 (Prime Type: related, unrelated) factorial design. Only RT values between 300 and 1500 ms and within two SDs from the mean were analyzed. Data from two bilingual participants with error rates of above 25% were discarded from the behavioral and ERP analysis. The bilingual results are reported in each section before the monolingual results.

### 3.3.2. ERP analysis.

All ERP analyses were done using MATLAB (version R2019a, Mathworks, Inc.) and EEGLAB 2021.0. Makoto's preprocessing pipeline (Miyakoshi, n.d.) was used for processing the EEG data. After data acquisition, EEG voltage values were re-referenced to the average voltage across all electrode sites. Artifacts from eye and muscle movements were rejected offline using Artifact Subspace Reconstruction (ASR) algorithm, cleanLine, and Independent Component Analysis (ICA) decomposition EEGLAB plugins. After data cleaning, visual inspection of data ensured that all the artifacts were removed. Epochs from 100 ms before (baseline correction) and 900 ms after the presentation of prime were extracted, and averaged waveforms were created for the first block and condition for each participant. The mean amplitudes were then measured in six time-latency windows (0-100 ms post-prime onset; 50-100, 100-200, 200-300, 300-500, and 500-850 ms post-target onset). Following Midgley and colleagues (2011), we selected these time windows to capture the N400 (300-500 ms), form-related components such as N250 (200-300ms), and late semantic effects (500-800 ms). The electrodes were divided into five clusters following Peeters et al. (2013): left anterior, LA (FP1, F3, F7, FC3, FT7); right anterior, RA (FP2, F4, F8, FC4, FT8); left posterior, LP (O1, P3, P7, CP3, TP7); right posterior, RP (O2, P4, P8, CP4, TP8); and vertical midline, VM (Oz, Pz, Cz, FCz, Fz). Mean amplitudes were created for each cluster in each time window. Data were imported to SPSS for further analysis.

## 3.4. Results

### 3.4.1. Bilingual behavioral results.

Overall, the grand mean RT to words was 707.50 ms and 793.86 ms to nonwords across all blocks in the experiment. Responses to nonwords became progressively faster and more accurate from the first to the fourth block, and the mean error percentage of nonwords was 12.42%. The grand mean accuracy to words was 0.94 across all blocks. Table 3.1 shows RTs in milliseconds and the percentage of correct responses in all blocks for words.

Table 3.1. *Mean RTs in Milliseconds and Mean Correct Responses for English Targets Primed by Related and Unrelated HPS Cognates, LPS Cognates and Noncognates in Bilingual Participants*

| | HPS cognates | | | LPS cognates | | | Noncognates | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Related prime** | **Unrelated prime** | **Priming** | **Related Prime** | **Unrelated prime** | **Priming** | **Related prime** | **Unrelated prime** | **Priming** |
| **Block 1** | | | | | | | | | |
| **RT** | 769.28 | 790.43 | 21.15 | 772.71 | 813.26 | 40.55 | 774.88 | 791.5 | 16.62 |
| **SD** | 174.15 | 161.56 | -12.59 | 139.09 | 186.6 | 47.51 | 154.76 | 166.86 | 12.1 |
| **Correct** | 0.95 | 0.94 | 0.01 | 0.94 | 0.90 | 0.03 | 0.96 | 0.95 | 0.01 |
| **SD** | 0.09 | 0.08 | 0.00 | 0.09 | 0.12 | -0.03 | 0.07 | 0.09 | -0.02 |
| **Block 2** | | | | | | | | | |
| **RT** | 685.03 | 712.84 | 27.81 | 725.56 | 718.42 | -7.14 | 710.51 | 730.26 | 19.75 |
| **SD** | 111.91 | 107.53 | -4.38 | 130.46 | 108.07 | -22.39 | 112.13 | 110.75 | -1.38 |
| **Correct** | 0.96 | 0.94 | 0.02 | 0.93 | 0.91 | 0.02 | 0.96 | 0.95 | 0.00 |
| **SD** | 0.06 | 0.05 | 0.00 | 0.10 | 0.08 | 0.02 | 0.06 | 0.05 | 0.01 |
| **Block 3** | | | | | | | | | |
| **RT** | 645.55 | 683.44 | 37.89 | 677.94 | 703.04 | 25.1 | 682.16 | 692.41 | 10.25 |
| **SD** | 121.63 | 106.45 | -15.18 | 128.98 | 125.88 | -3.1 | 124.62 | 118.13 | -6.49 |
| **Correct** | 0.96 | 0.95 | 0.01 | 0.93 | 0.95 | -0.02 | 0.95 | 0.94 | 0.01 |
| **SD** | 0.05 | 0.08 | -0.02 | 0.08 | 0.08 | -0.01 | 0.07 | 0.06 | 0.01 |
| **Block 4** | | | | | | | | | |
| **RT** | 629.91 | 648.1 | 18.19 | 634.91 | 660.76 | 25.85 | 654.61 | 672.48 | 17.87 |
| **SD** | 101.1 | 99.74 | -1.36 | 103.18 | 109.12 | 5.94 | 114.64 | 113.39 | -1.25 |
| **Correct** | 0.96 | 0.94 | 0.03 | 0.94 | 0.92 | 0.02 | 0.93 | 0.94 | -0.01 |
| **SD** | 0.06 | 0.09 | -0.03 | 0.08 | 0.09 | -0.01 | 0.08 | 0.07 | 0.00 |

**3.4.2. RT analysis.**

**All blocks:** There was a significant main effect for block, $\lambda = .62$, $F(3, 36) = 7.88$, $\eta_p^2 = .38$, $p < .001$. Block 1 ($M = 785.34$) was slower than Block 2 ($M = 713.77$, $p = .02$), Block 3 ($M = 680.75$, $p = .001$), and Block 4 ($M = 650.13$, $p < .001$). There was a significant main effect of prime, $\lambda = .59$, $F(1, 38) = 28.30$, ηp2 = .41, $p < .001$. RTs in related conditions ($M = 696.92$) were faster than those in the unrelated conditions ($M = 718.08$, $p < .001$). The main effect of word type reached significance, $\lambda = .39$, $F(2, 37) = 29.88$, ηp2 = .61, p < .001. Post hoc comparisons showed that RTs for HPS cognates ($M = 695.57$) were faster than LPS cognates ($M = 713.33$, $p < .001$) and noncognates ($M = 713.60$, $p < .001$). No significant differences between LPS cognates and noncognates were found. The interactions between block and word type, $\lambda = .60$, $F(6, 33) = 3.84$, ηp2 = .40, $p = .005$, and block, prime and word type, $\lambda = .61$, $F(6, 33) = 3.75$, ηp2 = .39, p = .005 reached significance.

**Block 1:** There was a significant main effect for prime, $\lambda = .80$, $F(1, 38) = 9.58$, ηp2 = .19, $p = .004$. Related RTs ($M = 772.29$) were faster than unrelated RTs ($M = 798.40$, $p = .004$). Post hoc comparisons showed that related primes significantly facilitated the processing of HPS cognates, $\lambda = .90$, $F(1,38) = 4.14$, $p = .04$ ), and LPS cognates, $\lambda = .84$, $F(1,38) = 7.49$, $p = .009$.

**Block 2:** There was a significant main effect for prime, $\lambda = .90$, $F(1, 38) = 4.65$, ηp2 = .10, $p = .037$. RTs in related conditions ($M = 703.68$) were faster than those in the unrelated conditions ($M = 716.18$, $p = .04$). There was a significant effect for word type, $\lambda = .71$, $F(2, 37) = 8.23$, ηp2 = .29, $p = .001$. LPS cognates were faster than HPS cognates ($p = .02$) and noncognates ($p = .001$). The interaction between prime and word type reached significance, $\lambda = .82$, $F(2, 37) = 4.42$, ηp2 = .17, $p = .018$. Further analysis showed that related primes significantly facilitated the processing of HPS cognates ($p = .01$) and noncognates ($p = .03$), $\lambda = .71$, $F(1,38) = 8.23$, $p =$

.001.

**Block 3:** There was a significant main effect for prime, $\lambda = .73$, $F(1, 38) = 15.23$, ηp2 = .27, $p <$ .001. RTs in related conditions ($M = 671.26$) were faster than those in the unrelated conditions ($M = 696.33$, $p < .001$). The main effect of word type reached significance, $\lambda = .65$, $F(2, 37) =$ 10.41, ηp2 = .34, <.001. The interaction between prime and word type reached significance, $\lambda =$ .85, $F(2, 37) = 3.45$, ηp2 = .15, $p = .04$. Further analysis showed that related primes significantly facilitated the processing of HPS cognates, $\lambda = .62$, $F(1, 38) = 25.30$, $p < .001$, and LPS cognates, $\lambda = .88$, $F(1, 38) = 5.60$, $p = .02$.

**Block 4:** There was a significant main effect for prime, $\lambda = .72$, $F(1, 38) = 16.56$, ηp2 = .28, $p <$ .001. RTs in related conditions ($M = 638.66$) were faster than those in the unrelated conditions ($M = 660.46$, $p < .001$). There was a significant effect for word type, $\lambda = .63$, $F(2, 37) = 12.17$, ηp2 = .37, $p < .001$. Noncognates were slower than HPS cognates ($p < .001$) and LPS cognates ($p < .001$). There was no significant interaction between prime and word type because related primes facilitated the processing of HPS cognates, LPS cognates, and noncognates.

**3.4.2.1. Accuracy analysis.**

**All blocks:** Analysis of error rates failed to show a significant main effect for block. However, a significant main effect for prime existed, $\lambda = .87$, $F$ (1, 38) = 6.14, ηp2 = .13, $p = .018$. Related primes ($M = .95$) led to more accurate responses than unrelated primes ($M = .94$, $p = .02$). Also, the main effect of word type reached significance, $\lambda = .65$, $F$ (2, 37) = 10.57, ηp2 = .35, $p < .001$. Post hoc comparisons showed that LPS cognates were selected less accurately than HPS cognates ($p < .001$) and noncognates ($p = .002$). However, no significant differences between HPS and noncognates were found.

**Block 1:** Analysis of error rates showed a significant main effect for prime, $\lambda = .86$, $F(1, 38) =$

6.56, ηp2 = .14, *p* = .014. Related primes (*M* =.95) resulted in more accurate responses than unrelated primes (*M* = .93, *p* = .02). Furthermore, the main effect of word type reached significance, λ = .74, *F*(2, 37) = 6.73, ηp2 = .26, *p* = .003. Post hoc comparisons showed that LPS cognates (*M* = .92) were selected less accurately than HPS cognates (*M* = .95, *p* = .01) and noncognates (*M* = .95, *p* = .005). However, no significant differences between HPS and noncognates were found.

**Block 2:** Analysis of error rates showed a significant main effect for prime, λ = .91, *F*(1, 38) = 6.90, ηp2 = .09, *p* = .048. Related primes (*M* = .95) resulted in more accurate responses than unrelated primes (*M* = .93, *p* = .04). Furthermore, the main effect of word type reached significance, λ = .75, *F*(2, 37) = 6.90, ηp2 = .25, *p* = .003. Post hoc comparisons showed that LPS cognates were selected less accurately than HPS cognates (*p* = .04) and noncognates (*p* = .002). Nevertheless, no significant differences between HPS and noncognates were found.

**Block 3:** Analysis of error rates failed to show any significant differences across conditions in Block 3.

**Block 4:** Analysis of error rates showed a significant main effect for word type, λ = .85, *F*(2, 37) = 3.62, ηp2 = .15, *p* = .036. Post hoc comparisons showed that HPS cognates were selected more accurately than LPS cognates (*p* = .04). A significant interaction was observed between prime and word type for HPS cognates, λ = .90, *F* (1, 37) = 4.37, *p* = .043. Related primes (*M* = .96) led to more correct decisions than unrelated primes (*M* = .94). Figure 3.2 illustrates difference scores (priming effects) for the RT (related prime values subtracted from the unrelated prime values) and accuracy (unrelated prime values subtracted from the related prime values across cognates and noncognates.

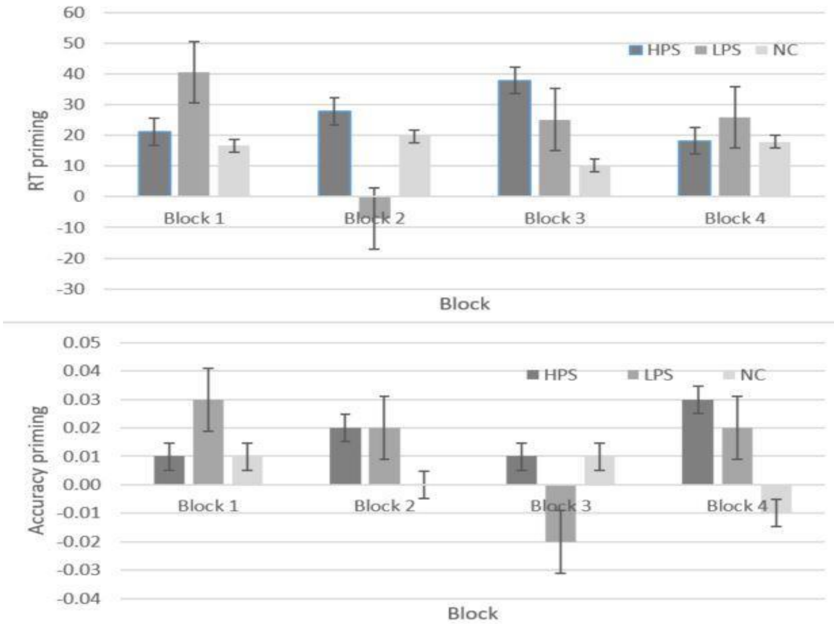



*Figure 3.2.* Priming effects for RTs and accuracy across HPS cognates, LPS cognates and noncognates in bilinguals

In summary, Block 1 was faster than other blocks. Related primes decreased RTs for target words more than unrelated primes. Generally, HPS cognates were faster than LPS cognates and noncognates. However, significant interactions between prime type, word type, and block were observed. Considering the interaction effect of prime and type in each block, related primes were processed faster than unrelated primes in HPS cognates and LPS cognates in Block 1, Block 3, and Block 4. Related LPS cognates continued to be processed faster than unrelated LPS cognates in Block 2. On the other hand, related primes decreased RTs of noncognates in Block 2 and Block 4. Moreover, HPS cognates were processed faster than LPS cognates and noncognates in Block 1 and Block 2. The main effect of word type showed that noncognates were processed more slowly than HPS cognates and LPS cognates in Block 4.

Error analysis of data with block, prime type, and word type as factors showed main effects of prime and word type. Related primes reduced errors more than unrelated primes. Also, HPS cognates and noncognates were processed more accurately than LPS cognates. Error analysis for each block showed an interaction between prime and word type for HPS cognates in Block 4. Related primes led to more accurate processing of HPS cognates than unrelated primes. Related primes reduced the number of errors more than unrelated primes in Block 1 and Block 2. Also, related primes produced more accurate responses in HPS cognates and noncognates than LPS cognates in Block 1 and Block 2. The same facilitative effect was observed for HPS cognates than LPS cognates in Block 4.

### 3.4.3. Monolingual behavioral analysis.

Overall, the grand mean RTs to words was 535.29 ms and to nonwords was 578.37 ms across all blocks. The grand mean of accurate responses to words was 0.94 and to nonwords was 0.88. Table 3.2 shows RTs in milliseconds and the percentage of correct responses in all blocks.

Table 3.2. *Mean RTs in Milliseconds and Mean Error for English Targets Primed by Related and Unrelated HPS Cognates, LPS Cognates and Noncognates in Monolingual Participants*

| | HPS cognates | | | LPS cognates | | | Noncognates | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Related prime** | **Unrelated prime** | **Priming** | **Related prime** | **Unrelated prime** | **Priming** | **Related prime** | **Unrelated prime** | **Priming** |
| **Block 1 RT** | 552.46 | 599.17 | 46.70 | 556.70 | 604.79 | 48.09 | 534.63 | 605.52 | 70.89 |
| **SD** | 89.59 | 90.28 | 0.70 | 94.19 | 95.80 | 1.61 | 86.05 | 88.18 | 2.12 |
| **Correct** | 0.96 | 0.94 | 0.03 | 0.94 | 0.92 | 0.02 | 0.93 | 0.95 | -0.01 |
| **SD** | 0.06 | 0.08 | -0.02 | 0.08 | 0.09 | -0.02 | 0.07 | 0.07 | 0.00 |
| **Block 2 RT** | 511.21 | 567.19 | 55.98 | 509.96 | 566.64 | 56.68 | 504.76 | 574.5 | 69.74 |
| **SD** | 85.52 | 83.39 | -2.13 | 78.29 | 74.94 | -3.35 | 84.23 | 78.51 | -5.72 |
| **Correct** | 0.96 | 0.94 | 0.02 | 0.92 | 0.91 | 0.02 | 0.96 | 0.96 | 0.00 |
| **SD** | 0.05 | 0.05 | -0.01 | 0.09 | 0.08 | 0.01 | 0.06 | 0.05 | 0.01 |
| **Block 3 RT** | 490.49 | 547.17 | 56.67 | 489.90 | 540.08 | 50.19 | 485.29 | 551.08 | 65.79 |
| **SD** | 69.64 | 65.10 | -4.53 | 69.36 | 71.85 | 2.49 | 79.17 | 71.35 | -7.82 |
| **Correct** | 0.96 | 0.95 | 0.01 | 0.93 | 0.95 | -0.02 | 0.95 | 0.94 | 0.01 |
| **SD** | 0.05 | 0.08 | -0.02 | 0.07 | 0.09 | -0.02 | 0.07 | 0.06 | 0.02 |
| **Block 4 RT** | 476.14 | 542.52 | 66.38 | 470.77 | 538.23 | 67.46 | 484.72 | 543.08 | 58.37 |
| **SD** | 73.85 | 71.61 | -2.24 | 67.63 | 89.62 | 21.98 | 84.15 | 84.81 | 0.66 |
| **Correct** | 0.95 | 0.94 | 0.01 | 0.94 | 0.90 | 0.03 | 0.96 | 0.94 | 0.02 |
| **SD** | 0.09 | 0.08 | 0.01 | 0.09 | 0.13 | -0.04 | 0.06 | 0.10 | -0.03 |

#### 3.4.3.1. *RT analysis.*

**All blocks:** A within-subjects analysis of variance was run with block, prime type, and word type as within-participants factors. There was a significant main effect for block, $\lambda = .66$, $F(3, 29) = 3.90$, $\eta_p^2 = .34$, $p = .022$. Block 1 ($M = 579.13$) was slower than Block 2 ($M = 543.16$), Block 3 ($M = 519.06$), and Block 4 ($M = 505.59$). There was a significant main effect of prime,

$\lambda = .04$, $F(1, 31) = 642.57$, $\eta p2 = .96$, $p < .001$. RTs in related conditions ($M = 507.46$) were faster than those in the unrelated conditions ($M = 566.01$).

**Block 1:** There was a significant main effect for prime, $\lambda = .17$, $F(1, 31) = 138.93$, $\eta p2 = .83$, $p < .001$. Related RTs were faster than unrelated primes. Interactions between prime and word type were observed, $\lambda = .73$, $F(2, 30) = 5.07$, $\eta p2 = .27$, $p = .013$. Post hoc comparisons showed that related primes significantly facilitated the processing of HPS cognates, $\lambda = .56$, $F(1, 31) = 22.41$, $p < .001$; LPS cognates, $\lambda = .39$, $F(1,31) = 44.79$, $p < .001$; and noncognates, $\lambda = .19$, $F(1,31) = 127.01$, $p < .001$.

**Block 2:** Block 3, Block 4: There was a significant main effect for prime; related RTs were faster than unrelated primes in these blocks sequentially, $\lambda = .19$, $F(1, 31) = 123.54$, $\eta p2 = .82$, $p < .001$; $\lambda = .08$, $F(1, 31) = 310.41$, $\eta p2 = .92$, $p < .001$; and $\lambda = .15$, $F(1, 31) = 158.66$, $\eta p2 = .86$, $p < .001$.

**3.4.3.2. *Accuracy analysis.***

**All blocks:** Analysis of error rates failed to show a significant main effect for block; however, there was a significant main effect for prime, $\lambda = .87$, $F(1, 31) = 4.63$, $\eta p2 = .13$, $p = .039$. Related primes ($M = .95$) led to more accurate responses than unrelated primes ($M = .94$). Also, the main effect of word type reached significance, $\lambda = .65$, $F(2, 30) = 8.13$, $\eta p2 = .35$, $p = .002$. Post hoc comparisons showed that LPS cognates ($M = .93$) were selected less accurately than HPS cognates ($M = .95$, $p = .001$) and noncognates ($M = .95$, $p = .007$).

**Block 1:** Error rates did not show any significant effects in Block 1.

**Block 2:** A significant main effect of word type was observed for error rates, $\lambda = .71$, $F(2, 30) = 5.96$, $\eta p2 = .28$, $p = .007$. LPS cognates were selected less accurately than HPS cognates ($p = .04$) and noncognates ($p = .005$).

**Block 3:** No significant effects were observed in this block.

**Block 4:** Error rates showed a significant main effect for prime, λ = .87, $F(1, 31) = 4.83$, ηp2 = .13, $p = .035$. Related primes resulted in more accurate responses than unrelated primes. Furthermore, the main effect of word type reached significance, λ = .76, $F(2, 30) = 4.66$, ηp2 = .24, $p = .017$. Post hoc comparisons showed that LPS cognates were selected less accurately than HPS cognates ($p = .04$) and noncognates ($p = .02$). Figure 3.3 illustrates difference scores (priming effects) for the RT (related prime values subtracted from the unrelated prime values) and accuracy (unrelated prime values subtracted from the related prime values across cognates and noncognates.

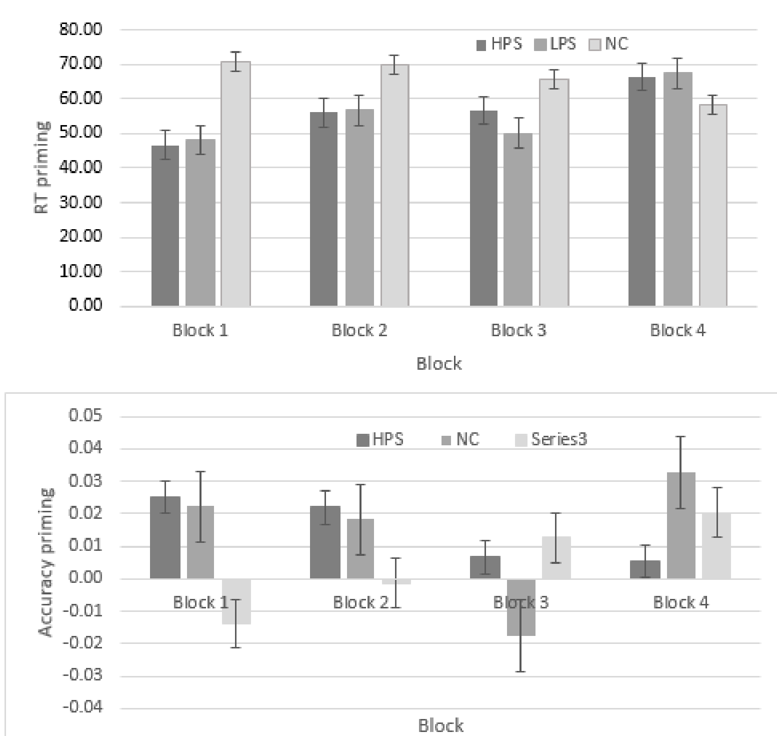



*Figure 3.3.* Priming effects for RTs and accuracy across HPS cognates, LPS cognates and noncognates in monolinguals

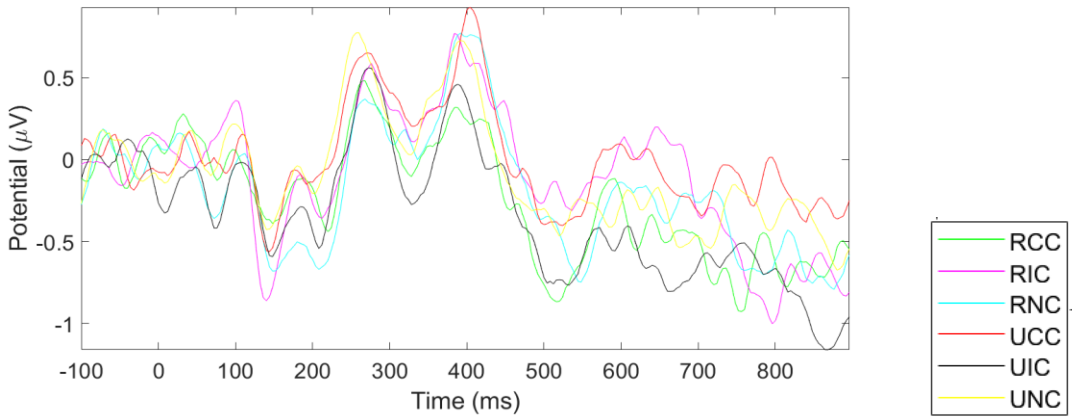
To summarize the findings for monolinguals, Block 1 was significantly faster than Block

3: Related primes were significantly faster than unrelated primes for HPS cognates, LPS cognates, and noncognates in all blocks (main effect of prime). However, word type did not show significant main effects. Error analysis of data did not show significant effects of block or significant interactions between prime type and word type for all target words. However, related primes were significantly more accurate than unrelated primes in Block 1 and Block 4.

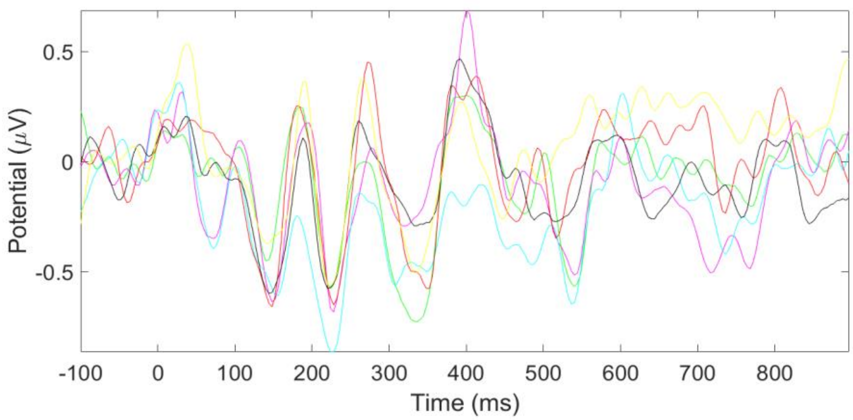
**3.4.4. ERP results.**

As described in 3.3.2., data were filtered, re-referenced to the average voltage across all sites, resampled, cleaned for muscle movements and eye artifacts, and epoched time-locked to the presentation of prime. The number of events (prime-target) remained for the analysis was 1018 (83.72%), 1030 (84.70%), 1020 (83.88%), 1018 (83.72%),1044 (85.85%), and 1034 (85.03%) in related HPS cognates, related LPS cognates, related noncognates, unrelated HPS cognates, unrelated LPS cognates, and unrelated noncognates, respectively, for the bilingual group. The data used for the analysis ranged from 70.83% to 100% for each participant. The number of events (prime-target) remained for the analysis was 954 (93.16%), 920 (89.84%), 928(90.63%), 938 (91.60%), 938 (91.60%), and 918 (89.65%) in related HPS cognates, related LPS cognates, related noncognates, unrelated HPS cognates, unrelated LPS cognates, and unrelated noncognates, respectively, for the monolingual group. The data used for the analysis ranged from 71.88% to 100% for each participant. Mean amplitudes were then measured and averaged across electrodes to create five clusters (LA, RA, LP, RP, VM). As the behavioral analysis showed that participants performed differently on the lexical decision task in each block, and as the first block is more reliable in eliciting automatic responses to the stimuli, only the EEG data in Block 1 were processed and analyzed.

