Cross-Language Morphological Activation: The Case of Arabic-English Bilinguals

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DEDICATION

To my seven-year-old son Mohammed, and my two-year-old son Milad; I love you to the moon and back. It is true that your growing desire that I leave my desk and come play with you may have caused some delays in the writing of many parts of this work, but the joy, happiness, and sense of responsibility which you brought to my life allowed me to go back and write twice as fast!

Having you by my side has filled every day of my life with an ineffable sense of peace and comfort.

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ABSTRACT

The role of morphology in bilingual lexical access is an under-investigated topic. Due to the overrepresentation of concatenative-based languages which inherently cannot adequately isolate effects of morphology from those of orthography and semantics, morphological processing had been relegated to a secondary role in lexical access. The present research utilized Arabic, a non-concatenative Semitic language, to investigate the role of morphology in bilingual language processing. Two experiments using translation recognition and masked lexical decision were conducted with Arabic-English bilinguals to answer two research questions: 1) Does (Arabic) morphology mediate cross-language activation? and 2) Is Arabic-English cross-language morphological activation task-dependent? Mixed effects models were employed to analyze Reaction times (RT) and Accuracy rates.

The results of both experiments suggest that morphological activation in the mental lexicon—in Semitic languages at least—is robust such that not only does activation spread
within language via morphology, but also across languages via morphological mediation. Further, the results showed that cross-language morphological activation cannot be explained by orthographic or semantic confounds. Morphological activation, thus, is not a result of the combined processing activity of orthography and semantics, as previously claimed.
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CHAPTER ONE: INTRODUCTION

Words are the backbones of human languages. It is true that in theory words are not the smallest unit of languages, but in practice they are the basic blocks from which meaning can be extracted. Indeed, we turn to dictionaries because of words. And probably two of the most common questions when learning a second language are, ‘how do you spell this word?’ or, ‘how do you pronounce that word?’

Although vocabulary knowledge is essential, and it is the first step in decoding the meaning of a text, we rarely think about how vocabulary knowledge is stored in and retrieved from our brains, or how lexical items from both languages are represented in the brain. Lexical access/retrieval does not only entail retrieving the semantic codes of a given word—which is simply the end-product of the lexical access process—but also capturing the orthographic, phonetic and morphological information. Psycholinguistic theories make different claims about the role of such linguistic dimensions in structuring and influencing the mental lexicon.

In the domain of bilingual lexical access, the reservoir from which linguistic information is gathered is much larger. For instance, bilinguals have at least two distinct labels for every concept, let alone the additional morphological, phonological and orthographic systems that they draw from. This leads to the logical question of how our brains channel activation through the relevant linguistic system while preventing interference from the other. Or how such a complex linguistic reservoir, which includes elements from both languages, is structured and controlled.
In language production, at least, it appears that bilinguals enjoy a good command of their choice of language use. In language comprehension, however, we cannot be quite sure how the existing cross-linguistic knowledge influences language processing and decoding. It is true that the bilingual subject does not seem to suffer overt intrusions from one language while reading a text in the other language for example. But to what extent does this overt ease with which bilinguals control the two languages entail a seemingly straightforward mental architecture through which processing flows? Researchers, therefore, seek to reveal the covert mental processing with which recourses from the two languages are regulated.

**Statement of the Problem**

Recent advances in the field of bilingual lexical access have informed us that the linguistic information from both languages collectively influences lexical processing. The term cross-language activation has been coined to suggest that lexical representations, along with their linguistic dimensions (e.g., phonology, orthography, semantics and morphology), from both languages are simultaneously activated, even in a single language context and without much control on the part of the bilingual subject. That is, bilinguals cannot simply shut off access to linguistic cues from one language while functioning in the other.

Upon closer scrutiny of the current literature, it can be concluded that the role that each dimension of linguistic representation (i.e., phonology, morphology, orthography and semantics) plays in structuring and influencing bilingual lexical processing is not of the same weight. For example, researchers have repeatedly shown that lexical activation can spread across languages based on phonology, orthography or semantics, which means that these linguistic dimensions represent a solid mental space through which activation is regulated.
Morphological representations, on the other hand, have traditionally been fused with the interplay between those of phonology/orthography and semantics (Boudelaa & Marslen-Wilson, 2004). Such fusion might not mirror the reality because phonology/orthography, semantics and morphology are three distinct domains of knowledge, each providing a unique type of information about lexical items (Boudelaa & Marslen-Wilson, 2005). That being said, unlike phonological/orthographic and semantic representations, morphological units are relegated to a secondary role in the current literature (Boudelaa & Marslen-Wilson, 2005).

The type of languages studied, to date, in lexical access research might have caused this dilemma. That is, most of what we know about bilingual lexical access in general, and morphological representations in particular, comes from research based on typologically similar Indo-European languages. Most Indo-European languages exhibit what is called concatenative morphology. In languages of this type, morphemic units are strung or concatenated in a linear manner. Consequently, any morphological relationship between lexical items is also confounded with semantics, phonological and orthographic relationships. In English, for example, the lexical items card/cards or friend/friendly are not only related morphologically, but also semantically, phonologically and orthographically. Thus, “the very nature of concatenative morphology makes it difficult to clearly tease apart effects of morphology from those of semantics and phonology and/or orthography” (Boudelaa & Marslen-Wilson, 2000, p. 32).

Non-concatenative languages such as Arabic or Hebrew, however, provide a way of resolving this issue. In such language systems, word building is not carried out in a linear manner. Morphological structure is complex, where morphemic units are intertwined one within the other (Boudelaa & Marslen-Wilson, 2000). Therefore, morphological relationships
in surface forms are independent of orthographic/semantic relationships. The nature of such languages makes them a fertile ground for investigating the role of morphology as constructing a separate mental representation (Boudelaa & Marslen-Wilson, 2005).

In the monolingual context, Arabic (due to its non-concatenative morphology) has already been exploited in many investigations which revealed important insights regarding the role of morphology in lexical access. For instance, we now know that activation not only spreads through semantics or phonological/orthographic relatives, but also through morphological relatives. On the contrary, the bilingual context suffers a dearth of research in this area. For example, and parallel to the monolingual research, we need to know if morphology—like phonology/orthography and semantics—mediates cross-language activation.

**Purpose of the Study**

Because empirical work on non-concatenative morphology in the bilingual context is scarce, the current study sets out to investigate the role of Arabic morphological representations in Arabic-English bilingual lexical processing. Research on phonological/orthographic and semantic representations in both monolingual and bilingual settings shows that such representations constitute a separate mental space through which activation spreads. Morphological representations, on the other hand, have been studied extensively only in the monolingual setting, which leaves a gap in our understanding of how morphological units influence the structure and activation of the bilingual mental lexicon.

Within this context, the first research question guiding this investigation is: 1) Does (Arabic) morphology mediate cross-language activation? Also, based on the fact that the sole
published work to find evidence that morphology influences bilingual lexical access was from a study that required conscious translation by the participants, I consider the possibility that cross-language morphological activation is task-dependent; hence, I ask: 2) Is Arabic-English cross-language morphological activation task-dependent?
CHAPTER TWO: LITERATURE REVIEW

Psycholinguists in the field of lexical access seek to answer questions such as how people take input from the environment (spoken or written) and match it to stored representations in the mind; they consider the nature of these representations and how they are connected. It is obvious that when you recognize a word, or see a word, you access its meaning (its semantic representation). This process of word-meaning mapping is obvious because it is what we can consciously observe. Nevertheless, lexical access is an incremental subconscious process, which tracks down the course of word recognition from the single phoneme input to the retrieval of a target word, along with its linguistic information.

Lexical access appears as a virtually effortless rapid process. However, below the level of consciousness lies a complicated mechanism which allows us to make sense of a given string of letters or string of phonemes. Lexical access models, which we turn to now, are designed to simulate such complex processes and provide a clear description of the different steps involved in matching a sensory input to stored lexical representations.

Models of Lexical Access and Language Processing

Theories of lexical access date back to the early 1970s (Kroll & de Groot, 2005). However, it was not until computational modeling had prospered that lexical access theories became more robust (Kroll & de Groot, 2005). Nowadays, computational models are considered essential for most language processing theories. In addition, such models are evaluated based on their capability of simulating empirical data (Kroll & de Groot, 2005).

Besides relying on computational simulations, most lexical access models are inspired by neural network models, and draw their broader architecture from connectionist
Connectionist principles, for instance, dictate that any form of processing involves simple processing nodes (analogous to neurons in the neural network) connected bidirectionally within a network. The nodes have different levels of activation (analogous to a firing rate), and influence each other’s activation, relative to their connection strength. Therefore, the models to be reviewed are called connectionist models, where the process of lexical access resembles, more or less, how neurons in the brain function.

Since the present manuscript focuses on bilingual lexical processing, the bulk of this section will cover models of bilingual language processing. However, such models, in one way or another, borrow their basic structures and tenets from monolingual models. Therefore, this section starts with a review of one monolingual model, setting the stage for the subsequent description of the bilingual language processing models.

Monolingual Lexical Processing

The TRACE Model

One of the earliest and most comprehensive accounts of how people match external stimuli with stored representations is the TRACE model (McClelland & Elman, 1986). TRACE is a connectionist localist model and was developed in two stages. The first phase of the model was called the Interactive Activation Model, which was put forward by McClelland and Rumelhart (1981). The interactive activation model was concerned with visual inputs only, that is, how people access stored forms based on visual stimuli. In 1986, however, McClelland extended the model to cover auditory stimuli. Therefore, TRACE, the final product, is a model for visual and auditory input.
According to McClelland and Rumelhart (1981), TRACE has three main properties. First, it enjoys three processing levels: feature level, letter/phoneme level and word level. Second, all connections between the levels are only excitatory, while connections within the levels are both inhibitory and excitatory. A third property of the model is that TRACE is highly interactive, where both bottom-up and top-down processes interact in recognizing the input. The notion of associating individual processing units with a priori linguistic elements (e.g., features, letters/phonemes, words), each constructing a separate realization, is what makes a model localist, as opposed to distributional models in which patterns of activation across multiple nodes are associated with linguistic units (Kroll & de Groot, 2005).

The basic level, from which processing starts, is the feature. In the feature level, there are feature detectors, one for each of several dimensions of speech sounds or visual shapes. These features can be short lines in different orientations, for visual processing, or acoustic cues, for auditory processing. The second level is where information about the letters (in case of visual input) and phonemes (in case of auditory input) are processed. Like the feature level, there are detectors for every letter and phoneme in the letter/phoneme level. The third level also has detectors for every word form representation, and it is where information about words are accessed (see Figure 1 and 2).
Figures 1 and 2. Basic architecture of TRACE. Connections with arrows at the end indicate excitatory influences; connections with round ends indicate inhibitory influences (McClelland & Rumelhart, 1981).

Each detector in every level is connected to the detectors in the following level. Such detectors influence one another relative to their activation level. The network is called “Trace” because the pattern of processing travels across the three levels, tracking and tracing the input, until a positive identification of a given word is detected.

The connections between the detectors are bi-directional. In addition, the network enjoys parallel processes. For example, as partial recognition of a feature occurs, a signal is sent to the letter level, which also sends a signal to the word level, all occurring simultaneously. The connections are also bi-directional in that once the beginning of a word becomes active, a signal is sent back to the letter level confirming the identification of the
letter. That is, activation travels back and forth in an interactive pattern until a whole word becomes active.

When a feature is detected in the input such as a vertical line, activation travels to all letters containing that feature (see Figure 3). Therefore, the letters H, N, M, etc., become activated. At the same time, the activated letters send within-level inhibitory connections to the other letters that lack this feature. In addition to sending within-level inhibitory connections, the activated letters also send excitatory connection to the word level, where the word(s) containing the letters become activated. The activated word(s) send feedback to the letter level, which reinforces the activated letters in the word.

![Figure 3. The interconnections of features in the visual input (McClelland & Rumelhart, 1981)](image)

Note that connections between levels are only facilitatory. That is, when a feature is identified, a facilitatory signal is sent to the letter level where all letter detectors sharing the same feature become activated. However, connections within levels are inhibitory. That is,
the activated letters inhibit each other’s activation level until a single one is left standing based on subsequent input from the feature level. In other words, the letter with the most support from the bottom-up features wins the activation.

So far, I have discussed the bottom-up nature of the model. In TRACE, top-down processes are essential to the activation of stored representations as well. McClelland and Rumelhart (1981) call bottom-up processing, “data driven,” because it relies on the given input as visual or auditory. Top-down processing, however, is called “conceptually driven” because it relies on the existing knowledge about word forms and their frequency. Top-down and bottom-up processing determine what we perceive in a joint manner.

When a word starts to be activated, our existing knowledge of this word sends top-down facilitatory activation to the letter level. For example, when stem starts to be activated as a result of bottom-up processing (i.e., from the letters s and t), our knowledge of what word might include this string of letters will cause the remaining letters of the word to be activated, e and m. That is, e and m in stem can be activated in the word level even before they receive bottom-up input.

This last point was discovered through what has been called the ‘word superiority effect,’ (Reicher, 1969) where recognition of letters and phonemes is faster and seemingly effortless when embedded in real words than when isolated or in pseudowords. TRACE perfectly explains this effect by suggesting that activation at the word level precedes that in the letter/phoneme level, which facilitates recognition of letters/phonemes in real words (Eysenck & Keane, 2010).

TRACE can also explain the ‘lexical identification shift’ (Ganong, 1980). In this phenomenon, identification of a phoneme category is influenced by word context. Norris,
McQueen, and Cutler (2003) had participants listen to words ending in the phoneme /f/ or /s/. In a different condition, these two phonemes were replaced by ambiguous sounds that were equally similar to /f/ or /s/ in their phonetic features. Listeners then had to categorize the ambiguous sounds as being /f/ or /s/. It turned out that those who heard the ambiguous sounds in the context of /s/ ending words favored the /s/ categorization. Nevertheless, those who heard the same ambiguous sound in the context of /f/ ending words favored the /f/ categorization. As predicated by TRACE, it seemed that top-down processing from the word level influenced phoneme categorization.

**Bilingual Lexical Processing**

*The Bilingual Interactive Activation Model Plus (BIA+)*

The discussion in this sub-section is divided into two parts. I first lay out a model that details the process of lexical access for bilinguals, mirroring that of monolinguals. The discussion then focuses on fundamental issues regarding the representation of cross-language knowledge in the bilingual brain.

The Bilingual Interactive Activation Model Plus (BIA+) is an extension of the original monolingual TRACE model discussed above. The BIA+ model was developed in two phases (Dijkstra & van Heuven, 2002; Dijkstra & van Heuven, 1998), but my discussion will be restricted to the updated version (i.e., BIA+), which overcomes the shortcomings of the original model (i.e., BIA). The BIA+ portrays bilingual lexical access as involving two coordinated processing systems: identification system and task/decision system.

**The Identification System.** The basic structure and functions of the identification system of BIA+ resemble those of the original TRACE model. The identification system has a single goal of identifying potential word candidates which match the evolving input the
best. It consists of five layers of nodes, representing five levels: features, letters/phonemes, words, semantics and languages. The feature level carries sub-lexical information corresponding to the two languages that the bilingual speaks. Similarly, the letter level contains units representing each letter from both languages. The word level consists of units for each word stored in the memory from both languages. The semantic nodes serve to supply the semantic information of the activated words from both languages. The representation of words in BIA+ reflects the integrated nature of the model where lexica from both languages are blended in one mental space. Furthermore, because letter/phoneme units activate words from both languages, the model adopts the assumption of non-selective access.

Non-selective access contrasts with another well-known hypothesis called selective access. Non-selective access maintains that bilinguals possess an integrated lexicon in which words from both languages are activated simultaneously during input processing. Bilinguals cannot control which language is activated or inhibited. In contrast, selective access holds that bilinguals have two independent lexica, corresponding to each language, which are selectively activated or inhibited. However, due to the integrated lexicon (i.e., non-selective access) that the BIA+ model assumes, language nodes are added to the system, which function to control language selection. That is, activated words, from either language, feed activation forward to the corresponding language node (see Figure 4). In addition, language nodes assist in identifying word candidates based on linguistic top-down/language-to-word processes.
There are connections between nodes at each level, as well as connections within levels. Therefore, features are connected to letters, which in turn are connected to words, etc. At the same time, letter units are interconnected, and word units are interconnected, etc. At each level, units that are consistent with the signal coming from the level below it are excited, whereas those inconsistent are inhibited. In addition, activated units in the word level feed activation back to the letters of which they are composed.

The visual input to the model activates corresponding sub-lexical and lexical representations, which in turn activate words and their phonological representations (from both languages simultaneously). Semantic information then becomes active, which generates

Figure 4. The identification system of BIA+. Arrowheads indicate excitatory connections; Circle heads indicate inhibitory connections (Dijkstra & Van Heuven, 2002)
feedforward input to the language nodes. Language nodes collect incoming activation signals and inhibit language-switching to lexical entries from the alternative language. Language nodes also interact with the initial word candidates selection based on top-down linguistic cues such as sentence context or previous linguistic knowledge. Therefore, the output of the identification system is competing word candidates from both languages, but with varying levels of activation.

