Lexical Access and Language Proficiency of Trilingual Speakers

By

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A dissertation submitted to the Graduate Faculty in Speech and Hearing Sciences
in partial fulfillment of the requirements for the degree of Doctor of Philosophy,
The City University of New York

2001

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This manuscript has been read and accepted for the Graduate Faculty in Speech and Hearing Sciences in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

8/30/01

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Abstract

LEXICAL ACCESS AND LANGUAGE PROFICIENCY

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Mira Goral

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Cross-language activation among the three languages of trilingual speakers was studied using a cross-language, translation-equivalent priming paradigm in a lexical-decision task. The effects of proficiency level in each language and the relative proficiency levels of the three languages on the priming results were assessed. The participants were 79 native speakers of Hebrew who had varying levels of proficiency in their additional languages, Arabic and English. Proficiency in the two non-native languages was measured by latencies and accuracy levels in a simple lexical-decision task in each language and by participants' self-reports. The experimental material included non-cognate translation equivalents in the three languages.

The results demonstrated the importance of level of non-native language proficiency and its effect on cross-language lexical activation. Overall priming effects were found from Hebrew primes to English targets, with decreased effects associated with increased English proficiency. Overall priming effects were not found in the opposite direction, from English primes to Hebrew targets, but the same decrease in effects with increased English proficiency was evident. No similar overall effects nor similar correlational effects were obtained between Hebrew and Arabic in either priming direction. Priming effects between the two non-native languages were significantly affected by the relative level of proficiency of the two languages. Facilitation effects were found when the prime language was of lower proficiency than the target language and when the two languages were of equally low proficiency. In contrast, inhibition effects were evident when the prime language was of higher proficiency than the target language. The results are discussed with respect to previous studies and current models of bilingual lexical processing and with emphasis on the importance of language proficiency. A preliminary model of multilingual lexical activation is subsequently proposed. Variables such as speed of processing and stimulus and task characteristics that are relevant to priming studies specifically, and to research on lexical processing in trilingual and multilingual speakers more broadly, are addressed.

Acknowledgments

This work is a peak in a climb I started quite some time ago. Along the way, I was taught, directed, supported, accompanied, and inspired by my advisor and committee chair, Loraine Obler. I have been most fortunate to be exposed to and benefit from her scientific thinking, her thoughtfulness, and her interests not only in neurolinguistic investigation, but also in her students and her colleagues around the world. She is a remarkable woman and I would like to offer her my deepest thanks.

I am grateful to Marty Gitterman for his continuous advice and for his confidence in me. I would like to extend my sincerest thanks to Elaine Klein for her scientific insight, enthusiasm, and warm support. It was my pleasure and my honor to have Judy Kroll as my outside reader. I appreciate her knowledge, hospitality, helpful comments and encouraging approach.

A research project of this sort cannot be accomplished without the assistance of many who participate in it in various ways and those who volunteer their time, or office, or knowledge, or experience, or all of these. I would like to thank Anat Ambar, Ofer Amir and his students at Al-Quds University, Ruth Berman, Jonathan Fein, Ken Forster, Ram Frost, Tami Gollan, Avishai Henik, Jim Jenkins, Ariela Lowenstein, Dorit Ravid, Debbie Raymond, David Rindskopf and the statistics seminar, Anan Safadi, Yael Sharvit and Gidi Avrahami, Joseph Shimron, Anat Stavans, Rafi Talmon and the students at the Arabic department at Haifa University, and Yishai Tobin. And I thank all the trilinguals who participated in the study, shared their insights and, invariably, expressed their interest in the questions that motivated this research.

Invaluable to me have been my much-missed friends in Israel and my dear friends that I have made in New York City and at CUNY. I also want to thank Loretta Walker, who was always there. I only wish Irv Hochberg could have been part of my last steps at the GC, as he was during my first.

And most of all I owe my family. My parents, who have always been there, near or far, and always behind me, always loving. My sister and her family, for all the help and all the love. Helene Blum, for her love, support, and inspiration. And my beloved Karl, who never tired to read or listen or be there, who believed in me even when I did not, who makes all this worth doing.

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Chapter 1: Introduction

Background: Two or More Languages in One Brain

Neurolinguistic and psycholinguistic studies of multilingual speakers investigate the extent to which various languages are represented separately in a single brain. Neurolinguistic evidence from bilingual and multilingual speakers suggests partial overlap in their language representation, with data supporting a certain degree of independence in the representation of coexisting languages. Evidence comes from studies with neurologically affected multilingual speakers as well as, most recently, brain-imaging studies with neurologically intact participants. Psycholinguistic evidence includes production and perception tasks of language processing in unilingual and multilingual conditions. The neurolinguistic evidence in the literature is often not comprehensive, but involves various levels of language processing (single words, sentences, discourse); the psycholinguistic studies focus predominantly on lexical representation and processing.

Examined below are neurolinguistic sources of evidence and psycholinguistic research on bilingual and multilingual speakers, an overview of recent methods used to explore the issue of multilingual lexical representation, and a review of priming studies and the theories behind them. In addition, findings regarding the role of language proficiency in language representation are discussed.

Finally, a summary of the review is followed by an outline of the predictions of the present study.

Neurolinguistic Evidence: Polyglot Aphasia, Cortical Stimulation, and Brain Imaging

Polyglot Aphasia

Various cases of multilingual speakers who experienced aphasia resulting from brain damage have been described by aphasiologists and other researchers over the decades (e.g., Albert & Obler, 1978; Charlton, 1964; Paradis, 1983). While the more common pattern of deficit and recovery shows parallel effects on all languages (e.g., Obler, 1984; Paradis, 1977), a substantial number of non-parallel effects received attention in the published literature. It is important to note that early reports are characterized by lack of details pertaining both to patients' history of language acquisition and proficiency, and to patients' measured language ability post-onset (e.g., Grosjean, 1998; Obler 1984; Obler, Levy & Goral, 1999). Nonetheless, the documented examples of non-parallel effects provide intriguing data and a basis for models of bilingual representation.

Several types of differential patterns have been reported in the literature. In such cases, one or several of the languages spoken by multilinguals prior to the onset of their impairment were affected differently following a single lesion (e.g., Nilipour & Ashayeri, 1989; Paradis, 1989; Watamori & Sasanuma, 1978). For example, a well documented study of a trilingual Farsi-English-German aphasic patient describes the course of differential, indeed alternating, recovery of the trilingual's three languages (Nilipour & Ashayeri, 1989). The patient was a native speaker of Farsi who was proficient in German and had a written and oral knowledge of English. His course of recovery from a left fronto-temporal lesion was characterized by several stages, beginning with no output, then alternating between several-day periods of output in German only and Farsi only, and finally regaining voluntary output in the three languages. Other studies report selective patterns of recovery, i.e., when one (or more) language (or languages) recovers while another language (or languages) does not. Cases with selective patterns comprise a substantial part of the differential-recovery cases reported, for example, about 25% of the cases summarized in Paradis (1977).

An example of selective recovery is the patient described in Schultze (1968, in Obler & Albert, 1978), who spoke Bulgarian as a first language and German, Russian, French, and English as additional languages. The patient was reported to recover Bulgarian skills first, followed by German and Russian, but did not recover the French and the English. It is not clear from the report, however, whether the remaining two languages recovered eventually or never recovered. Moreover, not many details are provided with respect to the level of the patient's premorbid proficiency in any of those languages.

An ultimate example of differential deficit would be different types of aphasia manifested in each of the languages of a bilingual or multilingual speaker. This is, however, extremely rare. One example of such marked dissociation of two languages of a multilingual speaker is the case described in Albert and Obler (1978). A right-handed woman, who was Hungarian-born but had learned French and English in late childhood and Hebrew at age 16, suffered a tumor and underwent surgery at age 35. She was subsequently diagnosed with Wernicke's aphasia in English but Broca's aphasia in Hebrew. Additional information about the specific manifestation of the language deficit of this case is needed in order to determine that language-specific consideration could not account for the apparent dissociation of deficit in the two languages (see, for example, Goral, 2001; Menn & Obler, 1990; Paradis, 2001).

Such reported cases of alternating or selective recovery led researchers to develop several theories regarding the organization and processing of more than one language. These include theories that assume that different languages may be served by different neural networks. In other words, the different languages are differently organized in the brain and therefore might be affected differently by a focal lesion. A related approach assumes that the different languages have both common and different underlying representations such that various patterns of parallel or differential deficit are possible. Others suggested that selective patterns of recovery are due to compromised resources and that all skills will gradually recover. Under this theory, cases of successive recovery, when the recovery of one language follows that of another, are accounted for by a compromised language system gradually regaining previous abilities. (For reviews see Albert & Obler, 1978; Fabbro, 1999; Paradis, 1977; Paradis, 1989). In addition to issues of organization and resource allocation, various researchers emphasized the role that factors such as age and manner of acquisition of the relevant languages and degree of language use around the time of the insult play in the recovery process. Unfortunately, these details are often missing from early reports of polyglot aphasia and clear relations between any of these variables and the pattern of aphasia and its recovery have not been identified. Indeed not only in early studies but in more recent studies of polyglot aphasia as well, it is difficult to obtain objective measures of pre-onset language proficiency and language use.

Despite the myriad factors that need to be considered (e.g., age of acquisition, manner of acquisition, frequency and context of use) and the missing details in many of the early reports of polyglot aphasia, it appears that at least in some of the cases, not all the languages of multilingual speakers are affected, nor recover, at the same rate or pattern. An intriguing account for differential effects is associated with differential representation or processing of the different languages within the language area. Evidence concerning this account comes from two types of experimental studies in multilingual speakers: cortical stimulation and brain imaging.