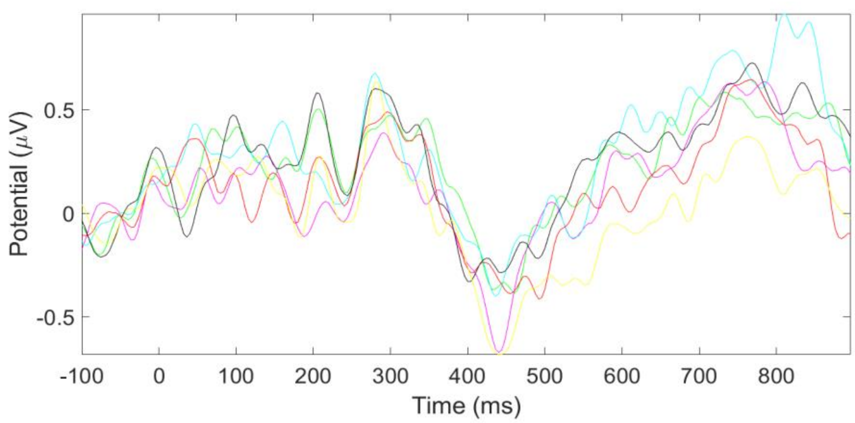
When designing the experiment, we wanted to maximize the number of trials we had for the ERP analysis, because with too few trials, we would likely not have an appropriate signal-to-noise ratio. However, when we did our behavioral analysis, we used block as a factor and we found that performance slightly changed across the block presentation. This suggests that exposure to the stimuli changed the way that participants later responded to these stimuli, which is not abnormal to expect in a priming study. For this reason, we ultimately decided to focus exclusively on the first block in the ERP analysis, as it was the only block that did not involve repeated exposure to the same stimuli. We decided to report the results, but interpret the block 1 of the behavioral and ERP analysis in the discussion sections of this dissertation. The mean amplitudes of the ERP waveforms for each condition per subject were extracted and entered into an analysis of variance. In the analyses, cluster (LA, RA, LP, RP, VM), prime type (related, unrelated) and word type (HPS cognates, LPS cognates, noncognates) were treated as independent variables. Figure 3.4 shows the mean amplitudes of the waveforms for the LA, LP, RA, RP, and VM clusters in the bilingual group.


Potential ($\mu$V)
0.5
0
-0.5
-1
-100
0
100
200
300
400
500
600
700
800
Time (ms)
RCC
RIC
RNC
UCC
UIC
UNC

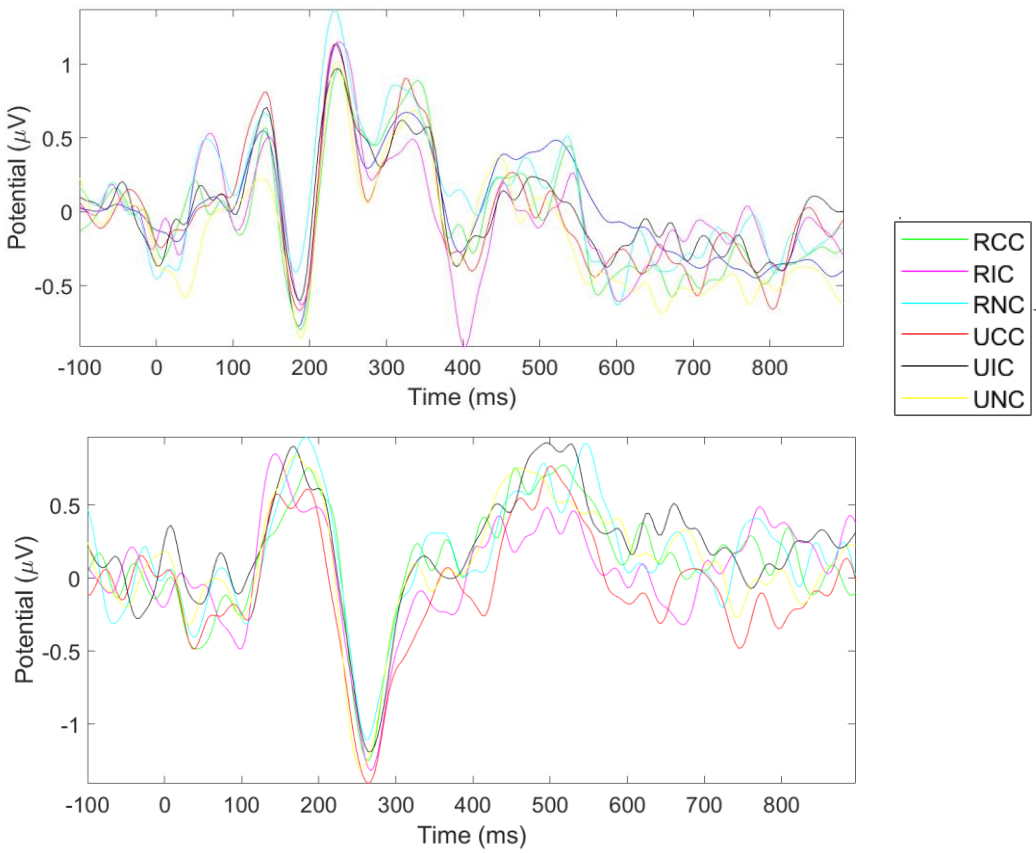
**LA**


Potential ($\mu$V)
0.5
0
-0.5
-100
0
100
200
300
400
500
600
700
800
Time (ms)

**RA**


Potential ($\mu$V)
0.5
0
-0.5
-100
0
100
200
300
400
500
600
700
800
Time (ms)

**VM**

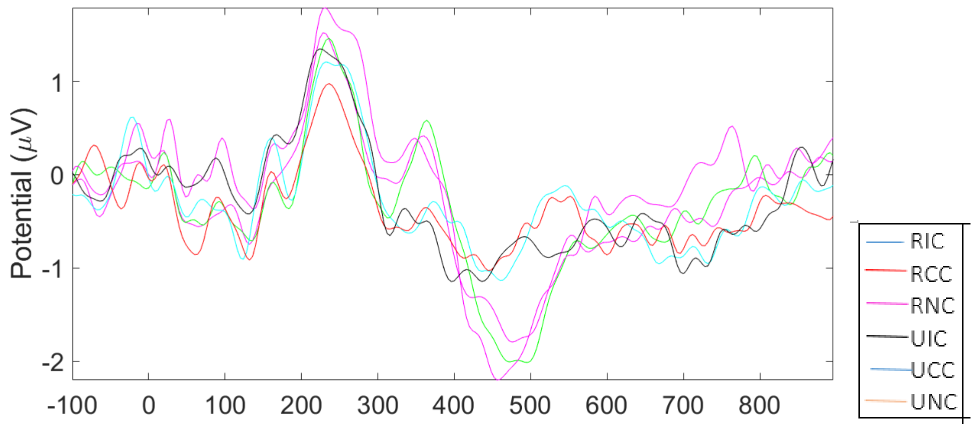



**LP**

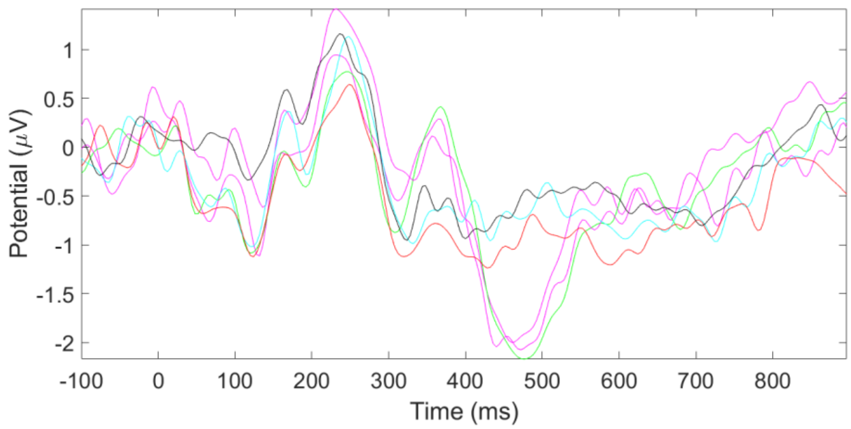
**RP**

*Figure 3.4.* The LA, RA, VM, LP, and RP clusters in bilinguals. The vertical axis shows the event-related potential in μV and the horizontal axis shows time in ms. Zero is the presentation of the prime.

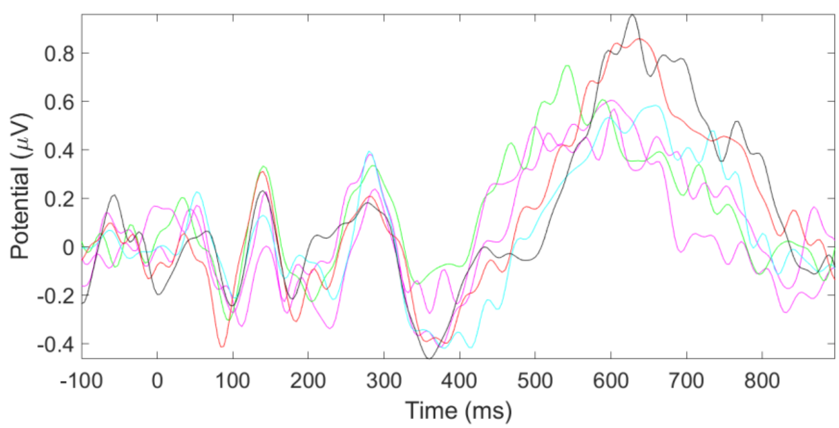
Figure 3.5 shows the mean amplitudes of the waveforms for the LA, LP, RA, RP, and VM clusters in the monolingual group. The results for both groups are reported in each time window below. The vertical axis shows potential (μV) and the horizontal axis shows time (ms).


Potential (μV)
1
0
-1
-2
-100
0
100
200
300
400
500
600
700
800
RIC
RCC
RNC
UIC
UCC
UNC

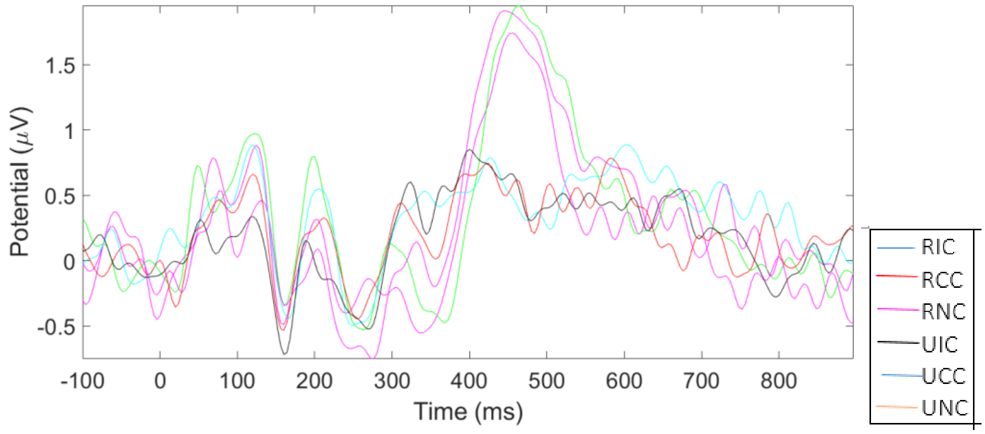
LA


Potential (μV)
1
0.5
0
-0.5
-1
-1.5
-2
-100
0
100
200
300
400
500
600
700
800
Time (ms)

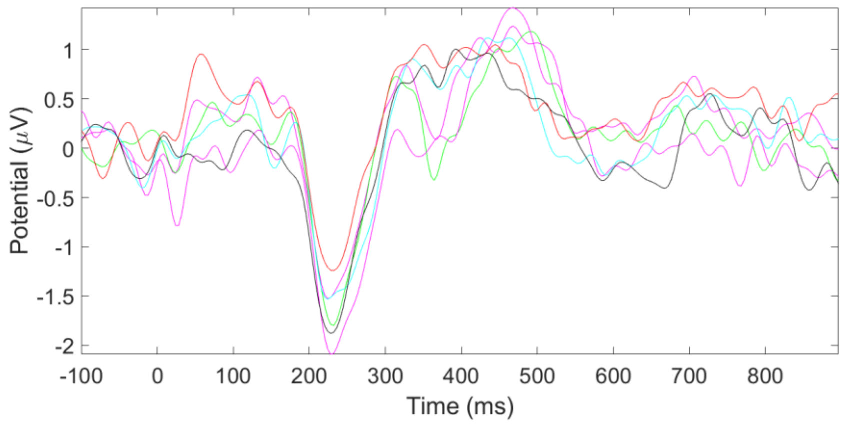
RA


Potential (μV)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-100
0
100
200
300
400
500
600
700
800
Time (ms)

VM




LP




RP

*Figure 3.5.* The LA, RA, VM, LP, and RP clusters in monolinguals. The vertical axis shows the event-related potential in μV and the horizontal axis shows time in ms. Zero is the presentation of the prime.

### 3.4.5. ERP results divided into time windows for bilinguals and monolinguals.

**The 0-100 ms post-prime onset**

**Bilingual group.** A significant main effect of prime type was found in the RA cluster with related primes producing more positive-going amplitudes than unrelated primes, $\lambda = .87$, $F(1, 37) = 5.69$, $\eta p2 = .13$, $p = .022$. A significant main effect of word type was observed in the LP with LPS cognates producing more positive amplitudes than noncognates, $\lambda = .80$, $F(2, 36) = 4.42$, $\eta p2 = .20$, $p = .019$. A significant interaction was observed between prime type and word type in the LA cluster, $\lambda = .87$, $F(2, 36) = 5.60$, $\eta p2 = .13$, $p = .023$. Related primes produced more positive-going amplitudes than unrelated primes for HPS cognates.

**Monolingual group.** A significant main effect of word type was observed in the LA cluster, λ = .78, *F*(2, 30) = 4.34, ηp2 = .22, *p* = .022; in the VM cluster, λ = .80, *F*(2, 30) = 3.55, ηp2 = .19, *p* = .041, with noncognates (*M*= .02, *SEM*= .14 in the LA cluster, and *M*= .08, *SEM*= .06 in the VM cluster) producing more positive amplitudes than LPS cognates (*M*= -.27, *SEM*= .12 in the LA cluster, and *M*= -.07, *SEM*= .07 in the VM cluster); and in the RA cluster, λ = .66, *F*(2, 30) = 7.84, ηp2 = .34, *p* = .002 , with noncognates (*M*=.02, *SEM*= .14 in the LA cluster, and *M*= .08, *SEM*= .06 in the VM cluster) producing more positive amplitudes than LPS cognates (*M*= -.27, *SEM*= .12 in the LA cluster, and *M*= -.07, *SEM*= .07 in the VM cluster) and HPS cognates (M= -.30, SEM= .12 in the LA cluster, and M= .01, SEM= .07 in the VM cluster).

**The 100-150 ms post-prime onset**

**Bilingual group**. A significant main effect of word type was observed in the VM cluster, *λ* = .83, *F*(2, 36) = 3.67, *ηp2* = .17, *p* = .036. Noncognates (*M*= .32, *SEM*= .17) produced more positive-going amplitudes than LPS cognates, (*M*= .01, *SEM*= .13). A significant interaction was observed between prime type and word type in the LA cluster, λ = .87, *F*(2, 36) = 5.60, ηp2 = .13, *p* = .023. Related primes showed more positive-going amplitudes than unrelated primes for HPS cognates.

**Monolingual group**. Significant main effects of word type were observed. Noncognates produced more positive amplitudes than HPS cognates in the LA cluster, λ = .82, *F*(2, 30) = 3.24, ηp2 = .18, *p* =.053, and HPS cognates and LPS cognates in the RA cluster, λ = .59, *F*(2, 30) = 10.30, ηp2 = .40, *p* < .001.

**The 100-200 ms post-target onset**

**Bilingual group.** Significant interactions were observed for HPS cognates in the RA cluster, λ = .83, *F*(2, 36) = 7.87, ηp2 = .17, *p* = .008. Related HPS cognates were more positive going than unrelated HPS cognates. Conversely, unrelated HPS cognates were more positive than related HPS cognates in the LA cluster, λ = .78, $F(2, 36) = 5.04$, ηp2 = .22, $p = .012$. Unrelated noncognates produced more-positive going amplitudes than related HPS cognates in the RP cluster, λ = .76, $F(2, 36) = 5.64$, ηp2 = .24, $p = .007$.

**Monolingual group.** A significant main effect of prime type was found, λ = .88, $F(1, 31) = 4.42$, ηp2 = .125, $p = .044$, with related primes producing more positive amplitudes than unrelated primes. A significant main effect of word type was found in the LA cluster, λ = .82, $F(2, 30) = 3.24$, ηp2 = .18, $p = .053$, and in the RA cluster, λ = .60, $F(2, 30) = 10.30$, ηp2 = .40, $p < .001$. Noncognates were more positive-going than HPS cognates in the LA cluster and more positive-going than HPS cognates and LPS cognates in the RA cluster.

**The 200-300 ms post-target onset**

**Bilingual group.** Significant interactions were observed in the VM cluster, λ = .72, $F(2, 36) = 7.17$, ηp2 = .29, $p = .002$. Related LPS cognates were more positive-going than unrelated LPS cognates, whereas unrelated noncognates were more positive-going than related noncognates.

**Monolingual group.** A significant main effect of prime type was observed, λ = .86, $F(1, 31) = 5.25$, ηp2 = .15, $p = .029$, with related primes producing more positive amplitudes than unrelated primes. A main effect of word type was found in the RA cluster, λ = .81, $F(2, 30) = 3.42$, ηp2 = .19, $p = .046$. Noncognates were more positive-going than HPS cognates in the RA cluster. Significant interactions were observed, λ = .78, $F(2, 30) = 8.55$, ηp2 = .22, p .006. Related noncognates produced more positive-going amplitudes than unrelated noncognates in the LA cluster. Unrelated noncognates and unrelated LPS cognates produced more positive-going amplitudes than related noncognates and related LPS cognates in the RP and LP clusters, respectively.

**The 300-500 ms post-target onset**

**Bilingual group.** Significant interactions were observed for HPS cognates in the RP cluster, λ = .83, *F*(2, 36) = 3.70, ηp2 = .17, *p* = .034. Unrelated HPS cognates produced more positive-going amplitudes than related HPS cognates, but unrelated HPS cognates produced more negative-going amplitudes than related HPS cognates in the LP cluster, λ = .89, *F*(2, 36) = 4.80, ηp2 = .12, *p* = .035.

**Monolingual group**. Significant main effects of prime type were found in the LP cluster, λ = .64, *F*(1, 31) = 17.80, ηp2 = .37, *p* < .001, and LA cluster, λ = .77, *F*(1, 31) = 9.35, ηp2 = .23, *p* = .005, with related primes producing more positive amplitudes than unrelated primes in the LP cluster, and unrelated primes producing more positive-going amplitudes in the LA cluster. Monolinguals showed significant interaction effects. Related primes produced more positive-going amplitudes for HPS cognates, λ = .86, *F*(2, 30) =5.01, ηp2 = .14, *p* = .033, LPS cognates, λ = .86, *F*(2, 30) = 5.04, ηp2 = .14, *p* =.032, and noncognates, λ = .73, *F*(2, 30) = 11.30, ηp2 = .27, *p* = .002 than unrelated primes in the LP cluster. Conversely, unrelated primes produced more positive-going amplitudes than related primes for HPS cognates, λ = .87, *F*(2, 30) = 4.52 ηp2 = .13, *p* =.042, and LPS cognates in the LA cluster, λ = .87, *F*(2, 30) = 4.51, ηp2 = .13, *p* =.042.

**The 500-850 ms post-target onset**

**Bilingual group.** A significant main effect of prime type was observed, λ = .66, *F*(2, 36) = 8.09, ηp2 = .18, *p* = .007, with related primes producing more positive amplitudes than unrelated primes in the LP cluster. A significant main effect of word type, λ = .84, *F*(2, 36) = 3.42, ηp2 = .16, *p* = .04, revealed that noncognates produced more positive-going amplitudes than LPS cognates. Significant interactions were observed in the LP cluster, λ = .66, *F*(2, 36) = 19.50, ηp2 = .35, *p* < .001; in the RP cluster, λ = .88, *F*(2, 36) = 4.98, ηp2 = .12, *p* = .032; and in the LA cluster, λ = .79, *F*(2, 36) = 4.94, ηp2 = .22, *p* = .013. Unrelated HPS cognates were more positive-going than related HPS cognates in the LP cluster. Related HPS cognates were more positive-going than unrelated HPS cognates. Unrelated HPS cognates were more positive-going than related HPS cognates in the RP cluster. Unrelated LPS cognates were more positive-going than related LPS cognates in the LA cluster.

**Monolingual group**. Related primes produced more negative-going amplitudes than unrelated primes in the LA cluster, λ = .86, *F*(1, 31) = 5.23, ηp2 = .14, *p* = .029, and in the RA cluster, λ = .85, *F*(1, 31) = 5.55, ηp2 = .15, *p* = .025. A significant interaction was observed in the LA cluster, λ = .84, *F*(2, 30) = 5.88, ηp2 = .16, *p* = .021. Related noncognates produced more positive-going amplitudes than unrelated noncognates.

To summarize the bilingual ERP findings, the electrophysiological data showed an early interaction between prime and word types in the 0-100 ms post-prime onset for HPS cognates, such that related HPS cognates showed larger positive amplitudes than unrelated primes in the LA cluster. Related primes produced more positive amplitudes than unrelated primes for HPS cognates at 100-200 ms post-target in the RP cluster, and 500-850 ms post-target in the LP cluster. Related primes showed more positivity at 300-500 ms post-target in the LP cluster. For LPS cognates, related primes produced at 200-300 ms post-target in the VM cluster and more negativity at 500-850 ms post-target in the RP cluster. For noncognates, unrelated primes produced more positivity in 200-300 ms post-target in the VM cluster. Main effects of prime type revealed that related primes were more positive than unrelated primes in 0-100 ms post-prime onset in the RA cluster and 500-850 ms post-target in the LP cluster. Main effects of word type were observed for LPS cognates at 0-100 ms post-prime onset in the LP cluster. Also, these effects were observed for noncognates at 100-150 ms post-prime onset in the VM cluster and

500-850 ms post-target in the VM cluster. LPS cognates produced more positive amplitudes than noncognates in the first time window. Conversely, noncognates were more positive than LPS cognates in the two other mentioned time windows.

To summarize the monolingual ERP findings, no interaction was observed between prime type and word type until 200-300 ms post-target for noncognates, and related primes yielded larger positive amplitudes in the LA cluster, but smaller, more negative amplitudes than unrelated primes in the RP cluster. Unrelated primes showed larger positive amplitudes than related primes for LPS cognates in the LP cluster. In 300-500 ms post-target onset, related primes showed larger positive amplitudes for all word types in the LP cluster. However, related primes showed smaller negative amplitudes for HPS and LPS cognates in the LA cluster. Related primes showed smaller negative amplitudes than unrelated primes for noncognates in the LA cluster. The main effects of word type started as early as 50 ms post-target onset for noncognates in centro-anterior regions and continued to the end of the 200-300 ms time window. Noncognates showed more positive amplitudes than one or both lists of cognates in each time window. The main effect of related prime type started at 100-200 ms post-target onset and continued to the last time window, while it showed interactions with cluster and word type from 200-300 ms post-target onset to 500-850 ms post-target onset.

## 3.5. Discussion

We aimed to investigate the integration of word features in the bilingual brain and examine the nonselectivity view in visual word processing in Persian-English bilinguals. In particular, we investigated the role of phonological similarity in visual word recognition by comparing the performance of Persian-English speakers on cognates with different degrees of phonological overlap (HPS and LPS cognates) and noncognates through collecting behavioral and ERP measures in a masked-priming lexical decision task. We intended to learn whether we could replicate the cognate effect previously reported in same- and different-script languages in Persian-English bilinguals. In addition, we aimed to understand whether the size of the cognate effect would correlate with the degree of phonological similarity of cognates in Persian and English and detect the earliest time window that the interaction between the prime and target would occur. The phonological account attributes the cognate effect to the addition of phonological similarity of cognates to their conceptual similarity and asserts that the size of the cognate effect correlates with the degree of phonological overlap between cognates across languages.

We recorded the RT, accuracy, and ERPs in four blocks. However, behavioral analyses showed that performances were different in each block. Thus, we limited the EEG analysis to the data from Block 1, as we considered Block 1 more reliable in eliciting spontaneous responses. The behavioral analysis of the data showed that, overall, related primes elicited faster responses than unrelated primes in the Persian-English and English monolingual control group. In addition to faster responses, related primes led to more correct decisions than unrelated primes in the bilingual group. No main effects of word type were observed on the speed of processing in both groups. However, related primes elicited more incorrect responses in LPS cognates than HPS cognates and noncognates in the bilingual group. Related primes decreased RTs in HPS cognates, LPS cognates, and noncognates in the monolingual group, while they reduced RTs in HPS and LPS cognates but not noncognates in the bilingual group.

In general, the ERP analyses showed significant interactions between prime type and word type, for cognates earlier and more often than noncognates, and more in the fronto-central clusters in the bilingual group. HPS cognates produced interactions between the prime type and word type in nearly all time windows, while LPS cognates did not. Significant main effects of word type were observed for LPS cognates and noncognates in the earliest time window; LPS cognates showed more positive amplitudes than noncognates. Noncognates, however, showed more positive amplitudes than LPS cognates at 100-150 ms prime-onset time and 500-850 ms post-target onset. The main effect of prime type appeared in the 0-100 ms and 500-850 ms time windows such that related primes were more positive-going than unrelated primes.

For monolinguals, no interactions between prime type and word type reached significance before 200-300 ms post-target onset. However, significant interactions were observed for all stimuli in the N400 time window. In addition, a late effect (500-850 ms time window) was observed for noncognates; a significant main effect of word type was observed at 100-150 ms post-prime onset in the centro-anterior clusters. Noncognates showed larger positive amplitudes than cognates. The main positive effect of related primes started at 100-200 ms post-target onset and showed interactions with cluster and word type into the 500-850 ms time window. To recap, cognates did not show any advantages over noncognates across all analyses, and significant interaction effects were found for cognates and noncognates in the N400 time window. In other words, monolinguals did not differentiate between cognates and noncognates, and they responded to all words similarly.

#### 3.5.1. The nonselectivity view.

Expecting to replicate the nonselectivity view observed in previous studies in different-script languages, we investigated the extent that the bilingual lexicon was integrated in Persian-English bilinguals. Together, the neural and behavioral data support the nonselective access to the bilingual word lexicon, as we observed significant main effects of prime type and interactions between the Persian prime and English target in RTs and ERP analyses. Related Persian primes accelerated the decision-making of English words more than unrelated primes (priming = 23.73 ms). Similarly, in the ERP analyses, interactions between prime type and word type were observed in most time windows as early as 0-100 ms post-prime onset and as late as 500-850 ms post-target onset for HPS cognates. These results support the connectivity of Persian and English languages in a bilingual brain, while emphasizing the role of phonological similarity in cross-language word recognition in English.

**3.5.2. The cognate effect.**

We compared cognates with noncognates to replicate the facilitative effect of cognates over noncognates and examined the effect of shared phonology in the absence of the orthographic similarity in Persian and English. Persian and English use Arabic and Roman scripts respectively. Thus, processing differences between cognates and noncognates should be attributed to the shared phonology in these two languages and not their similarity in script. As predicted, only HPS and LPS cognates showed the facilitative effect of related primes. In fact, shared phonology between the prime and target decreased RTs and led to significant interactions between prime type and word type in HPS and LPS cognates. Also, it led to more positive amplitudes for HPS and LPS cognates than noncognates in most time windows. Cognates shared phonological and semantic features in Persian and English, whereas noncognates shared only semantic features. Consequently, the facilitative effects of HPS cognates, as compared with noncognates, reflected the additive effects of phonological to semantic features. Phonological features seem to be essential in accessing words in the Persian-English lexicon. Failing to find widespread effects for noncognates could possibly result from the change of the script between Persian and English and the absence of phonological overlap in noncognates (Gollan et al., 1997).