The level of activation of a target word hinges, in part, on its frequency and its relation to other words in the lexicon (Dijkstra & Van Heuven, 2002). Between-language word frequency is accounted for in BIA+ by assuming various resting-level activations (see Figure 5). Words with high frequency are assigned higher resting-level activation, which means that such words need minimal input to be activated relative to competing but low frequency words. This mechanism applies to words in both languages simultaneously. Therefore, L2 vocabulary (assuming L2 is the non-dominant language) are represented with lower resting-levels compared to competing items from L1.

Figure 5. Illustration of how higher frequency words have higher resting level of activation than lower frequency words

Besides the frequency of the target word, the density and frequency of the competitors also influence recognition time. Activation of a target word can be slowed down
when competitors with higher frequency exist. However, the identity of the target word is
resolved with sufficient bottom-up input. In light of the above, the activation level of a given
target is determined by factors such as frequency of the target word, and its within- and
between-language neighbors (i.e., number and frequency of overlapping words—
competitors). Nevertheless, if the two languages differ in scripts, the number of competing
words—on the basis of orthography—can be much smaller, or even restricted to within-
language competition only. That being said, activation can also spread cross-linguistically on
the basis of phonology and semantics (Dijkstra & Van Heuven, 2002).

Phonological and semantic representations from both languages are activated slightly
later during word processing. Due to the assumed low resting-level of L2 words, their
Corresponding phonological and semantic codes will be delayed in activation relative to the
L1 codes. The delay assumption has been labeled ‘temporal delay assumption’ (Dijkstra &
Van Heuven, 2002).

The temporal delay assumption predicts that cross-linguistic effects based on
phonology or semantics are larger from L1 to L2 than vice versa, which has been
demonstrated experimentally (Dijkstra, Grainger, & Van Heuven, 1999). In addition, such
effects can be absent if the given task allows for direct processing of the faster codes (i.e.,
orthographic codes for L1), which will leave the slower codes (i.e., semantics and
phonology) no time to affect processing. This second assumption has also been demonstrated
in a “yes” or “no” lexical decision task on interlingual homographs (Dijkstra & Van Heuven,
2002). In this task, participants could use their knowledge from both languages (Dutch and
English in this case) to decide if the presented stimulus was a word (YES) or non-word (NO).
It turned out that the slower codes did not show any effects due to the demands for faster
processing of the faster code. That is, the response was based on the fastest available codes, i.e., the dominant language orthography.

**The Task/Decision System.** What we have witnessed so far in BIA+ is mainly activation connections, whether feedforward or feedbackward. Such processing can only nominate word-candidates which best match the input signal based on backward/forward connections (i.e., bottom-up data-driven process or top-down linguistic process). However, this mechanism is not sufficient for a successful output of the model, which is where task/decision schema comes in handy.

Dijkstra and van Heuven’s (2002) BIA+ model is influenced by Green’s (1998) findings, which show that task context by itself significantly alters bilinguals’ language control. Bilinguals’ performance in lexical decisions fluctuate as a function of experimental/trial differences, participant expectations or instructions. Such non-linguistic aspects are deemed contributing factors in word recognition (Green, 1998). Thus, in trying to accommodate this perspective, Dijkstra and Van Heuven assigned non-linguistic functions to the task/decision system, which affects the output criteria of the identification system and serves by arriving at one final recognized item.

Another reason for establishing a different layer of representation (i.e., task/decision schema) comes from studies investigating interlingual homophones or cognates (Dijkstra & Van Heuven, 2002). Interlingual homographs are words that are identical in orthography in two languages but which differ in meaning (e.g., ROOM in English and Dutch ‘cream’). Cognates are words sharing orthography and meaning in two languages (e.g., FILM in English and Dutch). The identification system alone cannot disambiguate interlingual homographs and cognates. The language node’s function of assigning words to languages is
not enough to arrive at one single lexical item for recognition. In case of cognates, for instance, the output of the identification system will be activating both cognate words from both languages without a mechanism to select/inhibit one. Furthermore, studies have shown that recognition of interlingual homograph reading is delayed, which shows that a different mechanism must be involved at later stages of processing to modify the output criteria of the system.

The task/decision system handles top-down information arising from non-linguistic factors such as instruction, task demands, task context or participant expectancies. The task/decision system does not influence the identification system directly, but rather leads only to an adaptation of decision criteria. After the identification system nominates word candidates based on bottom-up/top-down linguistic input, such information is handed over to the task/decision system to carry out the remainder of the task. The task/decision system determines which actions must be executed for a given task. For example, in case of parallel activation of interlingual homographs based on the identification system, the task/decision system favors the English equivalent if the task requires it and vice versa (see Figure 6).
Furthermore, this property of the model serves different language modes based on the input context (Holman & Spivey, 2016). That is, if the bilingual has been exposed to many English words only, the model will function in monolingual mode and will be relatively slow in processing incoming Dutch words and vice versa. If the bilingual has been exposed to alternating input between English and Dutch (as in code-switching), the model will be in bilingual status primed to process words from both languages. In fact, bilinguals in the laboratory exhibit wide cross-language activation when in a mixed language context, but relatively little cross-activation of the non-target language when in a single language context, which is the predicted effect of the BIA+ model (Holman & Spivey, 2016). This context
effect, guided by the task/decision system, explains how bilinguals limit interference from the irrelevant language.

*The Organization of the Bilingual Brain: Word Association Model vs. Concept Mediation Model*

One of the most persistent questions concerns the level of representation at which the two languages interconnect. In particular, previous research has tackled the issue of whether or not the two languages draw from the same conceptual memory. It was traditionally assumed that when bilinguals learn the second language, they usually do so by rote memorization, whereby the L2 labels are associated with the L1 labels. Therefore, in this sense, the L2 is connected to the L1 at the lexical level, rather than the conceptual level, to which only the L1 is associated.

Two prominent models of interlanguage connection provide different accounts of how the bilingual memory is organized: word association and concept mediation (Potter, So, Von Eckardt, & Feldman, 1984). In the word association model, L2 words are associated with L1 words such that L2 words can only access concepts through L1 mediation. That is, L1 is associated with the concept level but L2 is not. On the other hand, the concept mediation model proposes that both L1 and L2 have direct equal links to the conceptual level. In addition, both models make equivalent claims regarding images, which are linked directly to the conceptual level (see Figure 7). The latter claim is supported by both models due to previous research which has shown that words in L1 are named faster than images in L1 (Theios & Amrhein, 1989). The delay in picture naming was attributed to the fact that pictures are recognized only after concepts have been retrieved, which leads to correct
naming. However, plain word naming does not require accessing the concepts (Potter et al., 1984).

The shared assumption regarding images has been used as a basis for understanding the validity of the two models in explaining memory representation of bilinguals (Kroll & Stewart, 1994). That is, because the word association model assumes that L1 and L2 are directly connected in the lexical level, while images are connected to the concept level, then translation from L1 to L2 should be faster than naming images in L2. An individual translating from L1 to L2 would need to rely on overt lexical links which bypass conceptual access. The same individual, however, would need more time to name images in L2 since it requires accessing the conceptual level, and then the L1 labels, which ultimately leads to retrieving the L2 labels.

On the other hand, because the concept mediation model assumes that all L1, L2 and images have direct connections to the conceptual level, then translation into L2, as well as naming images in L2, should yield similar performance. That is, the individual will need to access the concepts in both conditions.
Potter et al. (1984) put this to the test with a group of Chinese-English bilinguals. The participants had to name pictures in L2 and translate words into L2. The results showed that naming in L2 and translating into L2 is virtually the same. In other words, both naming images in L2 and translating into L2 are concept-mediated, which is in line with the concept mediation prediction.

Explicit evidence for accessing the conceptual level in L2 comes from studies that manipulate the semantic relation of the stimuli (Kroll & Curley, 1988). Kroll and Curley (1988) argued that if the concept level is directly mediating L2, then manipulating the degree of semantic similarity of the stimuli should yield different reaction times. They presented participants with the regular picture naming and translation tasks. However, this time the stimuli were presented either in semantically categorized condition (e.g., words or pictures for clothing), or mixed condition (e.g., words or pictures for food, clothing and weapons all mixed together). The assumption was that if L2 has access to the concept level, then participants would benefit from presenting the stimuli in categorized blocks, relative to the mixed blocks.

Presenting the stimuli in categorized lists indeed affected reaction times, which proves that L2 is directly influenced by and connected to the concept level. However, the type of the effect was counterintuitive. It was expected that having semantically categorized lists would accelerate reaction times, where participants name (or translate) items faster when they appear in a coherent semantic theme rather than when they are in mixed groups. Contrary to this prediction, participants were slower in naming (or translating) in the categorized condition, relative to the mixed condition. That is, the effect was of interference rather than facilitation (Kroll & Curley, 1988).
According to Kroll and Stewart (1994), the interference effect in naming (and translating) in the semantically categorized list is due to the growing activation of related concepts. Multiple related lexical items are activated, which causes interference in choosing a best candidate. On the other hand, lexical items in the mixed condition are distinct along with their conceptual representations, which makes picking out a best candidate relatively effortless.

Further fine-tuning of the concept mediation model has revealed that the connection between L2 and the conceptual level is mediated by the level of competence in and exposure to the L2, as well as how the L2 was acquired (immersion vs. classroom) (Kroll & Curley, 1988). Kroll and Curley (1988) conducted a study with a wider range of bilinguals who varied in their L2 proficiency. For those who had studied the L2 for less than two years, translation was faster than image naming, which signified that L1 and L2 are linked in the lexical level (hence support for the word association model). However, for those who had studied the L2 for more than two years, translation and naming images was the same, which suggested that L2—as well as images—is concept-mediated (hence support for concept mediation model). The researchers concluded that bilingual memory displays a developmental shift, where it starts out resembling the word association architecture, but shifts toward the concept mediation architecture across development.

Another way of accommodating the two models is by suggesting that both models are accurate but simply differ in the links to the concept level. That is, both models assume that L1 lexical items and L2 lexical items are stored separately. In addition, both L1 and L2 share a common abstract concept level, regardless of how each is connected to the concept level.
Therefore, both models share the same hierarchy representation but differ in how each language finds its way to the concept level (Kroll & Stewart, 1994).

That being said, neither of the aforementioned reconciliations—developmental shift nor sharing a hierarchy representation—makes claims regarding the strength of connections in the models. That is, both word association and concept mediation models propose that L2 either has direct links to the L1 in the lexical level (word association) or through the concept level (concept mediation), but they do not talk about the nature and strength of such links, which leads to considering the next model.

**The Revised Hierarchical Model (RHM)**

Based on the previous two models, we would expect no difference between forward translation (i.e., L1 to L2) and backward translation (i.e., L2 to L1), since the links are of similar magnitude in both models. However, research shows that bilinguals are consistently faster in backward than in forward translation. Such translation asymmetry calls for modifications to the architecture of the previous models (Kroll & Stewart, 1994).

To accommodate the suggested reconciliations of the previous two models along with the translation asymmetry issue, the Revised Hierarchical Model (RHM) proposes that there are links connecting all the levels, but that the links differ in magnitude as a function of the relative frequency of the L2 and dominance of the L1 (see Figure 8). Therefore, unlike the word association model, the RHM dictates direct links between L2 and the concept level. Similarly, unlike the concept mediation model, RHM suggests direct bidirectional lexical links between L1 and L2. Furthermore, the RHM implements the following modifications. First, L1 is represented as having larger mental space, which reflects its dominance. Second, lexical associations from L2 to L1 are stronger than those from L1 to L2, which reflects the
natural initial direction of association when learning a second language. Third, both L1 and L2 have direct links to the concept level, but the links are stronger in case of L1 (Kroll & Stewart, 1994).

The RHM mimics the trajectory on which we learn our first and second language (Kroll & Stewart, 1994). That is, the first language establishes strong links with the concept level, where lexical items in L1 are connected to concepts. During the early stages of L2 learning, lexical items in L2 are associated with the L1, rather than the concepts. However, as proficiency in the L2 increases, direct links between L2 and concepts are established, but remain weaker than those between L1 and concepts. In addition, the initial lexical links from L2 to L1 do not disappear.

Based on the given model structure, RHM assumes that backward translation (single word translation) is lexically driven. Moreover, forward translation is conceptually mediated. Consequently, translation in the second condition should take longer than that in the first condition. Furthermore, because translation from L1 to L2 is conceptually-mediated, it

\[ \text{Figure 8. The Revised Hierarchical Model (Kroll & Stewart, 1994)} \]
should be sensitive to manipulation in the conceptual information. On the contrary, translation from L2 to L1 should be relatively immune to such manipulation. Lastly, the model predicts that recall of information should be better in case of forward translation since it is conceptually mediated (Kroll & Stewart, 1994).

Kroll and Stewart (1994) assessed such assumptions with a group of Dutch-English bilinguals. The participants completed translation and picture naming tasks in both languages. The stimuli were either presented in semantically categorized or mixed lists. At the end of the experiment, the participants completed a recall task where they listed as many words as possible from the previous conditions.

The results of the experiment supported the predictions made by the RHM (Kroll & Stewart, 1994). Participants were significantly faster in translating the words from L2 to L1, than the other way around. In addition, a significant effect of type of list (categorized or not) was observed when translating into L2, but not in the case of translating into L1. This proves that translating into L2 is conceptually mediated. Furthermore, recall was significantly facilitated only when the participants were translating from L1 to L2 due to the involvement of conceptual mediation, which also provides additional support to the conceptual links to the L1.

Linguistic Knowledge in the Bilingual Brain:

Language Selective vs. Language Non-Selective Access

Aside from the architectural map of how words from both languages are represented, and now that we have established that words from both languages build up links in the lexical level and to the conceptual level across development, a subsequent question arises: Can
bilinguals control access to a specific language? One of the long-lasting debates in the psycholinguistic literature is whether bilinguals can control access to just the linguistic elements associated with the language which is specified by the given context (Bijeljac-babic, Biardeau, & Grainger, 1997). The particular questions that surface in this area are as follows: in processing one language, are lexical items from the other language activated (i.e., cross-language activation)? Can bilinguals inhibit lexical items from the non-target language while functioning in the other language? On the surface level, it appears that bilinguals have a good command of their choice of language use, but how well does such overt ease of command reflect the inner covert mental processing?

Two prominent overarching theories of lexical access, which attempt to explain the process of lexical activation for bilinguals, are language selective access and language non-selective access (Dijkstra & van Heuven, 1998). Language selective access specifies that bilinguals can avoid interference from one language by suppressing it when working in the other language. As such, entrance to either language is selectively accessed. On the contrary, language nonselective access suggests that lexical representations from both languages are simultaneously activated during word input processing, even in a single language context and without much control on the part of the bilingual participant. That is, when bilinguals read/hear a lexical item in one language, activation spreads to overlapping content from both languages non-selectively, resulting in cross-language activation. For example, research on cognates suggests that bilinguals are faster to process/recognize cognates than monolinguals. The faster recognition was attributed to the fact that, for bilinguals, activation of cognates receives support from both languages rendering an assisted, thus faster, activation. Conversely, activation of cognates comes from one source for monolinguals (Dijkstra & Van
Heuven, 2002). In addition, research on translation recognition has repeatedly shown that bilinguals automatically and unconsciously activate the non-target language translation equivalent when processing lexical items in a target language (Gollan, Forster, & Frost, 1997; Grainger & Frenck-Mestre, 1998).

Broadly speaking, the selective/nonselective dispute is now almost settled due to mounting evidence in support of the latter (Dijkstra & van Heuven, 1998). Nevertheless, nonselective access is not a dichotomy of all-or-none. Historically, when addressing the selective /non-selective distinction, researchers tend to treat words as non-decomposed units containing the semantic, morphological and phonological/orthographic information. However, a more sophisticated view is one which distinguishes between the semantic, orthographic, phonological and morphological information (Dijkstra & van Heuven, 1998), and how each contributes to the process of lexical access.

Consequently, researchers began approaching the language access topic not only from a whole-word perspective, but also turned to the constituents that make up those words and started to examine their contribution to the language non-selective access issue. Therefore, representations at the semantic level, in particular, had long been believed to be accessed across-languages non-selectively (Dijkstra & van Heuven, 1998). Phonological (Nakayama, Sears, Hino, & Lupker, 2012) and orthographic codes (Bijeljac-babic et al., 1997) were also almost unanimously accepted as being shared and accessed across-languages non-selectively (only in same-script languages for the latter).

That said, such broad acceptance of non-selective access does not eliminate factors which can modulate or hinder the process such as language dominance, script similarity, proficiency level, direction of access (from L1 to L2 vs. L2 to L1), or the specific constituent
in question (Kroll, Sumutka, & Schwartz, 2005; Poarch & van Hell, 2014; Xia & Andrews, 2015).