Cortical Stimulation

Cortical stimulation studies with patients who suffer epileptic seizures (e.g., Ojemann & Whitaker, 1978; Rapport, Tan, & Whitaker, 1983) provide direct, albeit sparse, data about intrahemispheric organization of two languages in one brain. In cortical stimulation studies with epileptic patients, the cortex is exposed, under local anesthesia, for the purpose of locating the focus of the seizure. Electrical stimulation of the exposed cortex is used to determine the location of the motor and sensory centers and the language area. Ojemann and Whitaker (1978a, b) based their studies on the findings reported in Penfield and Roberts (1959) that electrical stimulation produced temporary impairment of speech and language. In Ojemann and Whitaker (1978a), the authors reported two cases of bilingual speakers who underwent such operations. The purpose of the study was to investigate whether stimulation to the language area would affect the two languages differentially. The first case was a native speaker of Dutch who learned English at age 25 upon emigrating to the United States. Dutch remained his preferred language. The language mapping was performed using a picture-naming task in the two languages. Prior to the stimulation, the patient was able to name all pictures in both languages. In their results, Ojemann and Whitaker reported several focal areas where naming in both languages was affected during the stimulation. Crucially, however, there were several sites where naming was disrupted only in English or only in Dutch. These differential areas were all within the language area in the left cerebral hemisphere. Their second patient, a native speaker of English with knowledge of Spanish since infancy, showed a similar pattern of results. While this patient was left-handed and her language area was found to be in the right cerebral hemisphere, she, too, showed areas of equal disruption and adjacent areas of differential effects in the two languages.

Several additional studies found support for partial differentiation of the disruption of the various languages of multilinguals during cortical stimulation (e.g., Rapport, Tan, & Whitaker, 1983). However, the number of individuals studied is small and the actual sites of disruption during the stimulation vary from one individual to another. Moreover, the participants in these studies suffer seizures that may have affected their neural organization and hence, generalizing from these individuals to the general population should be done with caution.

Brain Imaging

In recent years, bilingual processing in neurologically intact participants has been examined using brain-imaging techniques (e.g., Dehaene, Dupoux, Mehler, Cohen, Paulesu, Perani, Van de Moortele, Lehericy, & Le Bihan, 1997; Kim, Relkin, Lee, & Hirsch., 1997). With the development of imaging methods such as PET and fMRI, brain activity during language processing can be studied. Only a few studies have expanded their investigation to answer questions about bilingual organization in the brain. Those that did, however, found a complex pattern of results that enhanced what had been previously hypothesized for this organization. While the techniques are elaborate and sophisticated, the level of language processing possible in these studies has been limited mostly to perception or silent-production tasks. Several imaging studies that looked at individual data (e.g., Dehaene et al., 1997; Kim et al., 1997) appear to provide converging evidence for differential representation – within the language area – of the first language and the second (when it is learned later and/or less proficient) language of bilingual individuals.

Kim et al., (1997) studied 12 bilingual speakers of various language combinations (e.g., English-French, Korean-English, Italian-German) using functional Magnetic Resonance Imaging (fMRI). Six participants who learned both languages from infancy were categorized as early bilinguals and six who learned their second language late in childhood (with a mean age of initial exposure of 11) were categorized as late bilinguals. The task was an internal-monologue production task in the first language (L1) or the second language (L2) according to pre-specified cues. The imaging results showed that within Broca's area, in the left hemisphere, a common area of activation emerged for both languages of the early bilinguals. In contrast, two adjacent but significantly different areas of activation were consistently found for the two languages of all the late bilinguals.

Similar dissociation of the activation pattern of the two languages of bilingual speakers was found in Dehaene et al. (1997) using fMRI, and in Perani, Dehaene, Grassi, Cohen, Cappa, Dupoux, Fazio, and Mehler (1996), using PET scanning. Perani et al. (1996) studied the brain activation of nine right-handed native speakers of Italian who learned English as a second language after age 7. Their findings included activation in the classical language areas during participants' listening to stories in their first language, with virtually the same activation for all participants. As for activation during listening to stories in participants' second language, there was great variability among the participants and no one area was significantly more activated than the activation found in the control condition (listening to a story in Japanese, a language unknown to any of the participants).

When Klein, Zatorre, Milner, Meyer, and Evans (1995) summarized the activation data of their 12 bilingual participants in a PET study, they found no activation differences between the first and second languages of their participants. The variability of L2 activation found in Perani et al. can account for the lack of significant differences in the Klein et al. study. Klein et al. compared the activation of L1 and of L2 averaged across their participants. If their participants had great variability in their L2 activation as did the participants in Perani et al., no significant differences between L2 and L1 activation could have been detectable. Consistent with Kim et al. (1997), when comparing individual patterns of activation of the first and second languages, Dehaene et al. (1997) found systematic differences in their fMRI data between the areas activated during listening to L1 (French) and to L2 (English, learned after age 7), for all their eight participants.

By contrast, Perani, Paulesu, Galles, Dupoux, Dehaene, Bettinardi, Cappa, Fazio, and Mehler (1998) compared early and late bilinguals on a listening task in an fMRI study, including in both groups only participants who had attained high levels of L2 proficiency. They found no differences in the areas of activation during listening to L1 and to L2, in contrast to what Perani et al. (1996) had found when the late bilinguals had lower levels of L2 proficiency.

Indeed, several recent studies suggest that the crucial factor in bilingual brain-activation results is the level of L2 proficiency, rather than the age of L2 acquisition (e.g., Illes, Francis, Desmond, Gabrieli, Glover, Poldrack, Lee, & Wagner, 1999). Illes et al. reviewed the results obtained from recent brain-imaging studies with bilingual speakers and added their results from an fMRI study with Spanish-English bilinguals. In their study they used a semantic decision task for single words (i.e., participants were asked to decide whether a noun was concrete or abstract). Consistent with the conclusion of their review, Illes et al. found that the age at which participants' L2 was learned did not appear to play a role in the results. In contrast, level of L2 proficiency emerged as an important variable. Namely, when participants were proficient in both their languages, no differences in brain activation during processing in the two languages were detected. Differences in activation were found, on the other hand, when participants were not proficient in their second language.

A similar conclusion can be drawn from two studies reported by Chee and his colleagues (Chee, Caplan, Soon, Sriram, Tan, Thiel, & Weeks, 1999; Chee, Tan, & Thiel, 1999). Chee et al. (1999a) used a sentence-comprehension task in an fMRI study of Mandarin-English bilingual speakers. Sentences in each language were presented visually followed by a question that required a true or false button-response. Chee et al. found no differences in their highly proficient bilinguals' accuracy and response-time performance in the two languages. Crucially, they found that there were no differences in the areas activated during sentence comprehension in Mandarin and in English. The bilingual speakers included in Chee et al. (1999a) were all proficient in both languages and had all learned their L2 early in life; thus the finding of common areas of activation for both languages may be attributed either to the early age of acquisition or to the high level of proficiency (or to both). However, in a different study, Chee et al. (1999b) compared early and late learners, all highly proficient Mandarin-English bilinguals. The study employed fMRI imaging during a silent word-completion task (with visually presented partial words) in each language. They found no differences between the areas activated during processing the English words and the Chinese words. Moreover, there were no differences between the early and the late L2 learners, with complete overlap of activation of both languages in the left prefrontal areas (in 20 of the 24 participants).

The findings of these studies suggest that regardless of the age of acquisition of the second language, for proficient bilinguals, common areas are involved in word and sentence visual processing in both languages; this was true even when the two languages differ in their orthographic, phonological, and grammatical systems.

Contradictory results, however, have been reported in a few additional studies, including another recent fMRI study (Hernandez, Martinez, & Kohnert, 2000). Hernandez et al. tested six English-Spanish bilinguals on a picture-naming task in both languages and obtained fMRI data during participants' responses in each language separately as well as in a mixed-presentation condition. The response-time and error-rate results confirmed the results of a pre-test confrontation-naming task, which asserted that the six participants were more proficient in English than in Spanish. All participants had acquired both their languages before age 5. The fMRI results showed no reliable difference in activation areas for processing in the two languages despite the proficiency differences.

In sum, most published findings from these developing techniques that allow monitoring of brain activity during language processing support a certain degree of differential representation of bilinguals' two languages within the left hemisphere, at least when the second language is not learned in infancy and does not reach very high levels of proficiency. For proficient bilinguals and perhaps specifically for early learners who attained high proficiency, the same brain areas appear to be involved in the processing of both languages. Further research is warranted to better understand intrahemisphere organization patterns of two or more languages and the factors that influence this organization.

Psycholinguistic Evidence: Interdependent and Independent Representations

Psycholinguistic studies of bilingualism have focused predominantly on the lexical representation of bilingual speakers. Over the decades, a large number of studies have been dedicated to exploring lexical processes in bilinguals. Various paradigms have been used and in recent years, new techniques have been incorporated. The same fundamental issues have remained the focus of the investigation but the questions asked in early studies have been modified in recent research.

Early Studies

In his book "Languages in Contact", published in 1953, Weinreich identified three types of bilingual representation: coordinate, compound, and subordinate. In what he termed Type A, Coordinate representation, words of the two languages are stored separately in terms of both their conceptual and lexical representation such that, for a given word, there are two meaning units and two lexical units (see Figure 1). In Type B, Compound, words from the two languages are stored separately but have a common meaning, such that for a given word there is one compound meaning unit and two lexical units (see Figure 2).

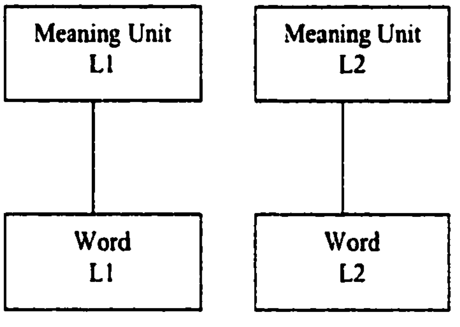

Figure 1. Coordinate Bilingual Representation (Adapted from Weinreich, 1953)

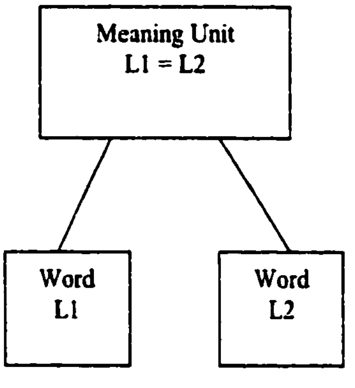

Figure 2. Compound Bilingual Representation (Adapted from Weinreich, 1953)

In Type C, Subordinate representation, words from the second language are interpreted through the words of the first language, that is, for a given word, both languages have the meaning representation of the first language and there are two lexical units. In this case, Weinreich distinguishes between the strong (or first) language and the weaker language (see Figure 3).