The null effect of related primes on noncognates versus the facilitative effect of related primes on cognates was also observed in a study of Persian-English speakers in an L1-L2 masked priming lexical decision task (Fotovatnia & Taleb, 2012). Fotovatnia and Taleb (2012) compared cognates with noncognates in a group of undergraduate students of TEFL (teaching English as a foreign language), who learned English formally in an academic setting and were identified as low-intermediate learners based on their performance on a proficiency test (Allan, 2004). Conversely, the participants in the current study were more proficient English speakers who used English in their day-to-day life. Interestingly, neither proficiency nor the daily use of English in an English-speaking country gave an advantage to processing noncognates. Thus, phonological similarity seems to be what connected the two language systems in the absence of the orthographic similarity in Persian-English speakers. Previous studies reported the cognate effect for different-script languages, such as Hebrew and English (53 ms, Gollan et al., 1997), Korean and English (34 ms, Kim & Davis, 2003), and Greek and French (48 ms, Voga & Grainger, 2007). Similar to these studies, our findings support the critical role of shared phonology of cognates in word recognition and access to the bilingual lexicon. This effect might appear at sublexical levels, as Hebrew, English, Korean, and Persian are alphabetic languages that share phonemes. As stated, noncognates did not show any priming effects in our study, providing even stronger evidence in support of the critical role of shared phonology in bilingual word recognition. This facilitation effect confirms the phonological account of the cognate effect.

#### 3.5.3. Testing the phonological account.

We predicted that cognates would show different degrees of priming effects if phonological information modulated cross-language visual word recognition in line with the phonological account; LPS cognates would show less priming effect than HPS cognates but more effect than noncognates (the second prediction of this study). Behavioral analyses failed to show consistent priming effects that match the degree of phonological overlap between Persian and English across HPS cognates, LPS cognates, and noncognates. In fact, we found 21.15 ms priming effects for HPS cognates versus 40.55 ms priming effects for LPS cognates in the RT analysis, confirming that LPS cognates used related primes more effectively than HPS cognates. Also, LPS cognates did not significantly show more priming effects when they were compared with noncognates.

ERP findings were also consistent with the behavioral results. We found interactions between prime type and word type for both cognate types but more for HPS than LPS cognates. These interactions appeared in time windows earlier than 300 ms post-target onset. However, the early interaction effect between prime type and word type occurred only for HPS cognates. Such effects were observed in time windows earlier than the time window associated with meaning (e.g., the N400 time window), which presumably reflected sublexical processing of words (Grainger & Holcomb, 2009). This interaction effect has also been observed in languages written with logographic characters 250 ms after the target onset (Xiong et al., 2020); cognates produced reduced FN250 as compared to control words in Chinese-Japanese bilinguals. Earlier than 300 ms interactions for cognates in different-script languages support the essential role of high-phonological overlap that facilitated the processing of HPS cognates more than LPS cognates and noncognates. Also, the observed facilitation at 300-500 ms target onset shows the ease of mapping form to meaning for HPS cognates. This observation confirms the importance of high phonological overlap in processing HPS cognates and accessing their meaning. We expected the same facilitation effect for LPS cognates in this time window, which is in line with the strong claim of the phonological account. No such effect was observed for LPS cognates and noncognates in these time windows. We did not observe larger positive amplitudes for HPS cognates than LPS cognates and accordingly larger positive amplitudes for LPS cognates than noncognates in time windows before 300 ms. Also, we did not observe smaller negative amplitudes for HPS cognates than LPS cognates and accordingly smaller negative amplitudes for LPS cognates than noncognates in 300-550 ms time window.

Comparing LPS cognates with noncognates showed that LPS cognates yielded more positive amplitudes than noncognates in the 0-100 ms post-prime time window (a significant main effect of word type). This time window reflects the sublexical processing for words (Grainger & Holcomb, 2009) such as mapping of orthographic information onto the phonological information and was easier and occurred earlier for LPS cognates than noncognates. This finding supports the strong claim of the phonological account, attributing the effect to the phonological similarity of LPS cognates in Persian and English and an absence of the effect to a lack of formal similarity between noncognates in both languages. However, LPS cognates showed less positive amplitudes than noncognates at 100 -150 and 500-850 ms post prime onset in the VM cluster. This observation does not support the strong claim of the phonological account and reflects an inhibitory effect that LPS cognates showed rather than an advantage for noncognates. The reason is that noncognates do not have orthographic and phonological similarity in Persian and English, and they failed to show any significant modulations of the N400 component in our study. Thus, any information altering the pattern of results in the 200-300 ms time window is most likely conceptual in nature. Hoshino et al., (2010) observed that the N250 component was modulated in noncognates due to conceptual processing in Japanese-English bilinguals.

Contrary to their faster processing, LPS cognates produced more incorrect decisions than HPS cognates and noncognates; participants made more errors when deciding whether LPS cognates were English words than HPS cognates and noncognates. HPS cognates and noncognates did not produce a significant number of errors, as the former were similar in pronunciation, while the latter were entirely different in spoken and written forms in Persian and English. In fact, LPS cognates can be placed on a continuum between HPS cognates and noncognates based on their phonological similarity. Thus, we can conclude that LPS cognates failed to show an advantage over HPS cognates, as they did not have sufficient degrees of phonological similarity across both languages. Accordingly, they provided more challenges for the bilingual group to decide whether they were English words. This issue explains why related LPS cognates were processed faster, but less accurately, than unrelated LPS cognates. Comparing the priming effect for HPS cognates (21.15 ms) to the priming effect for LPS cognates (40.55 ms), we conclude that LPS cognates benefited more from the related primes than HPS cognates in the RT analysis that captured more automatic responses than accuracy, which reflected the deliberate process of decision making. Analogous results were reported in a study where low-frequency cognates and less proficient participants benefited more from related primes than high-frequency cognates and more proficient participants (Nakayama et al., 2013).

Overall, the phonological overlap between the prime and target showed an advantage in word recognition in Persian-English speakers. Nevertheless, the effect size did not show a consistent relationship with the phonological similarity of cognates. Accordingly, our results support the claim of the phonological account (Voga & Grainger, 2007), and we attribute the cognate effect to the addition of the phonological to the semantic features of cognates. However, our results do not support the claim that the magnitude of phonological similarity correlates with the size of the cognate effect. We did not observe that LPS cognates produced fewer effects than HPS cognates, and more effects than noncognates, at least in Persian and English.

We observed that high phonological similarity modulated the amplitude of the P100 in the bilingual group, supporting the issue that phonological priming is more readily observable when the languages involved have different scripts (prediction three). Similar to our results, primes were processed 100 ms earlier (i.e., in the 100–200 ms time window) in Japanese-English bilinguals (Hoshino et al., 2010) than French-English bilinguals (Midgley et al., 2009). This finding supports what Gollan et al. (1997) state regarding the advantage that different-script languages show in processing the prime. According to Gollan et al., script differences between the prime and target cue the language processer to look for the prime in an appropriate lexicon upon presentation. After the prime is accessed, the prime activates the relevant features of the target word. On the other hand, when the prime and target share the script and the prime is masked, the processor searches the lexicon of the target word to find the prime and after failing to do so, it looks for the prime in the correct lexicon. This event produces a delay in the same-script condition. Hoshino et al. (2010) have provided another explanation. In masked priming studies, the presentation of the prime activates relevant orthographic representations, and in turn, these representations activate the relevant features of the target. After the target is recognized, it sends inhibitory effects to the words, with which it shares orthographic features, including the prime. This process occurs only if the prime and target share scripts. When the prime and target do not share scripts, the prime does not receive any inhibitory effects, and so the effect appears earlier.

The interaction between the prime and word types occurred at 200-300 ms post-target onset for monolinguals and 0-100 ms post-prime onset for bilinguals. However, monolinguals showed a larger priming effect on the RT for HPS cognates, LPS cognates, and noncognates (46.70 ms, 48.09 ms, 70.89 ms, respectively) than bilinguals (21.15 ms, 40.55 ms, 16.62 ms, respectively). The higher priming effect in monolinguals likely occurred because they were native speakers of English. Thus, they processed the words more efficiently. However, monolinguals failed to show the earlier priming effects for related primes, which was observed in bilinguals. This finding is unexpected because monolinguals made a lexical decision on the same prime and target words in the related condition (i.e., repetition priming). To illustrate, the target word *ambulance* was preceded by the word *ambulance* in the related but *newspaper* in the unrelated conditions. Indeed, we expected the priming effect to appear earlier in the monolingual group for two reasons: (a) related primes benefited from the similarity of both form and meaning, and (b) the prime did not receive any inhibitory effects from the target because the prime and target were the same word in the related condition. One possible reason for the lack of priming effect could be the lower frequency of reading and writing in English reported by these monolinguals. The bilingual group reported significantly higher reading and writing frequency rates (6.14, SD=1.4; 5.17, SD= 1.61) than the monolingual group (4.18, SD=.99; 4.57, SD=.50).

Our study found inconsistencies between RTs, accuracy, and ERP measures. For one, related primes facilitated the speed of decision-making in HPS and LPS cognates, but they did not affect accuracy in bilinguals. However, LPS cognates led to more incorrect decisions than HPS cognates and noncognates. To explain the findings, we attribute the RT to the automatic processes that contribute to word recognition and attribute accuracy to the processes that result in lexical decision. Also, we observed the main effect of word type in the form of positive amplitudes for noncognates in different time windows without observing any advantages in the RT and accuracy in monolinguals. Similar inconsistencies were observed by Kounios and

Holcomb (1992), who found no correlation between RTs and ERPs in a sentence verification task. These researchers concluded that RTs and ERPs involve different underlying cognitive operations. They attributed RTs to lexical decision-making, which is based on a task-dependent strategy, but the N400 to a separate semantic integration process.

The findings of our study support the main principles of the BIA+ model (Dijkstra & Van Heuven, 1998) while challenging a few claims. We observed that the lexical decision was influenced by factors that are attributable to the components of the model. Differences in the RT between cognates and noncognates likely reflect the output of the word identification system, as these differences result from the processes that are automatic and occur in real time. Accuracy reflects the output of the task schema and results from the processes that support decision-making. In line with the model, we expected that cognates and noncognates would show the grading effects of the phonological similarity on the RT; related primes should have made the task faster for HPS cognates than LPS cognates. Also, related primes should have made the processing of LPS cognates faster than noncognates. We expected a similar pattern for the accuracy of lexical decisions. These expectations are based on our assumption that cognates and noncognates differed from each other only in the degree of phonological similarity because their other lexico-semantic features such as frequency, abstractness, length, familiarity, and concreteness were controlled across the experimental conditions before data collection. Our findings confirm that the phonological similarity of cognates influenced the RT and accuracy of responses, but not as the model predicts. Different from the assertions made by the BIA+ model, the task language appears to bias word processing and accordingly influences task performance. Indeed, an interaction was observed between the phonological similarity of cognates and language information, supporting the conclusion that the speed of the processing of HPS cognates is not influenced by the related primes as much as that of the LPS cognates. Processing of the LPS cognates, on the other hand, is facilitated by the presentation of the related primes more than HPS cognates. LPS cognates, nonetheless, elicited more incorrect responses challenging the idea that LPS cognates were processed as English words. Instead, our findings suggest that when there is lower phonological similarity of cognates, participants attend to the target language and make a language decision as well as a lexical decision. However, in the BIA+ model, language membership information has no role in word identification, as this information becomes available too late to affect the word identification process. Our results do not support this claim of the model and suggest that language information does influence lexical decisions, at least more than the model postulates.

In addition to the issues discussed for cognates, related primes did not facilitate noncognate processing, although noncognates share meaning in Persian and English. The existence of cognates with varying degrees of phonological overlap likely created a specific composition list or "language context" (Comesana et al., 2014, p.3), which guided the participants to attend to the shared words in both languages and their phonological similarity. In other words, the existence of cognates with varying degrees of phonological similarity encouraged the participants to focus on cognates and the task language and accordingly overlook noncognates. These factors are attributable to the task schema, which may fail to affect the early processing of words being the presumed function of the word identification system in the BIA+ model. In other words, the effects of these factors must have been observed later in visual word recognition when the task schema took over. This effect is reflected in the accuracy of responses and not in the RT.

One way to address these questions is to compare the findings of the current study with those of similar studies that use the same task but with different requirements. In our study we asked participants to consider the speed and accuracy of their decisions when performing the task. What would have occurred if participants had been instructed to perform the task as quickly as they could? Alternatively, what would have occurred if participants had been asked to sacrifice speed in favor of accuracy? We suggest that the outcomes in each condition would be different. When the purpose is making the lexical decision faster, participants perform a simple lexical decision. Indeed, they simply decide if the item is a word in either language or a nonword, and they do not use language information as such. The cost in terms of accuracy would therefore be different for monolinguals and bilinguals assuming participants are asked to make lexical decisions regarding a particular language. On the other hand, when the task focus is accuracy, participants involve language information more than the other condition, and they make a language as well as a lexical decision. A comparison among our findings and the findings of proposed studies would clarify further these hypotheses.

Another approach to these raised issues is to compare the findings of the current study with those of similar studies that use different tasks. Those tasks should have different requirements and create different expectations for participants, thus providing grounds for observing how these factors interact with the task language. It would also be interesting to use false cognates with varying degrees of phonological similarity to understand how shared phonological and conceptual similarities interact with each other and with the task language when cognates have different meanings in both languages. Finding out the pattern of interaction that may be observed between the degree of shared phonology and meaning will help clarifying our findings. Also, removing noncognates from the list in studies with cognates and false cognates may clarify the effect of list composition or the language context in Persian-English bilinguals.

To conclude, orthographic similarity or dissimilarity plays a critical role in the architecture of the bilingual lexicon and how the mental lexicon accommodates words like cognates that have overlapping features in L1 and L2. Our findings, in part, support the phonological account of word processing that attributes the cognate effect to the shared phonological and semantic features of cognates in L1 and L2. However, our RT results do not support the hypothesis that the degree of phonological similarity generates the cognate effect in a continuous manner. We observed that HPS cognates showed advantages over LPS cognates and noncognates. This finding is consistent with the phonological account. However, we failed to observe that LPS cognates showed more priming effects than noncognates. In other words, cognate effects may not arise simply from the additive effects of phonological to semantic similarity.

Could it be that L2 proficiency modulates the effect of phonological similarity of cognates during lexical decision tasks in cross-language studies? Stated another way, do participants need to reach a certain level of L2 proficiency to benefit from cognates with lower phonological similarity in L2? Most participants in the current study were students or graduates of Canadian universities with at least 13 years of English studies in their home country, though their dominant language was Persian. Manipulating English proficiency might shed light on the complex interaction of the variables involved.

A final concern to address is that some researchers believe that lexical decision is not a word recognition task but really a word discrimination task where information such as familiarity allows the discrimination of words from nonwords (D. A. Balota & Chumbley, 1990; D. A. Balota et al., 2004). That is, these researchers believe that a yes/no task might not tap into the mental processes responsible for the semantic processing of words. We observed significant interactions between the prime and word type in the N400 time-window for cognates and noncognates. This observation suggests that these words were processed semantically by participants. However, similar future studies may use tasks such as semantic categorization that ensure deeper processing of meaning. Furthermore, picture and word naming tasks, which are more meaning- and form-oriented, respectively, can complement the findings of this study and test the phonological account in language production.

# Chapter 4. The Processing of Cognates and Noncognates in L1: An English-Persian Masked-Priming Paradigm

## Abstract

Event-related potentials (ERPs) and a masked-priming lexical decision task were used to investigate the interaction of phonological and conceptual features of words in visual word recognition in Persian-English bilinguals. Two lists of cognates (translation equivalents with form overlap) with varying degrees of phonological similarity and one group of noncognates (translation equivalents with no form overlap) were the stimuli in two experiments, in which the primes and targets were in English and Persian, respectively. In Experiment 1, we compared the standard prime duration of 50 ms with 70 ms to adjust the prime duration in the second experiment. In Experiment 2, we tested the phonological account which attributes the advantages that cognates have shown over noncognates in visual word processing studies to the phonological and conceptual overlaps in languages with different scripts. Related primes shown for 80 ms accelerated the processing of high phonological similarity (HPS) cognates more than other stimuli. However, HPS cognates produced more errors than low phonological similarity (LPS) cognates and noncognates. Related primes modulated the ERP amplitudes (N100) in HPS cognates earlier than LPS cognates and noncognates. The prime and word type interacted in LPS cognates from 100-200 to 500-850 ms post target onset, but not in noncognates.  Overall, the findings support the phonological account but did not demonstrate a relationship between the size of the cognate effect and the degree of phonological similarity of cognates in Persian-English bilinguals. Furthermore, related primes did not facilitate the processing of noncognates

even when increasing the prime duration from 50 ms to 80 ms in the English-Persian direction.

## 4.1. Introduction

Reading comprehension is a process in which orthographic forms are mapped onto meaning representations. This process is complex when bilingual readers read in one language because to read and comprehend the text efficiently, they may have to prevent interference from the nontarget language or keep its influence to a minimum (Droop & Verhoeven, 1998). To study how bilingual readers process written words, researchers have used cognates, which are the words that share form and meaning, and noncognates, which are the words that share meaning in the languages a bilingual knows in a masked translation-priming paradigm. In this paradigm, a word (called a prime) is presented rapidly before the target and is masked by a series of immediately preceding characters such as number signs (######). The rapid display of the prime followed by the presentation of the mask prevents the prime from being consciously processed. In cross-language studies, the prime and target are in different languages, and participants perform the task in the language of the target word. This paradigm can show the early influence of form and meaning for cognates and meaning for noncognates in visual word recognition in the language of the target. Cognates are specifically beneficial in these studies, as they show formal and lexical overlap across languages. Thus, they can indicate whether one language system influences the other language in a masked-priming paradigm when only words from one language are visually present. Overall, studies on cognates and noncognates provide insights into language processing and visual word recognition in a bilingual brain.

Masked-priming research on cognates and noncognates has supported access to the representations of a first language (L1) when reading in a second language (L2) in studies that have collected behavioral and neurological measures. Nevertheless, cognates and noncognates have shown different patterns. Masked primes in the dominant language facilitated the recognition of translation equivalents of cognates more than noncognates in L2 (de-Groot & Nas, 1991; Gollan et al., 1997; Kim & Davis, 2003; Voga & Grainger, 2007) and produced a smaller N400 component in cognates than noncognates (Midgley et al., 2011; Peeters et al., 2013).

The influence of L2 when reading in L1 has been inconsistent for cognates and noncognates. For example, the cognate effect was observed in de Groot and Nas (1991) but not in Gollan et al. (1997). Noncognates showed priming effects in some studies (Dunabeitia, Dimitropoulou, Uribe-Etxebarria, Laka, & Carreiras, 2010; Dunabeitia, Perea, & Carreiras, 2010; Duyck & Warlop, 2009) but not in others (Davis et al., 2010; Dimitropoulou, Duñabeitia, & Carreiras, 2011; Finkbeiner et al., 2004; Gollan et al., 1997; Hoshino et al., 2010; Jiang, 1999). These studies did not support the effect of masked primes in the nondominant language on noncognate translation equivalents in the dominant language. In one study, De Groot and Nas compared repetition and associative priming in Dutch-English compound bilinguals using a masked lexical decision task with the SOA of 60 ms (40 ms prime plus a 20 ms blank interval). Cognates showed repetition and associative priming effects while noncognates showed only repetition priming effects. Similarly, Gollan et al. studied bilinguals in Hebrew and English with the target words in the dominant language, once in English and another time in Hebrew. Neither cognates nor noncognates showed any priming effects in a masked priming lexical decision task. In another phase of data analysis, they selected 5% of participants with lower error rates and examined the priming effect in Hebrew-Hebrew and Hebrew-English conditions. Priming effects were only observed in the first condition.

#### 4.1.1. The phonological account of cognate priming effects.

Voga and Grainger (2007) used noncognates and cognates with varying degrees of phonological overlap in Greek-French bilinguals to explain the cognate effect in different-script languages. Cognates were primed by words that were once phonologically and conceptually unrelated and another time phonologically related but conceptually unrelated. The degree of phonological overlap affected cognate priming in the former condition, where the control words were phonologically and conceptually unrelated. Noncognates showed the priming effect when primes were conceptually related. The researchers concluded that cognates and noncognates have similar mental representations, but cognates have an additional phonological overlap in two languages, which provides cognates with advantages in bilingual visual processing.

According to the phonological account of the cognate effect (Voga & Grainger, 2007), cognates have phonological and conceptual overlap while noncognates have only conceptual overlap in two languages. This additional phonological overlap gives cognates an advantage in L1 and L2. The phonological account of the cognate effect was investigated in a series of masked-priming lexical decision experiments in Japanese-English bilinguals. These studies compared cognates, phonologically related words, and noncognates to study the nature of the phonological and conceptual overlap in these words. In one study, the cognate effect was compared with the phonological effect while proficiency and word frequency in the L2 were manipulated. Only cognates were found sensitive to proficiency and word frequency in the L2 (Nakayama et al., 2012). In another study, Nakayama et al. (2013) compared cognates with noncognates while manipulating the same variables. Cognates and noncognates were affected similarly by proficiency and word frequency in the L2 (Experiment 1). For cognates and noncognates, related primes facilitated the processing of low-proficient L2 bilinguals and low-frequent L2 words. Thus, conceptual overlap supports the processing of cognates and noncognates similarly. Overall, these experiments showed that processing cognates is similar to noncognates because they both have conceptual overlap across languages. However, cognates show an advantage over noncognates, as they have an additional phonological overlap in different-script languages. These findings therefore support the phonological account of the cognate advantage effect.

If the cognate advantage results from an additional phonological overlap in different-script languages, the effect size should correlate with the phonological similarity of cognates in the two languages. Testing this prediction, Nakayama et al. (2014) observed that high-phonological similarity (HPS) cognates showed more priming effects than low-phonological similarity (LPS) cognates in Japanese-English in the L1-L2 direction. However, the researchers could not compare LPS cognates with noncognates because cognates and noncognates are unavoidably written in different scripts in Japanese. To test if the size of the cognate effect was correlated with the phonological similarity of cognates in the L1-L2 direction, Fotovatnia and Jones (to be submitted for publication) compared HPS cognates, LPS cognates, and noncognates in a masked priming lexical decision task, combining behavioral with event-related potential (ERP) measures in Persian-English bilinguals. As predicted by the phonological account, related primes accelerated the processing of HPS cognates and LPS cognates more than unrelated primes, but no facilitation effects were observed for noncognates. Contrary to the phonological account, LPS cognates did not show an advantage over noncognates. In addition, LPS cognates elicited more incorrect decisions than HPS cognates and noncognates. ERP analysis showed interactions between prime and word types for HPS cognates from an early time window (0-100 ms post-prime onset). Undoubtedly, HPS cognates showed advantages due to their shared phonological and conceptual features, but Fotovatnia et al. did not observe any advantages for LPS cognates over noncognates in all analyses. These observations partially supported the phonological account of the cognate effect by relating the facilitative effect of high phonological similarity to faster processing of words in the L2.

Following this line of research, we aimed to investigate whether cognates and noncognates would show priming effects in the L2-L1 and whether the size of the phonological similarity of cognates would correlate with the cognate effect in the L2-L1 in a masked-priming paradigm using behavioral and ERP measures in a group of advanced Persian-English speakers.

#### 4.1.2. The discrepancy in priming effects.

As mentioned, the priming effect has been commonly observed in the L1-L2 direction but absent the L2-L1 direction. Three factors can explain why the L2 priming effect is absent in L1, which are L2 proficiency, the experimental task, and the prime duration. These factors may cause insufficient processing of the prime and prevent facilitative feedback from the higher level of conceptual processing to the prime's ongoing form-level processing (Hoshino et al., 2010). That is, when the prime is insufficiently processed, it cannot exert facilitative effects on the subsequent mapping of target form representations onto semantics during target processing.

Studies investigating the effects of L2 proficiency, task, and prime duration have brought mixed results. First, most masked-priming translation studies have shown the facilitative effect of L2 primes on L1 targets when the participants were native-like or highly proficient simultaneous bilinguals in L2 (Dunabeitia, Perea, et al., 2010). However, low-proficient L2 learners with a dominant L1 showed facilitative effects of L2 primes on L1 targets for noncognates (e.g., Duyck & Warlop, 2009). Moreover, L2 primes showed facilitative effects in repetition masked priming studies (Golan et al., 1997). Second, the experimental task may cause the priming effect to either appear or not appear. The findings, however, are not conclusive. For example, primes facilitated the processing of targets in a semantic categorization task, but not a masked priming lexical decision task (e.g., Finkbeiner et al., 2004; Grainger, 1998). However, advanced and low-proficient participants showed L2 priming effects in a masked priming lexical decision task in other studies (Dunabeitia, Dimitropoulou et al., 2010; Dunabeitia, Perea et al., 2010; Duyck & Warlop, 2009). Third, in priming studies, a prime is rapidly displayed to keep its processing under the level of consciousness. The prime, however, may be identified at the level of feature, letter, or whole word (Kouider & Dupoux, 2004), which will be the basis of its reconstruction. The standard prime duration in the L1 is 50 ms, which can create a partial awareness of the prime, and is sufficient to make a semantic interpretation in the L1 but not in the L2. Examining different prime durations to look for comparable prime durations in the L1 and L2, Wang and Forster (2014) showed that a 50 ms prime duration produced 78% correct responses in L1 Chinese but 55% correct responses in L2 English. The researchers found that prime durations of 70 ms, 80 ms, and 90 ms in English produced comparable error rates to the prime duration of 50 ms in Chinese. In Experiment 2, Wang and Forster displayed English primes for 80 ms to understand whether the prime would produce priming effects on Chinese targets in a lexical decision task, but they failed to observe any effects.

Aiming to explain the asymmetry in priming effects (i.e., priming in the L2 but its absence in L1), Midgley and colleagues (2009) examined masked repetition and translation priming in L1 and L2 in French-English bilinguals. Midgley et al. observed the effects of related primes on the N250 and N400 components in L1-L1, L2-L2, and L1-L2; related primes produced smaller negative amplitudes in both components. Conversely, related primes produced smaller negative amplitudes only in the N400 component in the L2-L1 direction. Midgley et al. attributed the lack of priming effects on the N250 to the slower processing of L2 than L1 primes, although they used the stimulus onset asynchrony (SOA) of 67 ms. Investigating the same topic, Hoshino et al. (2010) used a go/no go semantic categorization task with a prime duration of 50 ms in Japanese-English bilinguals. Related primes modulated the N150, the N250, and the N400 components in L1-L2 in slightly different patterns than Midgley et al.'s study. However, related primes did not modulate these components in L2-L1.

We designed this study to investigate the observed discrepancy in priming effects between L1 and L2 and to test the phonological account of the cognate effect in the L2-L1 in Persian-English bilinguals using a masked-priming lexical decision task. On the one hand, most cross-language studies have investigated the processing of cognates and noncognates in English, Chinese, and Japanese because these languages are orthographically different. English and Persian also have different scripts. However, these languages share phonemes, and they use phonological orthographic correspondences to convert written letters to phonemes. This similarity can influence the connection between the phonological systems of Persian and English and the effect that English may exert on visual word recognition in Persian. In addition, the specific features of English and Persian can affect the duration of English primes and require the prime to appear on the screen for a different duration than in previous studies. Overall, Persian and English provide a new language context to investigate the visual word processing. Thus, we first compared the prime duration of 50 ms in the L2-L1 and L2-L2 with that of 70 ms in the L2-L1 to find an effective prime duration to use in the subsequent study. No study has yet pursued these objectives in Persian-English bilinguals.