For example, bilingual speakers of specific languages can experience cross-language activation via phonology (Duyck, 2005), but less so via morphology (Duñabeitia, Dimitropoulou, Morris, & Diependaele, 2013). Furthermore, a considerable number of studies have suggested that cross-language activation is asymmetrical, with the dominant language (L1) activating and interfering with the non-dominant language (L2) but not the reverse (Jiang & Forster, 2001; Keatley, Spinks, & Degelder, 1994; Xia & Andrews, 2015). Additionally, morphological representations, in particular, are understudied. The role of morphology as mediating the process of cross-language activation is yet to be clarified. Hence, the present study serves this purpose by examining the role of morphology in bilingual lexical processing. Based on the aforementioned, when we talk about non-selective access, it is important to refer to the specific linguistic dimensions (phonology, semantics, etc.), as well as the direction which drives the nonselective access, for this process is not all-or-none.

**Cross-Language Activation**

There is abundant evidence which shows that lexical items from both languages are simultaneously activated through phonology/orthography or semantics. For example, Japanese-English bilinguals were faster to recognize English targets (e.g., guide) when primed by phonologically related Japanese words (e.g., /gaido/), relative to when primed by unrelated words. Nakayama et al. (2012) concluded that the phonological representations pertaining to both languages are integrated and accessed non-selectively. Researchers witnessed similar findings when the prime-target pairs posed semantic (Guasch, Sanchez-
Casas, Ferre, & García-Albea, 2011) or orthographic (for same-script languages) overlaps (Bijeljac-babic et al., 1997). Therefore, it appears that cross-language activation is mediated via phonology, orthography and semantics, separately. But how about morphology?

Can one give morphology similar weight to that of phonology/orthography and semantics and assume that cross-language activation is mediated through morphology? Before we can look into the contribution of morphology into the process, it is imperative to first recognize the genuine differences between phonology, orthography and semantics on the one hand, and morphology on the other.

**The Mechanism of Cross-Language Activation**

As explained in the TRACE and the BIA+ models, initial linguistic input to the mental lexicon activates potential word candidates. For example, the phonological sequence of /ka/ activates word candidates such as CAT, CAN and CAR. In the bilingual domain, activation spreads to word candidates in both languages non-selectively. That is, shared phonetic codes activate matching word candidates in both languages. For example, for an English-Spanish bilingual, the phonological sequence of /pɛː/ activates PEAR from English and PERRO from Spanish. This form of activation is referred to as either bottom-up activation or data-driven. It is bottom-up because it starts from the lower levels of activation, which are the features/phonemes (see above). Cross-language activation via orthography flows similarly but is based on visual input, where shared visual codes activate matching letters, and then word candidates in both languages. The Spanish orthographic form of PERRO, for instance, activates the English word PARROT, based on the bottom-up form overlap.
Cross-language semantic activation, on the other hand, is facilitated through a higher shared conceptual level, which is accessed by both languages (Kroll, Van Hell, Tokowicz, & Green, 2010). After the bottom-up activation has completed via shared acoustic/visual signals (phonology/orthography), word candidates become activated and are assigned to the corresponding language. Higher conceptual processing then takes place which activates the translation equivalents of the activated words in the other language, and any related forms, through association across languages non-selectively.

For instance, in Xia and Andrews’ study (2015), Chinese-English bilingual participants were faster to recognize the English word FOX when primed by its translation equivalent in Chinese 狐狸, relative to a control condition. This shows that bilinguals access the semantically equivalent item in the non-target language non-selectively (i.e., the translation). Not only that, but Spanish-Basque bilinguals were faster to recognize the Basque word AULKI, “chair,” when primed by the Spanish associatively related word MESA, “table.” These forms of semantic cross-language priming are triggered by shared conceptual processes.

Where morphological representations are concerned, monolingual and bilingual models of lexical access fall short in providing direct explanation of the role of morphology in lexical access. Nevertheless, it is a truism that, unlike phonology/orthography and semantics, morphemes are not shared across-languages; thus, cross-language morphological priming does not operate based on shared representations, which gives rise to a distinct stage of within-language processing. Indeed, current empirical work on morphological representations in bilinguals shows that cross-language morphological activation adheres to interwoven levels of activation (Duñabeitia et al., 2013; Kim, Wang, and Ko’s, 2011). In
such studies, the only way for cross-language morphological priming to occur is through non-target translation activation and within-language morphological decomposition.

For example, for the Arabic hikmah, “wisdom,” to prime GOVERNMENT, morphological decomposition of hikmah must take place first. Based on morphology, activation will spread within-language to morphologically related forms, among which is huku:mah, “government.” Upon activating huku:mah, its translation equivalent in English (GOVERNMENT) will also become active.

To reiterate, morphological cross-language activation is different in mechanism than phonological, orthographic and even semantic cross-language activation. Phonological and orthographic cross-language activation necessitate bottom-up, data-driven processing that is manifested in overt shared representations in the two languages. Semantic cross-language activation is mediated by higher shared conceptual links. On the other hand, morphological cross-language activation demands within-language morphological decomposition, combined with activating the translation equivalent in the non-target language.

What makes the mechanism of cross-language morphological activation unique is that whereas almost all languages share similar sets of sounds, alphabets (in cases of same-script languages) and concepts, they diverge in their morphological systems. Morphology tends to be language-specific in that each language is relatively distinct in how its morphemes are structured. Since morphology is language-specific, then cross-language morphological activation must involve within-language morphological processing. Therefore, before we can understand the role of morphology in the bilingual context, it is necessary to examine the status of morphological priming in the monolingual context. In other words, since cross-
language morphological activation requires a stage of within-language morphological processing, it is imperative to first examine within-language morphological processing.

The Role of Morphology in Monolingual Lexical Access

Models of monolingual lexical access have thoroughly scrutinized the role of phonology/orthography and semantics. Such linguistic constituents (i.e., phonology/orthography and semantics) are now widely believed to construct cognitive space and to influence the structure of the mental lexicon. Nevertheless, morphological roles have not been given as much attention or, at best, have been fused with the interplay of those of phonology/orthography and word meaning (Boudelaa & Marslen-Wilson, 2004b). Such fusion is problematic since phonology and orthography (form), semantics and morphology are three distinct domains of knowledge. Each provides a different type of information about lexical items (Boudelaa & Marslen-Wilson, 2005). That being said, morphological aspects do not have explicit representation in the monolingual lexical access models (Boudelaa & Marslen-Wilson, 2005).

An essential area of experimental monolingual research is in whether morphemes have a role in structuring the mental lexicon that is independent of phonological, orthographic or semantic involvement. However, most of what is known about lexical access relates to a few Indo-European languages, which are inherently immune to dissociating the role of morphology from semantics and phonology/orthography (Boudelaa & Marslen-Wilson, 2001). Because such languages cannot clearly show the role of the morpheme as an abstract cognitive organizing unit, its role has not yet been fully explored (Boudelaa & Marslen-Wilson, 2005).
Most of the morphology in Indo-European languages is concatenative, where word building is achieved by stringing or attaching morphemes one after the other (e.g., un-employ-ment) Hence, the orthographic/semantic integrity of the bare root is preserved. Consequently, any morphological relationship between lexical items is also confounded with semantic, phonological and orthographic relationships. For instance, the lexical items employ, employment and unemployment are related morphologically (they all share the same root), but also semantically, phonologically and orthographically. Thus, almost any experimental endeavor to isolate morphological effects is doomed to fail due to utilizing materials from concatenative languages, which are inherently resistant to proper morphological dissection. Stated differently, “the very nature of concatenative morphology makes it difficult to clearly tease apart effects of morphology from those of semantics and phonology and/or orthography”.

On the contrary, Semitic languages such as Arabic exhibit non-concatenative morphology. In this type, the bulk of word building is non-linear. Morphemes are intertwined and dispersed within the word as in huku:mah, “government,” and hikmah, “wisdom.” Although the two previous words are related in morphology (they both share the same root: H, K, M), the orthographic/semantic relationship of the two words is disrupted. Therefore, morphological relationships can be somewhat independent of form/meaning relationships. The nature of such languages makes them a fertile ground for investigating the independent role of morphology in the mental lexicon (Boudelaa & Marslen-Wilson, 2005).

**Morphology in Arabic**

Before reporting the findings of empirical research on Arabic morphological priming, I begin by briefly elaborating how Arabic morphology is structured. The most common type
of morphological formation cross-linguistically is affixation, which concerns attaching elements to a base form in a linear manner (Matthews, 1972). This is evident in most Indo-European languages such as English; where affixes and suffixes are appended to a base morpheme in a concatenative fashion to generate new inflected forms while the base morpheme remains intact.

Arabic—and other Semitic languages—on the other hand, exhibits a less common way of morphological formation. As a non-concatenative language, Arabic does not follow a linear system in adding elements to a bare morpheme. The surface form in Arabic can be decomposed into at least two bound morphemes: a root and a word pattern (Holes, 2004). Roots consist only of consonants and carry the broad semantic information of the word. Word patterns, on the other hand, consist primarily of vowels, but can also include consonants. Word patterns convey the morpho-syntactic information (Holes, 2004). Therefore, an item such as [naqala] “move,” can be analyzed into a root [ngl] and a pattern [faʕala]. Note that the pattern functions as a template, and its generic (i.e., fʕl) sequence can be replaced by any actual root. Such word patterns do not carry semantic meanings but simply dictate the morpho-syntactic information (i.e., syntactic meaning). However, the root (i.e., ngl) carries the broad meaning of, “movement or the act of moving.” Such broad meaning indicated by the root can vary in its case, state, tense, gender or number by being embedded into a word pattern that specifies such qualities. That is, the word pattern functions to slightly adjust the broad meaning according to the desired morphological property (i.e., male or female, nominative or accusative, singular or plural, indefinite or definite, etc.) (Holes, 2004).
Arabic has a number of fixed generic word patterns which any given root can adopt to provide the desired morpho-syntactic meaning. In our example, the root [ngl] can be inserted in the generic pattern [faːʕilun], which will render it [naːqilun], “one who moves.” By adopting other word patterns, we can ultimately have [nuqlatun] “a move”, [nuqila] “be moved.” Note that the same root (i.e., ngl) surfaces in all the previous word pattern examples (in bold). Similarly, one word pattern can be applied to different roots. For example, the generic word pattern [faːʕilun], which has the syntactic meaning of, “active participle,” can be used with numerous roots, but the same morpho-syntactic relation is preserved (e.g., [naːqilun] “one who moves,” [qaːtilun] “one who kills,” [kaːtibun] “one who writes,” [faːtiḥun] “one who opens,” etc. (Boudelaa & Marslen-Wilson, 2001).

Such division of root and word pattern in Arabic morphology is widely accepted and recognized by both native speakers and researchers (Boudelaa & Marslen-Wilson, 2004a). However, psycholinguists seek to corroborate if such division is also perceived cognitively. That is, is the mental lexicon structured in a way where a layer of morphological representation is accessed and processed? As stated before, morphological representations are commonly considered an end-product of the interaction between semantics and form. However, Arabic provides a chance for researchers to look into the possibility that morphological units are, in fact, separate cognitive processing units, such that their access is necessary for the successful identification of a given word.

According to Boudelaa and Marslen-Wilson (2000), what makes the root—which the present research focuses on—in Arabic a valuable domain for investigating the role of morphology independently of semantic and phonological/orthographic factors, is that the root surfaces in a word in a discontinuous manner. Consequently, a morphologically related pair
will have no exact left-to-right or right-to-left form overlaps (unlike, for instance, the case of the English pair *pain*-*painful*). Furthermore, and more importantly, some morphologically related pairs do not share obvious semantic relations. That is, roots in Arabic are highly productive in that they occur in many surface forms. Such surface forms sharing a root can have relatively strong-to-weak-to-no obvious semantic relationships, which makes an investigation of a relatively pure morphological nature feasible.

**Morphemes as Cognitive Units: Evidence from Arabic**

Boudelaa and Marslen-Wilson have carried out extensive work on the processing of Arabic morphology from a psycholinguistic perspective (Boudelaa, 2014; Boudelaa & Marslen-Wilson, 2001, 2004a, 2004b, 2005, 2011, 2013, 2015, 2000). Their very first finding that morphemes construct a distinct mental representation paved the road for more work on Arabic (Boudelaa & Marslen-Wilson, 2000). Such findings sparked additional investigations on related psycholinguistic topics such as the structure of the root in Arabic (Boudelaa & Marslen-Wilson, 2001), the internal structure of word patterns in Arabic (Boudelaa & Marslen-Wilson, 2004a), the mental representation of allomorphic variations in Arabic (Boudelaa & Marslen-Wilson, 2004b), and the time course of lexical access in Arabic (Boudelaa & Marslen-Wilson, 2005).

In 2000, Boudelaa and Marslen-Wilson investigated the status of the root as a potential abstract lexical unit in Arabic. The priming conditions presented to the participants were as follows: a pair sharing a root with semantic overlap *ʔidxaːl*- *duxuːl*, “inserting-entering,” a pair sharing a root but without semantic overlap *muḍaxaːlh*- *duxuːl*, “call-entering,” and other conditions to control for orthography and other confounds. The main findings of this experiment suggested that root priming was obtained without semantic
support. Pairs sharing the root—not semantics—facilitated each other’s recognition. That is, muda:xalh, “call-in,” activated duxu:l, “entering,” before the latter was even presented. This showed that the root was an underlying mental representation through which activation spreads. The overall results favored the view that morphological structures are abstract organizing units of the mental lexicon, independent of semantics and phonology.

Boudelaa and Marslen-Wilson did not stop there but conducted additional experiments which confirmed their initial findings, and helped deepen our understanding of how morphological units are cognitively perceived in Arabic (Boudelaa, 2014; Boudelaa & Marslen-Wilson, 2001, 2004b, 2005, 2015). Such comprehensive work on Arabic morphology has led Boudelaa and Marslen-Wilson (2005) to conclude, “The existing models of language processing and representation are mainly guided by what we know about Indo-European languages, and in particular English” (p. 234). Such overrepresentation of languages of one type, thus, has skewed our understanding of lexical access to be shaped mostly by what we know from those languages. However, if we are to present a more encompassing picture of how lexical access flows, we need to extract knowledge from typologically distinct languages such as Arabic.

To sum up, morphological cross-language activation is different in mechanism than that of semantics or form. Semantics and form, for the most part, are shared across languages but not morphological structures, which are language-specific. Therefore, cross-language morphological activation adheres to within-language processing. This reliance on within-language processing compels us to look at morphology in the monolingual context before considering its role in the bilingual context.
The majority of past monolingual research studies, which predominantly relate to Indo-European languages, have concluded that activation in the mental lexicon does not spread via morphology (Frost, Forster & Deutsch, 1997). In other words, morphological units are not abstract independent lexical units which are retrieved and activated during word processing. Instead, this line of investigation has proposed that the synergy between phonology/orthography and semantics gives rise to the retrieval of morphological information. And, since most bilingual lexical access research draws on monolingual research, the role of morphology in the bilingual context has rested on the assumptions from the monolingual context. In contradiction to this previous work, studies on Arabic, as a typologically-distinct language, show that morphology, in fact, plays an independent role in lexical access in the monolingual context. That is, activation spreads through morphology. This sets the stage for a novel investigation of morphology in the bilingual context, which is what the current experiments set out to achieve.

The Role of Morphology in the Bilingual Context

As stated, research in the bilingual context, in many cases, is shaped by what is found in the monolingual context. Thus, since research on monolingual morphological processing is scarce, research on bilingual morphological processing is even scarcer. In the realm of Arabic-English morphological processing, in particular, there are only—to the best of my knowledge—two empirical works: one published article (Qasem & Foote, 2010), and one unpublished doctoral dissertation (Al-Qahtani, 2017). When it comes to research not involving Arabic, there are only a handful of research studies which address the status of
morphology in bilingual language processing. I shall first review those not related to Arabic and demonstrate their shortcomings, before I delve into Arabic-based research.

Zhang, Van Heuven, and Conklin (2011) investigated whether or not L1 morphological decomposition occurs even in an exclusively L2 context. The authors used a lexical decision task on targets preceded by masked primes, all presented in English. However, unknown to the Chinese-English bilinguals, the stimuli concealed morpheme repetition. That is, when the prime and target were translated into Chinese, they shared a morpheme in Chinese (i.e., related morphologically). For example, in one stimulus, the English pair was *east-thing*. The Chinese translation of *east* is 东, which is also the first morpheme of the word *thing* “东西”. Compared to the unrelated condition, Zhang et al. (2011) reported that the response rate in the related condition was significantly faster. This facilitation effect was attributed to activating the morpheme in both words of the pair. In particular, they proposed that the participants underwent unconscious translation followed by morphological decomposition. To refer back to the study’s objective, L1 morphology was processed and activated even in a solely and exclusively L2 context.