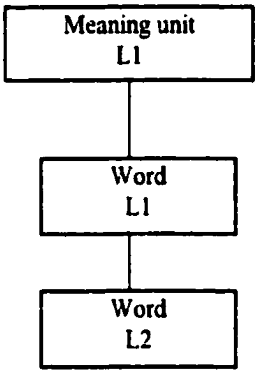

Figure 3. Subordinate Bilingual Representation (Adapted from Weinreich, 1953)

Ervin and Osgood (1954) modified Weinreich's definitions, collapsed types B and C into one, which they called compound, and emphasized the effect of manner of acquisition on the representation of the two languages. Languages learned at the same age in a similar context are more likely to yield a compound representation while languages learned at different ages in a different context will yield coordinate representation. Subsequent research attempted to find evidence for this theoretical distinction but no consistent experimental support was obtained.

Nevertheless, the general question of independent versus interdependent representation of the two languages of bilingual speakers continued to motivate a considerable number of studies over the years and as yet no conclusion has been reached.

Various paradigms have been used in the attempt to determine whether bilinguals have two distinct lexicons or a single, extended one, and if there are two, to what extent these two systems are interdependent or independent (e.g., Kolers & Gonzalez, 1980; Paivio & Lambert, 1981; Preston & Lambert, 1969). Preston and Lambert (1969) used a bilingual version of the Stroop test to address the question of independence. In the Stroop word-color test (Stroop, 1935), participants were presented with color words (e.g., "blue", "yellow") printed in colored inks. When asked to name the color of the ink of the printed word, participants took longer to name items for which the ink color and the word were incongruent (e.g., the word "blue" printed in yellow ink as compared to the word "blue" printed in blue ink).

The Stroop results demonstrated unintentional interference that occurred between the visual and verbal stimuli and led to a large number of subsequent studies investigating interference and attention processes. Preston and Lambert adjusted the Stroop method to study bilingual participants and included in their presentation both interlingual and intralingual conditions. In the interlingual condition, the language of the required response was different from the language of the to-be-ignored written stimuli. Their findings showed that the participants experienced interference when the language of presentation and the language of response were not the same. The authors concluded that while bilingual speakers are processing in one target language, their other language does not become completely inactivated.

Later studies using bilingual versions of the Stroop paradigm found similar interference from the to-be-ignored cross-language stimuli (Tzelgov, Henik, & Leiser, 1990; Tzelgov, Henik, Sneg, & Baruch, 1996). Tzelgov et al. (1996) further found that even when the to-be-ignored stimuli were Hebrew words written in English orthography, the Hebrew color names produced interference, demonstrating phonological processing of the written stimuli. It has been found (Albert & Obler, 1978; Magiste, 1984; Preston & Lambert, 1969) that more proficient bilinguals show larger interlingual effects (sometimes as large as the interference in the intralingual visual-verbal incongruence) than less proficient bilinguals. On the other hand, Tzelgov et al. (1990) showed that more proficient bilinguals were able to voluntarily decrease the amount of interference, for example, when being informed that one language was more likely to be the language of presentation. (Proficiency considerations will be addressed below.)

However, the unintentional activation of the non-target language found in Stroop studies might be, in part, due to the task-presentation conditions (namely, both languages are explicitly presented to the participants, either as the language of the stimuli or the language of response). Different patterns of interference may be found when only one of the two languages is explicitly presented to participants in a given task.

Indeed, other studies used tasks such as word reading, recall, and translation, presented in mixed as well as language-specific lists. Kolers and Gonzalez (1980), for example, presented their participants with unilingual and bilingual stimulus lists for reading and recall. They presented lists of 55 target words and compared the effects of exact repetitions, synonyms, and translation equivalents on item recall. They found that items presented twice within a list were significantly easier to recall than items presented only once. Interestingly, the same facilitation was obtained for items presented with their translation equivalent within the same list. Less facilitation was evident for items presented with their same-language synonyms within the same list. These findings appear consistent with interdependent representation of the two languages, however, Kolers and Gonzalez concluded that their findings did not support a common abstract representation of the meaning of related words. Instead, they emphasized that while their findings contributed to understanding bilingual processing, they did not necessarily indicate how the words are represented. They proposed that when presented with lists of words for recall, participants encode as much information as possible, including the language of presentation, and pointed out that the tasks used in bilingual studies should be taken into consideration when drawing conclusions about language representation and processing (an approach that has gained much support in recent years).

Paivio and Lambert (1981) employed similar off-line methods (reading, translation, and recall of single words) and found, for example, that participants recalled words they had translated (in writing) from one language to another significantly better than words that they simply copied down. Paivio and Lambert maintained that their findings supported the existence of two independent but interconnected verbal systems in bilinguals (as postulated in the bilingual extension of Paivio's dual-coding theory, see, for example, Paivio & Desrochers, 1980).

In contrast, various studies found evidence for slower processing when participants were presented with mixed rather than unilingual stimulus lists, and suggested that bilingual speakers take longer to perform a task when both languages are presented in one task because they need to switch between their two languages (e.g. Kolers 1966; Soares & Grosjean 1984).

Several researchers (Kolers & Gonzales, 1980; Kroll, 1993; Smith, 1997) have raised the question of whether the tasks used in studies of the sort described above can contribute to our understanding of how the two languages are represented and processed by bilingual speakers or whether they demonstrate what bilinguals can or will do under specific processing conditions. This question, together with the development of new experimental paradigms and improved measurement tools, led to an expanding number of studies investigating bilingual lexical performance.

In the last two decades, on-line paradigms measuring correctness and speed of response in tasks such as translating from one language to the other, word naming, and cross-language priming in lexical decisions have been employed to investigate bilingual representation (e.g., de Groot, Dannenburg, & van Hell, 1994; Dijkstra et al., 2000; Jared & Kroll, 2001; Kroll & Stewart, 1994; Schwanenflugel & Rey, 1986). The underlying assumption common to these investigations is that they examine elements of the semantic memory system of people who use, to various degrees, more than one lexical system. A brief introduction to the study of semantic memory will be followed by a description of current psycholinguistic paradigms and a review of pertinent findings.

Semantic Memory

Memory has been the focus of numerous studies in the larger area of psychology. For some time, psychologists and neuropsychologists have acknowledged the need to specify various types of human memory (e.g., Norman, 1970). A main contrast that has been established in the study of memory is that between semantic and episodic memory systems (Tulving, 1972). Based on this contrast, the semantic component of memory storage can be defined. Semantic memory is the storage of information that is necessary for the use of language. There, one's knowledge of words, concepts, and meanings and of rules for manipulating words and other verbal elements is organized. This knowledge is not very susceptible to loss of information. Examples of such knowledge include knowledge that the name of the month following *June* in the calendar is *July*, that there is an association between the words *doctor* and *nurse*, that the name of the machine used for typing is *computer*, and that the word for it in Hebrew is מחשב.[1]

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[1] Most theories of bilingual lexical storage would include words from both languages in the semantic memory (cf. Jiang & Forster, 2001).

To a great extent, this knowledge is independent of the sort of information stored in the episodic memory system.

Episodic memory contains information about personal experience such as events and their occurrence, temporal-spatial relations among them, autobiographical reference, and their connections to already stored events. It has been found that there is frequent reorganization and probably a fair amount of loss of the information in the episodic storage.

Examples of events include knowledge of having seen a movie yesterday, of having an appointment with a fellow student tomorrow at 10 o'clock, or having seen the word *computer* in a list of words presented 10 minutes ago. Questions regarding the independence of these two systems and the representation of non-native languages will be discussed further below.

Lexical Decisions and Priming

The most frequently used type of lexical-decision task is a visual one. In a visual lexical-decision task, participants are presented with strings of letters and are asked to decide whether each string is a word. Usually, participants are asked to press one key (on the computer keyboard, or a button on a button box) if they think a stimulus is a word and another key if they think it is a non-word. Accuracy and response latencies are recorded and analyzed. Decision times have been found to be influenced by various factors such as the relation between the words and the non-words and inherent characteristics of the words, including length, morphological complexity, and semantic ambiguity (e.g., Balota & Chumbely, 1984; van Hell, 1998).

When priming is used in lexical-decision tasks, a word, the prime, is presented briefly before the target word for which a decision is required. The prime may be the same item as the target, as in repetition priming – also termed identity priming – (e.g., Forster & Davis, 1984; Kirsner & Smith, 1974, in Smith, 1997), or related to the target in its visual and/or phonological form or in meaning. Primes that are semantically or associatively related to the target following them have been found to shorten lexical-decision latencies (for a detailed review, see Neely, 1991). Thus, response times to the target word *cow*, for example, are faster when presented after the word *calf* than response times to the word *cow* presented after the word *soap*.

Three main concepts have been suggested to account for priming effects (reviewed, for example, in de Groot, 1983; McNamara, 1992; Neely, 1991): spreading activation, compound-cue, and expectancy. The automatic spreading activation (ASA) account assumes that activation of a particular "location" in the semantic memory (i.e., the prime) automatically spreads along the links of the memory network and, thus, the activation levels of items linked to the activated location increase. If one of these activated items is then presented (as the target), its recognition is facilitated. Incorporated in this account is the assumption that activation of various items may occur but the level of activation needs to reach a threshold for a particular item to be selected (Morton, 1969). De Groot (1983) tested the scope of this spreading activation, i.e., whether the activation spreads one step, to immediately related words only, or whether the spreading activation extends beyond one step, to secondarily related words (words related via a mediator word, e.g., *bull* to *milk* via *cow*). De Groot conducted seven experiments using unmasked and masked (see below) primes in lexical-decision tasks with immediately and secondarily related pairs. She found facilitation for directly related pairs but not for secondarily related pairs, suggesting that the spreading activation extended only one step, to directly related lexical entries.