#### 4.1.3. Objectives and predictions.

The first experiment compared two prime durations in L2-L1, namely 50 ms and 70 ms, to find a suitable prime duration to use in Experiment 2. Wang and Forster (2014) found that a 50 ms prime duration in Chinese produced similar error rates as 70 ms, 80 ms, and 90 ms prime durations in English in Chinese-English bilinguals. We compared the prime duration of 50 ms and 70 ms in L2-L1 with 50 ms in L2-L2, using the same stimuli and task as in Experiment 2 in Persian-English bilinguals. In Experiment 2, we investigated the influence of L2 English primes on L1 Persian targets, collecting both behavioral and ERP measures. We expected to find a significant main effect of related primes as well as significant interactions between prime and word types in the behavioral and ERP analysis. We predicted that related primes would be faster than unrelated primes, and that they would modulate the N250 and N400 components due to the similarities of form and meaning in Persian and English. N400 is expected to be smaller over the central and parietal electrodes. We also predicted that related primes would modulate ERP components in an earlier time window than 300-500 ms for HPS cognates. These observations support the connection between the two language systems and the influence of the nondominant L2 on the dominant L1 in Persian-English bilinguals. The third objective of this study was to test the phonological account of the cognate effect by manipulating the phonological similarity of cognates in Persian and English, namely HPS and LPS cognates, and comparing them with noncognates. According to the phonological account of the cognate effect, phonological similarity affects the size of the cognate effect; the more phonological similarity between the prime and target, the greater the size of the cognate effect. Stated otherwise, if phonological similarity led to the cognate effect reported in previous studies and if this feature was additive, we expected that participants would perform better on HPS cognates than LPS cognates and noncognates. In turn, we expected that participants would perform better on LPS cognates than noncognates in the behavioral analysis. We also expected the lexical decision to be faster and more accurate for HPS than LPS cognates and noncognates, along with the earlier form-related effects of primes for HPS than LPS cognates and noncognates in the ERP measures. We also examined the processing of noncognates in the L2-L1 direction. Studies that compared cognates with noncognates have shown inconclusive results (Davis et al., 2010; Dimitropoulou, Dunabeitia, et al., 2011; Duyck & Warlop, 2009; Finkbeiner et al., 2004; Gollan et al., 1997; Jiang, 1999). To our knowledge, the present study was the first that tackled the issues detailed above by manipulating the phonological similarity of cognates in Persian-English bilinguals.

We used Persian and English because these languages share phonemes and ortho-phonemic rules to convert letters to phonemes. According to the bilingual interactive activation plus (BIA+) model (Dijkstra & Van Heuven, 2002), phonological representations of L1 and L2 are connected in a bilingual mind. Thus, similarity in phonemes and ortho-phonemic rules in Persian and English might highlight the role of the shared phonology and produce different results from cross-language studies with Japanese-English (e.g., Nakayama et al., 2014), Chinese-English (Hoshino et al., 2010; Jiang, 1999), Greek-English (Voga & Grainger, 2004), and Korean-English (Kim & Davis, 2003) bilinguals. In addition, different-script languages provide an ideal context to study when the phonological form and meaning representations of the prime activate relevant target representations. After the prime is presented, the prime activates a list of words with similar features including the target. Upon the presentation of the target, however, the target sends an inhibitory effect to suppress the prime and all other activated candidates. The prime facilitates the processing of the target if it wins this competition. This process occurs when the prime and target share scripts, and does not occur when they are in different scripts. Moreover, script differences increase the speed of the processing of the prime, as they help identify which lexicon to search for the prime (BIA+ model, Dijkstra &Van Heuven, 2002).

Overall, Persian and English provide a new bilingual context to pursue the objectives of this study. We collected response times (RTs), accuracy, and event-related potentials (ERPs) in a masked-priming lexical decision task. Response time (RT) shows the combined time it takes to recognize a word and make a lexical decision on it. ERPs, on the other hand, show continuous processing of stimuli, thus providing information about the time-course of the priming effects. Combining behavioral and neuroimaging techniques permits deeper investigation of the issues where results are otherwise contradictory. In both experiments, the prime was masked and subliminally exposed to (a) prevent conscious translation of English primes into Persian equivalents, (b) keep the prime processing automatic and under the level of consciousness (Forster & Davis, 1984), and (c) keep the word list monolingual. When the nontarget language is imperceptible (masked), it is optimally processed while influences the target language. Consequently, researchers can determine how early the shared phonological and semantic information about the prime integrates with that of the target, ultimately influencing target processing. Positive priming effects occur if the information about the prime is integrated with the information about the target. Indeed, the facilitation effect of the prime occurs if there is overlap between the orthographic, phonological, and semantic representations of the prime and target.

## 4.2. Experiment 1

Briefly stated, the purpose of Experiment 1 was to compare the prime durations of 50 ms and 70 ms in L2-L1 and 50 ms in L2-L2 to adjust the prime duration in Experiment 2.

### 4.2.1. Method.

#### 4.2.1.1. *Participants.*

Participants signed a consent form approved by the Wilfrid Laurier University Research Ethics Board (REB approval number, 5518). Twenty-two Persian-English bilinguals (4 males and 16 females) were recruited from a language institute in Broojerd, Iran. They were males and females who began learning English at the age of 11, with a mean age of 23.6 years. Participants received an average of 6.5 (range being 5.5 -7.5) in the listening and reading sections of the IELTS Academic Module. They were paid for their participation.

#### 4.2.1.2. *Stimuli and procedure.*

We used the data created by Fotovatnia et al. (2019) to select the stimuli in Persian and English.  Fotovatnia et al. have provided detailed explanations about the creation of the stimuli and collection of the lexico-semantic features of the words included in the dataset. Briefly stated, lists of words including cognates with differing phonological similarities and noncognates in Persian and English were selected. To determine the lexico-semantic features of the words (e.g., number of phonemes and letters, concreteness, and imageability) in English, the CLEARPOND database (Marian et al., 2012) was used. For the Persian words, a group of Persian-English bilinguals, which included staff and students who graduated or were currently studying in the English department at the Najafabad Branch, Islamic Azad University, Iran, rated the lexico-semantic features of words (e.g., familiarity with the English words and phonological similarity of cognates in Persian and English) on a 5-point Likert scale. Other features of words, such as word frequency in Persian, were determined through the MAHAK database (Sheykh-Esmaili et al., 2007). English nonwords were created through The English Project Website (elexicon.wustl.edu) while the Persian nonwords were created by ten monolingual speakers of Persian. In this study, 32 HPS cognates *bronze* (برنز/bʊ′rʊnz /), 32 LPS cognates *saffron* ( زعفران /zæfæ′rɑːn/), 32 noncognates *merchant* ( تاجر/tɑː′dʒɜr /), 48 fillers, and 230 nonwords were selected from the database. HPS (*M*=4.23, *SD*= .38) and LPS cognates (*M* = 2.61, *SD*= .33) significantly differed for the phonological similarity in the two languages, $t(60) = 18.87$, $p < .001$. The lexico-semantic features of the primes and targets were matched to prevent the confounding effects that these features could have on the findings. Table 4.1 shows the lexico-semantic features of the stimuli in all experimental conditions of the study. An analysis of variance on word features showed no significant differences between the related and unrelated primes on the number of letters, word frequency, and word familiarity in HPS and LPS cognates and noncognates. Also, no significant differences were observed in the number of letters and phonemes, word frequency, and neighborhood density of target words across cognates and noncognates (Appendix 3 & Appendix 4).

Table 4.1.*The Mean and SD of Lexico-Semantic Features of Low-Phonological Similarity Cognates (LPS), High-Phonological Similarity Cognates (HPS), and Noncognates (NC) in Related (R) and Unrelated (U) Conditions*

| | **English primes** | | | | | | **Persian targets** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **LPS** | | **HPS** | | **NC** | | **LPS** | **HPS** | **NC** |
| | **R** | **U** | **R** | **U** | **R** | **U** | | | |
| The number of phonemes | 5.66 (1.59) | 5.66 (1.59) | 5.66 (1.43) | 5.66 (1.43) | 6.19 (1.67) | 6.13 (1.68) | 5.75 (1.48) | 6.22 (1.56) | 5.69 (1.38) |
| The number of letters | 6.47 (1.7) | 6.44 (1.66) | 6.41 (1.77) | 6.59 (1.62) | 6.81 (1.73) | 7.06 (1.8) | 4.94 (1.41) | 5.56 (1.68) | 4.78 (1.54) |
| Frequency per million | 17.26 (24.20) | 16.9 (23.58) | 15.42 (21.02) | 14.94 (21.06) | 18.26 (21.02) | 16.8 (19.09) | 62.42 (217.97) | 56.03 (119.25) | 65.33 (109.01) |
| Neighborhood density | - | - | - | - | - | - | 32.34 (30.02) | 26.16 (24.53) | 34.75 (26.62) |
| Familiarity | 2.79 (.85) | 2.88 (.74) | 2.61 (.84) | 2.58 (.73) | 2.53 (.66) | 2.63 (.69) | - | - | - |

Participants received one of two counterbalanced lists and performed a masked- priming lexical decision task on a computer in the language institute. Related and unrelated primes for HPS cognates, LPS cognates, and noncognates were words such as *bronze* and *oyster* (target being برنز /bʊ′rʊnz /) *saffron* and *asphalt* (target being زعفران /zœfœ′rɑːn/), and *merchant* and *restroom* (target being تاجر /tɑː′dʒɜr /, respectively. Two counterbalanced lists were created. In the first list, half of the targets in each word group (cognates, noncognates, and fillers) were preceded by related primes and the other half by unrelated primes. In the second list, targets were preceded by different primes. Put differently, one target was preceded by a related prime in one list and an unrelated prime in the other list. For example, the word برنز was preceded by bronze (related prime) in one but *oyster* (unrelated prime) in the other list. Participants received words and nonwords in a random order.

Each trial consisted of a sequence of four visual events presented on a white background: a fixation point (+) for 500 ms, a row of number signs (##########) for 500 ms, the prime word with different time durations in each block, and the target word masked by flankers (>>>> target <<<<) that remained on the screen until the participant responded (Figure 4.1). A blank interval of 2000 ms separated the trials. Participants practiced the task using thirty trials before the main study.

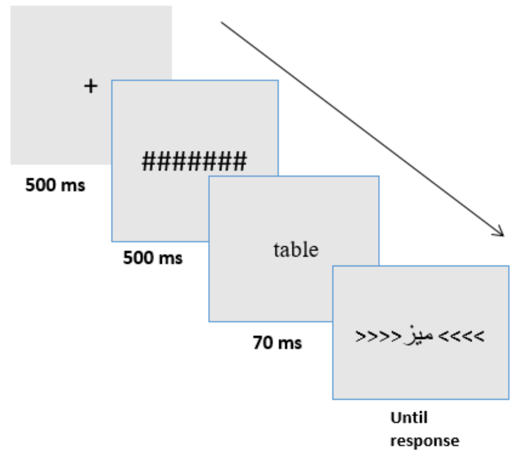



*Figure 4.1.*The masked prime lexical decision task

Each participant completed three blocks: English prime (50 ms) -Persian target (Block 1, EP50), English prime (50 ms) - English target (Block 2, EE50), and English prime (70 ms) - Persian target (Block 3, EP70). The block order was randomized between participants. To present the Persian and English stimuli, 14 pt. Nazanin font and 16 pt. New Times Roman font were used, respectively. Targets were flanked by brackets in case some aspect of the Persian and English scripts caused the prime and target to appear to be different lengths, which might cause participants to become aware of the primes. When asked during debriefing, no participant reported seeing any prime during the experiment.

### 4.2.2. Results and discussion.

Data were analyzed using a 3 (Block: 1, 2, 3) × 2 (Prime Type: related vs. unrelated) × 3 (Word type: HPS cognates, LPS cognates, noncognates) analysis of variance. We used Multivariate statistics to analyze RT and accuracy (Pallant, 2016) and reported the value of Wilk's Lambda when we observed a significant difference. The Bonferroni Post-hoc comparison was run when the main effects reached significance. Separate follow-up analyses explored interactions between the prime and word type using syntax (Field, 2017) because the IBM SPSS does not perform this analysis by default. No participant or item from the analysis was removed, as the error rate was below 20% in all conditions. Response latencies beyond the range of 300-1700 ms and 2.5 standard deviations were removed from the analyses. Less than 20% of the data were removed based on these criteria. Mean response latencies and error rates are presented in Table 4.2.

Table 4.2. *Mean RTs in ms and Accuracy for High-Phonological Similarity Cognates (HPS), Low-Phonological Similarity Cognates (LPS), and Noncognates in Related and Unrelated Conditions in Block 1(EP50), Block 2(EE50), and Block 3(EP70)*

| | HPS cognates | | | LPS cognates | | | Noncognates | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Related prime** | **Unrelated prime** | **Priming** | **Related prime** | **Unrelated prime** | **Priming** | **Related prime** | **Unrelated prime** | **Priming** |
| **Block 1** | | | | | | | | | |
| **RT** | 803.15 | 806.82 | -3.67 | 781.58 | 791.92 | -10.34 | 788.06 | 796.68 | -8.62 |
| **SD** | 86.03 | 95.74 | | 97.81 | 90.09 | | 77.95 | 106.57 | |
| **Accuracy** | 0.93 | 0.84 | 0.09 | 0.95 | 0.95 | 0.00 | 0.95 | 0.93 | 0.02 |
| **SD** | 0.09 | 0.27 | | 0.05 | 0.07 | | 0.05 | 0.07 | |
| **Block 2** | | | | | | | | | |
| **RT** | 870.40 | 876.01 | -5.61 | 916.11 | 917.59 | -1.48 | 901.97 | 908.57 | -6.60 |
| **SD** | 133.64 | 124.93 | | 135.31 | 109.96 | | 137.19 | 134.62 | |
| **Accuracy** | 0.88 | 0.87 | 0.01 | 0.88 | 0.81 | 0.07 | 0.89 | 0.90 | -0.01 |
| **SD** | 0.13 | 0.10 | | 0.17 | 0.18 | | 0.12 | 0.10 | |
| **Block 3** | | | | | | | | | |
| **RT** | 742.01 | 750.55 | -8.54 | 733.23 | 749.16 | -15.93 | 733.18 | 731.99 | 1.19 |
| **SD** | 64.11 | 62.20 | | 63.11 | 65.04 | | 62.96 | 92.15 | |
| **Accuracy** | 0.91 | 0.97 | -0.06 | 0.94 | 0.95 | -0.01 | 0.94 | 0.95 | -0.01 |
| **SD** | 0.09 | 0.05 | | 0.09 | 0.09 | | 0.06 | 0.05 | |

**4.2.2.1.** ***RT and accuracy analysis.***

Concerning RTs, there was a significant main effect of block, $F(2, 21) = 40.30$, $\lambda = .20$, $p < .001$, $\eta_p^2 = .79$. EP70 ($M$ = 740.02 ms) was faster than EP50 ($M$ = 794.70 ms) and EE50 ($M$ = 898.44 ms). EP50 was faster than EE50. There was a significant main effect of word type in EE50, $F(2, 22) = 6.30$, $\lambda = .63$, $p = .007$, ηp2 = .38. HPS cognates were faster than LPS cognates and noncognates. Regarding the error rate, there was a significant main effect of block, $F(2,21) = 11.11$, $\lambda = .49$ , $p = .001$ , ηp2 = .51. EE50 ($M$ = .87) elicited more errors than EP70 ($M$ = .94). There was an interaction between the prime and word type in EP70, $F(2, 21) = 7.70$, $\lambda^2 = .74$, $p = .011$. Related primes produced more errors than unrelated primes in HPS cognates. Figure 4.2. shows the priming effects for RTs and accuracy of responses for all word groups across all blocks.

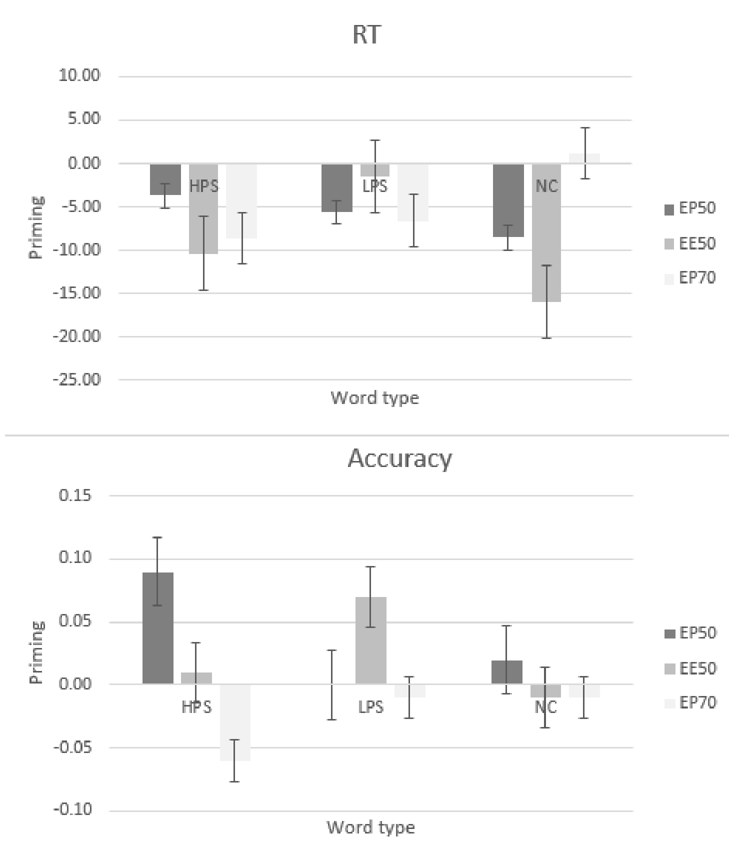



*Figure 4.2.* Priming effects for RTs and accuracy for HPS cognates, LPS cognates and noncognates across blocks

Experiment 1 was conducted to compare the prime duration in the repetition (English-English) and cross-language priming (English-Persian) conditions. The duration of the prime was 50 ms in the former, while it was 50 ms and 70 ms in the latter conditions. The results show that increasing the prime duration from 50 ms to 70 ms led to a significant interaction between the prime and word type and faster processing of word targets in the masked priming lexical decision task. Not surprisingly, EP50 and EP70 blocks were faster than EE50, and EP70 was faster than EP50. EE50 produced more errors than EP70. Interestingly, HPS cognates were faster than LPS cognates and noncognates in EE50 but not in the Persian blocks. We failed to observe significant interactions for RT between English primes and Persian targets. However, related primes elicited more errors than unrelated primes in HPS cognates than LPS cognates and noncognates in EP70.

Wang and Forster (2014) found no effect of prime duration in L2 in a lexical decision task in English, but they did find significant priming effects in a semantic categorization task. They found comparable error rates across Chinese as L1 and English as L2 were 50ms and 80ms, respectively, in the lexical decision task. We found an interaction between the prime and word types in the 70 ms condition. Consequently, we decided to set the prime duration to 80 ms to provide the English prime enough time for processing, and to increase our chance of finding significant interaction effects between the prime and target in Experiment 2.

## 4.3. Experiment 2

The purpose of Experiment 2 was to compare the processing of HPS cognates, LPS cognates, and noncognates in the L2-L1 direction using RT, accuracy, and ERPs. Previous studies did not find conclusive evidence to support a response time or accuracy advantage after presentation of related primes in a lexical decision task in the L2-L1 direction. Studying cognates with varying degrees of phonological overlap can test the phonological account (Voga & Grainger, 2004), and studying noncognates provides a testing ground for semantic priming in the absence of orthographic overlap across the prime and target. As the phonological account claims, the size of the cognate effect should correlate with the phonological similarity of cognates if the cognate effect is additive. We expected to find form-related effects mainly in the time windows that precede the N400 component and semantic-related effects in a 300-500 and 500-850 ms time window after the target onset.

### 4.3.1. Method.

#### 4.3.1.1. *Participants.*

Forty one male (n = 24) and female (n = 17) Persian-English bilinguals, who learned English as a foreign language, participated in this study. They included thirty-five former and six current graduate students with a mean age of 29.77 (*SD*= 3.82) years. Participants began studying English as a compulsory subject at junior-high school when they were 12 years old. The frequency at which they used English daily (measured on a *7*-point Likert scale) was *M* = 5.9 (*SD* = 1.03), *M* = 5.2 (*SD* =1.62), *M* =5.4 (*SD* = 1.46), *M* = 5.20 (*SD* = 1.79) in reading, speaking, listening, and writing, respectively. Participants received an average of 7.00 (*SD*= .58) on the Academic Module of IELTS. They lived in Canada for an average of 32.82 months before participating in this study and were recruited through a combination of flyers, posters, and Facebook advertisements. All participants were right-handed with normal or corrected-to-be-normal visual acuity and were paid for their participation.

**4.3.1.2. *Materials and instruments.***

The same stimuli in Experiment 1 were used in Experiment 2 in the L2 (English prime)-L1 (Persian target) direction. Nevertheless, we decided to set the prime duration to 80 ms, hoping that the prime would have enough time to be processed unconsciously but still exert effects on Persian targets.

**4.3.1.3. *Procedure.***

Participants were seated in a comfortable chair in a sound-attenuated booth (Raymond EMC, Ottawa, ON, Canada) within the Centre for Cognitive Neuroscience at Wilfrid Laurier University.  Before participating in the experiment, participants completed a biodata questionnaire and signed the consent form (REB approval number 5518). Stimuli were displayed in four blocks of equal length in the center of a 16-inch Dell P170S monitor with a refresh rate of 60 Hz using the STIM2 software and was located 50 cm in front of participants. Participants were asked to decide whether the combination of letters they saw on the screen was a word or nonword as fast and accurately as possible and press a different key on a response box (Neuro Scan, INC. STIM system switch response pad P/N 1141). EEG signals were recorded using a 64-channel cap (Electro-Cap International Inc.) and were referenced online to electrodes placed on each mastoid. To monitor eye-related artifacts, such as blinks and vertical or horizontal eye movements, additional electrodes were placed above and below the left eye as well as adjacent to both eyes. Participants were instructed to blink only when the fixation point (+) was presented, or between the trials. EEG signals were recorded with 12-bit precision using NeurosScan Acquire software (Compumedics, NeuroScan, Charlotte, NC) at the sampling rate of 250 HZ and amplified via two NeuroScan SynAmp 2 amplifiers. Electrode impedances were retained below 5 kΩ during the experiment. When debriefed, participants did not report having noticed the primes.

### 4.3.2. Results.

#### 4.3.2.1. *Behavioral results.*

Table 4.3 shows RTs and accuracy rates for words across the experimental conditions in each block. Overall, the grand mean of RTs across all blocks for words and nonwords was 671.32 and 682.71 ms, respectively.

Table 4.3. *Mean RTs in ms and Accuracy Rates for High-Phonological Similarity Cognates (HPS), Low-Phonological Similarity Cognates (LPS), and Noncognates in Related and Unrelated prime Conditions*

| | HPS cognates | | | LPS cognates | | | Noncognates | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Related prime** | **Unrelated prime** | **Priming** | **Related prime** | **Unrelated prime** | **Priming** | **Related prime** | **Unrelated prime** | **Priming** |
| **Block 1 RT** | 695.18 | 740.58 | 45.4 | 703.01 | 711.03 | 8.02 | 704.35 | 716.51 | 12.16 |
| **SD** | 108.31 | 115.73 | 7.42 | 103.06 | 94.7 | -8.36 | 92.58 | 103.78 | 11.2 |
| **Correct** | 0.92 | 0.91 | 0.01 | 0.95 | 0.96 | -0.01 | 0.95 | 0.97 | -0.02 |
| **SD** | 0.08 | 0.09 | -0.01 | 0.07 | 0.05 | 0.02 | 0.14 | 0.04 | 0.1 |
| **Block 2 RT** | 659.77 | 692.18 | 32.41 | 660.4 | 674.07 | 13.67 | 661.31 | 672.05 | 10.74 |
| **SD** | 90.02 | 97.23 | 7.21 | 95.92 | 87.36 | -8.56 | 92.4 | 82.36 | -10.04 |
| **Correct** | 0.94 | 0.96 | -0.02 | 0.94 | 0.94 | 0 | 0.95 | 0.95 | 0 |
| **SD** | 0.08 | 0.05 | 0.03 | 0.1 | 0.07 | 0.03 | 0.05 | 0.07 | -0.02 |
| **Block 3 RT** | 654.42 | 676.84 | 22.42 | 650.76 | 660.38 | 9.62 | 656.1 | 656.03 | -0.07 |
| **SD** | 111.99 | 86.29 | -25.7 | 104.95 | 93.98 | -10.97 | 103.42 | 99.53 | -3.89 |
| **Correct** | 0.95 | 0.92 | 0.03 | 0.96 | 0.95 | 0.01 | 0.95 | 0.97 | -0.02 |
| **SD** | 0.07 | 0.1 | -0.03 | 0.07 | 0.06 | 0.01 | 0.06 | 0.04 | 0.02 |
| **Block 4 RT** | 643.01 | 655.84 | 12.83 | 641.05 | 640.83 | -0.22 | 642.87 | 653.04 | 10.17 |
| **SD** | 111.35 | 96.07 | -15.28 | 113.87 | 90.94 | -22.93 | 95.46 | 95.05 | -0.41 |
| **Correct** | 0.93 | 0.91 | 0.02 | 0.95 | 0.94 | 0.01 | 0.96 | 0.94 | 0.02 |
| **SD** | 0.12 | 0.11 | 0.01 | 0.08 | 0.12 | -0.04 | 0.08 | 0.07 | 0.01 |

**4.3.2.1.1.** *RT analysis.*

**All blocks:** No main effect of block was observed for RT. However, prime type, λ = .60, $F(1, 38) = 26.34$, ηp2 = .40, $p < .001$, word type, λ = .77, $F(2, 37) = 5.43$, ηp2 = .23, $p = .009$, and interaction effects of prime and word type, λ = .78, $F(2, 37) = 5.15$, ηp2 = .21, $p = .011$, reached significance. RTs in related conditions were faster than unrelated conditions (*MD* = 15.62 ms). HPS cognates were slower than LPS cognates (*MD* = 9.49 ms) and noncognates (*MD* = 8.07 ms) in all blocks.

**Block 1:** The main effect of prime, λ = .54, $F(1, 39) = 33.01$, ηp2 = .46, $p < .001$, and interaction of prime and target for HPS cognates, λ = .64, $F(2, 38) = 22.04$, $p < .001$ reached significance. RTs in related conditions were faster than unrelated conditions in general and in HPS cognates.

**Block 2:** The main effect of prime, λ = .73, $F(1, 39) = 15.06$, ηp2 = .27, $p < .001$, and the interaction effect of prime type and word type, λ = .76, $F(2, 38) = 12.69$, $p = .001$, reached significance. RTs in related conditions were faster than unrelated conditions in general, and in HPS cognates.

**Block 3:** A significant interaction effect of prime type and word type for HPS cognates was observed, λ = .87, $F(2, 38) = 5.83$, $p = .02$. RTs in related conditions were faster than unrelated conditions in HPS cognates.

**Block 4:** No significant effect was observed for RT.

**4.3.2.1.2.** *Accuracy analysis.*

**All blocks:** (Figure 4.3): The main effect of word type, λ = .51, $F(2, 38) = 17.58$, ηp2 = .49, $p < .001$, and the interaction of block and word type, λ = .65, $F(6, 33) = 3.02$, ηp2 = .36, $p = .018$, reached significance. HPS cognates produced more errors than LPS cognates and noncognates.