This study can make claims about the unconscious translation to the L1 while functioning exclusively in the L2, but a less compelling claim about morphological facilitation in the L2 context. The authors’ conclusion regarding the morphological facilitation is problematic. As can be seen in the previous example, the prime shared the first morpheme of the compound word in the target. In other words, the whole prime word was repeated in the first segment of the target word. Therefore, any kind of facilitation in this condition could also be equally attributed to orthographic or phonological overlap, which
Zhang et al. (2011) did not control for. Morphological facilitation in this study, thus, could be driven by phonology/orthography instead of morphology.

While the Zhang et al. (2011) experiment lacked essential control conditions, Kim et al. (2011) study provided the necessary control for orthography as a potential confound in morphological priming. In addition, they had a bilingual context (i.e., primes in Korean, and targets in English), which makes any claims for cross-language activation more appealing. Furthermore, their study was a more direct assessment of cross-language morphological activation. In fact, their study is the closest I could find to what my proposed research intends to accomplish.

Kim et al. (2011) looked into whether morphology mediates cross-language activation. In a lexical decision task, participants responded to English targets primed by their translation equivalents in Korean while manipulating the morphological ending in the primes. For example, when the target was the English stem ATTRACT, the primes were either 매력적 “attractive,” (legal combination of stem and suffix), 매력화 “attractization,” (illegal combination of stem and suffix “non-word”), 매력trap “attractel,” (stem with pseudo suffix “non-word”), or 범죄자 “offender,” (unrelated).

Kim et al. (2011) hypothesized that if morphology is truly a mental unit which is retrieved in lexical access, then the Korean primes should be decomposed to their constituent morphemes (stem + suffix), which would result in automatic activation of the English equivalent of the Korean stem, “attract.” Thus, responding to the subsequently presented English target, “attract,” will be facilitated. However, this effect should occur only if the suffix is real. That is, even though “attractization” is a non-word as a whole, its constituents
are still legal morphemes. When decomposed, the stem should still facilitate target recognition. On the contrary, stems attached to a pseudo suffix (e.g., attractel) cannot facilitate target recognition because decomposition is not possible in the first place.

Kim et al. (2011) reported exactly the hypothesized effects. The authors claimed that since priming occurred only in the conditions where the suffix was real, and ceased when the suffix was pseudo, cross-language activation must be mediated by morphology. Furthermore, the fact that priming was prevented in the conditions where the stem was real but attached to a pseudo suffix eliminates any basis for orthographic-driven facilitation.

While the previous study attempted to provide evidence for cross-language morphological priming, it is obvious that the target-prime pairs in this study were related in semantics. Manipulating the morphological ending (i.e., 매력화 “attractization” - attract) does not remove the semantic traces. That is, the facilitation reported in this study could be regular translation equivalent priming rather than cross-language morphological priming. The authors included a condition that presumably served to control for semantics, which they referred to as non-interpretable (i.e., “attracticide”- attract), but semantic contamination still exists.

Indeed, failure to report cross-language morphological effects stems from the fact that the languages selected for investigation utilized a type of morphology which is inherently immune to pure within-language morphological effects to begin with (see my discussion on monolingual morphological research). That is, the very nature of the morphology (i.e., concatenative) used in these experiments makes it hard to isolate effects of phonology/orthography and semantics from those of pure morphology. Hence, based on the predominantly concatenative-based research on morphology, “one of the major findings in
morphological processing research of the last decade is that morphological relationships are not only exploited on a semantic basis but also on a purely orthographic one” (Duñabeitia et al. 2013, p. 971).

In Arabic, on the other hand, the bulk of morphology is non-concatenative. Morphemes are not strung one following the other, but are interleaved and dispersed throughout the word. On the one hand, two lexical items sharing a morpheme (the root, specifically) do not share exact left-to-right or right-to-left sequences of characters, nor do they share an affix. This makes controlling for orthography much more attainable. Moreover, the same broad meaning does not necessarily surface in morphologically related lexical items, which also makes controlling for semantics feasible. Now I move to studies which employed non-concatenative morphology to investigate the role that morphology plays in cross-language activation.

Non-Concatenative Morphology

Due to its overwhelmingly non-concatenative morphology, Arabic has been a fruitful terrain for investigating the role of morphology in the monolingual context. This section bridges the gap by reviewing how Arabic has been recruited to investigate the role of morphology in the bilingual context. As stated before, bilingual experimental work on morphology is scarce in general, and almost non-existent in the case of Arabic. Only two studies have been identified in this respect, Qasem and Foote (2010) and Al-Qahtani (2017).

Qasem and Foote’s Study

Although Qasem and Foote (2010) designed their study to investigate different theoretical issues, the underlying objective remains the same: investigating cross-language morphological activation. Specifically, they examined whether Arabic-English processing
involves automatic translation into the non-target language and within-language morphological decomposition.

In a translation recognition task, participants were presented with L2 words, followed by their L1 translation equivalents. Participants were asked to decide whether or not the second word was the correct translation. However, the correct translation equivalent in Arabic (e.g., shoulder-\textbf{katif}) was replaced, in critical conditions, by orthographically related distractors (e.g., shoulder- \textit{kahf} “cave”), morphologically related distractors (e.g., shoulder-\textit{taka:tuf} “unity”), or semantically related distractors (e.g. shoulder-\textit{raqab}b “neck”). In these critical conditions, participants were supposed to reject the distractors as translations of the English words. However, morphological distractors were hypothesized to be harder to reject than others.

Participants showed significant interference in rejecting all three types of distractors relative to the unrelated control condition. This reveals that the orthographic, morphological, and semantic neighbors of the correct translation equivalent (e.g., \textit{katif}) were all activated and interfered with the process, thus rendering them harder to reject. Nevertheless, when comparing the magnitude of the effect between the three types of distractors, morphological distractors were significantly harder to reject than orthographic distractors. That said, morphological distractors were not significantly different from semantic ones.

Since morphological distractors presented the highest amount of interference (at least compared to orthographic ones), morphemic units (i.e., the root) were assumed to be activated during the translation task. That is, the only way for SHOULD\textيري to activate taka:tuf “unity,” is via non-target language activation (SHOULD\textيري $\rightarrow$ katif) followed by
within-language morphological activation (katif → taka:tuf) (hence cross-language morphological activation).

There are caveats to the experiment which cast doubt on these conclusions. First, regarding the non-target language activation part, the researchers claimed that “This finding constitutes evidence for the lexical activation of the L1 during L2 processing” (p. 132), and “activation of the L1 translation equivalent may be an indispensable part of the L2 word processing.” (p. 137). Nevertheless, let’s not forget that the task at hand is translation. Experimental designs of this type have been criticized for being artificial (Zhang et al., 2011). The translation task makes any claims about automatic non-target language activation uncertain. Activating the L1 equivalent is not spontaneous but directed. It follows from this that morphological decomposition claims become less convincing. That is, having the participants function in translation mode encourages, as stated, conscious activation of the L1 equivalents which, in turn, facilitate extracting the L1 morpheme in question (the root). It would be more informative to see, for example, if the morphological units are processed even when completely uncalled for in the task at hand, which is what my second research question attempts to accomplish. That said, it is possible that the morphological representations influence bilingual lexical processing only in a task which deliberately requires translation, hence facilitating subsequent L1 morphological processing. My research intends to verify these assumptions.

Second, and more importantly, Qasem and Foote (2010) did not properly rule out semantics as a potential confound. First, when comparing the magnitude of the effects between morphology, orthography and semantics, only morphology and orthography turned out to be significantly different. That is, no proof in the current data suggest that
morphological effects are different from those of semantics. It is possible, based on this, that the effects of morphology are semantically-driven. Second, what makes ruling out the role of semantics imperative is that many of the prime-target pairs are semantically related. Upon careful scrutiny of the full set of stimuli used by the researchers (which is not available in the article but was obtained via personal communication with the researchers), it is obvious that semantic contamination is present. For example, BOOK was followed by maktab “desk,” where the latter is believed to be a morphological distractor. However, BOOK and maktab are also related by semantic association. The same goes for pairs such as tailor-xajt “thread,” illness - tamri:d “nursing,” refrigerator- ʔal3 “ice,” and week-sabʃh “seven.” It is obvious, then, that the prime-target relation is not simply that of morphology, but also includes semantics. Compounded by the lack of a statistically significant difference between the morphological and semantic conditions in response time, this confounding of semantics with morphology casts doubt on any conclusions of a purely morphological nature. The present research, however, included pairs which are judged by native speakers of Arabic to be semantically unrelated.

*Al-Qahtani’s Study*

Recently, in an unpublished PhD dissertation, Al-Qahtani (2017) has investigated Arabic to English translation and morphological priming in a more authentic automatic task. Her overall design is very similar to that of my current study. She had participants respond to English targets (e.g., quiet) which were preceded by either L1 morphologically related words (e.g., sakan “house”), L1 translation equivalents (e.g., sakin “quiet”), L1 semantically and morphologically related words (e.g., musakin “painkiller”), or unrelated primes (e.g., mustasha:r “advisor”). The primes were all masked, meaning that the participants were not
aware of their existence (refer to chapter 4 for discussion of masked priming tasks). Participants’ task was to decide whether or not the string of letters in the target were a word in English (lexical decision task). Al-Qahtani (2017) administered the same procedure in three experiments which only varied in the amount of time allowed between the start of the prime to the start of the target: 50ms, 80ms, and 200ms, respectively.

The relevant result for our purposes was that L1 morphologically related words significantly facilitated L2 target recognition in the 80ms experiment. That is, exposure to sakan “house,” activated the within-language morphologically related words, among which was sakin “quiet.” When subsequently presented with the target QUIET, participants easily recognized it since QUIET was already activated through its L1 translation equivalent (i.e., sakin).

Such conclusions can be criticized on two grounds. First, one-to-one mapping of Arabic-English translations was weak. For instance, sakin is not even the second translation that comes to mind when seeing QUIET, as two dictionaries have confirmed. That is, when seeing the word QUIET, participants are more likely to associate it with the Arabic equivalents huduʔ or sˁamt. In a psycholinguistic experiment of the current type, where lexical processing and reaction times are measured in milliseconds, it is not enough to provide a correct translation; the translation has to be strongly associated with the word in either language. Activating the right translation in the other language is key to arriving at the expected facilitation effect, especially given the fact that Arabic is rich with synonymous vocabulary. The pair FLAT- munbasitʕ, from the author’s stimuli, constitutes another example of a non-spontaneous, non-automatic English-Arabic translation, where FLAT is more associated with the Arabic equivalents shuqḥ “apartment” or musafʕah.
Part of the reason why one-to-one translation was hard to attain was that Al-Qahtani’s stimuli were not optimized for Arabic-English priming in the first place. The first goal of her experiments was to investigate root priming in Arabic only. And in administering the Arabic-English experiments, she simply translated the targets of the existing Arabic prime-target pairs. That is, the existing stimuli dictated the quality of translations, whereas in the current study the suitability of the translations guided stimulus selection. In addition, translations in the current study were confirmed by using two Arabic-English dictionaries as well as Arabic-English bilingual informants to make sure the translations were as spontaneous as possible (refer to chapter 3 for more information on this).

It is true that Al-Qahtani still found an effect regardless of the mentioned complication. However, this issue could explain the null effects in the two other experiments (i.e., 50ms and 200ms). And, where the effect was found (i.e., 80ms), it is possible that it was semantically-driven—as in Qasem and Foote (2010)—which brings us to the second point. Al-Qahtani (2017) acknowledged that, “ratings collected for semantic similarity showed that primes in the Root condition [morphology] did have a higher semantic similarity rating than the unrelated primes. Therefore, the effect of Root priming may also be attributable to this shared semantics activating the English target via conceptual links” (p. 158). This is not to say that morphology has absolutely no contribution to the facilitation effect, but until semantic influences are tightly controlled, we cannot be certain that morphology can independently mediate the process of cross-language activation, which is what the current research attempts to accomplish.

My study also differs from that of Al-Qahtani in that while Al-Qahtani recruited a broader range of grammatical classes (e.g., adjectives, nouns, verbs and verbal-nouns), I
mostly employed nouns (with only three adjectives in both experiments), since it is easier to control for one-to-one translations with nouns.

Summary

We have seen how morphology-based research is relatively limited, in general, in the monolingual context. Due to the inherent nature of the morphological units employed, researchers have long struggled to disambiguate effects of morphology from those of semantics and/or form. However, Semitic languages (e.g., Arabic or Hebrew) which adopt a typologically-distinct type of morphology showed that morphological representations constitute stand-alone mental representations through which activation flows. In the bilingual context, morphological research is even scarcer. When it comes to Semitic languages, only two studies were identified. The present research attempts to extend what has been accomplished in the monolingual context to the bilingual context. In particular, by exploiting Semitic languages, researchers were able to provide a much clearer account of the role of morphology in monolingual lexical access. Likewise, the current research used Arabic as a Semitic language to delineate the role of morphology in bilingual lexical access.

The main research questions guiding the investigation were: 1. Does (Arabic) morphology mediate cross-language activation? 2. Is Arabic-English cross-language morphological activation task-dependent? To answer these questions, the current research introduced two experiments. The first is a translation recognition task, and the second is a masked priming lexical decision task. Chapter 3 starts with a brief overview of the overarching sequential priming paradigm from which both experiments derive their tenets and underlying assumptions. The chapter then moves to detailing the methods and results of
the translation experiment. Chapter 4 lays out the methods and results of the masked priming lexical decision experiment. Chapter 5 presents conclusions pertaining to both experiments.
CHAPTER THREE: TRANSLATION RECOGNITION EXPERIMENT

The first experiment explores the role of morphology in an explicit bilingual context, where participants are deliberately and consciously functioning in Arabic and English. It is expected that the conscious involvement of both languages in this experiment will facilitate any role of the morphological units that could have been otherwise absent. Therefore, this experiment deals directly with the first research question: Does (Arabic) morphology mediate cross-language activation? If so, what is the strength and limit of such morphological activation? In other words, I first establish the role of morphology in a bilingual task—which presumably facilitates morphological processing—before I move to a more novel and complex monolingual task. Although one previous study has already found an effect of morphology in the bilingual context (Qasem & Foote, 2010), this study did not come without its shortcomings (refer to chapter 2 for a review). Therefore, I consider the present experiment to be more than simply a replication because it introduces some improvements in design which help overcome the flaws that hinder interpretation of Qasem and Foote’s results. The following space details how cross-language morphological activation was tested in the bilingual context.

Methods

The Sequential Priming Paradigm

The goal of psycholinguistic inquiry is to uncover the underlying mental processes through which people understand and produce language (Garrod, 2006). In doing so, psycholinguists have been using a range of different techniques; however, the sequential
priming paradigm is by far the most popular task which has been implemented (Spruyt, Gast, & Moors, 2011; Wentura & Degner, 2010).

Before I delve into the priming paradigm, it is important to draw a distinction between online vs. offline procedures when considering psycholinguistic investigation (Garrod, 2006). Offline procedures register the outcome of a mental process and collect results after processing routines have been completed. For example, participants can read or listen to a sentence and answer a follow-up question. Another example would be grammaticality judgment tasks. In these cases, the post-processing is what comes under scrutiny. Online procedures, on the contrary, tap into ongoing mental processing as it happens. Eye-tracking methods, which track and record the gaze of a participant reading words, reveal important cognitive insights about the nature of ongoing language processing. Likewise, brain imaging during language processing tasks is an online procedure that has generated unique insights into the timing of lexical processing. Priming procedures which examine the complexity of online processing as indexed by reaction latencies recorded as individuals process language are another example of online procedures.

The current research focuses on uncovering ongoing mental processing of morphological units in bilinguals and investigates the nature and representation of such units in the mind. Therefore, online procedures will be utilized. Among the online procedures, eye-tracking tasks require complex programming and analysis experience. In addition, brain imaging is explored more under the umbrella of neurolinguistics, which is beyond the scope of the current paper. Therefore, due to time and feasibility considerations—and given their popularity in the field—priming tasks, which Spruyt et al., (2011) refer to as the “prototypical cognitive research paradigm,” will be employed.
In a typical sequential priming task, participants are presented with a series of trials, consisting of pairs of words presented consecutively. The first member of the pair is called the prime, and the second is called the target. On critical trials, the relationship between the prime and target is manipulated, based on the goal of the inquiry. Other trials are included to serve as a base-line control to ensure that any influence is exclusively due to the manipulated factor. Researchers are then interested in participants’ performance on critical trials relative to control trials in terms of reaction time and accuracy.

Reaction time (RT) and accuracy are the dependent variables in most behavioral methods (Garrod, 2006). Measurement of the accuracy and time it takes to carry out a given task permit the investigator to make inferences about the mental processing of the task. That is, longer reaction times and higher error rates signal processing difficulty, or interference effects. On the contrary, shorter reaction times and lower error rates indicate smoother processing, or facilitation effects. In short, the complexity of mental language processing should be mirrored in the response latency and accuracy (Garrod, 2006). Therefore, priming effects—indexed in reaction time and accuracy—“could be a window to the inner structure of our cognition” (Wentura & Degner, 2010, p. 7).