The ASA can account for various findings of semantic priming reported in the literature but fails to account for others (Klinger, Burton, & Pitts, 2000; Neely, 1991). Moreover, several studies found evidence that questions the viability of spreading activation types of models. For example, Neely, Verwys, and Kahan (1998) discuss the finding of Balota and Paul (1996) that two primes related to each other and to the target had the same priming effect as two primes not related to each other but both related to the target. This finding raises questions about the spreading activation theory, unless the difference between the single and double effects was too small to be detected. Neely et al. set out to investigate priming effects when the prime is repeated twice as compared to when the two primes are unrelated to each other, under the assumption that identity priming usually shows large effects and therefore should be detected. But they, too, found that repetition of the prime actually reduced, not enhanced, the priming effect. In their experiments they used two primes that were identical as compared to one unrelated prime and a second prime that was related to the target. The first prime was masked, the second was visible. They concluded from their two experiments and from Balota and Paul's findings that repetition and semantic priming are reduced when the prime is presented twice and that this is in contrast to the prediction of a spreading activation account for priming.

The compound-cue concept pertains to global memory-search processes that are based on interrelations among lexical items (e.g., McNamara, 1992). Participants are assumed to use the pair of words (the prime and the target) as a compound cue: related words are assumed to have a larger familiarity value and to facilitate the search process as compared to unrelated words. An alternative account pertains to attention processes and expectancy-based strategies. That is, due to the presentation of the prime, participants anticipate the subsequent appearance of certain related words; if one of them is then presented (as the target), its recognition is facilitated. Researchers have debated the possible theories that can account for lexical activation and lexical representation of verbal material in the memory network (e.g., de Groot, 1983; Forster, 1998; Forster & Davis, 1984; Kintsch, 1972; McNamara, 1992, 1994; Neely, 1991; Tulving, 1972).

In the priming literature, priming effects are considered facilitation effects when response times to the target words are shorter in a specific prime-target condition than in another and inhibition effects if the response times are longer. For example, targets that were semantically related to the primes preceding them were found to yield faster response times than targets presented after neutral primes and unrelated primes. In contrast, targets that were unrelated to the primes preceding them have been found to yield slower response times than those following a neutral prime (e.g., Neely, 1991).

The concept of inhibition has received much attention in psycholinguistic investigations (e.g., Rafal & Henik, 1994) and has been further addressed in studies of bilinguals, for examples, when the Stroop paradigm was used (e.g., Tzelgov, Henik, & Berger, 1992; Tzelgov et al., 1996 and see above) and when issues of bilinguals' control over activation of their two languages were discussed (Green, 1986; 1998; van Heuven, Dijkstra, & Grainger, 1998).

Masked Priming

In masked priming, the prime is presented for a very short period of time, preceded or followed by a mask (typically a series of characters), such that the viewers do not have a conscious awareness of the prime. (The prime word may be followed by a mask, which is followed by the target or, preceded by a mask and followed by the target; in either case it is presented for a brief exposure.) It has been shown that even when participants were unable to report what the prime word was, often completely unaware that a word was presented prior to the target word, priming effects were still detected (Forster, 1985; Forster & Davis, 1984). Forster and Davis (1984) reported repetition priming effects using masked priming and assumed that the facilitation effect was due to the fact that the same item was accessed twice. In unmasked priming, it can be an episodic (memory) trace of the first presentation that facilitates access to the same item when presented a second time. In masked presentation, it is unlikely that an episodic trace would be available and the assumption is that the effect is lexical (rather than episodic). That is, the presentation of the prime, despite being masked, changes the level of activation of the target item and thus affects the speed of response (de Groot & Nas, 1991; Forster & Davis, 1984).

According to Forster, facilitation in accessing the target lexical representation occurs due to the prior accessing of the same representation during the perception of the prime. Partial priming is not expected based on this account and indeed, Forster and his colleagues did not find priming effects when the masked prime was orthographically similar but not identical to the target (e.g., Forster, Davis, Schoknecht & Carter, 1987). Orthographically similar non-word primes, however, were found to facilitate identification of targets in a naming task with masked primes in a series of experiments conducted by Humphreys, Evett, and Quinlan (1990). They demonstrated that facilitation occurred when several of the letters of a non-word prime were shared by the target. They thus found evidence for parallel activation of letters during the perception of the prime and the target and concluded that the priming effects were a function of both the number of common letters and their relative position in the word.

The specific processes that lead to the facilitation in responding to a target word after being exposed to a preceding word remain a source of debate and exploration. Forster and Veres (1998) provided a comprehensive discussion of several models that have been proposed to account for the patterns of lexical and form priming effects, masked and unmasked, that have been reported for both word and non-word targets. Forster (1998) discussed some of the advantages of using the masked priming paradigm and some of its shortcomings.

It has been generally accepted (e.g., Forster, 1998; Forster & Jiang, 2001) that priming effects found with the masked priming paradigm can be taken as reflecting automatic lexical processes that take place quickly and without the necessary awareness of the participants who perform these processes.

Cross-Language Priming

While extensive research on priming patterns has been carried out with monolingual participants, the paradigm has also been applied to bilingualism research. In a cross-language priming paradigm, the prime is a word in one language and the target is a word in another language. Two main cross-language relations have been used in cross-language priming: primes that are semantically related to the targets and primes that are the translation equivalents of their targets (e.g., Chen & Ng, 1989; de Groot & Kroll, 1997). In addition, differences between cognates, i.e., words that sound similar and mean roughly the same thing in the two languages (e.g., *coffee* in English and *cafe* in Spanish, and see below), and non-cognates, i.e., translation equivalents that do not share visual or phonological form (e.g., *house* in English and *casa* in Spanish) have been explored (de Groot & Nas, 1991; Gollan, Forster, & Frost, 1997).

Cross-language priming paradigms have been used in the attempt to identify the types of relations between the two lexicons of the two languages of bilingual speakers. However, different conclusions were drawn from the different results found in cross-language priming experiments (de Groot & Kroll, 1997; Schreuder & Weltens, 1993). Several researchers have found similar patterns of the facilitation reported for within-language priming, at least when the primes were in L1 and the targets in L2 (Gollan et al., 1997; Keatley, Spinks, & de Gelder, 1994; Williams, 1994). Others did not obtain cross-language effects or found weak effects (e.g., Kirsner, Smith, Lockhart, King, & Jain, 1984).

Several variables may affect the priming effects evident both within and between languages. These may pertain to inherent characteristics of the stimuli used or to the nature of stimulus presentation in the various tasks and procedures. Stimulus characteristics include the form and meaning relations between the prime and the target (e.g., Forster, 1985; Kroll & de Groot, 1997), and more generally, word frequency (and/or familiarity) and level of concreteness (e.g., Beauvillain, 1992; de Groot et al., 1994; de Groot & Hoeks, 1995). In addition, semantic relations among words within- and across-language, for example semantic overlap (e.g., Kroll & Tokowicz, 2001; Tokowicz, 2000; Tokowicz & Kroll, 1998) and cognate status (e.g., de Groot & Nas, 1991; Gollan et al., 1997; Sanchez-Casas, Davis, & Garcia-Albea, 1992; van Hell, 1998) play a crucial role in the effects obtained.

Task and procedure variables include the timing of the presentation sequence, for example the duration of stimulus presentation (e.g., Forster 1985;

Keatley et al., 1994) and the lag within stimulus presentation (e.g., de Groot & Nas, 1991; Keatley & de Gelder, 1992; Williams, 1994). Two presentation variables have been found to influence response-time results. One is the interval between the appearance of consecutive elements in each stimulus presentation, or the inter-stimulus interval (ISI) – for example, the time lag between the fixation point and the prime presentation. The second is the time lag between crucial elements in the sequence, or the stimulus onset asynchrony (SOA) – for example, the time lag from the beginning of the prime presentation until the beginning of the target presentation (e.g., de Groot, 1984; Neely, 1977).

Thus, for example, Keatley and de Gelder (1992) demonstrated that when participants were required to respond at fast rates, cross-language priming using semantically associated pairs disappeared while within-language priming effects were not affected. A cross-language priming effect at fast rate was, however, detected when the material comprised translation equivalents. To assess this timing effect, Keatley, Spinks, and de Gelder (1994) studied cross-language priming in Chinese-English bilingual participants (Experiment 1) using semantically related primes and translation equivalents, varying the lag between the presentation of the prime and the appearance of the target word (with SOA of 250 and 2000 ms). When Chinese (L1) primed English (L2) targets, significant priming effects were detected only in the short SOA presentation. The effect in the long SOA was not significant. No significant effects were detected when English (L2) primed Chinese (L1). This directional asymmetry was found also with Dutch-French bilinguals in Experiment 2, which compared semantically related and unrelated cross-language conditions in short SOAs. With translation equivalents, significant priming effects were detected in both L1-to-L2 and L2-to-L1 priming conditions, although larger effects were detected when L1 words primed L2 words. (This asymmetry will be addressed below.) Keatley et al. referred to the variability in the findings of previous studies and called attention to the way their designs vary (e.g., in SOA and in proportion of related pairs), which can explain the different results obtained in different studies.

SOA and other timing manipulations can serve as tools to assess theories of verbal processing. For example, Tzelgov and Eben-Ezra (1992) suggested that if attention or expectation processes are responsible for the priming effect, no priming would be predicted when participants do not have time to develop expectations, for example when the SOA is very short. Consistent with what was found in Keatley et al. (1994), Tzelgov and Eben-Ezra found cross-language priming even with a very short SOA (240 ms versus 840 ms), suggesting that the effect was not due to mere expectations. A similar rationale lies behind the masked priming paradigm, in which participants are not likely to develop expectations when they are not even aware of the prime.

In addition to these methodological issues, the relation between the two specific languages under investigation should be considered. It has been hypothesized that two languages that are related linguistically may have a different relation than two languages that are very different from each other (de Groot & Hoeks, 1995; Grosjean, 1998; van Hell, 1998). Moreover, several studies demonstrated that written words from languages that share orthography may be processed differently from words from two languages with different orthography

(Beauvillain, 1992; Gollan et al., 1997; La Heij, Starreveld, & Steehouwer, 1993; Menn & Obler, 1990). Indeed, some studies of bilingual visual processing address the question of whether a decision about the language of the stimulus precedes a lexical decision or whether the two processes – language decision and lexical decision – proceed in parallel (e.g., Beauvillain, 1992), and differentiate processing in two similar, versus two different, orthographies.