**Block 1:** The main effect of word type was significant, λ = .54, $F(2, 38) = 16.10$, ηp2 = .46, $p < .001$. HPS cognates produced more errors than LPS cognates and noncognates. In Block 2, no significant effect was observed.

**Block 3:** A main effect of word type, λ = .82, $F(2, 38) = 4.27$, ηp2 = .18, $p = .021$, and an interaction between prime type and word type for HPS cognates, λ = .90, $F(2, 38) = 4.48$, $p = .041$, were observed. HPS cognates produced more errors than noncognates. However, related primes elicited more correct responses than unrelated primes in HPS cognates.

**Block 4:** A main effect of prime type, λ = .86, $F(1, 39) = 6.37$, ηp2 = .14, $p = .016$, and word type was observed, λ = .79, $F(2, 38) = 4.94$, ηp2 = .21, $p = .013$. Unrelated primes and LPS cognates and noncognates produced more errors than related primes and HPS cognates. Figure 4.3 illustrates difference scores (priming effects) for the RT (related prime values subtracted from the unrelated prime values) and accuracy (unrelated prime values subtracted from the related prime values) across cognates and noncognates.

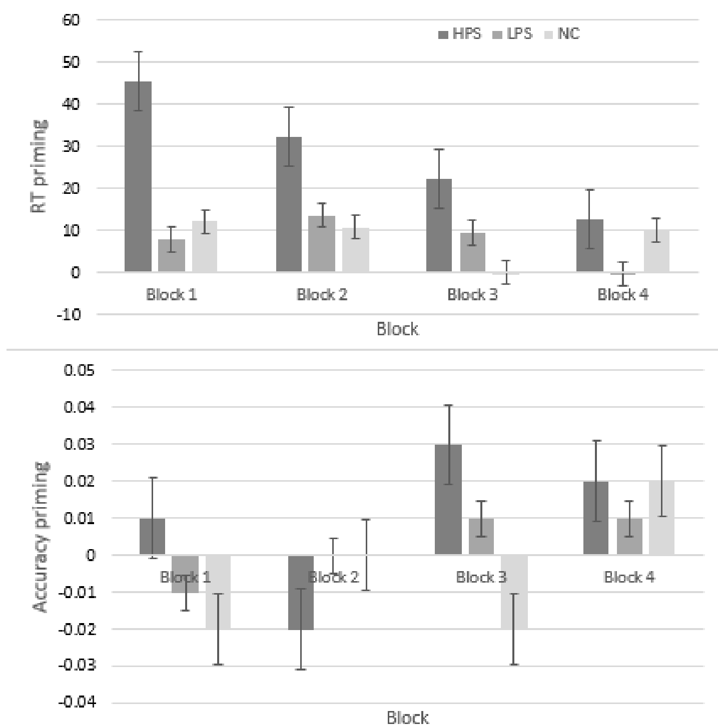


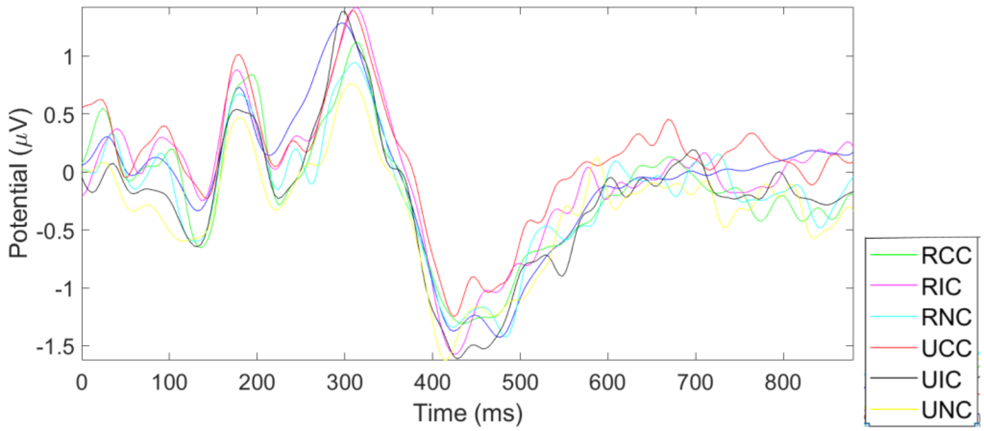

*Figure 4.3.* Priming effects for the RT and accuracy across HPS cognates, LPS cognates, and noncognates

In summary, related primes made the task faster in Block 1 and Block 2, but they increased accuracy only in Block 4. No main effect of word type was observed on RTs, but incorrect decisions were observed for HPS cognates in all blocks, except Block 2. Regarding interaction effects, related primes decreased RTs for HPS cognates in all blocks, except Block 4, while they increased the number of incorrect responses more than other stimuli.

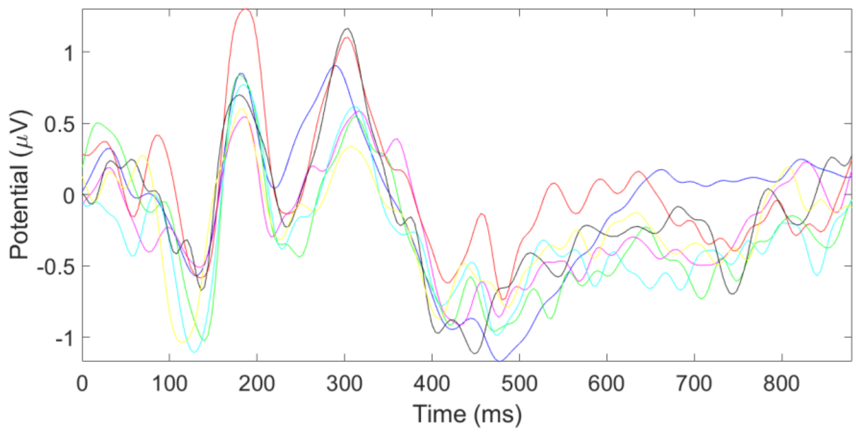
#### 4.3.2.2. *ERP results.*

##### 4.3.2.2.1. *Visual inspection of ERPs.*

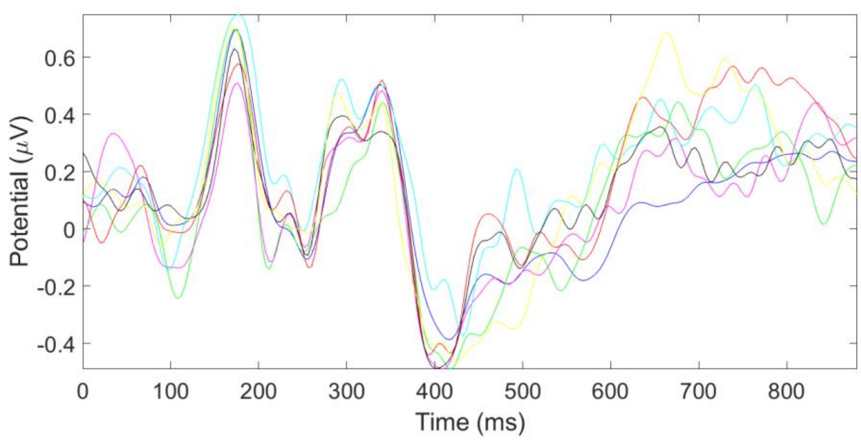
ERPs time-locked to primes from 25 electrode sites averaged in 5 clusters (LA, RA, LP, RP, MID) are plotted in Figure 4.4.


Potential (μV)
1
0.5
0
-0.5
-1
-1.5
0
100
200
300
400
500
600
700
800
Time (ms)
RCC
RIC
RNC
UCC
UIC
UNC

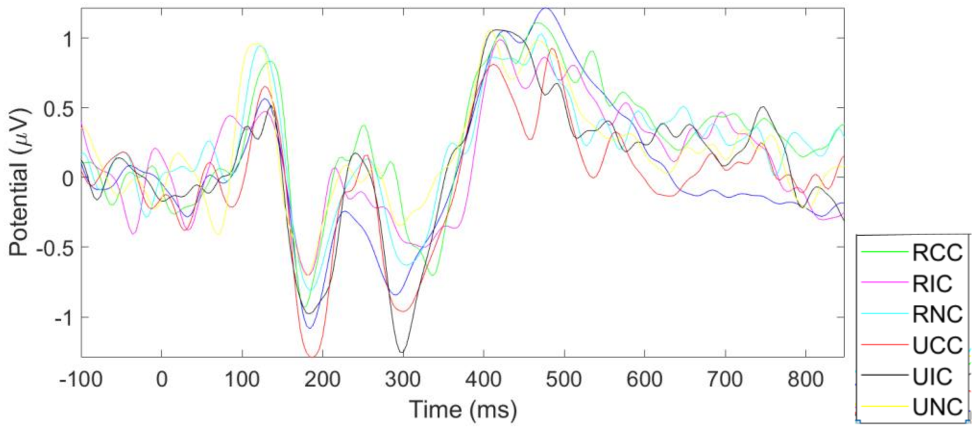
LA


Potential (μV)
1
0.5
0
-0.5
-1
0
100
200
300
400
500
600
700
800
Time (ms)

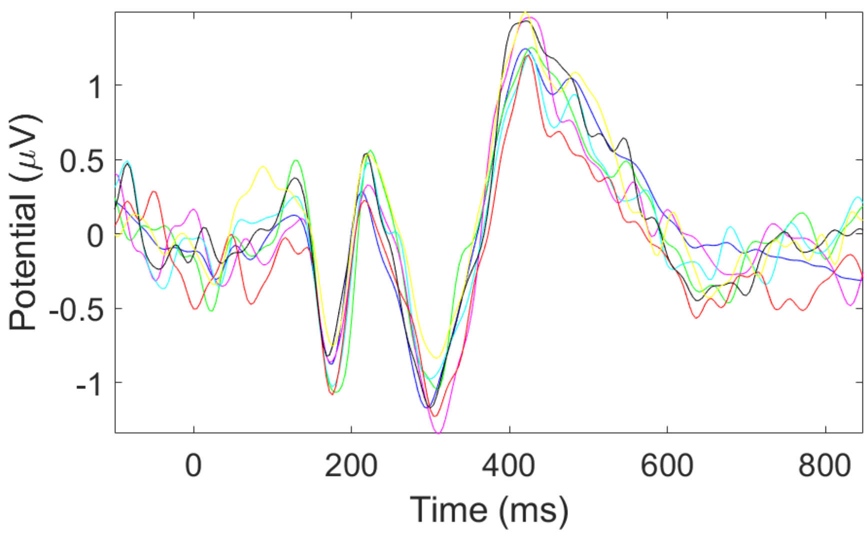
RA


Potential (μV)
0.6
0.4
0.2
0
-0.2
-0.4
0
100
200
300
400
500
600
700
800
Time (ms)

VM




LP




RP

*Figure 4.4.* The LA, RA, VM, LP, and RP clusters. The vertical axis shows the event-related potential in µV and the horizontal axis shows time in ms. Zero is the presentation of the prime**.**

**4.3.2.2.2.** *Individual Time-Window Analysis*

**The 0-100 ms post-prime onset**

A within-subjects analysis of variance on the mean amplitude values in this epoch revealed no significant main effects of prime, word type, or an interaction between these variables.

**The 100-150 ms post-prime onset**

A within-subjects analysis of variance on the mean amplitude values in this epoch revealed significant main effects of word type in the RA cluster, $\lambda = .85$, $F(2, 38) = 3.38$, $\eta p2 = .15$, $p = .044$. HPS cognates (*M*= -.41, *SEM*= .12) produced smaller negative-going amplitudes than noncognates (*M*= -.85, *SEM*=.13) in the RA cluster. Significant main effects of word type in the LP cluster were observed, λ = .84, *F*(2,38) = 3.53, ηp2 = .157, p = .039. HPS cognates (*M*= .36, *SEM*= .13) produced smaller positive amplitudes than noncognates (*M*= .76, *SEM*= .14) in the LP cluster. A significant interaction was observed between prime type and word type in the LA cluster, λ = .90, *F*(2,38) = 4.46, ηp2 = .10, p = .041. Related primes (*M*= -.25, *SEM*= .10) produced smaller negative-going amplitudes than unrelated primes (*M*= -.37, *SEM*= .12) in HPS cognates.

**The 100-200 ms post-target onset**

Significant main effects of prime type were observed in the RA cluster, λ = .86, *F*(1, 39) = 6.41, ηp2 = .14, p = .015, with related primes (*M*= .09, *SEM*= .11) producing less positive going amplitudes than unrelated primes (*M*= .31, *SEM*= 1.00). Significant main effects of prime type were observed in the LP cluster, λ = .88, *F*(1,39) = 5.14, ηp2 = .12, p = .029. Related primes (*M*= -.28, *SEM*= .13) produced smaller negative-going amplitudes than unrelated primes (*M*= -.51, *SEM*= .10). A significant interaction between prime type and word type was observed in the RA cluster, λ = .75, *F*(2,38) = 13.15, ηp2 = .25, p = .001. Related primes (*M*= .09, *SEM*= .10) produced smaller positive amplitudes than unrelated primes in LPS cognates (*M*= .48, *SEM*= .12). A significant interaction between prime type and word type was observed in the LP cluster, λ = .75, *F*(2,38) = 13.36, ηp2 = .26, p =. 001. Related primes (*M*= -.22, *SEM*= .11) produced smaller negative-going amplitudes than unrelated primes (*M*= -.60, *SEM*= .13) in LPS cognates.

**The 200-300 ms post-target onset**

Significant main effects of prime type were observed in the RA cluster, λ = .90, *F*(1, 39) = 4.40, ηp2 = .10, p = .043. Related primes (*M*= .29, *SEM*= .14) produced smaller positive amplitudes than unrelated primes (*M*= .47, *SEM*= .15). Significant main effects of word type were observed in the LA cluster, λ = .68, *F*(2,38) = 9.15, ηp2 = .33, *p* = .001. Noncognates (*M*= .44, *SEM*= .15) produced smaller positive amplitudes than HPS cognates (*M*= .82, *SEM*= .15) and LPS cognates (*M*= .72, *SEM*= .14). Significant main effects of word type were observed in the RA cluster, λ = .74, *F*(2,38) = 6.75, ηp2 = .26, *p* = .003. Noncognates (*M*= .16, *SEM*= .14) produced smaller positive amplitudes than HPS cognates (*M*= .55, *SEM*= .17) and LPS cognates (*M*= .45, *SEM*= .14) in the RA cluster. Significant main effects of word type were observed in the LP cluster, λ = .79, *F*(2,38) = 4.99, ηp2 = .21, *p* =.012 Noncognates (*M*= -.22, *SEM*= .12) produced smaller negative amplitudes than HPS cognates (*M*= -.55, *SEM*= .16) and LPS cognates (*M*= -.44, *SEM*= .14). Significant main effects of word type were observed in the RP cluster, λ = .80, *F*(2,38) = 5.00, ηp2 = .20, *p* = .012. Noncognates (*M*= -.57, *SEM*= .17) produced smaller negative amplitudes than HPS cognates (*M*= -.80, *SEM*= .18). A significant interaction between prime type and word type was observed in the RA cluster, λ = .84, *F*(2,38) = 7.48, ηp2 = .16, *p* = .009. Related primes (*M*= .26, *SEM*= .15) were less positive-going than unrelated primes in LPS cognates (*M*= .63, *SEM*= .17). A significant interaction between prime type and word type was observed in the LP cluster, λ = .88, *F*(2,38) = 5.18, ηp2 = .12, *p* = .028. Related primes (*M*= -.28, *SEM*= .14) were more positive-going than unrelated primes (*M*= -.59, *SEM*= .17) in LPS cognates. A significant interaction between prime type and word type was observed in the RP cluster, λ = .90, *F*(2,38) = 4.15, ηp2 = .10, *p* = .048. Related primes (*M*= -.59, *SEM*= .14) were more positive-going than unrelated (*M*= -.84, *SEM*= .18) primes in LPS cognates.

**The 300-500 ms post-target onset**

A significant interaction between prime and word type was observed in the RA cluster, λ = .82, *F*(2,38) = 3.47, ηp2 = .18, *p* = .04. Unrelated primes (*M*= -.26, *SEM*= .20.) were more positive-going than related primes (*M*= -.69, *SEM*= .17) in LPS cognates. A significant interaction between prime and word type was observed in the MA cluster, λ =.75, *F*(2,38) = 5.05, ηp2 = .25, *p* = .013. Related primes (*M*= -.014, *SEM*= .09) were more positive-going than unrelated primes (*M*=-.261, *SEM*= .10) in noncognates.

**The 500-850 ms post-target onset**

A significant interaction between prime type and word type was observed in the LA cluster, λ = .82, *F*(2,38) = 8.40, ηp2 = .18, *p* = .006. Related primes (*M*= -.24, *SEM*= .08) were more positive-going than unrelated primes (*M*= .01, *SEM*= .12) in LPS cognates. A significant interaction between prime type and word type was observed in the LP cluster, λ = .88, *F*(2.38) = 5.49, ηp2 = .12, *p* = .024. Related primes (*M*= .32, *SEM*= .08) were more positive than unrelated primes (*M*= .08, *SEM*= .10) in LPS cognates. A significant interaction between prime type and word type was observed in the RP cluster, λ = .87, *F*(2,38) = 5.92, ηp2 = .13, *p* = .02. Related primes (*M*= - .06, *SEM*= .07) were more positive-going than unrelated primes (*M*= - .31, *SEM*= .10) in LPS cognates.

In summary, the ERP analysis showed an early interaction between prime and word types for HPS cognates at 100-150 post-prime onset in the LA. Interaction effects were also observed for LPS cognates from 100 ms to 850 ms post-target onset. Related primes showed less positivity than unrelated primes in the 200-300 ms time window in the RA cluster and more positivity from 200 ms to 300 ms post-target onset over the posterior clusters. Related primes produced more positive amplitudes than unrelated primes for LPS cognates from 300 to 800 ms post-target onset in the LP. Related noncognates showed more positive N400 than unrelated noncognates in the VM.

#### 4.3.1. Data analysis.

RT, accuracy, and ERP data were analyzed using a within-subjects analysis of variance in IBM SPSS Statistics (Version 25). Following Pallant (2016), we interpreted the output of a Multivariate Analysis of Variance (MANOVA) for all analyses to avoid requiring the assumption of Sphericity and reported the values of Wilk's Lambda and Bonferroni to show significant effects.

During item analysis, a few targets with less than 75% correct response rates were replaced with fillers that attracted more than 75% correct responses and were in the same category as word targets to keep the number of items equal in each word group as much as possible. These items included the Persian translations of *typhus*, *mammoth*, *bulldozer*, *kayak*, *audience*, and *grocery*, which were replaced with *battery*, *jungle*, *grammar*, *method*, *yawn*, and *eraser*, respectively in Block 1. The items that were replaced with their Persian equivalents in other blocks were *bulldozer*, *raccoon*, *kayak*, and *audience* in Block 2; *typhus*, *raccoon*, *kayak*, and *audience* in Block 3; and *typhus*, *bulldozer*, *raccoon*, *kayak*, and *audience* in Block 4, in all analyses. Correct responses and RTs within 2.5 SD and 300-1500 ms were analyzed. The percentage of correct responses was between 91 and 97 in all blocks. Data were first analyzed with block as a factor, and then in each block using a 3 (Word type: HPS cognates, LPS cognates, noncognates) x 2 (Prime Type: related, unrelated) factorial design. The data were collected through the repetition of the same stimuli four times to maximize the number of trials for averaging the ERPs. However, the behavioral analysis of data showed that performances differed slightly across the blocks due to the exposure to the same stimuli over time. For this reason, it was decided to keep the behavioral analysis in the Results Section and limit the ERP analysis to the first block. Accordingly, only the results of the first block were used to interpret the findings in the discussions.

To process the EEG data, Makoto's preprocessing pipeline (n.d.) was used on MATLAB (version R2019a, Mathworks, Inc.) and EEGLAB 2021.0. EEG data were high-passed at 1 HZ and low-passed at 30 HZ. Voltage values were re-referenced to the average voltage across all electrode sites. Noise and artifacts from eye and muscle movements were rejected offline using the Artifact Subspace Reconstruction (ASR) algorithm, cleanLine, and the Independent Component Analysis (ICA) decomposition (EEGLAB, 2021.0). Visual inspection of data ensured the removal of all artifacts. The data used for the analysis ranged from 70.83% to 100% for each participant. The number of events (prime-target) remained for the analysis was 1128 (88.13%), 1128 (88.13%), 1142 (89.22%), 1142 (89.22%), 1124 (87.81%), and 1152 (90.00%) in related HPS cognates, related LPS cognates, related noncognates, unrelated HPS cognates, unrelated LPS cognates, and unrelated noncognates, respectively, for the bilingual group. Data were time-locked to the presentation of the prime and baseline corrected at 100 ms prior to its presentation to capture more precise time analysis. Epochs were extracted from 100 ms before and 900 ms after the prime presentation. Data were averaged for each condition and each participant in Block 1. We selected the time windows that reflected the processing of meaning, including the N400 component (300-500 ms post-target onset) and late semantic effects (500-800 ms post-target onset). We also selected time windows that reflected the processing of form: (a) 0-100 ms post-prime onset, (b) 50-100 ms post-target onset, (c) 100-200 ms post-target onset, and (d) 200-300 ms post-target onset (the N250, Holcomb & Grainger, 2006). The N400 is a negative-going component that appears when semantic processing is impaired (Midgley et al., 2011). Studies suggest that a 300-500 ms time window adequately captures the N400 effect (Sadeghi, Scheutz, Pu, Holcomb, & Midgley, 2013). The N250 reflects the mapping of sublexical form representations (letters and letter combinations) onto the lexical system in visual word recognition (Holcomb & Grainger, 2006). Two windows were used to capture the N400 activity: one was between 350-500 ms and is found in most studies in L1, and the other was between 500-650 after the target observed in L2 translation priming (Midgley et al., 2009). Following Peeters et al. (2013), we averaged mean amplitudes to create five clusters as follows: left anterior, LA (FP1,F3,F7,FC3, FT7); right anterior, RA (FP2, F4,F8,FC4,FT8); left posterior, LP (O1,P3,P7,CP3,TP7); right posterior, RP (O2,P4,P8,CP4,TP8); and vertical midline, VM (Oz,Pz,Cz,FCz,Fz).

#### 4.3.2. Discussion.

The purpose of the present experiments was two-fold. First, we compared the prime durations of 50 ms and 70 ms in two English-Persian blocks with the prime duration of 50 ms in an English-English block. We used a masked priming lexical decision task to adopt an appropriate prime duration in Experiment 2. The results of Experiment 1 showed that lexical decisions were performed faster in EP70 than EP50. Also, in EE50, related primes made the decision-making faster in HPS than LPS cognates and noncognates. In EP70, related primes elicited more errors in HPS cognates than unrelated primes. Overall, we observed a significant difference between 50 ms and 70 ms prime durations in Persian blocks. Thus, we increased the prime duration to 80 ms in Experiment 2 to allow more time for the processing of the prime and raise the possibility of priming effects on word targets while keeping the prime processing below the level of consciousness. Prime durations between 70 ms and 90 ms in L2 English were found comparable to the prime duration of 50 ms in L1 Chinese to produce the same error rates. These durations caused similar prime awareness and similar level of semantic activation in these two languages (Wang & Forster, 2014).

Second, we tested cross-language cognate and noncognate translation priming in a different group of Persian-English bilinguals, using a masked priming paradigm, and collected behavioral and ERP measures in five-channel clusters to determine the influence of the nondominant language on visual word recognition in L1. In addition, we manipulated the phonological similarity of cognates in Persian and English to investigate the time-course of the interactivity of phonological and meaning representations in the absence of orthographic similarity between these languages. Comparing HPS with LPS cognates and noncognates provided an appropriate ground to examine whether phonological information had cumulative effects on visual word recognition in languages with no orthographic overlap.

**4.3.2.1.** ***Supporting the nonselectivity view and the cognate effect.***

The first objective in Experiment 2 was to replicate the findings of the studies that showed the influence of L2 on the dominant L1 (Dijkstra, Timmermans, et al., 2000; Duyck, Assche, Drieghe, & Hartsuiker, 2007; Pu, Medina, Holcomb, & Midgley, 2019; J.G. van Hell & T. Dijkstra, 2002; W. J. van Heuven, B., Dijkstra, & Grainger, 1998; Xiong et al., 2020) using cognates and noncognates in a different-script bilingual group, which had not been studied before. We observed the main effect of prime type in RT and ERP measures. Related primes made the task faster than unrelated primes, and they modulated the ERP amplitudes from 100 ms until 500 ms post-target onset. Furthermore, significant interactions between prime and word types showed that related primes decreased the speed of processing of HPS cognates in all blocks except Block 4. Similarly, prime and word types interacted to modulate ERP amplitudes in HPS and LPS cognates. In this study, primes were masked and only target words were displayed in Persian. This situation created a monolingual setting, where the implicit effects of the nondominant English language were observed on the dominant Persian language. These findings suggest that English and Persian were activated in parallel while participants were performing the task and that participants could not ignore English when making decisions in Persian. The effects of the nondominant on the dominant language provides a stronger support for the nonselectivity view of word processing across these languages than vice versa.

The results of our study support the so-called cognate effect observed in previous studies in L1 and attribute the effect to the shared phonological similarity in Persian and English. This effect is a stronger support for the nonselectivity view of bilingual word processing than the cognate effect in L2 because it shows that bilinguals cannot block the nondominant language when the setting is monolingual and only the dominant language is present. The cognate advantage observed in L1 may result from participants' increased exposure to the same form-meaning association in L2, which is observed when bilinguals have daily contact with native speakers of L2. This situation does not occur in language institutes as an academic subject rather than a means of communication; this is how participants in this study experienced English.

**4.3.2.2.** ***Absence of the noncognate effect.***

The next objective of the present study was to test the noncognate priming effect of L2 English on L1 Persian. Although we displayed the English prime for 80 ms to allow participants to process the prime longer than the L1 prime, we did not observe any priming effects for noncognates. Similar to our findings, noncognates did not show any priming effects in L2-L1 in Japanese-English (Hoshino et al., 2010) and French-English bilinguals (Midgley et al., 2009) in a semantic categorization task. Conversely, both studies reported translation effects on the N250 and N400 components for noncognates in the L1-L2 direction. The N250 component reflects the form-level processing of words (orthographic and phonological features), while the N400 component indicates the processing of meaning. As Japanese and English do not share orthographic features and as noncognates share meaning in two languages, the appearance of the N250 component for noncognates should reflect shared conceptual features. In fact, the form-level feedback that related primes received in the N250 time window can be attributed to the conceptual features that were activated at higher levels of processing. L2 primes produced slower and less robust effects than L1 primes. Thus, they failed to provide noncognates with an advantage in the L2-L1 direction in most studies. Different from Hoshino et al. (2010) and similar to Gollan, et al. (1997), Fotovatnia and Jones (to be submitted for publication) did not find priming effects for noncognates in Persian and English in L1-L2 or L2-L1, but unlike Gollan et al., they found priming effects for cognates in L2-L1. Gollan et al. found no facilitative effects of the related primes for cognates and noncognates in Hebrew-English bilinguals in L2-L1.

The absence of priming effects for noncognates in L2-L1 is not consistent with the predictions of the revised hierarchical model (RHM, Kroll & Stewart, 1994), as RHM predicts that cognates and noncognates should produce stronger priming effects in the L2-L1 than L1-L2 direction. According to the RHM, L2 words are learned by creating direct connections between L2 lexical representations and their L1 translation equivalents, which will be used to access the conceptual system in the initial stages of learning an L2. As learners develop their knowledge of the L2, they create conceptual links that connect the L2 words directly to the conceptual system. The existence of direct lexical links between L2 words and their L1 equivalents should have produced stronger priming effects in terms of faster responses and modulations in the N250 and N400 components in the ERP analysis in L2-L1 when related primes preceded the targets. Participants in this study were advanced learners of English, and by extension, used English daily in Canada for academic and nonacademic purposes. Thus, we expected them to have developed strong L2-L1 lexical connections, which would have resulted in the modulations in the N250 and also direct conceptual links, which would have modulated the N400 component in the ERP analysis. We did not observe any noncognate priming effect in L2-L1, supporting the absence of such lexical connections and conceptual links in this group of bilinguals.