Priming is said to occur when the response accuracy/RT to the target is influenced as a function of the previously shown prime, relative to a control condition. The rationale behind priming is that any influence of the prime on the target must imply that the mental representation of the prime and target are interconnected and overlap in such a way that activating the representation of the prime either activates the representation of the target, or activates the representation of a competitor (Forster, 1999; Neely, 1991). That is, the prime could pre-activate or inhibit activation of the representation of the target, depending on
whether they share common mental representations or competing ones. If, for instance, an
individual is faster and more accurate in recognizing that table is a word when it is primed by
chair, relative to a neutral prime, then it can be inferred that a shared semantic representation
facilitates performance in this condition. But when the prime inhibits recognition of a target
word, the prime and target are said to constitute competing mental representations.

**Overview of Translation Recognition Tasks**

Translation recognition tasks emerged in the early 1990s; since then, they have been a
popular method utilized by a number of psycholinguists in investigating the bilingual lexicon
(Sunderman, 2014). In fact, many of the predictions of the RHM were tested using
translation recognition tasks (Sunderman, 2014). The task is simple: participants see a pair of
words in two different languages. The participants need to decide if the two words are
translation equivalents or not and respond by pressing a YES or NO key (Sunderman, 2014).

The translation recognition task has two sets of trials: one in which the decision
would be “yes” (correct translations) and one for “no” (incorrect translations). The critical set
for analysis is the one that requires the participants to reject the translation pair and press
NO. In this set of trials, the correct translation equivalent is replaced by a number of
distractors that are phonologically, orthographically, morphologically or semantically similar
to the correct translation equivalent, depending on the goal of the experiment (Sunderman,
2014).

Researchers are then interested in whether any of the distractors affect participants’
ability to reject a given translation. If an interference effect shows up, then this implies that
the type of the distractor in question overlaps in its representation with the correct translation.
For example, in the correct translation pair of wisdom - hikmah, the correct translation (i.e.,
hikmah) could be replaced by the morphological distractor huku:mah “government”. If this distractor (which is morphologically related to the correct translation) affects response time or accuracy, relative to a control word, then it must be because lexical access in the mind of Arabic-English bilinguals involves morphological decomposition.

This task adheres to the same tenets and underlying assumptions of the sequential priming paradigm and exploits the same behavioral measures of RT and accuracy. However, since the critical trials in this task involve rejecting a translation consisting of a distractor, the effect will always be of interference; that is, longer RT and higher error rates are associated with difficulty in rejecting a given translation (Sunderman, 2014).

**Participants**

Thirty-one participants were recruited for this experiment, two of whom were female. They were adult native speakers of Arabic who spoke English as a second language. All participants were students at a public university in the US and came from different majors. The majority of the participants were undergraduate students in their senior year, but a few (n= 5) were graduate students. To be considered for graduate/undergraduate study in American universities, all international applicants must demonstrate high levels of English proficiency by getting a certain score on the TOEFL, or completing intensive English courses before enrolling in an academic degree program. This, in addition to the fact that all participants had spent at least three years in their program of studies, makes it safe to conclude that the participants were advanced in their English proficiency and homogenous in their Arabic-English dominance. Most participants were from Saudi Arabia, except one from Yemen, one from Oman, one from Jordan, two from Kuwait, and two from Syria.
Even though the demographics of the sample indicated that all participants were advanced in their proficiency of both English and Arabic, I still collected language dominance scores for the purpose of including a quantitative measure of language dominance as a covariate in the data analysis. That is, I wanted to evaluate the effect of morphology after statistically controlling for language dominance. I utilized the Arabic-English electronic version of the Bilingual Language Profile (BLP) to measure Arabic-English dominance levels (Birdsong, Gertken, & Amengual, 2012). The BLP is a self-reporting tool assessing language history, proficiency, use and attitudes in two languages; in this case, Arabic and English. Participants received a link in their e-mails that allowed them to complete the questionnaire and submit it online. The researcher then received a file containing a number of sub-scores for both languages, and a total language dominance score. The language dominance score ranges from -218 to +218, where a score nearing zero indicates balanced bilinguals, a positive number signals a trend towards English dominance, a negative number signals a trend towards Arabic dominance.

As expected, almost all participants were Arabic dominant but with varying degrees. The scores obtained ranged from -108 to -0.72, with a mean of -61, and standard deviation of 26. Hence, a few participants were balanced bilinguals or near balanced, but the majority were Arabic-dominant.

**Materials**

The translation recognition experiment consisted of three priming conditions: morphological, orthographic and semantic. The orthographic and semantic conditions were included in the experiment to distinguish effects of morphology from those of semantics or orthography, and to better understand the sole contribution of morphological processing. The
critical (i.e., experimental) targets, in all conditions, were Arabic words which were related to the translation of the English primes. Since participants responded to words which were related to the correct translation of the primes, and not the correct translations themselves, these related targets will be referred to as distractors.

In the morphological condition, the distractors were Arabic words which were morphologically related to the translation of the English primes (hence, morph-distractors). Morphological relationship was operationalized as two words which are derived from the same root. Wehr’s (1979) Arabic-English dictionary of modern written Arabic, which arranges entries by root, was consulted to select or validate all the related pairs in this condition. In addition, to establish a baseline against which the morpho-distractors could be compared, I generated a control for each distractor (hence, morpho-control). Accordingly, each prime word was paired with a distractor and a control. Table 1 illustrates the prime-target relationships in the morphological condition.

Table 1
Example of Prime-Target Relationships in the Morphological Condition of the Translation Recognition Experiment.

<table>
<thead>
<tr>
<th>Prime</th>
<th>Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Book</td>
<td></td>
</tr>
<tr>
<td>kita:b”</td>
<td>kati:bah “battalion”</td>
</tr>
<tr>
<td></td>
<td>(distractor)</td>
</tr>
<tr>
<td></td>
<td>Jina:zah “funeral”</td>
</tr>
<tr>
<td></td>
<td>(control)</td>
</tr>
</tbody>
</table>

Note. An Arabic translation of the English prime and English translations of the Arabic targets are in quotation marks. The letters in bold in the Prime and Distractor are the overlapping root.
One confound that can influence processing in the morphological condition is that of orthography. In Arabic, two lexical items which share a root will necessarily share some letters, also rendering them related in orthography. Therefore, to rule out the potential influence of orthography, and to confirm that any effect in the morphological condition is exclusively due to morphology, I had to measure the role of orthography and separate it from that of morphology. The distractors in the orthographic condition were related, in form, to the translation of the primes (orth-distractors). Relation in orthography was operationalized as pairs of words which share at least three letters in the onset or differ in only one or two letters, but do not derive from the same root. As a baseline control for the orth-distractors, unrelated targets have been matched to the same primes (orth-control). See Table 2 for an example of the prime-target relationships in the orthographic condition.

Table 2

Example of Prime-Target Relationships in the Orthographic Condition of the Translation Recognition Experiment

<table>
<thead>
<tr>
<th>Prime</th>
<th>Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>envelop</td>
<td>zˁifr “nail”</td>
</tr>
<tr>
<td>“zˁarf”</td>
<td>shayab “mess”</td>
</tr>
</tbody>
</table>

(distractor) (control)

Note. An Arabic translation of the English prime and English translations of the Arabic targets are in quotation marks.

Related pairs in the morphological condition can be particularly susceptible to semantic confounds as well since Arabic words which derive from the same root usually
draw on the same broader semantic domain. However, in some cases, there is no discernable semantic relationship between morphologically related words. To ensure that semantic priming would not affect processing in the morphological condition, the morphologically related pairs used in the experiment were restricted to word pairs that were not semantically related. This latter criterion is a novel contribution compared to the study of Qasem and Foote (2010), in which several morphologically related pairs were also semantically related. This criterion was met by thoroughly and rigorously scanning more than 500-pages of the Wehr (1979) dictionary and carefully selecting the few eligible pairs that were semantically unrelated (e.g., tree-fighting, police-condition, hair-poet, etc.). As an additional measure, and to enhance the validity of the initial stimulus selection, the pairs were evaluated by two Arabic-English bilinguals who were enrolled in PhD programs in language-related fields, but who were blind to the goals of the study. The consultants were presented with the experimental word pairs along with additional word pairs that were only slightly semantically related. The consultants then assessed semantic similarity across all pairs. The reviewers rated all experimental pairs as semantically unrelated. After this process of selection and evaluation, any potential effect in the morphological condition can be safely attributed to morphological processing, rather than to semantic processing.

As an additional measure of control, I included a semantic condition to gauge the potential influence of semantic similarity alone. The distractors in this condition were semantically related—but morphologically unrelated—to the correct translation of the primes (hence, sem-distractors). Unrelated controls were also generated for each semantically related distractor (sem-control). Semantic relation was operationally defined as pairs which were either related by inclusion (e.g., head-hair), association (e.g., knife-spoon), opposition (e.g.,
introduction-conclusion) or semantic proximity (e.g., donkey-horse). Of course, such classification can be subjective. Therefore, a subset of the pairs which could not be unambiguously assigned to a single semantic relation were presented to the bilingual consultants to corroborate their semantic relation status. Table 3 illustrates the prime-target relations in the semantic condition.

Table 3

*Example of Prime-Target Relationships in the Semantic Condition of the Translation Recognition Experiment*

<table>
<thead>
<tr>
<th>Prime</th>
<th>Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Star</td>
<td>sama? “sky”</td>
</tr>
<tr>
<td>“naẓm”</td>
<td>(distractor)</td>
</tr>
<tr>
<td></td>
<td>difaːf “defense”</td>
</tr>
<tr>
<td></td>
<td>(control)</td>
</tr>
</tbody>
</table>

*Note.* An Arabic translation of the English prime and English translations of the Arabic targets are in quotation marks.

Since the related targets (i.e., distractors) are compared against the unrelated targets (i.e., controls) in the corresponding condition, the distractors and controls were matched in frequency and word length. Psycholinguistic factors such as frequency and word length have been shown to play a significant role in word recognition (Dijkstra & van Heuven, 1998; McClelland & Elman, 1986). For instance, if the controls are less frequent or longer than the distractors, then research suggests that participants would have more difficulty recognizing
the controls. Difficulty in recognizing and processing the controls—compared to the
distractors—would introduce a confound into the study. Therefore, for the current study, the
distractors and their controls within each condition were matched in frequency and word
length, and differed only in the factor being investigated: sharing morphology, orthography
or semantics with the translation of the primes.

As far as frequency is concerned, the lexical database for Modern Standard Arabic
(Aralex) (Boudelaa, & Marslen-Wilson, 2010) was consulted. Aralex assigns frequency
counts to lexical items based on a corpus of 40 million words. Paired sample t-tests showed
no significant differences between the mean frequency for the distractors compared to their
controls in the morphological condition, $t(35) = -0.41, p = 0.68$; in the orthographic
condition, $t(35) = -0.67, p = 0.50$; and in the semantic condition, $t(35) = -0.41, p = 0.68$. With
regards to word length, deliberate one-to-one exact matching of the number of Arabic
graphemes was ensured between each distractor and its control. Thus, within each condition,
and for each prime, the distractor had the same number of letters as its control. This may not
be apparent from the examples in Tables 1 - 3 since the Arabic distractors are presented in
their Roman alphabetic transliterations.

As illustrated in Tables 1 - 3, the distractors, in all conditions, are related to the
primes through translation. In other words, priming hinges upon activating the correct
translation equivalent of the primes. Therefore, the Arabic translation of the English primes
had to have one-to-one translation mapping, which warranted further controlling of the pairs.
To ensure consistency in translations, all primes were compared in two Arabic-English
dictionaries, Almaany and Wehr’s (1979), for comparability of translations. Further, any
English primes with multiple translations were reviewed by the bilingual informants. Only translations which were consistent across the four sources were included in the experiment.

**Design**

The same set of English primes (n=36) were used in all three conditions. Each prime word was paired with six targets: two per condition. Within each condition, each prime was paired with a distractor and a control (i.e., morph-distractor, morph-control, sem-distractor, sem-control, orth-distractor and orth-control). Thus, the experimental stimuli consisted of 216 word pairs, 108 related and 108 control. Each priming condition had 36 related pairs and 36 control pairs. The stimuli were evenly assigned to six counterbalanced lists (A – F). For example, in List A, the 36 English primes were paired with six morph-distractors, six morph-controls, six sem-distractors, six sem-controls, six orth-distractors, and six orth-controls. The other lists had the same primes, but with a different selection of targets, such that all targets appeared once per list (see the Appendix for a full list of stimuli). In this design, each participant completed only one list, and thus viewed each prime only once, along with a subset of the targets. This was necessary to avoid threats to internal validity. For instance, effects of repeated exposure to the same prime on RT was eliminated with this design.

All the pairs described so far are incorrect translations, requiring a NO response. However, for participants to make a decision, an equal number of correct translation pairs requiring a YES response were included in each list (i.e., fillers). That is, 36 correct translation pairs were added to each list, totaling 72 pairs per list. Since each participant would complete only one list, the correct translation pairs were the same across lists. In sum, each participant responded to 72 pairs, half of which were correct translations, and half of which were incorrect translations. The incorrect translation pairs (n=36) were distributed
across the three priming conditions. Each priming condition had 12 pairs, divided between related and unrelated in the corresponding condition in each list.

**Procedure**

Participants were tested individually in a laboratory setting. The experiment was carried out using SuperLab5, which was installed on the researcher’s personal laptop. When the experiment started, an instruction page appeared, briefly explaining the experiment. The participant pressed a button to begin the experiment. A fixation mark was presented on the screen (+) for 500ms. The fixation was replaced by the English prime for a duration of 400ms. The prime was followed by a brief 100ms blank screen, which was followed by the Arabic target for 3000ms, or until the participant made a response. The participants were instructed to decide as quickly and accurately as possible whether the two presented words were translation equivalents or not. A blue sticker was attached to one button on the keyboard for YES responses, and a red sticker on a different button for NO responses. The software measured reaction times in milliseconds, and recorded accuracy on each trial. Practice trials of 14 pairs were added at the beginning of the experiment, which resembled the experimental trials in type.

**Hypotheses**

Given the fact that participants were explicitly asked to perform a translation task, which would facilitate cross-language activation in the first place, I hypothesized that rejecting a translation would be inhibited by the presentation of all types of distractors. Further, based on Qasem and Foote’s (2010) findings, I hypothesized that morphologically related distractors would generate more interference than either semantic or orthographic
distractors, and that the effect of morphology would be independent of orthography and semantics. That is:

Hypothesis 1: Rejecting a translation will be inhibited by the presentation of the morphological, orthographic and semantic distractors compared to their controls.

Hypothesis 2: Morphological distractors will show stronger interference effects than orthographic/semantic distractors, and these effects will be independent of effects of orthography and semantics.

Results

For the RT analysis, only correct responses were included (N = 1001). RTs that were less than 300 ms or greater than 1500 ms were excluded. Also, outliers were identified and removed using the boxplot.stats function, which was applied to each relatedness group in the three conditions. Overall, data trimming resulted in a loss of 8.5% of the responses. Average RTs and standard deviations, as well as percentage accuracy rates for each group within the three priming conditions, are reported in Table 4.
Table 4

<table>
<thead>
<tr>
<th></th>
<th>Distractor targets</th>
<th>Control targets</th>
<th>Interference effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>morphology</td>
<td>848 (177)</td>
<td>728 (156)</td>
<td>120 ms</td>
</tr>
<tr>
<td></td>
<td>87%</td>
<td>98%</td>
<td></td>
</tr>
<tr>
<td>orthography</td>
<td>834 (219)</td>
<td>749 (165)</td>
<td>86 ms</td>
</tr>
<tr>
<td></td>
<td>89%</td>
<td>99%</td>
<td></td>
</tr>
<tr>
<td>semantics</td>
<td>848 (246)</td>
<td>770 (176)</td>
<td>77 ms</td>
</tr>
<tr>
<td></td>
<td>88%</td>
<td>98%</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Standard deviation in parentheses. Interference effect is the difference between the distractor and control RTs.