In a series of studies, Dijkstra and others (e.g., de Groot, Delmaar, & Lupker, 2000; Dijkstra, Timmermans, & Schriefers, 2000; Dijkstra, van Jaarsveld, & Brinke, 1998) studied the effects of interlingual homographs (i.e., words that share form characteristics but differ in their meaning) on word processing. The results of these studies suggest that, at least when the two languages under investigation share their orthography, bilingual readers do not begin the process of lexical access by selecting the target language. Rather, evidence from non-target-language influence on word processing suggests that a non-language-selective process activates words from both languages and only then, as language-specific items are activated, language selection occurs (see the Bilingual Interactive Activation model below).

In summary, several findings emerged from the studies that have used cross-language priming paradigms. Priming effects were found from the first language to the second language (e.g., Gollan et al., 1997; Jiang, 1999) but weaker or not reliable effects were found from primes in the second, less proficient, language to L1 targets (e.g., Jiang, 1999; Keatley et al., 1994). In addition, stronger priming effects were found for cognates than for non-cognates (e.g., de Groot & Nas, 1991; Gollan et al., 1997). Masked-priming paradigms were found to yield smaller priming effects than unmasked-priming paradigms but the effects found in a masked paradigm cannot be easily attributed to conscious strategies and expectations developed by the participants. Furthermore, effects were found for similar as well as different pairs of languages (de Groot & Nas, 1991 for Dutch and English; Gollan et al., 1997 for Hebrew and English), at least for translation equivalents that were cognates.

On-Line Production: Naming and Translating

Additional on-line paradigms used in bilingual research include production tasks such as translation tasks and picture and word naming. In translation production tasks, participants are presented with a word in one language and are asked to rapidly produce a translation equivalent in the other language. As in lexical decision tasks, response times and error rates are measured. Both forward translation, i.e., from L1 to L2 and backward translation, from L2 to L1, have been employed, yielding similar results in some studies (e.g., de Groot et al., 1994, experiment 2) and different results in others (e.g., Kroll & Stewart, 1994). Several studies found that translation from L2 to L1 (backward) yielded faster response times by dominant, non-balanced, bilingual participants than translating from their L1 to L2 (e.g., Kroll & Stewart, 1994; Sanchez-Casas, et al., 1992).

Both picture naming and word naming (i.e., saying aloud visually presented words) have been used in bilingual studies (see Kroll & Sholl, 1992). While picture naming is assumed to involve processes of accessing a concept (semantic level) prior to production of a name (lexical level), researchers have debated whether during word naming, the semantic level is accessed and whether naming processes are different in L1 and L2 (Potter, Son, von Eckardt, & Feldman, 1984; Smith, 1997). As in translation and priming tasks, stimuli and procedure variables have been found to influence the results (see for example, Altarriba, 1992; Keatley, 1992; van Hell, 1998).

Recent Studies: Findings and Models

In recent decades, the distinction between a conceptual-semantic storage and a lexical storage, found in Weinreich's definitions of bilinguals, has resurfaced (without a necessary association to manner of language acquisition). In a paper published in 1984, Potter, Son, von Eckardt, and Feldman proposed three hypotheses for lexical representation of bilingual speakers (Figures 4-6). Their approach concerned the way L2 is represented in relation to L1. They postulated distinct lexical representations for the two languages and a shared conceptual memory.

Their word-association hypothesis assumes direct connections between the lexical representation of L2 and L1 and an indirect access from L2 words to the conceptual representation, through the corresponding L1 words. This can be seen as a variation of Weinreich's subordinate type. The concept-mediation hypothesis, on the other hand, assumes direct connections between each language and the conceptual memory. According to this hypothesis, there are no direct connections between L2 and L1 words. The connection between the two lexicons is mediated through the conceptual-semantic representation. This view can be seen as a variation of Weinreich's compound representation. A third hypothesis, the developmental hypothesis, assumes initial lexical connection (word association) between L2 and L1 and a development of direct connections to the conceptual-semantic representation as L2 develops, with the underlying assumption that with increased proficiency, the connections change.

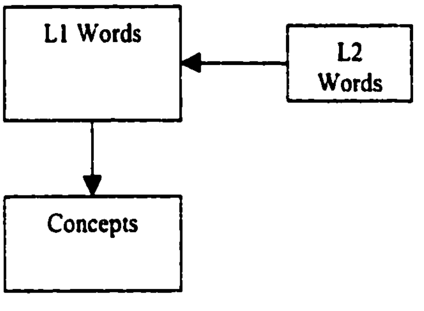

Figure 4. The Word Association Hypothesis (Adapted from Potter et al., 1984)

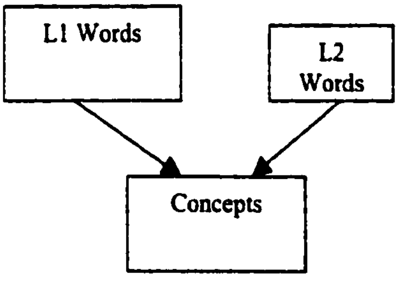

Figure 5. The Concept Mediation Hypothesis (Adapted from Potter et al., 1984)

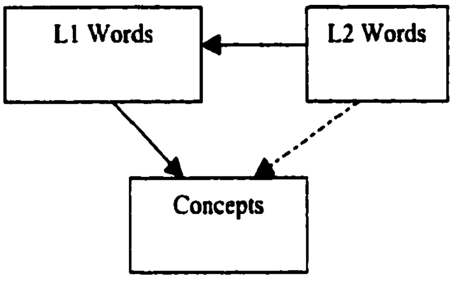

Figure 6: The Developmental Hypothesis (Adapted from Potter et al., 1984)

These hypotheses were tested by Potter et al. (1984) who conducted two experiments and concluded that support was found for the concept mediation hypothesis. In their first experiment, they tested 24 Chinese-English bilinguals who were living in the US, speaking and reading both languages regularly. Participants were asked to name pictures in their L2 and to translate words from L1 to L2. Potter et al. hypothesized that if the word association model is correct, translating from L1 to L2 should be direct and faster than naming pictures in L2, in contrast to the concept mediation model, according to which the stages on the route to naming in L2 in picture naming and in forward translating are similar.

The results showed that participants' latencies in the two tasks did not differ, consistent with the predictions of the concept mediation model. In their second experiment, Potter et al. tested whether the same pattern of results would be obtained for less proficient participants. They found that their 28 English-French bilinguals provided similar support for the concept mediation hypothesis in showing shorter latencies in L2 picture naming than in translating from L1 to L2. Potter et al. interpreted the longer latencies in the translation task to indicate that translating from L1 to L2 was completed via the underlying conceptual representation of the two languages rather than by using direct associations between the two languages. Yet, the lack of difference between the response latencies in the two tasks used in Potter et al. could not be considered conclusive evidence for their concept mediation hypothesis.

Subsequent studies, employing on-line translation between the two languages, cross-language semantic priming and other tasks, were conducted in an attempt to assess Potter et al.'s hypotheses. Kroll and Stewart (1994) showed evidence for semantic access during translating from L1 to L2 but not from L2 to L1, thus supporting concept mediation only in the forward direction – from the first language to the second. In their experiments they demonstrated that monolingual participants were slower to name pictures when the pictures were presented organized by categories (such as "clothing"). They further showed that 24 proficient Dutch-English bilinguals were sensitive to the semantic context (i.e., demonstrated the same interference in the categorized presentation as did the monolinguals) during translating from L1 to L2, but not during translating from L2 to L1.

Based on these findings, Kroll and Stewart suggested a revised model, assuming asymmetry of connections between the two languages. They assumed stronger word associations from L2 to L1 and weaker word associations from L1 to L2. Similarly, they assumed stronger association from L1 to the conceptual storage and weaker from L2 (see Figure 7).

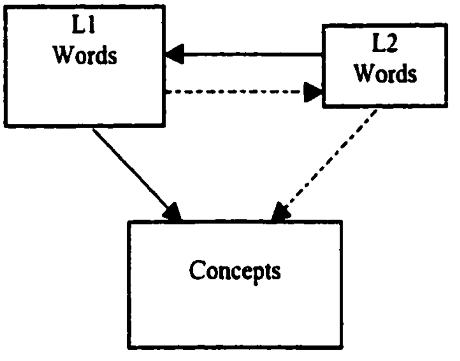

Figure 7. The Revised Hierarchical Model (Adapted from Kroll & Stewart, 1994)

Findings supporting this directional asymmetry in the connection between the two languages include, for example, these of Sholl, Sankaranarayanan, and Kroll, 1995, and Tzelgov and Eben-Ezra, 1992. Sholl et al. (1995) tested the effect of picture naming in L1 and in L2 on translation in both directions (from L1 to L2 and from L2 to L1). Based on the revised hierarchical model (RHM), concept mediation is expected in the process of translating from L1 to L2 (but not in translating from L2 to L1) and thus accessing concepts during the picture naming task is expected to facilitate the translation (of the words that were produced in the picture-naming task) in this direction. Sholl et al. found the effect they predicted: response times in L1-to-L2 translation decreased after picture naming (as compared to translating words that were not named in the picture naming task) in both L1 and L2, with a stronger effect following naming in L2. In contrast, no effect was detected in L2-to-L1 translation. Sholl et al. took their findings as further support for the asymmetric relations between the lexicons of the two languages, as assumed in the RHM. These results, however, may be interpreted as a function of the facilitation in accessing L2 words during the naming task that then facilitates the translation task (access in L2 would otherwise be slower). The authors referred to this possibility in a footnote, but the issue has not been resolved.

In a study designed to explore the processes of word translation, de Groot, Dannenburg, and van Hell (1994) assessed the contribution of various semantic and familiarity variables to translation performance. De Groot et al. used a regression model to analyze translation data from Dutch-dominant Dutch-English bilinguals. They compared their data from a backward (L2 to L1) translation task to comparable data from forward (L1 to L2) translation reported in de Groot (1992). De Groot et al. (1994) showed that in contrast to a strong version of an asymmetry model, both the backward and the forward results demonstrated that semantic variables play a role in the translation process. However, a smaller effect could be detected in the backward translation (L2-to-L1) data, consistent with a weak version of asymmetry.