Interestingly, we observed a positive relationship between the noncognate effect and the IELTS scores $r(37) = .325$, $p = .041$, but no relationship between the cognate effect and English proficiency scores. This finding further highlights the importance of the knowledge of L1 and the role of the phonological overlap in processing HPS cognates in the present study.

The absence of a priming effect for noncognates in L2-L1 supports that the cognate priming effect observed in the present study initiated from the phonological similarity of cognates. Presumably, the effects reflected sublexical processes, as shown by the related primes that facilitated the processing of HPS and LPS cognates in the time windows before 300-550 ms post-target onset. Conceptual priming occurred at the lexical level and was absent in our experiment for noncognates. Similar to our findings, Nakayama et al. (2013) did not find any priming effects for noncognates in L2-L1, but they observed priming effects for cognates. This priming effect, they strongly believed, originated from the sublexical processing of cognates given that these effects did not interact with L2 proficiency and word frequency in L2.

**4.3.2.3.** ***Testing the phonological account.***

In addition to the two objectives of this study, we pursued testing the phonological account of the cognate effect in Experiment 2. Consistent with this account, we expected the phonological similarity between words in the two languages to cause more priming effects for HPS cognates, lesser priming effects for LPS cognates, and no priming effect for noncognates. We found that HPS cognates were faster than LPS cognates, and they showed earlier effects in the ERP analysis than LPS cognates. However, we did not find the predicted results for the LPS cognates.

We observed an early interaction effect between the prime and word types in HPS cognates at 100-150 ms post-prime onset. Also, related primes decreased word decision RT in HPS cognates (45.4 ms) more than LPS cognates (8.02 ms) and noncognates (12.16 ms). These observations highlight the importance of high-phonological overlap in visual word processing in Persian-English bilinguals and support the hypothesis that English and Persian words are connected at the level of phonological representations. Like HPS cognates, we observed significant interactions in LPS cognates in the ERP analysis. However, the interactions started later than HPS cognates (i.e., at 100-200 ms post-target onset) and continued until 500-850 ms post-target onset. Related primes showed less positivity than unrelated primes in the 200-300 ms time window in the RA cluster and more positivity from 200 ms to 300 ms post-target onset over the posterior clusters. This finding suggests that the mapping of orthographic to phonological representations was easier for LPS cognates over posterior clusters. We further speculate that mapping phonological representations to meaning required less neural resources for this group of cognates over these regions due to the more positivity of related than unrelated primes at 300-500 ms post-target onset. It is highly possible that LPS cognates activated the existing posterior L1 knowledge (Midgley et al., 2011). This group of cognates faced less competition when mapping orthographic to phonological representations in Persian, as LPS cognates were regarded as original Persian words more than HPS cognates. These conclusions agree with other observations in our study.

ERP analyses showed that interaction between the prime and word type was later in L2 than in L1 (Chapter 3). Similar to our results, an earlier interaction in L1 than in L2 has been found in previous studies. For example, in Midgley et al.'s study (2011), the cognate effect started at 200 ms in L1 (English) and was distributed across the scalp from 300-500 ms but did not continue to a 500-800 ms time window. In L2 (French), cognate effects started at 300 ms and were widespread after 550 ms. A similar pattern was observed for the cognate effect in our study, although the effect occurred earlier in our study than in other studies. For example, the phonological priming appeared in Japanese-English bilinguals at 200-250 ms in L2 (Ando et al., 2014) and Dutch-English bilinguals and English monolinguals at 120-180 ms in L2 but at 180-280 ms in L1 (Timmer & Schiller, 2012). We also observed similar results to those of Fotovatnia and Jones (under review). We observed that Persian primes interacted with English targets earlier (at 0-100 ms post-prime onset, Fotovatnia & Jones) than English (L2) primes (at 100-150 post-prime onset in the present study) in HPS cognates. In the present study (Exp. 2), related English primes interacted with Persian targets earlier than the studies we have just reported.

Conversely, high-phonological overlap increased the number of errors in HPS cognates more than LPS cognates and noncognates. We observed that related primes produced modulations from 100 to 500 ms post-target onset for LPS cognates. Related primes also produced smaller positive amplitudes than unrelated primes in all conditions in the RA cluster, but they produced more positivity at 100-200 post-target onset in the LP cluster. Presumably, the higher phonological similarity between two phonological representations of cognates made it harder for the participants to decide whether the target was a Persian word. One reason might be the frequency that the participants used English compared to Persian in their day-to-day lives. Participants lived in an English-speaking province in Canada, so while they spoke Persian with family and friends on social occasions, they spoke English more frequently at school, work, and in other public locations. We found a positive relationship between the time the participants had resided in Canada and their reported listening frequency, speaking frequency, reading frequency, and writing frequency in English, $r(37) = 48.$, $p$=.005; $r(37) = .72$, $p$< .001; $r(37) = .43$, $p$=.014; and $r(37) = .46$, $p$=.008, respectively. While speaking Persian and English simultaneously, participants used cognates more than noncognates. Thus, the connections between cognates were made stronger than noncognates in their two languages. These connections may have helped participants perform the task faster, as they could access the concepts faster for cognates than noncognates.

Increasing exposure to cognates in English, nonetheless, made the lexical decision more challenging in Persian, particularly for cognates with high-phonological overlap. We also observed a positive relationship between the reported reading frequency and RT in HPS cognates, $r(37) = .34$, $p = .039$; participants who reported a higher reading rate in English performed the task faster. The results of the ERP analysis showed that the amplitudes of HPS and LPS cognates were more positive and larger than noncognates from 200 to 500 ms post-target onset over the anterior clusters, while they produced larger negative amplitudes than noncognates in posterior clusters.

A reversed cognate effect was observed in Midgely et al.'s study (2011) at 300 ms post-stimulus onset but in L2 French. They attributed this observed anterior N400 distribution to lower proficiency in the L2 and the competition that cognates face when mapping their orthographic onto phonological forms. These researchers argued that cognates produced comparatively larger posterior N400 because they activated the existing posterior L1 system. Noncognates produced little activity over these regions because their representations in the L2 were not yet fully developed in their low-proficient speakers. They speculated that the cognate effect will expand to the posterior regions of the brain when proficiency increases in L2 and thus making L2 representations more stable. Put differently, advanced L2 speakers are not expected to show more anterior N400 distributions and a reversed cognate effect in L2. Midgley and colleagues also hypothesized that the reverse cognate effect reflected the competition that cognates had while mapping their orthographic onto their phonological representations in French and English; cognates have one orthographic and two phonological representations, and these phonological representations compete against each other. No such competition is available for noncognates that have one orthographic and one phonological representation in French and English.

In our study, we observed a reversed cognate effect in the time windows that are associated with sublexical (200-300 ms time window) and conceptual (300-500 ms time window) processing of words in posterior clusters but in L1. There are two differences between our study and Midgley et al.'s study (2011). Our participants were more advanced than the participants in their study, as their overall average of self-reported reading frequency in L2 was 3.6 in their study vs. 5.9 in our study, and they obtained an average of 7 on an academic module of IELTS. Also, these effects were observed in the dominant language in Persian and English, which are languages with different scripts. Thus, cognates face no competition resulting from the same reading and two different pronunciations they observed in English and French. We, however, present a similar explanation. For one, noncognates showed more positive amplitude in the posterior clusters than cognates, as their processing relied mainly on the L1 knowledge in these areas, which is also supported by Midgley and colleagues. Recall that the lexical decision was in Persian, which was the dominant language for participants. At the same time, related primes were more positive over the posterior and more positive over the frontal clusters for LPS cognates in the 200-300 ms, as related primes facilitated their mapping of orthographic to phonological representations. This effect was reflected in the RT analysis.

**4.3.2.4. *Related LPS shown more negativity.***

We observed significant interactions between prime and word types in LPS cognates from 100 to 850 ms time windows. Related primes were less positive-going than unrelated primes between 100 and 300 ms post-target onset in the RA cluster, while they were more positive going than unrelated primes in posterior clusters in the same time window and the postN400 time window. However, the behavioral analysis did not show any priming effects in LPS cognates. For the ERP analyses, we expected related primes would produce larger positive amplitudes in the N250 and smaller negative amplitudes in the N400 components, compatible with the phonological account of the cognate effect. In line with the phonological account of the cognate effect, we also hypothesized that LPS cognates were processed more slowly than HPS cognates and faster than noncognates. A discrepancy between the behavioral and ERP measures appeared in our study.

This type of discrepancy in the results of neural and behavioral measures was also observed in previous studies. Bice and Kroll (2015) observed no priming effects in behavioral analysis but found priming effects in their ERP analysis of English-Spanish beginning learners. The learners showed larger negative amplitudes in the N400 component for cognates than noncognates but no significant behavioral effects in a lexical decision task in English. Bice and Kroll attributed the appearance of negative amplitudes to the effects that the developing L2 had on L1; learners in their study attempted to decrease the influence of their developing L2 knowledge on the L1 system by suppressing cognates, as they mistook cognates as being solely part of their L1 knowledge. Similarly, learners showed slower performance but greater parallel activation and inhibitory control in L1. Bice and Kroll agreed with (McLaughlin, Osterhout, & Kim, 2004) that ERP effects precede behavioral effects but maintained that the magnitude and direction of such effects needed further investigation. We have reached the same conclusion, as we observed the influence of the developing English on Persian in this study.

We found that prime and word types significantly interacted in LPS cognates in the ERP analysis, but they failed to interact in the behavioral analysis. We presume that these ERP effects are detectable before behavioral effects arise for LPS cognates. Unexpectedly, unrelated English primes produced more positive amplitudes in form-related components, such as the N250, and they produced smaller negative amplitudes in the N400 component. As discussed before, we also observed a discrepancy between the behavioral and ERP results in HPS cognates. HPS cognates produced negative amplitudes in a 100-150 prime-onset time window, and the related primes produced smaller negative amplitudes. Related primes also decreased RTs but increased incorrect decisions in HPS cognates. Different from Bice and Kroll’s study (2015), our participants were advanced learners of English, who used English and Persian simultaneously. They used English in society and Persian at home and in meetings with friends and relatives. Consequently, they encountered cognates more frequently than noncognates, as cognates are found in both languages. The appearance of ERP modulations in the LPS cognates supports that participant attempted to avoid the influence of their developing English on the yet dominant Persian. We conclude that the appearance of the ERP effects on LPS cognates although detectable, were insufficient to alter their behavioral responses. Hence, we predict that more frequent use of English as an L2 results in changing the speed and outcome of the processing of LPS cognates in a masked-priming lexical decision task in Persian-English bilinguals. This topic requires further investigation.

Overall, we failed to observe consistent graded effects across all experimental conditions when we analyzed ERP and behavioral results for HPS cognates, LPS cognates, and noncognates. We observed that HPS cognates showed ERP and behavioral priming effects, LPS cognates showed ERP priming effects, and noncognates showed neither ERP nor behavioral priming effects on the lexical decision in Persian. Cognates are part of L1 knowledge, but as individuals use L2 more frequently for communication, they encounter cognates more often in that language. Consequently, participants in our study found it faster to make a lexical decision on HPS cognates but harder to keep the two language systems apart. LPS cognates possess less phonological similarity in two languages than HPS cognates. Thus, they require more time to develop a similar pattern of processing to HPS cognates. Future studies that involve Persian-English bilinguals that have resided in Canada longer and have used English more often than Persian can test this prediction.

## 4.4. Conclusion

The present study investigated visual word recognition to test the nonselectivity view of bilingual word processing and the phonological account of the cognate effect in L2-L1 in a less-examined different-script bilingual population. The phonological account presumes that HPS cognates should show advantages over LPS cognates, and LPS cognates should show advantages over noncognates in behavioral measures. However, we used behavioral and ERP measures and showed that the processing of HPS cognates, LPS cognates, and noncognates in L2-L1 did not conform to those predictions. HPS cognates were processed faster but elicited more errors, than LPS cognates and noncognates, and they caused modulations in the N100. LPS cognates showed no advantages over noncognates in RT and accuracy but showed modulations in the ERP components. Different from cognates, processing of noncognates was not affected by priming. The absence of priming effects for noncognates is consistent with previous research utilizing a masked priming lexical decision task in L2-L1.

Future research with beginners and more balanced Persian-English bilinguals could allow us to determine whether the same stimuli produce a different pattern of results in these populations. Comparing cognates with varying levels of phonological overlap in Persian and English with noncognates shows the extent that the two languages are connected at the phonological level in the absence of orthographic similarity. Moreover, it is also possible that different patterns of processing for cognates and noncognates in L1 are due to learning an L2, even at the early stages of L2 learning, which would further support the nonselectivity view in this group of bilinguals. In addition, a similar study that uses a semantic categorization task with more focus on meaning, and word naming with more emphasis on word production, could show how much the results are independent of the experimental task and the modality of processing.

# Chapter 5. General Discussion

## 5.1. Overview of the Chapter

A brief review of the literature on the cognate effect and the role of the phonological similarity of words in cross-language studies is presented in the following section. The purpose and methodology of the studies as well as the behavioral results of the second and third studies are discussed in the context of this previous literature. Following this discussion of the behavioral results is a discussion of the ERP results observed in each study. Finally, the implications of the findings and suggestions for future research are presented.

## 5.2. The Review of Literature

Although it is not known precisely how many people are bilingual, it is estimated that more than half of the world's population knows two or more languages (Ansarin & Saeeidi-Manesh, 2017; Grosjean, 2010). Research on bilingualism is important considering this growing bilingual population (Ju & Luce, 2004; Kroll, Bobb, & Wodniecka, 2006; Kroll & Stewart, 1994; Lagrou et al., 2011; Marian et al., 2003). Bilinguals access two language systems and researchers are interested in understanding how they recognize words in each language and how the words in one language influence the recognition of words in the other language. Evidence for the effect of one language on the other language comes from studies on cognates (words that share phonological and/or orthographic as well as semantic features in two languages) and noncognates (words that share semantic features in two languages) among other word types such as homophones, homographs, and false cognates, using a masked-priming lexical decision task. In this task, a short presentation of a prime enables the subliminal processing of the word prime (Forster & Davis, 1984), influencing the decisions and thoughts (Merikle, 2000), and behavior

(Jiang & Forster, 2001; Zhou et al., 2010) of participants. This task also allows the same word target to follow a related prime in one condition and an unrelated prime in another condition. Hence, the differences caused by primes help elucidate the influence of a first language on L2 processing, and vice versa.

Studies on cognates have shown faster word decision-making in similar-script and different-script languages in L1 (de-Groot & Nas, 1991; Gollan et al., 1997; Kim & Davis, 2003; Voga & Grainger, 2007) and L2 (de-Groot & Nas, 1991); this pattern of responses is known as the cognate facilitation effect (Cristoffanini et al., 1986; de-Groot & Nas, 1991; Dijkstra et al., 1999; Dijkstra, Miwa, Brummelhuis, Sappelli, & Baayen, 2010; Dijkstra & van Heuven, 1998; Lemhöfer et al., 2004; Lemhöfer, Spalek, & Schriefers, 2008; Peeters et al., 2013; Sáchez-Casas et al., 1992; J.G. van Hell & T. Dijkstra, 2002). Similarly, cognates have been shown to elicit smaller N400 amplitudes in ERP studies in L1 and L2 (Dunabeitia, Dimitropoulou, et al., 2010; Midgley et al., 2011; Peeters et al., 2013). The evidence for a noncognate effect is equivocal. However, noncognates have been shown to have greater facilitative effects in RT and error rates in the L1-L2 than in the L2-L1 direction (Dimitropoulou, Dunabeitia, et al., 2011; Gollan et al., 1997; Jiang, 1999; Kim & Davis, 2003; Voga & Grainger, 2007).

There is controversy over the origin of the cognate effect. It is hypothesized that the effect is related to task difficulty (Chee, Lee, Soon, Westphal, & Venkatraman, 2003; Chee, Westphal, Goh, Graham, & Song, 2003) or word features (Gerard & Scarborough, 1989) such as cross-linguistic phonological and semantic similarities (Dijkstra et al., 1999; Francis, 1999; Gerard & Scarborough, 1989). However, the emergence of the cognate effect and the lack of consistent finding regarding the noncognate effect has led to an emphasis on the role of the phonological and orthographic similarity in languages with similar scripts (Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Lemhöfer et al., 2004) and an overreliance on phonology in L2 for languages with different scripts (Voga & Grainger, 2007). If this view, called the phonological account of the cognate effect, explains the cognate effect properly in different-script languages, the cognate effect should correlate with the degree of the phonological similarity of cognates in the two languages. Testing this prediction is possible when cognates with HPS are compared with cognates with LPS and with noncognates that are translation equivalents with no phonological similarity in bilinguals who speak different-script languages. Using Persian and English eliminates the effect of orthographic similarity of the scripts while simultaneously isolating the effect of phonological similarity when cognates with varying degrees of phonological similarity and noncognates are compared. Finally, EEG recordings can complement the behavioral data-collection techniques, as they show the electrical activity of the brain while a task is completed. Employing both measures helps elucidate whether inconsistent results in the literature depend on the techniques used, while also adding data with temporal resolution to more fully uncover processes that guide language perception.

This dissertation focused on the behavioral and neural measures of the cognate effect to show whether masked translation priming correlated with the degree of phonological similarity between cognates and noncognates in Persian-English bilinguals. Further, this study aimed at understanding whether masked translation priming for cognates would be observed across Persian and English and whether the asymmetry in cross-language priming (i.e., facilitative priming effects in L2 but not in L1) would occur for noncognates in this group of bilinguals.

This dissertation comprises three studies. The first study involved the creation of a database to use in the subsequent studies of this dissertation and measured the lexico-semantic features of the chosen words; the lexico-semantic features of words have been found to be critical in previous bilingual studies on word recognition and processing. The second study compared the size of priming effects in HPS cognates, LPS cognates, and noncognates in a lexical decision task with a Persian prime and an English target in Persian-English and English monolingual speakers. Finally, the third study used the same methodology, stimuli, and task as the second study, but in the opposite direction (i.e., a prime word in English and a target word in Persian).

## 5.3. Behavioral Results

We collected four blocks of data in all studies. However, statistical analyses showed that participants performed differently across blocks in the experiments. Thus, we reported the results obtained in block 1 in the previous chapters and in this section. The first block, we believe, reflects the nature of word processing more accurately because participants saw the stimuli for the first time. Below, the findings will be discussed in a broader context.

Regarding the behavioral analysis, we found consistent results across groups. Related primes decreased the RT in cross-language and same-language conditions. However, the priming effect was larger in the monolingual group (55.23 ms) than in bilingual groups (26.10 ms and 25.19 ms in the Persian-English and English-Persian directions, respectively). Related primes increased correct lexical decisions in the Persian-English direction, while they did not show any facilitatory effects in the English-Persian and the monolingual group. We noted that related primes decreased the RT in the bilingual groups. This facilitatory effect shows that bilinguals benefited from the presence of the other language system in doing the task. In other words, bilinguals could not ignore their other language system and the prime automatically affected the RT for all participants. This is called nonselectivity in language processing and has been supported by research studies (Dijkstra et al., 2010; Dijkstra, Timmermans, et al., 2000; Duyck et al., 2007; Pu et al., 2019; J.G. van Hell & T. Dijkstra, 2002; W. J. van Heuven et al., 1998; W. J. van Heuven & Dijkstra, 2010; W. J. B. van Heuven, Schriefers, Dijkstra, & Hagoort, 2008; Zhou et al., 2010). Unsurprisingly, a related priming condition led to larger effects for monolinguals than bilinguals, which seems reasonable considering the fact that English was the L1 for monolinguals and L2 for bilinguals, and monolinguals also benefited from repetition priming.

Comparing the findings across groups demonstrated that cognates have a special status for bilinguals, as related primes significantly decreased the RT in HPS cognates and LPS cognates in the Persian-English study (Chapter 3) and HPS cognates in the English-Persian study (Chapter 4, Experiment 2). Related primes, nonetheless, decreased the RT significantly in both cognates and noncognates in the monolingual group. Related primes facilitated the processing of HPS cognates similarly across Persian-English, English-Persian and English-English groups (40.55 ms, 45.40 ms, 46.70 ms in the, respectively). Related primes decreased the RT for cognates. However, the priming effect was larger in LPS cognates (40.55 ms) than HPS cognates (21.15) in Persian-English. Conversely, related primes decreased the RT only in HPS cognates (45.40 ms) in the English-Persian direction. This observation supports the hypothesis that higher phonological similarity in cognates produces stronger cross-linguistic effects than lower phonological similarity, as LPS cognates did not produce consistent effects across the experimental conditions.

Regarding noncognates, no priming effects were observed in bilinguals, but significant priming effects were observed in the monolingual group (i.e., 70.89 ms). The absence of the priming effect for noncognates was unexpected, especially in Persian-English, as these words shared conceptual features across the two languages and this effect was observed in other studies in same- and different-scripts languages in L2 (de-Groot & Nas, 1991; Dimitropoulou, Dunabeitia, et al., 2011; Duyck et al., 2007; Duyck & Warlop, 2009; Gollan et al., 1997; Jiang, 1999; Jiang & Forster, 2001; Kim & Davis, 2003; Voga & Grainger, 2007; Williams, 1994). However, this observation and the unexpected pattern we observed for cognates with varying degrees of phonological similarity suggest that the lack of orthographic similarity affected word processing and word recognition in this population.

The bilingual groups showed a different pattern for the accuracy of responses. Persian-English speakers made more errors in LPS cognates in English (Chapter 3), but more errors in HPS cognates in Persian (Chapter 4). One issue is worth mentioning; we noticed that LPS cognates benefited more from the related primes than HPS cognates (40.55 ms. vs. 21.15 ms) in the Persian-English experiment (Chapter 3). Conversely, HPS cognates showed large priming effects (45.40 ms), while LPS cognates did not show any priming effects in the English-Persian direction (Experiment 2, Chapter 4). This pattern is consistent with the error rate in cognates; LPS cognates elicited more errors when the target was in English but larger priming effects in the RT (40.55 ms) than HPS cognates. Similarly, HPS cognates elicited more errors when the target was in Persian but larger priming effects in the RT when the target was in Persian (45.40 ms) than LPS cognates.

## 5.4. ERP Results

Evidence that cognates have a special status was also apparent in the ERP analysis for bilingual groups. For the time windows prior to the 300-500 ms post-target onset window, we observed significant interactions between the prime and word type for HPS cognates in the bilingual groups, and this interaction was earlier when the prime was in Persian (100 ms post-prime onset) than in English (100-150 ms post-prime onset). This observation is not surprising, as Persian was the dominant language for the bilingual participants. Thus, participants benefited more from L1 primes than L2 primes. Recall that L1 primes were only on the screen for 50 ms, but L2 primes were shown for 80 ms. L2 primes were presented longer than L1 primes because the L2 prime duration is controversial in the literature, and we found that the duration of 70 ms significantly affected performance in another group of Persian speakers (Chapter 4, Experiment 1). We did not observe any interaction effects in the monolingual group until 200-300 ms post-target. This delay in the interaction suggests that the change of script between the prime and target helped bilingual speakers to notice the prime earlier than the monolingual group.

Different from the bilingual groups, the monolingual group showed a significant main effect of word type in the anterior scalp regions for noncognates from 50 to 300 ms post-target onset. In monolinguals, noncognates showed either positive amplitudes in the 50-300 ms time windows when cognates were negative or more positive than cognates. This effect lasted until 300 ms post-target onset, and thus may not be attributable to the effect of word frequency or other lexico-semantic features of words. Indeed, previous studies have shown that the effect of word frequency fails to occur earlier than 300-550 ms post-target onset (Ando et al., 2014). We also used the CLEARPOND database (Marian et al., 2012) to match the lexico-semantic features of English stimuli including English frequency across the experimental conditions. Even so, we cannot rule out the possibility that noncognates were somewhat conceptually different from cognates for monolinguals, which caused these effects to appear.

Two additional issues are worth mentioning. First, if we accept the possibility that noncognates showed these effects due to their lexico-semantic features, we suggest that databases such as the CLEARPOND should be updated regularly to accurately reflect word features that may have changed over time. Second, the lexico-semantic features of words may be highly subject to individual differences and accordingly sample dependent (Johns, Jones, &

Mewhort, 2016). In other words, the way that word frequency is measured matters with regard to the sample to which the measure is applied.

Essentially, the frequency of occurrence is one of the strongest predictors of visual word processing (Monsell, Doyle, & Haggard, 1989), and it explains 30% to 40% of the variance in it (Brysbaert et al., 2016). Word frequency is measured differently and not all the ways to measure it are equal. A frequency measure for psychology undergraduate students, for example, is better to be based on a corpora of television subtitles (Brysbaert & New, 2009), social media (Gimenes & New, 2016; Herdağdelen & Marelli, 2017), and blogs (Gimenes & New, 2016), while it is better to be based on books for older adults. Using a combination of sources may produce better results (Brysbaert et al., 2016). Scholars also advise that frequency lists be adapted to the learning history of the sample participants (Johns, Jones, & Mewhort, 2016). That is, frequency measures should be tailored to the specificities of participants' learning history such as the number of hours they watch television, their favorite authors, how active they are on social media, and textbooks they study. This makes frequency measures sensitive to sampling and subsequently to the study outcomes. For example, studies have supported the dependency of the frequency effects of university students on their vocabulary size. Students with larger vocabulary size showed more frequency effects than students with smaller vocabulary size (Davies, Arnell, Birchenough, Grimmond, & Houlson, 2017; Mandera, Brysbaert, & Keuleers, 2016).

These effects are presumably more influential in cross-language studies because they make differences in the language exposure, and thus making the frequency measures that are taken based on L1 corpora less applicable to L2 research. The aforementioned shortcomings can be mitigated when the percentage of people who know a word is also included in frequency measures. This new measure is called word prevalence and has been found to explain another 7%

of response times in a lexical decision task (Brysbaert et al., 2016). This kind of measurement, however, has not been made for English words yet. Lack of tailoring word frequency and other lexico-semantic features of words to the characteristics of specific samples in a study may limit the interpretation of the study findings. Future studies might consider applying these strategies to improve data-collection procedures.

Nonetheless, the main effect of word type for noncognates in monolinguals did not affect our conclusions, as our main purpose in selecting a monolingual English-speaking group was to ensure that this group would not show any interaction effects for cognates. We intended to ensure that any interaction effects in cognates were specific to the bilingual groups rather than the monolingual group. Our conclusions might have been different if the monolingual group had shown significant interaction effects for HPS cognates and LPS cognates while showing no interaction effect for noncognates.

We compared the N400 time window (300-500 ms post target onset) in bilingual and monolingual groups. Significant interactions were observed between the prime and word type for HPS cognates, LPS cognates, and noncognates in the monolingual group but only for HPS cognates in the Persian-English study and LPS cognates in the English-Persian study. For monolinguals, related primes facilitated word recognition in all experimental conditions. In fact, they produced smaller amplitudes for the N400 component for cognates and noncognates. This observation suggests that because monolinguals did not have another language system to influence the processing of the cognates or the noncognates, there were no differences in the neural processing of cognates and noncognates by the presentation of the prime. Bilingual groups and the monolingual group showed similar patterns of responses in this time window, as related primes produced larger amplitudes than unrelated primes in the LP region. However, these amplitudes were positive in the monolingual group but negative for HPS cognates in bilingual groups. In fact, related primes were more positive-going than unrelated primes for HPS cognates in the Persian-English group and for LPS cognates in the English-Persian group.