The RT data were analyzed with linear mixed effects models fitted with the lme4 package (version 1.1-21) in R (Bates, Mächler, Bolker, & Walker, 2015; R Core Team, 2018). Generalized binary logistic regression models were calculated for accuracy rates. As targets across conditions were not matched, I analyzed each condition separately. For the RT analysis, TargetType and Dominance were entered into the models as fixed effects. TargetType had two levels: distractor and control. Dominance was the participants’ dominance score from the BLP. The latter was entered into the model primarily as a covariate to control for the varying language proficiencies among the participants. All models included random intercepts for participants and items. As part of model selection, I began with the maximal model structure, where by-subject and by-item random slopes for the effect of TargetType were also included. However, the model failed to converge so I had to retreat to the simplified model of fixed effects and random intercepts only. Table 5 presents the model results for the three conditions.
Table 5

**Combined RT models for the three conditions**

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Std. Error</th>
<th>df</th>
<th>t value</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morph-distractor</td>
<td>129.60</td>
<td>13.66</td>
<td>226.19</td>
<td>9.49</td>
<td>&lt; 2e-16</td>
</tr>
<tr>
<td>Orth-distractor</td>
<td>85.09</td>
<td>17.04</td>
<td>245.82</td>
<td>4.99</td>
<td>1.13e-06</td>
</tr>
<tr>
<td>Semantic-distractor</td>
<td>76.12</td>
<td>19.93</td>
<td>230.46</td>
<td>3.82</td>
<td>0.00017</td>
</tr>
</tbody>
</table>

*Note.* The estimates shown are in comparison to the control reference level in the corresponding condition.

Consistent with Hypothesis 1 participants were significantly slower to reject the morphologically related distractors than they were to reject the unrelated controls, $t(226) = 9.48, p < .001$. The same effect emerged in the orthographic condition, $t(245) = 4.99, p < .001$, and the semantic condition, $t(230) = 3.81, p < .001$. Looking at the descriptive statistics, the morphological condition yielded the highest interference effect (120 ms) relative to the orthographic condition (86 ms) and the semantic condition (77 ms). Nevertheless, the size of the interference effect is not enough to rule out the existence of orthographically-driven effects in the morphological condition. Follow-up correlation analysis was conducted to ensure the legitimacy of morphological effects. No correlation between size of priming effect in the morphological condition and amount of orthographic overlap was found, $t(34) = -0.68, p = 0.49$, which lends support to the idea of primarily morphological processes causing the interference effects in the morphological condition. In other words, trials in which participants experienced more interference from the morphologically related targets were not the same trials in which orthographic overlap was greater. As for semantic confounds in the morphological condition, the strict criteria applied during stimulus selection and validation ensure that morphological effects were not semantically driven. Together, the larger effect
size in the morphological condition and the lack of correlation between morphological and orthographic interference lend support to Hypothesis 2.

The same model structure and variables in the RT analysis were applied in the accuracy analysis. The only difference was including incorrect responses. Accuracy results confirmed those of RTs, with participants in the distractor trials—in all three conditions—responding significantly less accurately relative to the corresponding control trials (see Table 6 for model results). These results ensure that there were no speed-accuracy trade-offs. That is, in the distractor trials, participants were slower and less accurate. If, for example, they were slower but more accurate, then this would suggest strategic involvement in performance. In sum, presentation of targets that were morphologically, orthographically or semantically similar to the actual translations of the English primes slowed participants’ ability to reject the targets as translations, and led to more errors relative to unrelated target words.

Table 6

*Combined accuracy models for the three conditions*

<table>
<thead>
<tr>
<th>Condition</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>z value</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morph-distractor</td>
<td>-1.89</td>
<td>0.56</td>
<td>-3.38</td>
<td>0.000715 ***</td>
</tr>
<tr>
<td>Orth-distractor</td>
<td>-3.15</td>
<td>1.05</td>
<td>-3.00</td>
<td>0.00263 **</td>
</tr>
<tr>
<td>Semantic-distractor</td>
<td>-2.17</td>
<td>0.64</td>
<td>-3.36</td>
<td>0.000773 ***</td>
</tr>
</tbody>
</table>

*Note.* The categorical dependent variable is Correct or Incorrect, with Incorrect as the reference level. For each condition, the control trials are the reference level.
CHAPTER FOUR: MASKED LEXICAL DECISION EXPERIMENT

The second experiment served as a test of task-dependency. The goal of the experiment was to find out if cross-language morphological activation occurs even in a monolingual task—which, intuitively, would not facilitate cross-language morphological activation as much as in the bilingual translation task. Therefore, the second experiment addressed the second research question: Is Arabic-English cross-language morphological activation task-dependent? To the best of my knowledge, no previous published work has attempted to investigate cross-language morphological activation in a masked lexical decision task.

The most apparent differences between the translation experiment and the lexical decision experiment were in the context and objective of the tasks at hand. Whereas the lexical decision experiment was virtually monolingual, the translation experiment was presented in an explicit bilingual context. Furthermore, the bilingual/monolingual distinction of the context of the task in the two experiments was emphasized and even more pronounced in the objective assigned to the participants. That is, the lexical decision experiment required the participants to make a lexical decision about English words. The translation experiment, however, required the participants to make a translation decision on English and Arabic words. The fact that participants were required to evaluate translations in the translation experiment guaranteed the involvement of conscious processing of the two languages by actively utilizing knowledge from both languages, thus paving the way for cross-language morphological activation. In contrast, conscious knowledge was drawn from one source, i.e., English, in the lexical decision task. It is possible that the morphological representations of Arabic only influence processing in a task which directly and explicitly involves Arabic
(translation task), and disappear when Arabic is neither perceptually present nor needed for task completion (lexical decision task). However, if cross-language morphological activation is revealed, even in the monolingual task, this would show that Arabic morphological representations are very robust and are activated by Arabic-English bilinguals even when they are not necessary for task completion. The following section provides a detailed account of the monolingual task.

Methods

Overview of Masked Lexical Decision Tasks

Masked priming lies under the umbrella of the sequential priming paradigm. It is one branch of priming which compensates for the shortcomings of others. In traditional priming paradigms, participants witness the presentation of two stimuli: prime and target. However, this design has been criticized on the basis that results obtained using these procedures can be contaminated by strategic effects (Forster & Davis, 1984; Wentura & Degner, 2010). For example, when viewing a sequence of primes followed by targets, which are related or unrelated in some respects, participants can develop expectations about dimensions of stimuli to attend to which influences their reaction time. That is, reaction times are no longer purely a function of the properties of the stimuli in question, but a function of the participants adopting a specific routine based on the structure of the procedure as well. That being said, the strategic effect is mitigated with short Stimulus-Onset Asynchronies (SOA) (i.e., the duration of time between the start of the prime and the start of the target) (Neely, 1977).

Masked priming, developed by Forster and Davis (1984), is used to prevent participants’ awareness of the existence of primes, or the whole priming event (Wentura &
Degner, 2010). In this paradigm, the prime is presented for a very brief duration—usually 40 – 80 milliseconds—and embedded between two masks: forward and backward masks which are presented for 500 ms. The masks can be letter strings, hash marks (i.e., ###), or some type of pattern. The forward and backward masks, along with the brief presentation of the prime, prevent awareness of the existence of primes, thus ruling out any possible strategic effect. That said, lack of active awareness of the prime does not imply that the prime representation is inaccessible in subconscious lexical processing (Forster & Davis, 1984).

In fact, despite the absolute lack of awareness of the presence of the prime, researchers continue to report robust effects of masked priming. For instance, using this method, a number of studies have reported strong priming effects via phonology (Jouravlev, Lupker, & Jared, 2014), orthography (Bijeljac-Babic et al., 1997), morphology (Boudelaa & Marslen-Wilson, 2005; Zhang et al., 2011) and translation recognition (Grainger & Frenck-Mestre, 1998; Xia & Andrews, 2015). In general, it has been shown that masked priming is robust in morphology, weaker in orthography, and fairly weak or inconsistent in semantic priming (Forster, 1999; Frost, Kugler, Deutsch, & Forster, 2005; Wentura & Degner, 2010).

**Participants**

The same participants recruited for the translation experiment completed the lexical decision experiment.

**Materials**

All specifics regarding materials outlined for the translation experiment apply to the lexical decision experiment, except for the following. Since the same participants completed both experiments, I had to come up with a different set of stimulus pairs for the lexical decision experiment. Also, due to the short prime display in this experiment (i.e., masked
priming), the primes had to be in the participants’ first language. Numerous studies have reported stronger priming effects when the masked primes are presented in the participants’ first language (Xia & Andrews, 2015). Therefore, for the current experiment, the primes were in Arabic, and the targets were in English.

Similar to the translation experiment, the lexical decision experiment had 36 English targets, each paired with morph-related, morph-control, sem-related, sem-control, orth-related and orth-control primes. In the critical trials, the primes are morphologically, orthographically or semantically related to the translation equivalent of the targets. Furthermore, the related primes matched their controls in word length and frequency. Tables 7 to 9 illustrate the conditions. Paired sample t-tests showed no significant differences between the mean frequency for the related primes compared to their controls in the morphological condition, $t(35) = -0.04, p = 0.96$; in the semantic condition, $t(35) = -1.68, p = 0.10$; and in the orthographic condition $t(35) = -1.03, p = 0.31$. 
### Table 7

*Example of Prime-Target Relationships in the Morphological Condition of the Lexical Decision Experiment*

<table>
<thead>
<tr>
<th>Primes</th>
<th>Target</th>
</tr>
</thead>
</table>
| мисд’аа са “region”  
(related)       | лог “мисд’эн” |
| мустава “level”  
(unrelated)     |             |

*Note.* English translations of the Arabic primes and an Arabic translation of the English target are in quotation marks. The letters in bold in the Related Prime and Target are the overlapping root.

### Table 8

*Example of Prime-Target Relationships in the Orthographic Condition of the Lexical Decision Experiment*

<table>
<thead>
<tr>
<th>Primes</th>
<th>Target</th>
</tr>
</thead>
</table>
| т’аби:бэ “female doctor”  
(related)       | природа “т’аби:Ш” |
| мустамъ “community”  
(unrelated)     |             |

*Note.* English translations of the Arabic primes and an Arabic translation of the English target are in quotation marks.
Table 9

Example of Prime-Target Relationships in the Semantic Condition of the Lexical Decision Experiment

<table>
<thead>
<tr>
<th>Primes</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>sala:mh “safety” (related)</td>
<td>danger “xat‘ar”</td>
</tr>
<tr>
<td>sİna:Şh “industry” (unrelated)</td>
<td></td>
</tr>
</tbody>
</table>

*Note. English translations of the Arabic primes and an Arabic translation of the English target are in quotation marks.*

**Design**

The design was the same as in the translation experiment. However, the fillers in this experiment were non-words, or pseudowords, constructed from real words by replacing a few letters to generate phonologically and orthographically legal non-words. For each of the six lists created, there were six morph-related pairs, six morph-control pairs, six sem-related pairs, six sem-control pairs, six orth-related pairs and six orth-control pairs, in addition to 36 non-words, totaling 72 pairs per list. As stated before, the lists were constructed such that a particular target or prime appeared only once within a list. The other lists had the alternating primes for the 36 targets (see the appendix for a full list of stimuli).

**Procedure**

Similar to the translation experiment, the participant read the instruction page and then pressed a button to begin the experiment. A fixation mark was presented on the screen for 500ms. The fixation mark was followed by a forward mask of hash symbols (####) for 500ms, which was directly followed by the Arabic prime for 80ms. A backward mask of the
same hash symbols then reappeared for 150ms. The English target was then displayed for 2500ms, or until the participant made a response (see Figure 9). Participants were instructed to decide as quickly and accurately as possible whether or not the target was a correct word in English by pressing a YES or NO button designated on the keyboard. Practice trials of 14 pairs were added at the beginning of the experiment which resembled the experimental trials in type.

Figure 9. Illustration of the structure of one trial

As far as the participants were concerned, the whole task was in English. They were asked to simply decide if a given string of letters was a word or non-word in English. Due to
the brief presentation of the Arabic primes (80ms), as well as the forward/backward masks, most participants were unaware of the Arabic primes, which they verified at the completion of the experiment, similarly to several previous studies (Xia & Andrews, 2015). Even those participants who noticed the appearance of Arabic letters could not decipher what the letters composed.

The lexical decision experiment was completed in the same setting as the previous one. After one experiment was completed, the researcher would enter the room to start the second experiment. Also, the sequence of experiments was alternated with every new participant. Both experiments took about 18-20 minutes to complete.

**Hypotheses**

Based on Boudelaa and Marslen-Wilson’s research (Boudelaa, 2014; Boudelaa & Marslen-Wilson, 2001, 2004a, 2004b, 2005, 2011, 2013, 2015, 2000), we already know that Arabic masked primes will spread within-language activation to other morphologically related Arabic target lexical items. In our case, for instance, for a pair such as hikmah “wisdom” - GOVERNMENT “huku:mah,” the prime hikmah will activate huku:mah based on within-language morphological connections. However, in the current experiment, I hypothesize that hikmah will activate huku:mah, which in turn will facilitate recognition of its translation equivalent, GOVERNMENT. That is:

**Hypothesis 3:** Recognition of the English targets will be *facilitated* in the morph-related trials compared to the morph-control trials.

**Hypothesis 4:** Given the previous findings that within-language masked priming with Semitic languages is robust in morphology, weaker in orthography, and almost non-existent in semantics (Forster, 1999; Wentura & Degner, 2010; Frost et
al., 2005), the morphological facilitation will be distinct from orthographic facilitation. Furthermore, there will be no facilitation in the semantic condition.

**Results**

In addition to applying the same trimming procedures as in the translation experiment, two participants who had unusually slow RTs—signaling a strategic approach to the task—were removed. Overall trimming resulted in a loss of 14% of the 955 original responses. Table 10 shows descriptive statistics for RTs and accuracy rates for each condition.

Table 10

<table>
<thead>
<tr>
<th></th>
<th>Related Primes</th>
<th>Control Primes</th>
<th>Facilitation Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>morphology</strong></td>
<td>830 (149)</td>
<td>875(204)</td>
<td>45 ms</td>
</tr>
<tr>
<td></td>
<td>93%</td>
<td>90%</td>
<td></td>
</tr>
<tr>
<td><strong>orthography</strong></td>
<td>853 (179)</td>
<td>903 (232)</td>
<td>49 ms</td>
</tr>
<tr>
<td></td>
<td>95%</td>
<td>92%</td>
<td></td>
</tr>
<tr>
<td><strong>semantics</strong></td>
<td>873 (203)</td>
<td>912 (218)</td>
<td>39 ms</td>
</tr>
<tr>
<td></td>
<td>95%</td>
<td>92%</td>
<td></td>
</tr>
</tbody>
</table>

*Note. Standard deviation in parentheses. Facilitation effect is the difference between the related and control RTs.*

The statistical method and software were identical to the previous experiment. Like the targets in the translation experiment, the primes across conditions in the lexical decision experiment were not matched; thus, analysis was performed for each condition separately. Per each condition analysis, PrimeType (related vs. control), Dominance and Length were fixed effects. Dominance and Length were introduced primarily as covariates. Length was
the number of letters in the English targets. All models included random intercepts for participants and items, as well as by-Participant and by-Item random slopes for the effect of PrimeType. The three model results are grouped in Table 11.

Table 11

**Combined RT models for the three conditions**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>df</th>
<th>t value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morph-related</td>
<td>-51.32</td>
<td>21.24</td>
<td>33.99</td>
<td>-2.42</td>
<td>0.02</td>
</tr>
<tr>
<td>Orth-related</td>
<td>-53.50</td>
<td>24.88</td>
<td>35.48</td>
<td>-2.15</td>
<td>0.04</td>
</tr>
<tr>
<td>Semantic-related</td>
<td>-35.76</td>
<td>22.41</td>
<td>27.45</td>
<td>-1.60</td>
<td>0.12</td>
</tr>
</tbody>
</table>

*Note. The estimates show the difference between the related and control (reference) trials per each condition.*

As can be seen, participants responded significantly faster to the morphologically related targets than they responded to the unrelated control, *t*(33) = -2.41, *p* < .05, consistent with Hypothesis 3. This facilitation effect is also present in the orthographic condition, *t*(35) = -2.15, *p* < .05, but absent in the semantic condition, *t*(27) = -1.59, *p* > .05, as predicted by Hypothesis 4. The lack of semantic effects in this experiment provides additional evidence that semantic effects in the translation recognition experiment, and in general, are distinct from morphological effects. However, due to the absence of clear-cut morphological effects that are different from orthographic effects, I conducted an additional correlational analysis to test whether morphological effects can be explained by orthographic overlap. The test returned null results, *t*(33) = 0.67, *p* = 0.50, which confirms that morphological effects are independent of orthographic effects. In other words, trials in which the effects of cross-
language morphological priming were greater were not the same trials in which orthographic overlap was greater.

Accuracy analysis in the lexical decision experiment returned null results within all conditions (see Table 12). Nevertheless, overall accuracy in the experiment was high, which shows that participants were completing the task as expected. In the morphological and orthographic conditions, specifically, marginally better accuracy (3%) in the faster condition rules out speed-accuracy trade-offs. In general, the translation recognition task described in Chapter 3 was unlike the lexical decision task in that the former deliberately confused the participants by presenting a related distractor in place of the correct translation. Consequently, it was foreseeable that conditions would have a high impact on accuracy in the translation experiment, but little to no effect in the lexical decision experiment.