Various degrees of directional asymmetries were reported by researchers using different cross-language priming paradigms. While several studies did not detect any cross-language priming effects (e.g., Kirsner, Brown, Abrol, Chadha, & Sharma, 1980), others found them in the forward, when L1 primed L2 words, but not in the backward (L2-to-L1) direction (e.g., Gollan et al, 1997; Jiang, 1999). Gollan et al. examined the performance of Hebrew-dominant and English-dominant Hebrew-English bilinguals using a masked-priming paradigm. Both cognates and non-cognates were used in both L1-priming-L2 and L2-priming-L1 directions. They examined priming-direction effects as a between-subject variable and prime-type effects (cognates versus non-cognates) as a within-subject variable. They found significant priming effects for cognate pairs in both L1-priming-L2 and L2-priming-L1 conditions. Priming effects for non-cognate pairs were found in the forward (L1-priming-L2) condition only.

However, a few studies were able to detect significant priming effects from L2 to L1. Significant priming effects when L2 primed L1 words were found by Keatley et al. (1994), as mentioned above. Keatley et al. used translation equivalents in an unmasked presentation (Experiment 3) and found that their Dutch-French bilinguals showed priming effects in both priming directions, with smaller effects when L2 primed L1. Furthermore, Williams (1994) found that English-French bilinguals demonstrated priming effects from L2 prime words to L1 target words when the primes were masked. Williams used both semantically similar pairs and translation-equivalent pairs in cross-language priming conditions. He found cross-language priming for semantically associated pairs when the prime was unmasked (experiment 1B) but not when the prime was masked (experiment 1A). With translation-equivalent pairs, significant effects were detected even when the primes were masked (experiment 1A). Moreover, significant effects were found in both directions, i.e., from L1 to L2 (experiment 1A) but also from L2 to L1 (Experiment 2B), for translation-equivalent pairs when the prime was masked. Williams took his results as further support for the existence of common semantic elements in the encoding of words from the two languages of bilingual speakers.

The revised hierarchical model can account for some of the asymmetry in the reported findings, in particular for the various degrees of semantic involvement detected during participants' performance on translation and naming tasks. Moreover, the direct lexical connections from L2 to L1 assumed in the model can conceivably predict strong priming effects in this direction (i.e., when L2 words prime L1 targets). On the other hand, if L2 words rely on L1 word representation, accessing L1 prime words may be expected to facilitate the access of L2 words, thus predicting strong priming effects in the direction from L1 primes to L2 targets (as has been found in most cross-language priming studies).

Other accounts for the directional asymmetry of the cross-language priming effects have been discussed. These include speed of lexical access in the more- and the less-proficient languages (Forster & Jiang, 2001; Gollan et al., 1997; Jiang, 1999) and differential representation of L2 as compared to L1 words (Jiang, 2000; Jiang & Forster, 2001).

With respect to speed of access, it is possible that the difference between the two directions is not in the strength of connections, but rather, in the speed of processing L1 versus L2 words. L1 words are accessed faster and any process of activation would be faster as well, whereas L2 words require more time to be accessed and to activate related items. This can explain stronger priming from L1 to L2 than from L2 to L1, as well as the larger semantic effects evidenced in L1 to L2 direction (more time allows activation of various features and representation levels). It may not explain the stronger lexical connections found in several studies, evident, for example, by faster translations from L2 to L1 than from L1 to L2 (but additional semantic levels may be involved in the translation process). Jiang (1999) tested the speed of access hypothesis with English-Chinese bilingual speakers and found that even when given a longer SOA, no priming effects from L2 to L1 were detected. However, this conclusion should be viewed with caution because within the framework of a masked-prime paradigm as used in this study, longer durations of the items presented might lead to perception of the prime and so it is not possible within this paradigm to allow markedly longer processing time.

With respect to a differential representation of non-L1 languages, Jiang (2000) suggested that the representation of L2 words was fundamentally different from that of L1 words, particularly in initial stages of L2 acquisition. According to his model of L2 lexical acquisition, at early stages of L2 development, L2 words are represented as lexemes, with no independent semantic and syntactic features. At these stages, L2 words can be viewed as (episodic-memory) associations to their comparable L1 words and to the L1 words' conceptual representation. With increased proficiency, L2 words may gain independent lemma representation and depend less on their comparable L1 words. Jiang and Forster (2001) tested the hypothesis that the association between L2 words and L1 words is episodic in nature (rather than lexical). In other words, they propose that the representation of L2 words is not a pure linguistic representation but rather consists of associative connections to L1 words. In a series of masked-priming experiments using Chinese-English translation equivalents, Jiang and Forster found support for lexical-episodic dissociation in the two processing directions – translating from L1 to L2 (lexical) versus from L2 to L1 (episodic).

In an attempt to further specify the relations between the representation of words from two languages, de Groot and her colleagues (de Groot, 1993; Kroll & de Groot, 1997) presented the Distributed Lexical/Conceptual Feature Model. The model is based on the understanding that words in one or two languages may share some aspects of word form and some aspects of word meaning. The strength of connections between a given pair of words (from the same language or from two different languages) is determined by the degree of overlap between the two words, or the number of shared lexical and semantic features (see Figure 8). The model assumes that more activation spreads across languages when words from the two languages share more conceptual features. Moreover, the degree of activation of words from two languages or the interference between them is also determined by the degree of consistency in the mapping from forms to meanings within and across languages.

For example, the word *fort* in English shares both its form and its meaning with the word *fort* in Dutch. As mentioned above, such pairs are referred to as "cognates". Several researchers have used the term "semi-cognates" to identify words that share their meaning and most (but not all) of their form, for example: the words *police* in English and *politie* in Dutch. "Non-cognates" are translation equivalents that do not share form similarities. Two words might share their form but differ in meaning, for example, the word *glad* in English means "happy", the word *glad* in Dutch means "slippery"; such words are referred to as "false friends" or "interlingual homographs". Here too, the words may be identical as in the latter example or close in form: the word *frio* in Spanish may resemble the word *free* in

English but the two words differ in meaning. Finally, translation equivalents (regardless of whether their forms are similar or different) might share all or only some of their meaning. Generally, concrete words tend to have more similar meanings across two languages than abstract words (Tokowicz, 2000). For example, the word *cow* in English and פרה in Hebrew are virtually identical in their meaning, but the word *letter* in English and the word אות in Hebrew share only parts of the meaning (the word in Hebrew means letter as in grapheme but not as in letter in the mail), and the word *free* has several translation equivalents in Hebrew (corresponding to various parts of its meaning in English).

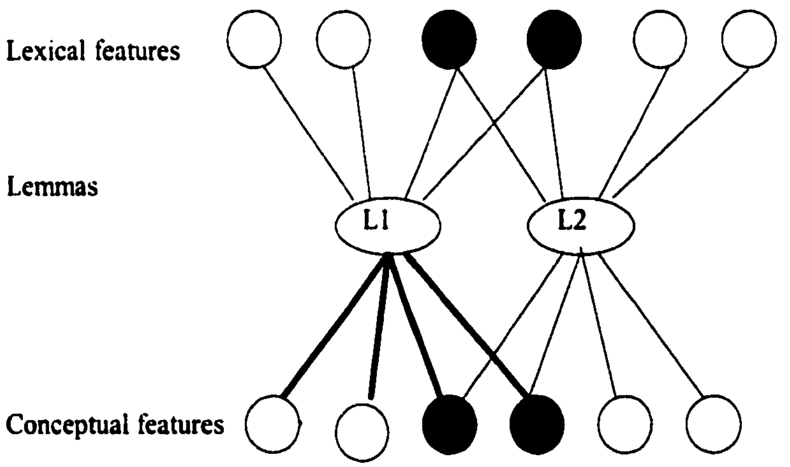

Figure 8. The Distributed Lexical/Conceptual Feature Model (adapted from Kroll & de Groot, 1997)

While the models reviewed thus far pertain to the representation of the two languages of bilingual speakers, it should be emphasized that most data accumulated to date are drawn from performance of bilinguals on specific tasks and are thus more likely to bring us closer to understanding language processing than language representation, related as the two may be. Grainger and Dijkstra (1992) took this into consideration and addressed the issue of the bilingual lexicon with a processing, rather than a representation approach. The framework that was subsequently proposed, the Bilingual Interactive Activation (BIA) framework (Dijkstra & van Heuven, 1998), assumes an integrated bilingual lexicon (see Figure 9). In the BIA model, the initial stages of word access during word recognition are language-independent; any word presentation will activate words from both languages. Accordingly, variables that influence monolingual word recognition, such as orthographic neighbors and word frequency (e.g., Grainger, 1990) will be relevant to the bilingual participant. Moreover, these variables will pertain to words from both languages, for example, the number of orthographic neighbors of a given word should include neighbors from both languages (Grainger & Dijkstra, 1992).

The BIA model assumes that both languages are part of the lexical representation of bilingual speakers and that words from both languages are linked (Dijkstra & van Heuven, 1998; Dijkstra, van Jaarsveld, & Brinke, 1998). Bottom-up processes of word recognition begin prior to language selection. Specific word-nodes may get further activation and processes of competitor inhibition will lead to language selection. Evidence regarding the influence of the non-target language in various lexical tasks (e.g., de Groot et al., 2000; Dijkstra et al., 2000; Jared & Kroll,

2001) suggests that both languages are active even in a relatively monolingual mode (cf. Grosjean, 1997). It is important to note that the BIA assumptions may need to be modified when considering languages with markedly different orthographies, for which initial perception of a (written) word stimulus may lead to an immediate language decision, prior to further processing toward word access.