Also, while related primes did not significantly influence accuracy in the monolingual group, they produced more incorrect responses for LPS cognates in Persian-English and HPS cognates in English-Persian groups. Put differently, we observed the inhibitory effect of Persian primes on HPS cognates in the form of more incorrect lexical decisions when significant interactions between prime and word types were found in the ERP analyses. Similarly, we observed no inhibitory effect of Persian primes on English targets for LPS cognates in the form of higher error rates in LPS cognates when no significant interactions were observed in the ERP analysis.

Overall, related and unrelated primes produced negative amplitudes in the 300-500 ms time window in bilingual groups and positive amplitudes for all stimuli in the monolingual group in the LP region. However, related primes were more positive-going than unrelated primes in bilingual groups. Two explanations are in order. Overall, monolinguals found the lexical decision task less challenging because they were able to access the conceptual system easier. Indeed, they possessed one language system and received the same words as primes and targets in the experiment. On the other hand, bilinguals found the task more challenging because they had to make a lexical decision on targets that were preceded by primes in a different language, making cross-language access to the conceptual system more challenging. In addition, HPS cognates and LPS cognates behaved differently but consistently in behavioral and ERP analyses in bilinguals. These observations support the claim that bilinguals used language membership information when making lexical decisions. More about this proposal is discussed in 5.5 below.

We did not observe any significant interaction between prime and word types in the ERP analysis for noncognates in bilinguals. This lack of interaction is consistent with the behavioral results, which failed to show any interaction between prime and word type for noncognates. Thus, it seems reasonable to conclude that orthographic similarity is necessary to facilitate the recognition of noncognates and emphasize the role of higher phonological overlap between cognates, as LPS effects were inconsistent in Persian and English. Alternatively, we can look for another nonlinguistic explanation, as discussed in the following paragraphs.

Regarding the 500-800 ms time window, related primes showed more positive amplitudes than unrelated primes in the Persian-English group in HPS cognates, while they showed more positive amplitudes in LPS cognates in the English-Persian group in the LP. Similar to this observation, Peeters et al. (2013) reported significant modulations of the P600 for cognates, which was absent in Midgley et al.'s findings (2011). These studies had similar objectives but different tasks and participants. Peeters et al. attributed the appearance of the P600 for cognates to the use of a lexical decision task in their study as compared to the use of a semantic categorization task in Midgeley et al.'s study. Peeters and colleagues hypothesized that different readings of cognates in French and English created a conflict for cognates in the lexical decision task. These readings were irrelevant to the semantic categorization task. A similar explanation is appropriate in our study. Related primes showed more positive amplitudes than unrelated primes in Persian-English in HPS cognates, while they showed more positive amplitudes in LPS cognates in English-Persian. These observations are consistent with the accuracy analysis, where LPS cognates elicited more errors in the former and HPS cognates elicited more errors in the latter condition. Stated differently, this late effect shows easier lexical decision for HPS cognates in Persian-English and easier lexical decision for LPS cognates in English-Persian directions due to the influence of language information in the lexical decision.

## 5.5. Merging the Behavioral and ERP Major Findings

Below, the major findings that emerged from the behavioral and ERP analyses will be discussed in broader terms. Overall, the analyses support (1) cross-lingual phonological effects on visual word recognition and nonselective access to the lexicon in alphabetic languages with different scripts, (2) the phonological account in processing cognates in languages with no shared orthographical characters, and (3) potential modulations of cross-lingual phonological effects by the task decision component and language nodes (the BIA+ model) based on the degree of similarity between Persian and English phonology.

### 5.5.1. Cross-lingual phonological effects and nonselective access.

First, this study showed the main effect of related primes and the interaction between prime and word types in cognates in English and Persian in behavioral and ERP analyses. These findings supported the connection between these two languages in the mental lexicon and the integration of English words in the Persian system in a bilingual brain. These findings argue for the nonselectivity of visual word recognition and highlight the role of shared phonology. Phonological similarity appears to support visual word recognition: We observed significant interactions between the related prime and word type in the LA cluster in the 100 ms post-prime onset time window in Persian-English and in the 100-150 ms post-prime onset time window in English-Persian, as well as the facilitative effects of related primes in English and Persian for cognates but not for noncognates. These time windows show the presentation of the prime and the first 50-100 ms presentation of the target. We do not know much about this early effect, but we suggest a few hypotheses. First, this effect might be spurious and not real, but the fact that it occurred in two studies supports that it is genuine. Furthermore, this effect was observed only in the bilingual groups and not in the monolingual group. Thus, it might be due to the script change, and for some random reasons, we observed it only for HPS cognates. Second, the effect was observed only for HPS cognates rather than LPS cognates and noncognates. This observation supports the role of higher phonological similarity between the prime and target. Also, the effect appeared earlier in the Persian-English than English-Persian directions, as the prime is assumed to be processed faster and more effectively in the L1 than in the L2, providing even more support for the early effects of the higher phonological similarity.

Modulations that occur between 50 ms to 150 ms after the stimulus onset show that the access code for word recognition is phonological in nature (Ashby, Sanders, & Kingston, 2009). ERP studies have shown that phonological information is available as early as 80 ms after the stimuli's onset in masked priming paradigms when the prime and target are congruent phonologically (Ashby et al., 2009). Overall, this is a kind of effect that should be followed up in future research. This early effect is as significant as other effects observed in this study.

It should be mentioned that a key factor in showing the interaction of two language systems is to observe whether the nondominant language affects the processing of the dominant L1. This effect has mainly been observed with balanced and early-acquired bilinguals (Dunabeitia, Perea, et al., 2010) but is smaller (Duyck & Warlop, 2009) or absent in late bilinguals (Gollan, et al. 1997). However, in this study, the L2 prime showed significant effects in Experiment 1 (Chapter 4) with a prime duration of 70 ms and Experiment 2 (Chapter 4) showed the same pattern of results with a prime duration of 80 ms in cognates in unbalanced yet advanced Persian-English speakers. Similar to these findings, significant effects of L2 primes were observed with an SOA of 150 ms (50 ms prime duration and a 100 ms blank), but no priming effect was observed with an SOA of 60 ms (50 ms prime duration and a 10 ms blank) in low proficient Korean-English bilinguals (Lee et al., 2018). Lee et al.'s study (2018) presented the prime for a longer duration to ensure the prime had enough time to influence the lexical decision but remain below the level of consciousness.

Our findings demonstrated that English L2 knowledge influences the processing of written Persian when it is one's first language (Chapter 4) and that the L1 knowledge affects L2 processing (Chapter 3). However, priming effects were earlier in the Persian-English direction than in the English-Persian direction. Put differently, these findings support a temporal delay in the activation of L2 word candidates. This is explained by the BIA+ model (Dijkstra & Van Heuven, 2002). In cross-language situations, word processing starts with orthographic information activating sublexical and lexical level representations of word candidates in the reading language. This process occurs in parallel and depends on the resting level activation of the individual items and the orthographic similarity of word candidates. The resting level activation of word candidates reflects their subjective frequency, and is higher in L1 than in L2, and thus performed faster in L1 than in L2 (Dijkstra et al., 2002). In fact, there is a lag in the activation of relevant features in L2 due to the lower subjective frequency of L2 representations. Lower subjective frequency has led to the appearance of earlier and larger priming effects in the L1-L2 than in the opposite direction, thus creating task effects if the task requires participants to use phonological and semantic information in L2. In fact, task demands have been shown to affect the outcomes of cross-language studies (e.g., Dijkstra et al., 1999; Lemhofer & Dijktsra, 2004).

Regarding noncognates, our results failed to show any significant interactions between prime and word types on the RT, accuracy, or ERPs in all time windows. Noncognates, however, produced fewer errors than LPS cognates in Persian-English and HPS cognates in English-

Persian directions. Insofar as the cognate effect has been established in the literature in a masked priming lexical decision task in different-script languages in the L1-L2 direction (Gollan et al., 1997; Jiang et al., 1999; Kim & Davis, 2003; Peeters et al., 2010; Voga & Grainger, 2007), the null effect for noncognates in the same direction appears to be specific to the Persian-English study. Previous studies reported noncognate effects in terms of faster and more accurate lexical decisions after presentation of related primes in different-script languages in the L1-L2 direction (Dimitropoulou et al., 2011; Gollan et al., 1997; Jiang et al., 1999; Jiang & Forster, 2001; Kim & Davis, 2003), but not in the L2-L1 direction (Gollan et al., 1997; Jiang & Forster, 2001; Dimitropoulou et al., 2011; Jiang et al., 1992).

Language proficiency is an essential factor in bilingual language research and. Thus it is a critical variable to consider in our studies. Proficiency is a factor that can explain the appearance of cognate and noncognate effects in L1 in balanced or early bilinguals. L2 proficiency also showed interactions with the cognate and noncognate effects (Nakayama et al., 2012 & 2013). In these studies, both types of words showed more priming effects for the low-proficiency than high-proficiency participants. In another study, more proficient participants showed facilitation, and less proficient participants showed inhibition when orthographic similarity of cognates increased (Broersma, Carter, & Acheson, 2016).

Thus, we tried to select advanced Persian-English speakers in all studies and control for this variable across the experimental conditions. First, participants had similar cultural backgrounds and studied in the same educational system. English is part of the educational curriculum in Iran and starts at senior high school. Also, English for specific purposes (ESP) is a compulsory course in undergraduate and graduate programs at university. Additionally, participating in language classes is common among individuals, especially those who have planned to continue studying abroad. Next, the participants in our study obtained high IELTS scores, with reading rates higher than monolinguals. High proficiency in English helped to ensure our findings, and especially the absence of the noncognate effects, were not due to low L2 proficiency.

One might argue that L2 proficiency and other individual differences within or across the experimental groups, such as the immigration date to Canada, might have influenced the results. For one, this study was not a mixed between-within factorial analysis, and we did not statistically compare the bilingual groups using an analysis of variance. Also, each individual performed on all word types in each condition. Finally, we are more confident about unsystematic differences among the participants when the sample size is 30 or more.

We attribute these unexpected findings for noncognates to the task requirements and language context specific to our studies and discuss the results in the context of the BIA+ model (Dijkstra &Van Heuven, 2002) in the following paragraphs.

**5.5.2. Partial support for the phonological account.**

The present study adds to the previous research by supporting the phonological account, which attributes the cognate effect to the phonological similarity of cognates and their semantic features across two languages. HPS cognates in the present studies showed significant effects in RT in English and Persian. Also, HPS cognates were the only stimuli that produced an early significant interaction effect of the prime and word type in the ERP analyses. However, LPS cognates showed facilitatory, inhibitory, and null effects in an unexpected pattern in Persian and English, which goes against one of the predictions of the phonological account. Indeed, the present findings do not support a gradual decrease in priming effects from cognates with higher phonological similarity to cognates with lower phonological similarity and to noncognates. Also, LPS cognates did not show more facilitative effects in the RT in English than noncognates. In fact, noncognates did not show priming effects for either language. Furthermore, contrary to our expectations, related primes decreased the RT in the Persian-English direction and not in the English-Persian direction in LPS cognates. The pattern for cognates and noncognates was even more complicated when the number of errors was analyzed. Contrary to our expectations, cognates did not elicit fewer errors than noncognates. Even HPS cognates elicited a different pattern of errors than LPS cognates across Persian-English and English-Persian experiments.

Previous research with same-script languages has shown that priming effects produce inhibitory effects at the lexical orthographic level due to the similarity of their orthographic forms across languages and the consequent competition between the items with similar spellings (Dimitropoulou et al., 2011). Cross-script studies have usually shown no competition at this level, as scripts are different (Ando, et al., 2015; Nakayama et al., 2012; Nakayama et al., 2014; Nakayama, et al., 2013; Kim & Davis, 2003; Zhou, et al., 2010). However, in our study, the phonological overlap across languages may have caused interference and created inhibitory effects for cognates in some experimental conditions. Indeed, differing degrees of phonological overlap created different outcomes for the number of errors in lexical decisions in both lists of cognates. Similar to our findings, Khan (2012) found unexpected results for cognates when she created balanced and unbalanced frequency lists to understand whether word frequency affected the processing of cognates in Urdu and English. The frequency of the prime and target words was the same (high-frequent prime and target, and low-frequent prime and target) in balanced lists, while it was different in unbalanced lists (high-frequent prime and low-frequent target and vice versa). She found a reverse cognate effect for the unbalanced frequency lists (high-frequent Urdu-low-frequent English; low-frequent Urdu- high-frequent English) and a lack of the cognate effect in Urdu. To explain the discrepancy between her results and those reported in the literature, she quoted Dijkstra and Van Heuven (2002). They attributed the different results across experiments where the same stimuli, task, and population are used to nonlinguistic factors including task demands or participant expectations rather than relative activation levels of cross-language items. A similar explanation could apply to our findings, as we observed inhibitory effects of cognates in the same population using the same task and stimuli.

Indeed, there is substantial evidence that task demands, participant expectations, and the strategies participants use to respond influence word recognition (e.g., Dijkstra et al., 1999; Lemhofer & Dijkstra, 2004). These variables might explain both the facilitatory and inhibitory effects in our study, as discussed below.

#### 5.5.3. Graded effects of cross-lingual phonological similarity

Although very speculative, our pattern of results may suggest that participants judged HPS cognates to be words borrowed from English but considered LPS cognates to be original Persian words. This hypothesis is supported by the finding that LPS cognates elicited more incorrect responses than HPS cognates and noncognates in Persian-English, and LPS cognates showed more priming effects than HPS cognates in the RT in the same direction. To explain the findings, we hypothesize that the high phonological similarity of HPS cognates across the languages misled participants into identifying HPS cognates as English words and LPS cognates as Persian words. This subjective categorization of the words may have interacted with reading the different Persian and English scripts. Indeed, one question that arises by this conjecture is whether the list of HPS cognates included more words of English origin than that of LPS cognates, and it was this issue that caused the unexpected pattern of results to occur. A close inspection of the stimuli showed that the HPS cognate list included one word of Persian origin, while the LPS cognate list included six words of Persian origin. Also, most words in either list were from Latin, French, Greek, Italian, Arabic, Spanish, etc. It is unlikely, however, that the derivation of the words would cause any effects because these loanwords have been used in Persian for many years, and few participants will know the etymology of the words. To illustrate, the word خاویار (*caviar)* is originally borrowed from Italian and Turkish, *تیفوس (typhus)* from Latin, and شکر *(sugar*) from Sanskrit by Persian, but few Persian speakers would be aware of the source of these words. Furthermore, we matched the lexico-semantic features of words such as frequency, concreteness, imageability, and familiarity with English words across the experimental conditions before data collection. Finally, these words were selected randomly and not based on specific contexts or genres. Indeed, as participants learned English as an L2, they might have seen those words in English texts more than in Persian texts. Such objective frequency changes familiarity to the words (i.e., subjective frequency), and as shown in Chapter 2, familiarity is the best predictor of lexical decision. The participants in our experiments were graduate students and advanced learners of English. However, they studied in different programs. Thus, they were exposed to different texts in English, which might have affected their familiarity with the English stimuli differently.

Another important issue to discuss is that the participants who judged the concreteness and imageability of concepts in Persian and familiarity to English words were different from the participants who took part in the main studies (Chapter 3 and Chapter 4, Experiment 2). We did not want participants to see the stimuli in advance of participating in a primed lexical decision task. It might be important to consider having the same participants make judgements regarding the word features after participating in the lexical decision task in future studies to account for individual differences.

In general, our findings support the claims made by the BIA+ model (Dijkstra & Van Heuven, 2002) and the Multilink model (Dijkstra et al., 2019), which postulate that a word identification and a task decision system with both bottom-up and top-down processing are responsible for visual word recognition. We, however, agree with Van Kesteren, Dijkstra, and De Smedt (2012) that a sublexical source of language membership information should be added to the BIA+ model, which may activate this information before full lexical access. We would also believe that allowing feedback from the language membership nodes to the lower level, as the Multilink model permits, can better explain our results. In accordance with these models, there are three tentative explanations for our findings. First, the expectations and strategies participants selected to accomplish the lexical decision task affected the accuracy of lexical decisions across the experimental conditions. We used a masked priming lexical decision task and before the task participants received the same written and oral instructions; they were asked to look at the screen, decide whether the item they saw on the screen was a word or nonword in English (Chapter 3) or in Persian (Chapter 4), and hit a specific button to indicate "yes" and another to indicate "no", as quickly and accurately as possible. The findings, however, suggest that the task language and script differences affected the participants' judgment. If this is indeed the case, participants would perform the actual task (i.e., lexical decision), a language decision task, or a combination of the two tasks over the course of the experiment. In a language decision task, a "yes" response is bound to lexical information in one of the languages, while a "no" response is tied to lexical information in the other language and nonwords. This explanation seems plausible, as it highlights the flexibility of stimulus-response bindings to participants' expectations and strategies observed in previous work (Dijkstra & van Heuven, 1998).

As such, our findings support the assumption that visual word recognition results from the cooperation of word identification and task/decision systems (BIA+, Dijkstra & Van Heuven, 2002). The word identification system works on the bottom-up linguistic information such as orthographic and phonological features of words and top-down information such as contextual particulars. The word identification system feeds the information to the task/decision system, as the one-sided arrow shows in Figure 1.2, and the task/decision system works on this output. We observed the facilitatory and inhibitory effects of related primes for cognates on the lexical decision, which was presumably initiated by the degree of phonological similarity in Persian and English. As Persian and English do not share scripts, the shared phonological features activated candidates from both languages after the orthographic information triggered the whole process. The model initiates the process with an early preconscious automatic level of processing and proceeds to an attention-sensitive level in which the task system adapts itself to the specificities of the task. Clearly, the task system is affected by the strategies that participants used to perform the task by providing the most relevant responses. Stated differently, within the BIA+ model, the task/decision system determines how to bind the outcome of the word identification system to the responses required to perform the task so that the best performance is achieved. In a similar vein, Khan (2012) explained her unexpected findings in Urdu-English by suggesting that both intra-level (e.g., word frequency) and extra-level (e.g., task demands) factors play a role in lexical decisions. The former is used by the word identification system and the latter by the task schema in the BIA+ model.

There is, however, one concern about an assumption of the model stating that the word identification system is modular and not affected by other components of the system. Modularity entails the automaticity of processing (Hartsuiker & Moors, 2017), and that is why the model proposes an early preconscious automatic level that reflects the function of the word identification system. However, we observed that LPS cognates did not elicit decreased RTs as expected in Persian. Similarly, noncognates failed to elicit decreased RTs in both English and Persian. We expected that similarity of form and meaning in LPS cognates and meaning in noncognates exerted facilitatory effects on the RT. It seems that the BIA+ model does not account for these observations and the hypothesized word identification system might receive feedback from task requirements or language membership information at some point during visual word recognition.

Within the BIA+ model and in the lexical decision task, the task system provides either a “yes” or “no” answer after the word identification system completes word processing and sends an output to it. When sufficient lexical information is provided by an activated candidate at a specific time, the task system binds it to a “yes” response, while lack of such information triggers a “no” response. Various sources of information are used in parallel in this process, but the BIA+ model gives the orthographic information a leading role. In bilinguals, the task lexical information functions independently of which language the word belongs to, and the task system binds “yes” to words and “no” to nonwords in either language without the language decision playing a role. However, our findings showed that this does not always occur, and presumably, the task system uses information provided by the language component. Stated differently, participants made both a language and a lexical decision in the experiments.

Language membership is the identification of a language to which a word belongs and is the function of language nodes in the BIA+ model. Language nodes use specific features of a word such as orthographic or phonological information to provide language tag representations by the connections they have with the language-specific form representations (Dijkstra & Van Heuven, 1998). Language nodes are located within the word identification system and are connected to it with one-sided arrows, meaning that language information does not influence word activation or the rejection of nontarget words, which is accomplished by the word identification system. The BIA+ model does not allow language nodes to receive any feedback from the task schema that uses nonlinguistic information (Figure 1.2).

According to the model, language nodes retrieve language membership too late to affect word identification. Research, however, has shown that language information becomes available early enough to be used by the word identification system and affects language and lexical decision tasks (Casaponsa, Carreiras, & Dunabeitia, 2015; Hoversten, Brothers, Swaab, & Traxler, 2017; Oganian, Korn, & Heekeren, 2016; Vaid & Frenck-Mestre, 2002; Van Kesteren et al., 2012). In fact, the language component can play an active role in the lexical decision, if necessary, with regard to the participants' expectations of the task and the strategies they adopt. For example, orthographic bias in Spanish and English modulated the N2 and the P3 components in posterior electrodes, 150-200 ms after the presentation of words and nonwords in Spanish-English bilinguals (Hoversten et al., 2017). These modulations were observed for words and nonwords before the N400, thus supporting a prelexical processing stage in which a bilingual brain decodes the orthographic language membership cues such as bigram frequency before a single lexical candidate is uniquely identified. Orthographic information such as illegal characters or marked orthographic bigrams also delayed both lexical and language decisions (Casaponsa et al., 2015; Oganian et al., 2016; Vaid & Frenck-Mestre, 2002; Van Kesteren et al., 2012). If this information were only available after lexical access, as the BIA+ model postulates, it could not influence lexical processing in real-time and might instead affect task/decision processes after lexical access (Van Kesteren et al., 2012). These findings support the proposal that language information is available before meaning is processed. Thus, it modulates cross-language activation, and contributes to subsequent suppression of nontarget language representations in case there are discrepancies in language membership information (Casaponsa et al., 2015; Casaponsa & Duñabeitia, 2016; Hoversten, Brothers, Swaab, & Traxler, 2015).

These findings strongly support the Multilink model (Dijkstra et al., 2019) because this model gives a more significant role to the language membership nodes and the task/decision system than the BIA+. The Multilink model permits language membership nodes to send feedback to the lower level of orthographic representations in the word recognition system (Figure 1.3). This model further allows the task/decision system to select particular representations for output, set parameters, and specify responses depending on the task and the incoming stimulus. This system examines the release of the response by checking task requirements such as the language membership of the input and output and the degree of orthographic, phonological, and semantic activation of words.

The second explanation is that "language context" (Comesana et al., 2014, p.3) interacts with the phonological similarity of words to affect visual word recognition. That is, phonological similarity interacted with the language direction to elicit more incorrect responses in English for LPS cognates but more incorrect responses in Persian for HPS cognates. Unexpected observations for cognates and the null effect of noncognates might have resulted from the manipulation of the phonological similarity of words to create cognates with varying levels of phonological similarity, leading to the specific composition of the list of stimuli used for the studies.

Similar to our study, Comesaña et al. (2014) observed that including two types of cognates and a group of noncognates in one experiment and removing identical cognates from the list in the second experiment produced two different outcomes. The authors specifically manipulated the degree of overlap between the orthographic and phonological features of identical and nonidentical cognates in Catalan-Spanish balanced bilinguals in Spanish, which was used less frequently than Catalan, in an effort to demonstrate cognate effects. In their Experiment 1, participants performed a lexical decision task on a list of identical cognates, nonidentical cognates, noncognates, and pseudowords. Cognates had different degrees of orthographic (O) and phonological (P) overlap; identical (O+P+, O+P-), and nonidentical (O-P+, O-P-). Only identical cognates produced faster responses than noncognates, while nonidentical cognates produced more errors than other stimuli, though nonsignificantly. Further analysis of their cognates showed faster performance on P- and more errors on O- words.

In Comesaña and colleagues' (2014) Experiment 2, identical cognates were removed from the list and nonidentical cognates were divided into high overlap (O+P+, O+P-) and low overlap (O-P+, O-P-) lists. The results showed that nonidentical cognates were processed more slowly than noncognates. The researchers used their findings to argue for the effect of language context, experimentally defined as the composition of the list of stimuli, and its interplay with the O and P representations of cognates. They concluded that the existence of identical cognates in their first experiment made the list of the stimuli a bilingual language context, allowing participants to use their stronger L1 links to the semantic representation of words to make a lexical decision in their nondominant language. Conversely, the removal of identical cognates from the list made it a monolingual language context in the second experiment. Thus, participants failed to take advantage of their stronger L1 links to send effective feedback to lower levels of processing. Furthermore, two O representations for nonidentical cognates made their processing slower than noncognates due to a competition between the two O representations.

To recap, when the task was in English, the list may have biased participants towards the

English language in our study. Thus, we found a facilitative effect in RT for HPS cognates, but this effect was smaller than the effect for LPS cognates; related Persian primes produce smaller effects in HPS than LPS cognates (21.15 ms vs. 40.55 ms, respectively). If we continue the same line of reasoning, HPS cognates produced more correct decisions than the LPS cognates, but the lower phonological similarity created inhibitory effects for LPS cognates. Indeed, lower phonological similarity suppressed correct lexical decisions for LPS cognates. Conversely, when the task was in Persian, the list biased participants in favor of Persian. High phonological similarity still decreased the speed of processing, but this effect was larger (45.40 ms) than the cognate effect observed for the HPS cognates in the first condition (21.15 ms). Similar patterns were reported by Nakayama et al. (2012), who observed larger priming effects for low-frequent word targets and less proficient participants in Japanese and English. In other words, related primes quickened the weaker condition more.

Inhibition is an essential part of the BIA+ model, the Multilink model, and Green's IC system (1998), as it can suppress the activated nontarget words to ensure the production of outputs only in the target language. However, the amount of inhibition depends on different mechanisms in these models. In the BIA+ and the Multilink model, the language node that is more strongly activated sends the activation to the most appropriate word in that language. This word crosses the recognition threshold in that language and is released, while the other activated candidates are inhibited. In the IC model, conversely, the amount of inhibition depends on language dominance, meaning that more inhibition is necessary to suppress the stronger dominant language than the weaker nondominant language.

As discussed, after input presentation and activation of the target and nontarget words in two languages, the word recognition system considers one language strong and the other weak.

This process originates from the stronger activation of the language tag in the BIA+ and Multilink and language dominance in Green's IC model. Afterward, inhibition suppresses the activated words in the weaker language. If we follow the same logic, English was a stronger language and context for the HPS cognates and noncognates in the lexical decision in English, but it was weaker for the LPS cognates. Thus, more priming effects occurred for the weaker LPS cognates than the other two types of words, and LPS cognates produced more incorrect responses. Conversely, Persian was considered a weaker language and context for HPS cognates and noncognates but stronger for the LPS cognates in the lexical decision in Persian. Thus, HPS cognates received more priming effects and were inhibited more strongly, resulting in more incorrect responses for this type of word.

The third explanation uses the lexical quality hypothesis (Perfetti & Hart, 2002). According to this hypothesis, visual word recognition results from the contribution of orthographic, phonological, and semantic components. These components are different in people with different reading abilities, which affects visual word recognition. Within this framework, Yates and Slattery (2019) argue that lexical decisions are made once the information in the response buffer reaches a threshold and that the time to reach the threshold is influenced by two sources: the quality of the orthographic connections in the reading system measured by spelling recognition, and the quality of the orthographic connections in the spelling system measured by spelling production. According to this hypothesis, the advantages one finds for a specific set of words in a language should also be tested against the quality of the orthographic connections in the reading system measured by spelling recognition and production. This can be a critical issue because reading in one language requires the consideration of how the orthographic information is formed in the memory (Holmes & Carruthers, 1998). Current models of spelling hold that an orthographic representation of a word is developed as a result of repeated exposures to the word in various contexts. This representation codes how the word is spelled (Brown & Ellis, 1994; Seymour, Bunce, & Evans, 1992) and underlies spelling recognition and production, and reading (Holmes & Carruthers, 1998).