Table 12

Combined Accuracy Models for the Three Conditions

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Std. Error</th>
<th>z value</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morph-related</td>
<td>0.47</td>
<td>0.47</td>
<td>0.98</td>
<td>0.32</td>
</tr>
<tr>
<td>Orth-related</td>
<td>0.46</td>
<td>0.54</td>
<td>0.85</td>
<td>0.39</td>
</tr>
<tr>
<td>Semantic-related</td>
<td>0.31</td>
<td>0.54</td>
<td>0.57</td>
<td>0.56</td>
</tr>
</tbody>
</table>

*Note.* The categorical dependent variable is Correct or Incorrect, with Incorrect as the reference level. For each condition, the control trials are the reference level.
CHAPTER FIVE: DISCUSSION

The present study is an attempt to provide an account of the role of morphology in bilingual lexical processing; in this case, Arabic-English. While the literature is replete with research concerning phonological/orthographic and semantic processing, morphology has rarely been considered as a subject matter in investigating cross-language activation. It is for this particular reason that a recent article by Boudelaa (2018) concludes that, “Future research will have to determine whether other aspects of language processing, such as morphological processing, can also be subject to a unitary processing procedure in Arabic–English bilinguals” (p. 925). The current study addresses this gap by introducing two psycholinguistic experiments, presumably necessitating different levels of morphological activation. The first was the translation recognition experiment, an explicit bilingual context, which intrinsically would engage cross-language processing, although at what levels was not yet clear. The second was the lexical decision experiment, a virtually monolingual context, in which cross-language processing is irrelevant to the task demands, but may nevertheless occur. The two experiments were guided by two research questions, on which we elaborate in the following pages.

**Does (Arabic) Morphology Mediate Cross-Language Activation?**

The first research question sought to replicate the results obtained by Qasem and Foote (2010), but with more robust control of stimulus selection. The first question taps into the general notion of whether or not morphology influences bilingual language processing at all. Like Qasem and Foote, I used a translation recognition task to answer the first question.
If cross-language morphological activation does exist, it must be manifested in a task which induces cross-language activation in the first place, i.e., a translation task.

The results of the translation recognition experiment show that morphological distractors yielded a significant interference effect (see Figure 10). That is, when presented with the morphologically related distractor, participants were slower to reject the translation compared to when the distractor was unrelated. This shows that morphology is an abstract cognitive unit which influences processing during translation tasks. To illustrate, when the participants were presented with the prime, TEAM, activation not only spread to its translation equivalent, fariːq, but also to other lexical items that shared the root FRQ such as firaːq “separation.” Therefore, when subsequently presented with the target firaːq, it was already activated by the prime TEAM; as such, interference occurred due to the need to reject an obviously incorrect translation, but which overlapped in cognitive representation with the correct one. In addition, this interference effect was greater than that in the orthographic or semantic conditions, which allows us to conclude that Arabic morphology does mediate cross-language processing. Overall, the results support Hypotheses 1 and 2 which read:

1. Rejecting a translation will be inhibited by the presentation of morphological, orthographic and semantic distractors compared to their controls.

2. Morphological distractors will show stronger interference effects than orthographic/semantic distractors, and these effects will be independent of effects of orthography and semantics.
Indeed, while all conditions experienced significant interference effects between distractors and controls, the morphological condition posed the highest amount of interference, which suggests that participants struggled the most in rejecting the morphological distractors. The latter is not surprising, nevertheless, as morphological distractors in Qasem and Foote’s (2010) study also yielded the highest interference; this attests to the robustness of Arabic morphological activation during bilingual word processing. Our study, however, differs from that of Qasem and Foote by showing that morphologically related words compete during lexical access even when there is no obvious semantic overlap.

Figure 10. Translation Recognition Reaction Times.
Taken together, the results of the current experiment, as well as that of Qasem and Foote, show that cross-language morphological activation is, perhaps, an inevitable process when consciously functioning in two languages in a task such as a translation task. Furthermore, the fact that all types of distractors interfered in processing shows that in translation tasks, the between-language connections are sensitive to such interference due to the intrinsic nature of the task, which actively requires processing both languages in the first place. That said, it would be more interesting to find out if cross-language Arabic morphological mediation would surface even if the task was irrelevant to the L2, which is what the next experiment was designed to reveal.

Is Arabic-English Cross-Language Morphological Activation Task-Dependent?

The second research question functioned as a follow-up which probed the limits of cross-language morphological activation. In particular, whether or not cross-language morphological processing would prevail even when the task did not explicitly prompt cross-language activation by design. It is possible that the Arabic morphemes influence cross-language processing only when the task itself directly activates them. Thus, the second question put to the test a novel notion in the literature, namely, assessing the task-dependency of cross-language morphological activation.

To investigate this question, a lexical decision experiment was completed which revealed that cross-language Arabic morphological activation continues to influence processing even in an English monolingual context. To illustrate, when participants were presented with the Arabic masked prime َناهِر “daylight,” which they did not have an active awareness of, activation spread to other related words by root such as َناهر “river.”
Further, when they were subsequently asked to make a lexical decision about the English target RIVER, it was already activated, which made the retrieval process of the related target significantly faster than retrieval of unrelated words.

Notice here, that unlike the translation experiment, participants were not required to translate, they only actively saw and were required to decide on the legitimacy of some English words. Further, the Arabic primes were masked. Any Arabic effect was thus unconscious and could not be attributed to strategic use. This makes any conclusions about automatic cross-language morphological activation even more convincing. That is, now we can say with more confidence that Arabic morphemes are solid cognitive lexical units which are activated and retrieved during bilingual word processing, independent from semantics and orthography, and are not restricted to performing explicit bilingual tasks (e.g., translation tasks).
Besides morphology, significant facilitative effects also resulted from orthography (see Figure 11). This was not the case, however, for masked semantic primes. The absence of semantic effects in this experiment serves as additional evidence that morphological effects—in both experiments—were not semantically driven. In addition, the correlational analysis revealed that higher orthographic overlap does not correlate with stronger facilitation effects in the morphological condition, which suggests that morphological effects are also independent of orthographic effects. Overall, the current findings support Hypotheses 3 and 4 which read:

1. Recognition of the English targets will be facilitated in the morph-related trials compared to the morph-control trials.
2. Given the previous findings that within-language masked priming with Semitic languages is robust in morphology, weaker in orthography, and almost non-existent in semantics (Forster, 1999; Wentura & Degner, 2010; Frost et al., 2005), the morphological facilitation will be distinct from orthographic facilitation. Furthermore, there will be no facilitation in the semantic condition.

**The Root Morpheme as an Independent Cognitive Processing Unit in Semitic Languages**

The effects triggered by morphology, orthography and semantics in the experiments are qualitatively unique. That is, the morphological, orthographic and semantic information in a word constitute distinct mental representations and lead to different activation paths in the mental lexicon. Morphological activation, in particular, is not a result of the combined processing activity of orthography and semantics, as previously believed (Frost et al., 1997). The latter conclusion could not have been reached in Qasem and Foote’s study though. That is, Qasem and Foote could not disassociate effects of semantics from those of morphology. As explained before, many of their morphologically related words were also semantically related; e.g., book – desk; refrigerator – ice; lawyer – protection; key – opening, etc. By contrast, the stimuli used in this research were composed of morphologically related pairs which were the furthest possible from being semantically related, as the pool of reviewers attested (e.g., official – drawing; book – battalion; neck – sergeant; fish – thick).

Since current bilingual research has yet to investigate Semitic languages in depth, we must consult monolingual research in our discussion regarding the independent status of morphology. Indeed, insights on morphology in the bilingual context can be drawn from
research in the monolingual context, since the former is a continuation of the latter. After extensive work on Arabic morphology, Boudelaa and Marslen-Wilson repeatedly reported that morphological effects are more salient and dominant and, thus, take precedence over orthographic and semantic effects. Based on our present findings, however, we can add that morphological effects are salient even during bilingual language processing.

In fact, strong independent effects of morphology are not uncommon with Semitic languages in general. Frost et al. (1997) investigated the status of roots in Hebrew, while controlling for confounds such as orthography and semantics, to find that activation of roots can be pre-lexical; this means that roots and words derived from the roots are retrieved even before activation spreads based on orthographic similarity. This finding is in sharp contrast with findings derived from Indo-European/concatenative languages, which relegate pure morphological activation to post-lexical level processing. Further, pre-lexical root prioritizing is also evident in eye-movement research which looks into the optimal viewing position (OVP), i.e., the position in the word where word identification is maximal. Deutsch and Rayner (1999) reported that the OVP is modulated by the location of the first letter of the root morpheme in Hebrew. Further, Deutsch and Rayner suggested that “lexical information, such as root location, is picked up by the reader on the basis of parafoveal vision, and is used to govern initial landing position.” (p. 418). This implies that the process of identifying nonadjacent meaningful letters (the root) is pre-lexical and even below the level of consciousness.

Another line of research which illustrates the uniqueness of morphological processing in Semitic languages, compared to Indo-European languages, comes from studies showing the transposed-letter effect. The transposed-letter effect is when jumbled letters prime intact
words (e.g., sawndcih–SANDWICH). This phenomenon is so common in Indo-European languages that a considerable number of monolingual lexical access models have been invented to account for it. Consequently, it was taken for granted that lexical coding in the mental lexicon is flexible in terms of letter-position. Not only that, but most of these models “have argued that letter-position flexibility reflects general and basic brain mechanisms” (Frost, 2012, p. 265). Nevertheless, and as always, the relatively neglected Semitic languages were found to sharply contrast with this phenomenon.

For instance, Perea, Mallouh, and Carreiras (2010) created two sets of trials in trying to solicit this transposed-letter effect in Arabic. In the first set, the transposition affected the root-letter order. For example, ʕabi:d - baʕi:d [“slaves–far”], where the root in the prime was ʕ.B.D, but B.ʕ.D in the target. In a second set of trials, the transposition was done in a way that did not affect the order of the root letters as in qjas - juqas [“measurement–will be measured”] (root letters are in bold). The task was masked lexical decision. The interesting finding pertains specifically to the first set of trials, where transposition affected root-letter order. Here, and based on research from Indo-European languages, the transposed-letter effect should be detected since it presumably results from orthographic overlap between the prime and target. However, Perea et al. (2010) detected the effect only when the root-letter order was intact (in the second set of trials). Similar results have also been reported in Hebrew (see Frost, 2012).

Indo-European languages, thereby, exhibit flexible letter-position coding, whereas Semitic languages display rigid letter-position coding (Frost, 2012). In Semitic languages (Arabic and Hebrew in particular), lexical space is dense where the same set of three root letters can be reordered to produce new words, each with its own meaning and derived forms.
(Perea et al., 2010). For instance, the root S.B.H (which carries the general meaning of swimming) can be reordered to produce the root H.S.B (to calculate), and S.H.B (to withdraw). Plus, each root has its own derived forms by inserting it into different abstract word patterns. In other words, the same set of root letters, along with a limited number of word patterns, can be used in different combinations in order to generate new words. English, by contrast, mainly utilizes aligning or adding, or substituting phonemes to generate derivations, and not by changing morpheme order, as in Arabic root morphemes. We can, for example, add “–ment” to the base word JUDGE, to create JUDGMENT; however, we cannot rearrange the letters in JUDGE to create new words. In fact, most words in English are recognized by their unique set of letters regardless of their order. This feature is what makes recognition of the jumbled JUGDE or SNAWDCIH effortless; the reason is that there are simply no other words in the lexicon which share the same set of letters; in other words, no other words competing with them (Frost, 2012). Therefore, unlike European languages, in Semitic languages, “the order of the root letters is allowed only a minimum degree of perceptual noise to avoid the negative impact of activating the “wrong” root family” (Frost, 2012, p. 378).

Patients with letter-position dyslexia (LPD) provide additional evidence for how the structure of the specific lexical space impacts cognitive processing. Specifically, LPD patients display difficulties in registering the position of letters within a word. This condition, however, was found to hinder reading in Semitic languages, but not so much in European languages. Shetreet and Friedmann (2011) conducted a study where an English-Hebrew speaker developed reading difficulties after an ischemic infarct. Surprisingly, his reading performance in English was close to normal; thus, he could not be diagnosed with LPD. Only
after testing reading in Hebrew did he show symptoms of LPD; where he displayed obvious reading impairment. Furthermore, pure cases of LPD are generally rarely reported in European language speakers, but are much more prevalent among Hebrew speakers (Friedmann & Rahamim, 2007). Frost (2012) explained that because failure to attend to letter position in Hebrew mostly results in activating the wrong root family, which leads to the perception of unintended words, LPD in Hebrew yielded significant reading difficulties. Letter position errors in English, on the other hand, rarely result in perceiving actual alternative words, and thus LPD did not impact reading in English as much.

Consequently, Frost suggested that, in fact, the cognitive system extracts from different writing systems different linguistic information, depending on the deep structural properties of the printed words. This concerns, above all, the contribution of individual letters to word meaning and recognition. More broadly construed, reading builds on lexical processing which is established with the spoken language. For example, if Arabic speakers have already learned that the order of consonants in a tri-consonantal root has the potential to change the core meaning of the word, then it is sensible to assume that Arabic-speakers are already highly sensitive to phoneme order prior to learning to read because it allows them to detect the root morpheme. In turn, this fundamental aspect of lexical processing will shape reading in Arabic. Proficient readers in Arabic learn what information in the orthographic code is most helpful for supporting previously established word identification processes. As such, they may become more sensitive to letter order than speakers of Indo-European languages where transposition of phonemes or their corresponding graphemes within the word might not generate competing word forms. Put differently,
Since the lexical system seeks out patterns in the environment in order to acquire, store, and access linguistic knowledge in an efficient way, it is the domain of knowledge that is most consistent and regular that will gain more weight in determining the way the mental lexicon is organized. This will vary cross-linguistically since speakers of different languages make differential choices of the way they encode meaning. In Semitic languages the most consistent and recurrent patterns are those provided by the morphological domain. (Boudelaa & Marslen-Wilson, 2005, p. 229).

Therefore, it is hard to claim that there is a single universal lexical access pathway governing all languages as some lexical access models seem to suggest. It all depends on the linguistic environment in which the cognitive system operates, which, in turn, is modulated by phonological, morphological and orthographic considerations.

In the end, most of the findings reviewed above pertain to the monolingual context. They were referred to in order to shed some light on the uniqueness of morphological elements in Semitic languages, and how this contrasts with typologically distinct languages such as English. This line of research shows how morphology influences lexical access and governs the mental lexicon, particularly for speakers of Semitic languages. However, it is not yet clear how all of this transfers to the bilingual context where a Semitic language is only one of the spoken languages of the bilingual individual. How such robust and salient within-language morphological representations influence bilingual processing is fertile ground for further exploration. The current investigation is one attempt in this novel direction.
The Status of Orthographic and Semantic Activation

The main focus of the current research was morphological processing; however, since we witnessed cross-language orthographic and/or semantic activation, it makes sense to include a section elaborating on their mechanism in the case of Arabic-English processing.

As far as cross-language orthographic activation is concerned, the type of languages used will have a bearing on the mechanism of orthographic effects, in particular, whether or not the two languages of the bilingual share similar script. When they do, there is an abundance of research which suggests that bilinguals draw from the same orthographic reservoir, which is shared by the two languages non-selectively. For instance, examining French-English bilinguals, Bijeljac-Babic, Biardeau, and Grainger (1997) reported that reaction times in a masked lexical decision task to English targets (e.g., DIET), were significantly slowed when primed by orthographically related words from French (e.g., DIEU), compared to when primed with unrelated words (e.g., VENU). Such interference effects are indicative of competition for selection that results from the non-selective access to orthography from both languages.

The aforementioned study, nevertheless, pertains to same-script languages, where the printed script corresponds to both languages and thus excites activation from both languages based on overt alphabetic overlap. But how about when the overt alphabetic similarity does not exist, as in the case with distinct-script languages such as Arabic and English? Here the mechanism of cross-language orthographic activation cannot rely on overt alphabetic similarity. That is, we cannot say that the orthography is shared by both languages. Instead, it now follows a mechanism similar to that of morphology, via translation. A few studies have investigated the non-selective orthographic access to the other language when the two
languages are qualitatively distinct in script. For instance, Mishra and Singh (2014) utilized eye-tracking methods where participants heard a sentence in English containing a critical word (e.g., GUN “bandook,” in Hindi), while simultaneously visually presented with four Hindi words: an orthographic distractor of the correct translation equivalent of the critical English word (e.g., BANDAR), as well as three unrelated Hindi words. Participants disproportionately fixated the orthographic distractor relative to the unrelated words, which suggests, according to the authors, that participants activated the orthographic competitors of the translation equivalent of the critical English word. In other words, the only way for GUN to influence fixation of BANDAR is if participants activated not only the translation equivalent of GUN, which is BANDOOK, but also other lexical items which are orthographically related such as BANDAR; so, when they see BANDAR, they orient their vision towards it more often than other unrelated words. Similarly, in the current lexical decision task, orthographic priming occurred via translation mediation. The pair, for instance, shaʿb “nation,”- HAIR is related by orthography through translation, where shaʿb overlaps in orthography with the translation equivalent of the English target HAIR “shaʿar.”