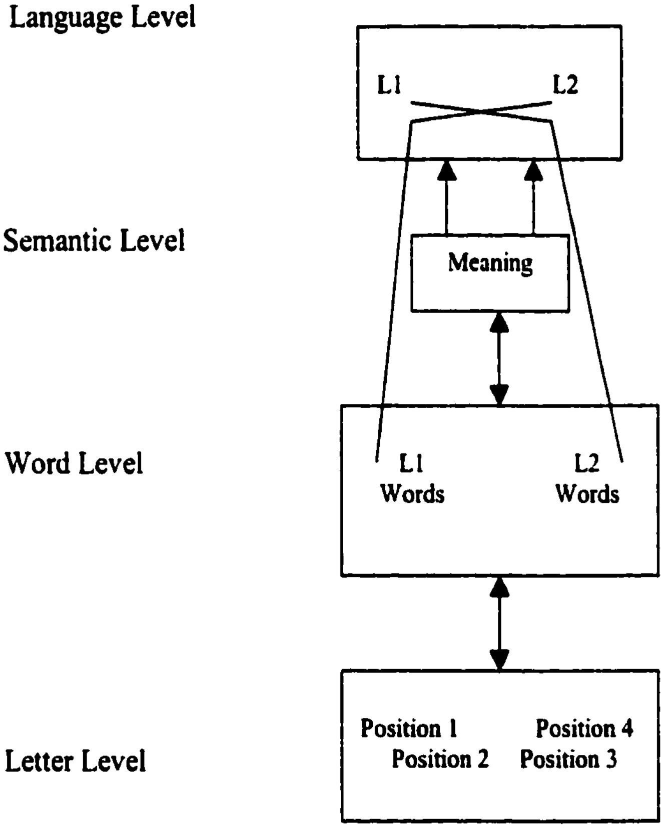

Figure 9: The Bilingual Interactive Activation (BIA) Model (adapted from Dijkstra et al., 1998)

In summary, current research suggests that bilinguals' performance is influenced by several variables, including task demands and stimulus choice. Questions regarding the degree to which bilinguals are able to separate their two languages are still unresolved.

More than Two Languages: Studies of Trilingual Speakers

While early reports of polyglot aphasia often discussed multilingual speakers and the relations among their languages, psycholinguistic studies have focused predominantly on bilinguals, speakers of two languages. In recent years, however, several psycholinguistic studies have expanded the discussion to trilingual and multilingual speakers. Most of these studies focused on issues of language learning, metalinguistic abilities, and processes of transfer among the languages (e.g., Cenoz & Genesee, 1998; Jessner, 1999; Klein, 1995; Leung, 1998).

Comparing monolingual and multilingual speakers who were all beginning learners of English (matched for a number of variables including manner and time of English learning), Klein (1995) found that in an English grammaticality judgment and correction task, multilinguals showed significantly better knowledge of English verb subcategorization than monolinguals, as well as better knowledge of target grammatical features related to the specific verbs tested (e.g., preposition stranding). Her results are consistent with several additional studies that found better ability to learn a non-native language after a second language had been learned (e.g., Eisenstein, 1980; Thomas, 1992).

Analyzing patterns of language transfer in third language learning, Leung (1998) found evidence for transfer from participants' L2 English to their L3 French. Furthermore, the structure that was transferred from L2 was one that was influenced by the structure of participants' L1 (Chinese) and was thus considered an interlanguage feature. Leung tested university students in Hong Kong, native speakers of Chinese, who had learned English as their second language at school (but did not reach native-like proficiency) and French as a third language at the university (for three years). She analyzed participants' production data as well as their performance on grammaticality judgment tasks in English (L2) and French (L3). While two of the three syntactic structures investigated did not show effects between the two non-native languages, one structure involving constituent movement revealed a reliable effect of the L2 (interlanguage) on L3 production and on a judgment task.[2]

Only a few studies have addressed issues of lexical representation and lexical access with speakers of more than two languages (Abunuwara, 1992; de Groot & Hoeks, 1995; van Hell & Dijkstra, submitted). These studies focus on the proficiency

[2] The use of the terms L2 and L3 has not been consistent in the literature. L3 has been used to refer to the language learned after L2, or to a non-native language of lower proficiency than L2. Of course, order of learning and proficiency do not always coincide. I will be referring to any language that is not L1 as "non-native language" or "non-L1". In the present study, I deliberately included participants with varied relative proficiencies in their two non-native languages.

differences between the second and third languages and thus will be discussed in the following section.

Language Proficiency and Language Representation

The developmental hypothesis (Kroll & de Groot, 1997; Potter et al., 1984) postulates that the relations between the two lexicons begin as strong word associations from L2 to L1 and change, with increased L2 proficiency, to more direct connections between L2 and the conceptual system and to less dependence on L1 words.[3] Indeed, language proficiency has been found to have an effect on the outcome of various tasks performed by bilinguals. For example, a stronger asymmetry was found between translation tasks performed from L1 to L2 and from L2 to L1 (i.e., when participants were given a word in L1 and were asked to translate it to L2 and vice versa) for non-proficient bilinguals than for highly proficient bilinguals (de Groot et al., 1994). In addition, different relations between naming pictures in L2 and translation were identified in more-proficient and in less-proficient bilinguals (Chen & Leung, 1989 for children and adults; Kroll & Curley, 1988; see also Kroll & de Groot, 1997; Kroll & Sholl, 1992).

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[3] While various levels of non-L1 proficiency are discussed in the present study as well as in the literature reviewed here, in all cases L1 remained participants' most proficient language; thus, issues concerning L1 attrition are not considered.

Thus, for example, in their summary of evidence for asymmetric L1 and L2 lexical processing of non-proficient bilinguals, Kroll and Sholl (1992) reviewed results from several studies that used tasks such as translation, picture naming and word naming (i.e., reading aloud written words). They found supporting evidence for a shift from reliance on L1 words during L2 word processing, at early stages of L2 learning, to direct access of concepts during L2 word processing at higher levels of L2 proficiency. Evidence included the findings from two groups of English speakers learning German (Kroll & Curley, 1988). Kroll and Curley compared more- and less-proficient speakers of German L2 on their performance in L1 and L2. While the two groups did not differ in their performance in English (word and picture naming), they differed in their L2 performance. Specifically, the less-proficient participants were faster in translating from L1 to L2 than naming pictures in L2 (as would be predicted by an L2-to-L1 word-association representation), whereas the more-proficient participants did not demonstrate a significant difference in their performance on the two tasks.

Faster response times were also found by Kroll and Curley in translating from L2 to L1 than from L1 to L2, but the difference in response times in the two directions was larger for their less-proficient L2 speakers than the difference found by Kroll and Stewart (1990, in Kroll & Sholl, 1992) for highly proficient L2 speakers. This directional asymmetry in translation tasks has been reported in additional studies (e.g., de Groot et al., 1994), as has been the findings of smaller differences between the two translation directions for more-proficient bilinguals (de Groot et al., 1994; de Groot & Nas, 1991). Furthermore, the faster response times that have been reported for cognates than for non-cognate translation pairs have been found with less-proficient bilinguals, but the cognate advantage was smaller when participants were highly proficient in their L2 (e.g., de Groot et al., 1994; Kroll & de Groot, 1997).

Chen and Leung (1989) compared the performance of three groups of native speakers of Chinese: adult proficient bilinguals (who had studied English for more than 12 years), adult beginners (who had studied French for two-three years), and child beginners (who had studied English for about two years) on picture naming, word reading, and word translation, and found that the three groups differed in their performance. Proficient Chinese-English bilinguals demonstrated no significant differences in response times and error rates when they were asked to respond in their L2 to either pictures or Chinese words (i.e., picture naming in L2 and translating from L1 to L2). In contrast, adult beginners were faster in translating from L1 to L2 than in picture naming in L2. The group of child beginners showed faster responses to picture naming in L2 than in word translation from L1 to L2. The authors took these results as further support for the word-association hypothesis and the reliance on L1 words during L2 processing at early stages of L2 learning. (The results from the child beginners, on the other hand, demonstrated faster response times for picture naming in both L1 and L2, providing evidence for strong reliance on concept access or even on picture-word links in early L2 learning.)

Additionally, proficiency was found to play a role in studies that used the Stroop test (as reported above), demonstrating increased interference in the interlingual incongruent conditions (when participants were asked to name the color of the ink in one language and the word was in their other language) with increasing

L2 proficiency (e.g., Preston & Lambert, 1969; Tzelgov et al., 1990) as well as possibly increased control over lexical activation in various bilingual situations with increased proficiency (Smith, 1997; Tzelgov et al., 1990). A version of the Stroop paradigm was used by Abunuwara (1992) to further investigate the role of proficiency in these patterns of interference, looking at speakers of three languages.

Abunuwara (1992) approached the question of proficiency and representation in a within-subject rather than between-subject design and investigated the relations among the three languages of native speakers of Arabic who had acquired Hebrew and English. Using a trilingual version of the Stroop test (Experiment 1) and a word- and picture-naming task (Experiment 2), Abunuwara tested the hypothesis that the relations between L2 and L1 change with increased L2 proficiency. Further, Abunuwara suggested that by looking at the relations among the three languages of trilingual speakers, the developmental hypothesis could be tested. In his predictions, interference between L1 and L2 and L1 and L3 was expected but the interference from L1 to L2 was expected to be smaller than the interference from L1 to L3. No interference was expected between the third language and the second language. Abunuwara found that, as predicted, there was very small interference between L2 and L3. In addition, the interference from L1 to L3 was larger than that from L1 to L2. Indeed, the effect between L1 and L2 was virtually symmetric in contrast to the largely asymmetric effect between L1 and L3 with larger effect from L1 to L3 than from L3 to L1.

Abunuwara concluded that these findings supported the developmental hypothesis and were not consistent with strong independent nor strong interdependent approaches. Based on these results, and the results of his second study, Abunuwara found support for an independent representation of a more proficient language and no interdependent relation between two non-native languages. It should be noted, however, that little information about the participants' level of proficiency in the two languages – L2 and L3 – can be found in Abunuwara's report; if for all participants, L2 was markedly more proficient than L3, the results could indeed be taken as evidence for changing relations between L1 and an additional language with increasing proficiency. Additional concern may be the linguistic relation between L1 and L2 (Arabic and Hebrew for seven of the 10 participants) and L1 and L3 (Arabic and English for seven of the 10 participants).