## 5.6. Implications of Findings

On the one hand, the results of this dissertation contribute to the understanding of the cognitive processes that underlie visual word recognition in bilinguals who know languages with different scripts. We observed that HPS between words with shared conceptual features (i.e., cognates) facilitated visual word processing. This observation supports the models of bilingual word recognition that emphasize the role of phonological overlap in processing words in languages with different scripts. We observed that HPS cognates were processed faster than LPS cognates and noncognates. Faster processing of HPS cognates suggests that the processing is automatic (DeKeyser, 2001; Segalowitz & Hulstijn, 2005) and that the knowledge of HPS cognates is more implicit than the other two lists of words. It seems that bilinguals rely on L1 and use it when processing this word type (Ghazi-Saidi, 2012). However, the reliance is influenced by factors such as task requirements, language membership information, language context and the quality of orthographic information insofar as the lexical decision task is concerned.

On the other hand, these results should encourage language teachers to consider the significant role of cognates in expanding the learner’s vocabulary knowledge in L2 by relying on the equivalents of cognates in L1. Teachers can directly teach cognates (Proctor et al., 2011), emphasize the similarities between them in L1 and L2 (Bravo, Hiebert, & Pearson, 2007), or raise the learner’s awareness of cognates in two languages (A. Otwinowska-Kasztelanic, 2007b) and increase learning outcomes. These strategies can help both beginner and advanced learners of a language to expand their vocabulary knowledge in the L2 and increase their motivation to learn an L2 altogether.

Expressing the significant role of cognates in learning L2 vocabulary, Rusiecki (1980) listed 200 cognates in English and Polish. He suggested that these words are understandable by Polish speakers who do not have any knowledge of English. Otwinowska-Kasztelanic (2007b) referred to the great number of cognates that were shared between English and Polish (exceeding two and a half thousand words) and stated that these words are part of the lexicon of an educated adult. He cited research that showed how highlighting these cognates in beginner English classes enabled learners to use them in their speech and improve their language proficiency accordingly. In an oral description task, these learners displayed more confidence and willingness to take risks in using the same cognates. Interestingly, these cognates only appeared in the speech of advanced Polish learners of English after years of studying the L2. In fact, beginner English learners developed their vocabulary knowledge faster than advanced learners of English, as they were helped to notice cognates through an awareness-raising instruction. Research also showed that cognate-based instruction resulted in better learning and retention of English words in Laki-English (Amini & Salehi, 2017) and Persian-English (Gholami et al., 2015) bilinguals.

In the current study, we showed that the degree of phonological similarity of cognates in Persian and English influenced the speed of processing and accuracy rates in the lexical decision task in the L2 and L1. Persian-English bilinguals processed HPS cognates faster in both L1 and L2. However, accuracy rates differed in Persian and English; participants showed higher error rates for LPS cognates in English but higher error rates for HPS cognates in Persian. These results suggest that English teachers should consider the degree of phonological similarity of cognates and raise their learner's awareness of this word type . This dissertation did not have pedagogical goals to understand whether the degree of phonological overlap makes a difference in teaching cognates. Further research is required to clarify this issue.

This study has limitations related to sampling and the way lexico-semantic features of words were measured. These issues may limit the generalizability of the findings. The sample size across the experiments was different. Also, the mean age of the bilingual groups differed noticeably from that of the monolingual group, except the bilingual group who participated in Experiment 1 in the English-Persian Study with the mean age of 22 years old (Chapter 4). This group was closer in age to the monolingual group. The monolingual group was younger than the bilingual groups with the mean age of 18.53 (SD = 1.02), while the bilingual groups were older with the mean ages of 32.26 (SD = 5.67) and 29.69 (SD = 3.61) in the main experiments of this dissertation study (Persian-English in Chapter 3, and English-Persian, in Experiment 2 Chapter 4, accordingly). Bilingual participants were recruited through a combination of flyers and advertisements placed on boards or posted on the social media, and people who responded to the study invitation were graduates as well as masters and Ph.D. students at the time of this dissertation study. Accordingly, we selected this population and proficiency level in English.

One of the objectives of the study was to include lower- proficiency Persian-English speakers in the experiments to compare them with advanced Persian-English speakers. However, no one belonging to this population volunteered to participate in this study. On the other hand, monolingual speakers were undergraduate students recruited through the PREP, who participated in our study for course credits. We required that the monolingual group acquired English as their native language and that they did not have any knowledge of another language. Such a population is hard to find in Canada because a large proportion of the Canadian population speaks another language at home and students who receive their primary and/or secondary education in Canada are familiar with French. Monolingual participants, however, stated that they did not have any knowledge of a second language. We however can not eliminate the possibility that they might have had familiarity with French.

Second, the lexico-semantic features of words were measured using two samples that differed from the participants who performed the lexical decision task in the main EEG studies. Cognates were also divided into HPS and LHS cognates based on a questionnaire distributed among a different group of Persian-English bilinguals. Although it is common to use questionnaires to collect such information, this method may be subjective and sample dependent. Researchers advise that these features be measured in the sample who participates in the study.

Another limitation might be the differing ratios of female to male participants in the experimental and control groups. Current research indicates sex differences in specific cognitive abilities, with women showing superiority in verbal abilities compared to men (Ardila, Rosselli, Matute, & Inozemtseva, 2011; Herlitz, Airaksinen, & Nordström, 1999; Maitland, Herlitz, Nyberg, & Nilsson, 2004; Wirth et al., 2007).Words are recognized in three stages where (Zwitserlood, 1989) (a) word forms are extracted, and their semantic and syntactic features will be available, (b) one or more lexical representations are selected, and (c) lexical elements are integrated by being fit in higher order meaning representations.

Findings show that females are more likely to engage in the elaborative processing of the meaning of verbal (or verbally encoded) information than males (Maitland et al., 2004). Women showed advantages in higher-order semantic processing (third stage according to (Zwitserlood, 1989) in ERP studies. They showed an earlier and longer lasting effect in the N400 component when they read semantically related and unrelated word pairs. However, men and women did not show any differences in P1-N1 pattern supporting similar lexical semantic access in both sexes (Wirth et al., 2007) when the early and possibly automatic lexical–semantic access in visual word recognition is concerned (Sereno, K.F., & Posner, 1998; Sereno & Rayner, 2003). ERP studies also reported a larger amplitude in word reading, (from 70 to 1200 ms, Skrandies, Reik, & Kunze, 1999) and reduced latencies in the N4 component (Taylor, Smith, & Iron, 1990) in women.

On the other hand, researchers have found the linguistic superiority of females over males to have relatively small effect sizes, which explains about 1%-2% of the variance in the normal population (e.g., Wallentin, 2020). For this reason, gender differences in language are negligible when focusing on the whole population, but these differences manifest themselves when focusing on language deficits.

We believe no potential issues raised from this discrepancy in our study's results. Our purpose in these studies was to examine the effects of the degree of phonological overlap on the processing of cognates and noncognates, and both males and females performed the lexical decision on all three kinds of words in each study. For one, the interaction effect observed for HPS cognates occurred early, and previous studies failed to show any sex differences in the first stage of word recognition as defined by Zwitserlood (1989). Also, if we hypothesize that women recognized words differently from men, the effects should have been observed on all word types in our studies. There might be the possibility that gender interacts with word type or that nonlinguistic information and other cognitive control systems, and this interaction creates sex differences. Future research should address these issues. Overall, no reviewed studies considered sex a confounding variable in the visual recognition of cognates and noncognates.

## 5.7. Suggestions for Future Research and Conclusions

The findings of this dissertation can be investigated using tasks that create different expectations, and thus requiring participants to adopt various strategies to perform them. A similar study can be conducted using a masked priming paradigm with tasks such as go/no go and word-naming to change task requirements, while focusing on the meaning or formal features of words, respectively. It will also be critical to test the extent to which cognate primes with varying phonological similarities and noncognate primes in Persian and English can activate the conceptual features of target pictures. Using EEG, for example, can complement behavioral measures to determine the extent to which the phonological similarity of HPS cognates facilitates their speed of processing and conceptual understanding, removing the effect of language context or list composition. Also, EEG may show the effects that are still undetectable by behavioral measures. Indeed, we observed ERP effects for LPS cognates, which we predicted, occurred prior to behavioral effects. Finally, further studies could address these issues by manipulating language context in terms of the composition of the list of stimuli. Noncognates can be included in a list one time with and another time without LPS cognates to understand whether list composition can lead to different outcomes.

The present dissertation provides evidence for the key role of cross-linguistic phonological similarity of cognates in visual word recognition in the absence of orthographic overlap. By analyzing cognates and noncognates in Persian-English bilinguals, this dissertation has shown that higher phonological similarity of cognates in these languages provides advantages to visual word recognition, but the facilitative effects did not correlate with the degree of phonological similarity in cognates. Also, the absence of semantic priming for noncognates, which was unexpected, raises the question of why noncognates failed to show any advantages due to their semantic overlap in Persian and English. In line with the BIA+ model, the unexpected findings may be the result of the participants' expectations and strategies that they adopted to complete the task, and language context.

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# Appendices

**Appendix 1.** *List of Words in English and Persian, Low-Phonological Similarity Cognates (1), High-Phonological Similarity Cognates (2), Noncognates (3), and Fillers (4)*

| Type | Related list | Related List | Unrelated list | Unrelated list | Type | Related list | Related list | Unrelated list | Unrelated list |
|---|---|---|---|---|---|---|---|---|---|
| 1 | امبولانس | ambulance | شطرنج باز | Newspaper | 2 | اسپری | Spray | دانشیار | Fridge |
| 1 | خاویار | caviar | بلغور | plasma | 2 | استاندارد | Standard | نگهداری | treatment |
| 1 | آسم | asthma | سهم | gossip | 2 | برنز | Bronze | کلنگ | Oyster |
| 1 | اسفناج | spinach | نردبان | cactus | 2 | بلدوزر | Bulldozer | آشوبگر | cathedral |
| 1 | اسکلت | skeleton | لیموترش | musician | 2 | بیسبال | Baseball | چایخانه | downtown |
| 1 | باکتری | bacteria | سالنامه | machinery | 2 | پرسنل | personnel | سرزمین | ceremony |
| 1 | پری | fairy | گره | suite | 2 | پروتئین | Protein | دادستان | prophet |
| 1 | پسته | pistachio | کلاغ | clarinet | 2 | پسورد | password | سفارت | embassy |
| 1 | پیژامه | pajamas | رفوزه | flashlight | 2 | پیانو | Piano | دنده | mirror |
| 1 | توالت | toilet | آشپز | giant | 2 | تاکسی | Taxi | منشی | garage |
| 1 | تیفوس | typhus | چهره | samba | 2 | ترافیک | Traffic | لبخند | robbery |
| 1 | زعفران | saffron | استخر | asphalt | 2 | تست | Test | بافت | gold |
| 1 | ستاره | star | باشگاه | trip | 2 | تلفن | telephone | روزنه | cigarette |
| 1 | سوسیس | sausage | قصاب | trophy | 2 | توریست | Tourist | اجناس | sunlight |
| 1 | شامپانزه | chimpanzee | آدمکش | blackberry | 2 | دایناسور | Dinosaur | ویراستار | broccoli |
| 1 | شکر | sugar | طلوع | engine | 2 | دیپلمات | diplomat | دخانیات | organism |
| 1 | شکلات | chocolate | مدرس | magazine | 2 | راکون | Raccoon | کاموا | Seagull |
| 1 | غزال | gazelle | مغول | apron | 2 | رستوران | restaurant | تلسکوپ | Gentleman |
| 1 | فرمول | formula | تسخیر | calendar | 2 | روبات | Robot | معتاد | Peanut |
| 1 | قناری | canary | روسری | fabric | 2 | سمینار | Seminar | حکومت | Junction |
| 1 | کابل | cable | ساقه | flesh | 2 | سیندروم | syndrome | پارکینک | Prophecy |
| 1 | کاندیدا | candidate | مخترع | specimen | 2 | صندل | Sandal | اجازه | Cabbage |
| 1 | کلوپ | club | آجر | month | 2 | فسیل | Fossil | قلاب | Gadget |
| 1 | کنگره | congress | خواننده | gravity | 2 | کایاک | Kayak | خنچه | Veggie |
| 1 | گروه | group | ساعت | crime | 2 | گلف | Golf | تابه | Photo |
| 1 | لب | Lip | دام | arrow | 2 | لنز | Lens | عرش | Grape |
| 1 | لیمو | lemon | روضه | parade | 2 | لیست | List | چشم | Store |
| 1 | ماموت | mammoth | کمد | seaside | 2 | وبسایت | Website | قلمرو | Cupcake |
| 1 | موش | mouse | تور | hawk | 2 | تایر | Tire | چکمه | Apes |
| 1 | مومیایی | mummy | کوتوله | snack | 2 | بازار | Bazar | هدف | Teacup |
| 1 | ویروس | virus | خنده | drama | 2 | تومور | Tumor | ذغال | Stamp |
| 1 | یاسمن | Jasmin | دلاور | sunrise | 2 | کیوسک | Kiosk | چماق | Teapot |

| Type | Related list | Related List | Unrelated List | Unrelated list | Type | Related List | Related list | Unrelated list | Unrelated list |
|---|---|---|---|---|---|---|---|---|---|
| **3** | چکش | Hammer | کپک | pepper | 4 | تئوری | theory | فردوس | Pride |
| **3** | موم | Wax | تز | Pond | 4 | تونل | tunnel | باغچه | Sweat |
| **3** | افق | Horizon | سحر | pilgrim | 4 | جنگل | jungle | دندان | Outfit |
| **3** | پشیمانی | Regret | بیهودگی | silence | 4 | رادیاتور | radiator | نمکدون | handicap |
| **3** | تاجر | Merchant | سرمه | restroom | 4 | کاراته | karate | صرافی | haircut |
| **3** | تاریکی | Darkness | دریچه | gambling | 4 | کازینو | casino | تنبک | Dragon |
| **3** | تنوع | Diversity | مراتب | hesitation | 4 | کوپن | coupon | منار | Pupil |
| **3** | جایزه | Prize | زندان | Swell | 4 | مولکول | molecule | سرخرگ | novelist |
| **3** | حضار | Audience | آیینه | shoulder | 4 | ویولن | violin | کبابی | Tomato |
| **3** | حلقه | Ring | روغن | Fish | 4 | تهدید | threat | اجلاس | Image |
| **3** | خوابگاه | Dormitory | بیابان | dressmaker | 4 | چادرنشین | nomad | دریاسالار | Shaver |
| **3** | خواربار | Grocery | اتاقک | lemonade | 4 | خزنده | reptile | ماهیگیر | chemist |
| **3** | خویشاوند | Relative | گردگیری | magician | 4 | خطا | error | عقد | Theft |
| **3** | دامن | Skirt | جلگه | ladder | 4 | خمیازه | yawn | نسکافه | Sieve |
| **3** | دستبند | Bracelet | قولنامه | terminal | 4 | خیریه | charity | فاجعه | romance |
| **3** | رژلب | Lipstick | سیسمونی | umbrella | 4 | رفتار | behavior | محور | objection |
| **3** | سرباز | Soldier | گوساله | medicine | 4 | سرطان | cancer | مسافر | Script |
| **3** | سیاره | Planet | گردن | licence | 4 | پاک کن | eraser | نیشکر | Mover |
| **3** | صنعت | Industry | رسانه | territory | 4 | سیخ | skewer | قوچ | Faucet |
| **3** | عابر | Pedestrian | سپر | calculator | 4 | مخلوط | mixture | گلچین | rotation |
| **3** | عضو | Member | نش | senior | 4 | واکنش | reaction | فراغت | comfort |
| **3** | علم | Science | برق | travel | 4 | کابوس | nightmare | نزاع | underwear |
| **3** | گورخر | Zebra | تپانچه | cradle | 4 | شکم | tummy | مورچه | Milk |
| **3** | مایع | Liquid | آرد | bicycle | 4 | رحم | womb | مودم | Rice |
| **3** | محقق | Researcher | رودخانه | bridegroom | 4 | نمودار | chart | پیامک | Sport |
| **3** | مشتری | Customer | فرزند | incident | 4 | مداد | pencil | وکیل | Flower |
| **3** | معجزه | Miracle | مقصد | desire | 4 | روح | ghost | سود | Nerve |
| **3** | مغز | Brain | ماست | Gold | 4 | ماسک | mask | کاسه | Sand |
| **3** | میانبر | Shortcut | خلبان | opponent | 4 | دهکده | village | آسفالت | Library |
| **3** | میوه | Fruit | سوخت | Wolf | 4 | شامپو | shampoo | هیزم | Turkey |
| **3** | شعر | Poem | چاپ | Item | 4 | کاندو | condo | پانیز | Squad |
| **3** | گنجشک | Sparrow | هزارپا | lettuce | 4 | ملت | nation | هنر | Effect |
| 4 | بژ | Beige | خیش | Geese | 4 | روبان | ribbon | کهیر | Priest |
| 4 | گالری | Gallery | پرسش | cocktail | 4 | قرن | decade | قصد | Writer |
| 4 | گرامر | Grammar | سمفونی | refund | 4 | خرگوش | rabbit | انگور | Orange |
| 4 | لامپ | Lamp | نقب | crown | 4 | قفس | cage | بلیت | Deck |
| 4 | متد | Method | ترشی | virtue | 4 | موشک | rocket | غنچه | Jacket |
| 4 | منو | Menu | زنگ | Sofa | 4 | دلقک | clown | انجیر | Beast |
| 4 | باطری | Battery | گوهر | railroad | 4 | شکوه | glory | پوسته | Radar |
| 4 | پروژکتور | Projector | نگارستان | tablecloth | 4 | پل | bridge | باغ | Pocket |

**Appendix 2.** *Features of Cognates and Noncognates of Persian and English Words Across High-Phonological Similarity Cognates (HPS), Low-Phonological Similarity Cognates (LPS), and Noncognates (NC) in Related (R) and (U) Unrelated Conditions, Persian-English Study*

| | **Persian primes** | | | | | | **English targets** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **LPS** | | **HPS** | | **NC** | | | | |
| | | | | | | | **LPS** | **HPS** | **NC** |
| | **R** | **U** | **R** | **U** | **R** | **U** | | | |
| The number of phonemes | 5.75 (1.48) | 5.75 (1.48) | 6.22 (1.56) | 5.75 (1.48) | 5.69 (1.38) | 4.78 (1.54) | 5.66 (1.56) | 5.66 (1.42) | 6.19 (1.67) |
| The number of letters | 4.94 (1.41) | 4.63 (1.26) | 5.56 (1.68) | 5.06 (1.37) | 4.78 (1.54) | 4.78 (1.39) | 6.47 (1.7) | 6.41 (1.78) | 6.81 (1.73) |
| Frequency per million | 62.42 (217.97) | 69.63 (213.52) | 56.03 (119.25) | 54.30 (114.23) | 65.33 (109.01) | 65.58 (107.66) | 17.26 (24.02) | 15.41 (21.02) | 18.26 (21.02) |
| Neighborhood density | - | - | - | - | - | - | 2.85 (5.18) | 2.72 (3.72) | 2.56 (3.96) |
| Concreteness | 3.83 (.79) | 3.66 (.73) | 3.80 (0.69) | 3.51 (.86) | 3.45 (0.86) | 3.58 (.83) | - | - | - |
| Imageability | 3.93 (.75) | 3.89 (.66) | 3.96 (.63) | 3.73 (.65) | 3.88 (.58) | 3.8 (.66) | - | - | - |
| Pronunciation similarity | - | - | - | - | - | - | 4.23 (.38) | 2.61 (.33) | |
| Familiarity | - | - | - | - | - | - | 2.79 (.85) | 2.63 (.84) | 2.53 (.66) |

**Appendix 3.** *One-way ANOVA on the Word Features of Persian Words Across Word Types. Number(No), related(R), unrelated (U).*

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| **R_No_letters** | **Between Groups** | 11.02 | 3.00 | 3.67 | 1.59 | 0.196 |
| | **Within Groups** | 280.18 | 121.00 | 2.32 | | |
| | **Total** | 291.20 | 124.00 | | | |
| **R_No._Neighbors** | **Between Groups** | 1419.00 | 3.00 | 473.00 | 0.70 | 0.553 |
| | **Within Groups** | 80921.87 | 120.00 | 674.35 | | |
| | **Total** | 82340.87 | 123.00 | | | |
| **R_frequency** | **Between Groups** | 34847716.91 | 3.00 | 11615905.64 | 0.44 | 0.722 |
| | **Within Groups** | 3137695933.98 | 120.00 | 26147466.12 | | |
| | **Total** | 3172543650.88 | 123.00 | | | |
| **R_imageability** | **Between Groups** | 1.93 | 3.00 | 0.64 | 1.42 | 0.241 |
| | **Within Groups** | 54.56 | 120.00 | 0.45 | | |
| | **Total** | 56.49 | 123.00 | | | |
| **R_concreteness** | **Between Groups** | 1.55 | 3.00 | 0.52 | 0.75 | 0.146 |
| | **Within Groups** | 82.71 | 120.00 | 0.69 | | |
| | **Total** | 90.26 | 123.00 | | | |
| **R_No_Phonemes** | **Between Groups** | 5.69 | 3.00 | 1.90 | 0.82 | 0.483 |
| | **Within Groups** | 278.34 | 121.00 | 2.30 | | |
| | **Total** | 284.03 | 124.00 | | | |
| **R_frequency_Mahak** | **Between Groups** | 9161347781.92 | 3.00 | 3053782593.97 | 0.33 | 0.802 |
| | **Within Groups** | 1110667123832.52 | 121.00 | 9179067139.11 | | |
| | **Total** | 1119828471614.43 | 124.00 | | | |
| **R_frequency _milllion** | **Between Groups** | 19982.83 | 3.00 | 6660.94 | 0.33 | 0.802 |
| | **Within Groups** | 2422599.35 | 121.00 | 20021.48 | | |
| | **Total** | 2442582.18 | 124.00 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **U_No_letters** | **Between Groups** | 3.18 | 3.00 | 1.06 | 0.56 | 0.641 |
| | **Within Groups** | 228.29 | 121.00 | 1.89 | | |
| | **Total** | 231.47 | 124.00 | | | |
| **U_No_Neighbors** | **Between Groups** | 1714.16 | 3.00 | 571.39 | 0.75 | 0.522 |
| | **Within Groups** | 91682.36 | 121.00 | 757.71 | | |
| | **Total** | 93396.51 | 124.00 | | | |
| **U_No._Neighbors** | **Between Groups** | 59184686534.76 | 3.00 | 19728228844.92 | 1.04 | 0.376 |
| | **Within Groups** | 2249102509424.37 | 119.00 | 18900021087.60 | | |
| | **Total** | 2308287195959.13 | 122.00 | | | |
| **U_Imageability** | **Between Groups** | 1.31 | 3.00 | 0.44 | 0.96 | 0.415 |
| | **Within Groups** | 55.08 | 121.00 | 0.46 | | |
| | **Total** | 56.39 | 124.00 | | | |
| **U_Concreteness** | **Between Groups** | 0.72 | 3.00 | 0.24 | 0.37 | 0.778 |
| | **Within Groups** | 79.30 | 121.00 | 0.66 | | |
| | **Total** | 80.02 | 124.00 | | | |
| **U_frequency_Mahak** | **Between Groups** | 11707768523.08 | 3.00 | 3902589507.69 | 0.45 | 0.721 |
| | **Within Groups** | 1060166416481.60 | 121.00 | 8761705921.34 | | |
| | **Total** | 1071874185004.67 | 124.00 | | | |
| **U_frequency_million** | **Between Groups** | 25537.11 | 3.00 | 8512.37 | 0.45 | 0.721 |
| | **Within Groups** | 2312446.65 | 121.00 | 19111.13 | | |
| | **Total** | 2337983.76 | 124.00 | | | |

**Appendix 4.** *One-way ANOVA on the Word Features of English Words Across Word Types. Number(No), related(R), unrelated (U).*

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| R_familiarity | Between Groups | 1.11 | 3.00 | 0.37 | 0.61 | 0.612 |
| | Within Groups | 72.30 | 119.00 | 0.61 | | |
| | Total | 73.41 | 122.00 | | | |
| R_ familiarity _sum | Between Groups | 235.51 | 3.00 | 78.50 | 0.53 | 0.205 |
| | Within Groups | 17773.22 | 119.00 | 149.35 | | |
| | Total | 194108.73 | 122.00 | | | |
| Pronunciation | Between Groups | 42.12 | 2.00 | 21.06 | 187.19 | 0.000 |
| | Within Groups | 8.66 | 77.00 | 0.11 | | |
| | Total | 50.78 | 79.00 | | | |
| R_No._letters | Between Groups | 15.68 | 3.00 | 5.23 | 2.11 | 0.102 |
| | Within Groups | 349.38 | 141.00 | 2.48 | | |
| | Total | 365.06 | 144.00 | | | |
| R_No._phonemes | Between Groups | 9.71 | 3.00 | 3.24 | 1.41 | 0.395 |
| | Within Groups | 324.66 | 141.00 | 2.30 | | |
| | Total | 344.37 | 144.00 | | | |
| R_frequency_million | Between Groups | 150.36 | 3.00 | 50.12 | 0.14 | 0.938 |
| | Within Groups | 51566.50 | 141.00 | 365.72 | | |
| | Total | 51716.86 | 144.00 | | | |
| R_No._Neighbors | Between Groups | 1.59 | 3.00 | 0.53 | 0.03 | 0.992 |
| | Within Groups | 2347.85 | 140.00 | 16.77 | | |
| | Total | 2349.44 | 143.00 | | | |
| U_familiarity | Between Groups | 2.22 | 3.00 | 0.74 | 1.53 | 0.211 |
| | Within Groups | 57.67 | 119.00 | 0.48 | | |
| | Total | 59.89 | 122.00 | | | |
| U_familiarity _sum | Between Groups | 31 | 3.00 | 1043.26 | 1.43 | 0.237 |
| | Within Groups | 86739.54 | 119.00 | 728.90 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Total | 89869.32 | 122.00 | | | |
| U_No._letters | Between Groups | 8.10 | 3.00 | 2.70 | 1.03 | 0.381 |
| | Within Groups | 313.99 | 120.00 | 2.62 | | |
| | Total | 322.09 | 123.00 | | | |
| U_No._phonemes | Between Groups | 5.84 | 3.00 | 1.95 | 0.81 | 0.491 |
| | Within Groups | 288.90 | 120.00 | 2.41 | | |
| | Total | 294.74 | 123.00 | | | |
| U_frequency_million | Between Groups | 961.72 | 3.00 | 320.57 | 0.85 | 0.468 |
| | Within Groups | 45133.94 | 120.00 | 376.12 | | |
| | Total | 46095.66 | 123.00 | | | |
| U_No._neighbors | Between Groups | 2.53 | 3.00 | 0.84 | 0.08 | 0.970 |
| | Within Groups | 1240.15 | 120.00 | 10.33 | | |
| | Total | 1242.68 | 123.00 | | | |
| Nonword_prime_letter | Between Groups | 6.04 | 3.00 | 2.01 | 0.75 | 0.526 |
| | Within Groups | 323.40 | 120.00 | 2.70 | | |
| | Total | 329.44 | 123.00 | | | |
| Nonword_prime_phoneme | Between Groups | 1.24 | 3.00 | 0.41 | 0.18 | 0.908 |
| | Within Groups | 270.43 | 119.00 | 2.27 | | |
| | Total | 271.67 | 122.00 | | | |
| Nonword_frequency | Between Groups | 552.81 | 3.00 | 184.27 | 0.60 | 0.613 |
| | Within Groups | 36579.77 | 120.00 | 304.83 | | |
| | Total | 37132.59 | 123.00 | | | |
| Nonword_No._letters | Between Groups | 8.45 | 3.00 | 2.82 | 1.12 | 0.343 |
| | Within Groups | 353.99 | 141.00 | 2.51 | | |
| | Total | 362.44 | 144.00 | | | |
| Nonword_No._neighbors | Between Groups | 37.03 | 3.00 | 12.34 | 1.07 | 0.363 |
| | Within Groups | 1622.86 | 141.00 | 11.51 | | |
| | Total | 1659.89 | 144.00 | | | |