Orthographic priming, however, is intrinsically interwoven with phonological priming since the relationship between two words in spelling typically entails a relationship in phonology. There is some evidence, nevertheless, that suggests that what bilinguals access during cross-language activation is perhaps the sound and not the spelling of the non-target language. Wu and Thierry (2010) presented Chinese-English bilinguals with English word pairs and asked them to judge their semantic similarity. Unknown to the participants, the semantically unrelated pairs concealed a relationship in the L1 through translation. The critical English pairs either carried sound repetition in Chinese (e.g., Jing Yan-Jing Ya) with
no spelling repetition (经验-惊喜), or spelling repetition in Chinese (e.g., 会计-会议) with
no sound repetition (e.g., Kuai Ji—Hui Yi). Wu and Thierry detected a significant priming
effect only when the English pairs concealed sound repetition in Chinese, suggesting that
orthographic cross-language activation may, instead, be phonological cross-language
activation.

That noted, until additional research supports the above finding, our study
differentiates between orthographic vs. phonological priming based on the modality utilized.
Since in the current experiments the participants read the stimuli which are visually presented
to them, we refer to the effect as orthographic. But these results may well reflect cross-
language phonological activation as well.

Unlike orthography, semantics are relatively always shared across languages,
provided that the bilingual subject obtains an adequate level of proficiency in the other
language. According to the RHM model, with an advanced degree of proficiency in the
second language, the conceptual level is linked to both languages. Therefore, in the
translation experiment, for instance, when participants first saw the word GOLD, activation
automatically travelled in the semantic network to other related words from both languages
such as SILVER in English, or its translation equivalent in Arabic “fidʾah.” And when
participants are subsequently presented with fidʾah as a potential translation of GOLD,
participants have difficulty in rejecting this semantically related candidate, compared to an
unrelated word.
Limitations and Suggestions for Future Research

Research in bilingual morphological processing is in its infancy. And in science, it is the collective contributions of multiple research efforts that dictate our understanding of the studied phenomenon, rather than the insights of an individual research study. Therefore, any additional evidence in support of our novel finding is already a valuable contribution. However, sampling, in particular, is an area in which future research can improve. The current study recruited 31 Arabic-English bilingual participants for two experiments. Sample size was sufficient to reveal significant effects using the current paradigm, but may not be sufficient for all types of tasks. Further, these bilingual participants shared an important trait which distinguishes them from the average Arabic-English speaker. That is, the study was conducted in the USA, on individuals who had obtained a scholarship to study abroad. Students who go to the United States for academic purposes are chosen due to their distinguished achievements in their schools or careers. Furthermore, these students use their second language, English, in this context more than their native language, Arabic. Therefore, it is possible that their exceptional language competence and experience influences the way their two languages interact in the mental lexicon, which renders them incomparable to the average Arabic-English bilingual speakers in the Kingdom of Saudi Arabia. Thus, a potential direction for future studies is to look into varying proficiency levels of Arabic-English bilinguals to figure out whether language use and competence moderate cross-language morphological activation.

Secondly, having the participants complete two unrelated experiments might have caused some spill-over effects, such that their performance in the second experiment was influenced by their performance in the first experiment. However, to mitigate this, the order
in which each participant completed the experiments was alternated with every other participant. That said, future research might benefit from refraining from having the same group of participants complete two different experiments in the same setting.

Aside from overcoming these limitations, future research can also expand the findings with regards to translation asymmetry. For the translation experiment, both the current study and that of Qasem and Foote (2010) implemented only backward translation. While previous research shows that directionality is an influential predictor in cross-language activation in general (Xia & Andrews, 2015), it remains to be seen if directionality is vital in morphological cross-language activation. The current study did not prioritize assessing priming asymmetry since the experiments were of distinct types. A potential question in this regard, however, is whether or not morphological mediation will continue to influence cross-language activation bidirectionally.

The Current Results in Light of the RHM Model

It is important to start by noting that the RHM model was originally designed to account for language production phenomena (Kroll & Stewart, 1994). However, since its advent, several researchers have extended the model to correctly explain their comprehension data (Kim et al., 2011; Qasem & Foote, 2010), in addition to Kroll herself in Sunderman and Kroll (2006). Furthermore, in a later paper, Kroll acknowledged the capability of RHM in explaining some recognition phenomena: “Given what we now know after fifteen years of research, the assumption of parallel activation can be incorporated into the RHM to be able to also account for word recognition data” (Kroll et al., 2010, p. 374). Moreover, while the RHM model is not concerned with the precise dynamics of lexical recognition, its wider
focus on how word-to-concept mappings are developed and accessed during both languages’ processing makes it a suitable candidate to look at word connections in the bilingual mind in general.

It is also important to remark that the overarching mental connections proposed by the RHM model are not restricted to a specific task such as translation. Instead, the model is meant to provide a general mental architectural map of how the two languages are connected and interact. Thus, in theory, the model’s basic assumptions can be tested out using any appropriate experimental paradigm. It is true that Kroll and Stewart (1994), who designed the RHM model, employed translation tasks, but they referred to studies which utilized different bilingual tasks in support of their model assumptions. Furthermore, Brysbaert and Duyck (2010) consulted research which used a variety of bilingual tasks to cast doubt on some of the assumptions of the RHM model. Therefore, in the present experiments, both the translation task, which involved backward bilingual processing (L2-L1), and the lexical decision task, which involved forward bilingual processing (L1-L2), should adhere to the assumptions of the RHM model.

According to the RHM model, lexical links from L2 to L1 are stronger than in the opposite direction. Also, although the conceptual level is connected to both languages, the connections are stronger in the case of L1 (refer to chapter three for a complete description of the model). Given the assumptions, we would expect backward processing (L2-L1) to be lexically-driven, with little or no semantic mediation depending on L2 proficiency. Indeed, this has been born out in the translation experiment where lexical factors (morphological/orthographic) yielded stronger effects than semantic ones. It is worth mentioning here, nevertheless, that the existence of semantic effects at all in backward
processing is not consistent in the literature. For example, both Kroll and Stewart (1994) and Sholl, Sankaranarayanan, and Kroll (1995) reported that backward processing was immune to semantic effects. While the RHM model does explain that with high enough proficiency in L2, the conceptual level becomes more readily accessible in the L2, which results in semantic mediation in backward processing, both of these studies claimed that their participants were proficient in the L2, but still failed to obtain semantic effects. Consequently, it seems that the proficiency threshold above which L2 becomes connected to the concept level is fuzzy.

Nonetheless, this inconsistency might be justified when we take a closer look at the participants’ background in the present study, on the one hand, and that of Kroll and Stewart and Sholl et al., on the other. In our current study, the participants were residents of the L2 country, and were enrolled in bachelor- or graduate-level degrees in the L2. They were immersed in the L2 environment at the time of the experiments. On the contrary, the participants of the two abovementioned studies did not study/live in the L2 country, at least the authors did not say so, and only confirmed their high L2 proficiency by self-report. Accordingly, it is possible that the participants in the current study possessed a higher level of proficiency and immersion in the L2 than participants in the other two studies, which enabled them to experience semantic mediation in backward processing.

Otherwise, the culprit might be the experimental stimuli themselves. Talamas, Kroll, and Dufour (1999) divided their participants into two L2 proficiency groups, high and low, and administered a translation recognition task. Initially, only the high proficiency group was affected by the semantically related words. However, the authors introduced a new variable consisting of similarity ratings of the semantically related pairs ranging from 1, “more similar pairs,” to 7, “less similar pairs.” After running the analysis with the new variable, the low
The high proficiency group was affected by the semantically related pairs regardless of the degree of similarity in the pairs. This finding led the authors to conclude that the reliance on lexical links in L2-L1 processing, which with increasing proficiency in the L2 transfers to more reliance on conceptual links, is, first, a matter of degree and not “an absolute change in the nature of the information that is accessible to the learner” (p. 45). Further, and more importantly, this developmental transition is moderated by the featural similarity between words. This may explain the discrepancy between the studies. That is, it is possible that, regardless of the proficiency level of the participants, the stimuli used by the two initial studies exhibited lower levels of semantic similarity, and thus did not supply adequate semantic overlap to affect processing.

Another assumption that the RHM model makes is that L1-L2 processing should be semantically mediated. The model does not disregard lexical connections; however, it does suggest that L1-L2 processing should be more heavily affected by semantic manipulations than lexical ones. Contrary to the model predictions, RTs in the lexical decision experiment (i.e., L1-L2 processing) were facilitated only by lexically related words (morphological and orthographic manipulations), and no effect resulted from semantic manipulation.

The absence of semantic effects in the lexical decision task can partially be explained by the temporal delay assumption which asserts, among other things, that when orthographic representations of a given word become active, they begin to activate the related phonological and semantic codes, which suggests a delay in activating the semantic codes relative to the lexical and pre-lexical ones. On top of that, the lexical decision task employed masked priming, which does not allow sufficient time for word processing in the first place.
As such, only the faster codes (i.e., morphology/orthography), which are based on surface lexical manipulation, produced the effect. However, the slower codes (i.e., semantics), which tend to be activated slightly later during word processing, did not have enough time to affect processing. That is, the semantic representations of the prime words were not given sufficient time to be processed and eventually produce the expected effect.

On the contrary, primes in the translation experiment stayed on the screen for 400 ms, which allowed enough time for their semantic codes to be extracted and subsequently influence target recognition. In fact, one of the main reasons why masked primes were used in the lexical decision task was on the grounds that masked priming was reported to be immune to semantic effects, but sensitive to lexical ones. And, since our goal was to separate morphological effects from semantic confounds, masked priming was utilized.

Therefore, undoubtedly, the type of task used in experimental psycholinguistics has a bearing on the results (Dijkstra & Van Heuven, 2002). While the translation task involved both languages in processing and provided sufficient time for processing to be completed, the masked lexical decision task restricted conscious processing to one language and did not provide, relatively, sufficient time for semantic processing to completed. Coupled with the fact that semantic codes are generally activated relatively later during word processing, semantic effects were absent in the lexical decision task (i.e., L1-L2 processing).

But why didn’t the RHM model predict the semantic activation behavior in the masked task? While the RHM model was designed to provide a general scheme of how any two languages are represented and interact in the mental lexicon, the authors only used translation tasks in building the model. Accordingly, RHM generalizations might not apply to other linguistic tasks, or at least may not be well-suited to them. Further, the authors mostly
relied on typologically-similar languages in assessing the model’s assumptions. We have seen, in a previous section, how lexical access is uniquely established in the mental lexicon of Semitic language speakers. Therefore, it might be fair to suggest that while the RHM model can surely predict most of bilinguals’ processing behavior, based on any pair of languages, it is best-suited to the languages it was originally based upon, and that additional modifications are needed to account for the unique characteristics of typologically distinct languages. In short, the RHM model needs not only acknowledge that various languages might display different patterns of lexical connections, but also different linguistic tasks can facilitate specific connections between the L1 and L2 while suppressing other connections.

Models of Lexical Access and Semitic Languages

Throughout this paper, we have repeatedly pointed to areas where the current models of lexical access seem to be inadequate in capturing the characteristic features of lexical access in Semitic languages. Frost and Marslen-Wilson are two of the prominent names in the field who addressed this discrepancy between what the diverse population of languages display in terms of unique characteristics on the one hand, and the emphasis of lexical access models on modelling the particular characteristics of a few Indo-European languages on the other. Frost (2012), for instance, provided a detailed account of five typologically distinct languages (Chinese, a Sino-Tibetan language; Japanese, an Altaic language; Finnish, a Finno-Ugric language; English, an Indo-European language; and Hebrew, a Semitic language) as an example of the linguistic diversity found in the world’s languages. Boudelaa and Marslen-Wilson (2005) remarked that the corresponding orthography, which contains the morphological/phonological information, is efficiently optimized in accordance with how the
mental lexicon of the language is organized. Frost (2012) further put it in evolutionary terms when he claimed that different orthographies do not evolve arbitrarily, but rather are optimized to provide their readers with the maximal phonological and morphological information; thus, “the cognitive system that processes language must be tuned to the structure of the linguistic environment in which it operates” (p. 266).

If that is the case, then how can a single model account for the variations found in distinct languages? In his advocacy of ‘a universal model of reading,’ Frost (2012) suggested that lexical access models should focus on finding what he labelled as reading universals, which must be abstract and general enough to fit all writing systems and their cross-linguistic differences. Such universals aim at specifying the common cognitive operations responsible for reading across diverse printed scripts. Furthermore, since lexical access models are mostly concerned with word identification, and since words have morphological, semantic, phonological and orthographic properties, universality dictates that whatever generalizations we draw about one linguistic property based on a certain language must be constrained by what we know about the other linguistic properties from other languages: “It should be emphasized that the theoretical value of a model is independent of the prevalence of the language that is being modeled” (Frost, 2012, p. 274).

That being said, a number of scholars have doubted the existence of fundamental reading universals shared by all languages, let alone the plausibility of constructing a universal model of lexical access. Coltheart and Crain (2012), for instance, argued that while there are universals of language, there are not universals of reading. Neither do all writing systems share universal properties, nor do the cognitive information-processing systems implicated in reading different scripts display common features. Behme (2012) added that
models that can satisfy the needs of all reading aspects across languages at once are unattainable with the available technology. As such, a call for universality in reading is premature at best. Instead, separate models might be necessary to account for aspects pertaining to specific languages or language groups.

Nevertheless, all, including Frost, have concurred that if universal models are currently beyond our reach, existing and emerging models need to explicitly acknowledge their scope as well as the languages being modeled or targeted. As such, these models cannot be taken as part of general reading theory, but can apply to a set of languages and not others.

**Conclusions**

Morphological processing is an under-investigated topic in the realm of lexical access, compared to orthographic or semantic processing. On the grounds that morphological activation is simply a by-product of orthographic and semantic processing, most lexical access models either do not allocate a specific stage during which morphological elements are retrieved and processed, or ignore morphemes altogether in the process of lexical access. What brought about this relegation of morphological processing to a secondary role in lexical access in the first place is the overrepresentation of languages in the literature which inherently cannot offer a better explanation due to the nature of their morphological systems. Semitic languages, on the contrary, whose root morphemes serve as a pedestal for word recognition, provide fertile ground for investigating morphological processing, and provide an alternative perspective on how morphological units can function as stand-alone elements in shaping and organizing the mental lexicon of Semitic language speakers.
While first language research has managed, at least rudimentarily, to put to use Semitic languages in investigating morphological processing, bilingual research is almost nonexistent in this regard. The present study recruited Arabic, as a Semitic language, to bridge the gap between what we know about Semitic language morphology in the monolingual context and how that transfers to the bilingual context. The results indicate that root morphology in Semitic languages is very robust, such that not only does activation spread within language via morphology, but also across languages via morphological mediation.

As stated before, models of lexical access, which are mostly built around evidence from Indo-European languages, do not reflect the distinctive morphological structure of Semitic languages. Realistically, though, because languages are intrinsically diverse, which in turn can adjust the way the cognitive systems of their users structure the corresponding mental lexicon, a single lexical access model simply cannot capture the distinctive idiosyncratic features pertaining to all languages or language groups. Instead, models of lexical access should, firstly, acknowledge this limitation and, secondly, straightforwardly declare their scope. It follows that even experimental researchers should be critical in defining their goals and generalizing their results. The current study, for one, aims to generalize to lexical access in Semitic languages only. While the current experiments might be narrow in goal, such individual pieces of knowledge can build vastly toward a model of lexical access in Semitic languages. Furthermore, if a universal model of lexical access becomes, after all, a feasible object, researchers invested in modeling lexical access can and should piece together the contributions from typologically distinct languages—such as the current work—in their pursuit of a universal model of lexical access. As Boudelaa and
Marslen-Wilson (2005) put it, “If we are to build a viable theory of language processing that captures the universal properties of language without failing to acknowledge the idiosyncratic characteristics of different languages, we need to sample typologically different languages” (p. 234).
## Appendix

1. Stimulus list for the translation experiment

<table>
<thead>
<tr>
<th>Prime</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prime</strong></td>
<td><strong>Morph-distractor</strong></td>
</tr>
<tr>
<td>1</td>
<td>Eye &quot;عين&quot;</td>
</tr>
<tr>
<td>2</td>
<td>Flag &quot;علم&quot;</td>
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Note: The table contains a mix of English and Arabic words with their translations.
2. Stimulus list for the lexical decision experiment

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Unemployment

"بطالة"

Nature

"طبيعة"

Virgin

"عذراء"

River

"نهر"

Cheese

"جبن"

Window

"نافذة"

 Miracle

"معجزة"
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