Following Abunuwara, de Groot and Hoeks (1995) compared the relations between L1 and a strong L2 (a highly proficient non-native language) and L1 and a weaker L3 (a less proficient non-native language) in trilingual Dutch-English-French speakers. De Groot and Hoeks employed two tasks: translation production, i.e., given a word in one language, participants are asked to produce the translation equivalent in the other language, and translation recognition, i.e., given a pair of words, participants are asked to judge whether the two words are translation equivalents or not. They compared the performance of 48 trilingual participants in two conditions: translation from L1 to L2 and translation from L1 to L3. Crucially, they varied the level of concreteness of their stimuli, hypothesizing that if forward translation (from L1 to non-L1) is performed via concept mediation, the semantic characteristics of the words used will influence performance. Specifically, according to the developmental hypothesis, translation to a less proficient language is not accomplished via concept mediation while translating to a highly proficient language is; thus, a concreteness effect was expected in the L1-to-L2 conditions but not, or less so, in the L1-to-L3 conditions. In the translation-recognition task, de Groot and Hoeks found that, as predicted by the developmental hypothesis, a significant difference between concrete and abstract words was evident in translating from L1 to L2 but not in translating from L1 to L3. In the translation-production task, they found a strong concreteness effect, namely, concrete words were translated faster than abstract words in the L1-to-L2 translation condition. In translating from L1 to L3, on the other hand, the difference in response time between abstract and concrete words was not reliable, but a large percentage of no responses to abstract words was observed. While both conditions, translation from L1 to L2 and from L1 to L3, showed differences between concrete and abstract words, the pattern of results obtained in these two conditions was different.

Overall, de Groot and Hoeks (1995) concluded that their data demonstrated that only with the more proficient non-native language, participants used the conceptual representation in the translation task, consistent with the developmental hypothesis. However, de Groot and Poot (1997) suggested, based on their translation data from participants of three levels of proficiency, that the shift from reliance on word association to concept mediation in translation processes may not be gradual and may happen at early stages of acquisition. De Groot and Poot found differences in performance among their three groups of L2 proficiency, with overall faster response times and smaller error- and omission-rates for the more proficient participants. Crucially, however, they did not find differences in the level of conceptual involvement among the three participant groups, as was demonstrated by the equally large imageability effect at all proficiency levels.

Support for different relations between L1 and a proficient non-native language and L1 and a less-proficient non-native language can be found in the results of a study reported by van Hell and Dijkstra (submitted). Trilingual native speakers of Dutch with highly proficient L2 English and less-proficient L3 French were tested in a monolingual lexical decision task in Dutch. The Dutch words were either cognates of English words, of French words, or non-cognates. Van Hell and Dijkstra found that even though their participants were not aware of any multilingual aspect of the experiment (the task was in Dutch only; the trilingual aspect of the study was not revealed to the participants, who were recruited for a number of additional studies), response times to Dutch words that were cognates of English words (Experiment 2) or of French words (Experiment 3) were significantly faster than those to non-cognates. However, no similar facilitation was found for the Dutch words that were cognates of French words for participants who had low levels of French proficiency (Experiment 2).

Additional support for the effect of language proficiency was found by Basden, Bonilla-Meeks, and Basden (1994). They used priming in a word-fragment completion task and included a study phase of word-reading, mental-translation, and written-translation conditions. The word-completion task contained words that appeared in the study phase and new words. Their participants comprised proficient, Spanish-English bilinguals who learned their L2 early, and beginning, Spanish-dominant bilinguals. Both groups showed greater priming effects for words that appeared in the translation conditions than in the read-only condition. However, while the low-proficiency bilinguals showed a significant difference between words from the read- and mental-translation conditions, they did not show a significant difference between words from the mental- and written-translation conditions; the proficient bilinguals showed significant differences between each pair of conditions. Moreover, priming effects were found for proficient bilinguals when word lists were presented in each language separately as well as when the lists were mixed and included both languages, but beginning bilinguals did not demonstrate significant priming in the unmixed lists. The authors took their results as further support for the relation between lexical access and conceptual access and L2 proficiency. It appears that the relative levels of activation of the two languages, depending on presentation and task variables, influence bilingual performance.

Van Heuven, Dijkstra, and Grainger (1998), in contrast, found only scarce evidence for proficiency effects in a word recognition task, using a progressive demasking paradigm (participants were asked to push a button when they could identify a gradually demasked visually presented word). Van Heuven et al. manipulated the orthographic neighborhood size, within language and across languages, and compared performance of highly proficient and less-proficient Dutch-English bilinguals. They found that while the number of orthographic neighbors affected performance in both L1 and L2, no significant differences were found between the more- and less-proficient groups, except on one measure; namely, highly proficient bilinguals were found to be affected by the number of L2 neighbors when the English-target list was presented before the Dutch-target list but low-proficient participants showed no such effect. The authors concluded that even at high proficiency, the influence of one language on the processing of the other may not be under voluntary control of the speakers. It is not entirely clear under what task conditions proficiency differences affect the results nor at what levels of proficiency these differences can be detected.

In addition, as summarized above, evidence from brain-imaging studies of bilinguals suggests that brain areas that are involved in processing the two languages change with second-language proficiency such that while differential activation was found for non-proficient bilinguals, similar activation areas emerged for the two languages of proficient bilinguals (e.g., Illes et al., 1999).

Among studies that employed cross-language priming paradigms, using various language combinations (e.g., de Groot & Nas, 1991; Gollan et al., 1997; Jiang, 1999), most studies reported proficient to highly proficient bilinguals as their participants and the data are insufficient to systematically assess the role of proficiency in the priming effects obtained.

The way proficiency level is determined is yet an additional variable that should not be overlooked. Proficiency measures that have been reported in the literature include self-rate language-proficiency scales (e.g., de Groot & Hoeks, 1995; Jared & Kroll, 2001; Kroll & Stewart, 1994) and response times and accuracy rates on simple lexical-decision tasks (e.g., Chee et al., 1999; de Groot & Hoeks, 1995). In a large number of the studies, no objective measures of proficiency are reported and the only information about participants' proficiency provided by the authors is a summary paragraph of the number of years L2 has been formally learned.

In sum, participants' proficiency in their non-native language(s) is a crucial factor that contributes to the variability of results reported in the literature. The specific relations between the non-native language proficiency and its lexical connections to the native language have not been fully identified. Moreover, mixed and even contradictory results suggest that the picture is a complex one with a range of cross-language associations. The relation between the two non-native languages has virtually not been explored, even in studies that included trilingual speakers (de Groot & Hoeks, 1995; van Hell & Dijkstra, submitted). Nor have the effects of proficiency in the lexical connections among non-native languages been formally assessed to date.

Rationale and Predictions

Summary of Background

Theories concerning the relations between the two languages of bilingual speakers have generally been consistent with one of three assumptions: shared lexical representation of the two languages at all or at some representation levels (e.g., Dijkstra et al., 2000; Fox, 1996; Kolers & Gonzalez, 1980); shared conceptual representation of the two languages but separate lexical representation of L2 with varying lexical and conceptual connections (e.g., Kroll & Stewart, 1994); or independent lexical representation of L1 with an associative representation of L2 (Jiang & Forster, 2001). Models of the bilingual lexicon distinguish several levels of lexical representation and different relations may be assumed for form, semantic, and conceptual levels of word representation. A number of variables have been found to affect the results obtained from the different tasks that have been used to learn about bilingual representation and processing. These include word type, sequence of presentation, relation among the languages, and task demands (e.g., de Groot & Kroll, 1997; Dijkstra et al., 2000; Gollan & Kroll, 2000; Grosjean, 1998). Moreover, most researchers acknowledge that the relations between the two languages may change with increased L2 proficiency (e.g., de Groot & Hoeks, 1995; Kroll, 1993; Kroll & Sholl, 1992).

Further, a directional asymmetry in tasks such as translation from one language to the other and cross-language primed lexical decision has been reported (e.g., de Groot & Hoeks, 1995; Gollan et al., 1997; Kroll & Stewart, 1994; Jiang, 1999). Both the revised hierarchical model (Kroll & Sholl, 1992; Kroll & Stewart, 1994) and an associative (episodic rather than lexical) representation of L2 (Jiang, 2000; Jiang & Forster, 2001) predict differences between processing in the two directions (from L1 to L2 and from L2 to L1). An additional account for this directional asymmetry, discussed, for example, by Forster and his colleagues, pertains to the speed of lexical processing of less-proficient languages. If L2 words require a longer time than L1 words to be accessed, differences in the lexical processing in the two directions are expected. Degrees of controlled activation and inhibition of the two languages have also been advanced as a possible account for the complex patterns of results obtained in various studies on bilingual lexical processing (e.g., Green, 1998).

In order to determine the effects of level of proficiency and speed of access on the directional asymmetries reported in the literature, it is necessary to dissociate two inherent features of L2: that L2 words are acquired after L1 words and the concepts associated with them have been acquired; and that L2 is less proficient than L1 and hence is processed more slowly. One way to assess the role of speed of access is by studying the lexical relations among the languages of trilingual speakers. In cross-language priming between two languages of lower proficiency, access to both primes and targets is expected to be relatively slow; such a study has not been carried out to date. Investigating lexical effects between two non-native languages can also be useful in testing the prediction that the representation of languages other than L1 is not lexical in nature. If these non-proficient languages are represented lexically, lexical effects between them are expected (whereas if non-native language representation is non-lexical, no cross-language effects are expected between two non-native languages). Moreover, based on pilot interviews with multilingual speakers, there appears to be lexical interference between two non-proficient languages. These effects are likely to be related to level of proficiency and may decrease with increased proficiency of L2 (as was demonstrated, for example, by weak interference between a highly proficient L2 and L3 found in Abunuwara, 1992).

In addition, understanding the relation among more than two languages in multilingual speakers has been the focus of a growing number of studies in the last decade (e.g., Cenoz & Genesee, 1998; Hoffmann, 1999; Klein, 1995). Issues concerning L3 learning (i.e., learning a second non-native language), the relations between L1 and various non-native languages, and proficiency, use, and sociolinguistic considerations of more than two languages have been addressed in current research. To date, only a few studies have focused on lexical representation of more than two languages (Abunuwara, 1992; de Groot & Hoeks, 1995) and the focus of these studies has been the relations between the first language and the two additional languages. Very little is known about the relations between two non-native languages.

The present study employed a masked translation-equivalent priming paradigm in a lexical decision task to explore the lexical relations among the three languages of trilingual speakers. The relations between the first language and each of the two non-native languages were assessed as well as the relations between the two non-native languages. The goal of the study was to examine the effects of language proficiency on cross-language priming. Participants with varying levels of proficiency in their non-native languages were included; priming effects among the three languages, as a function of their proficiency levels, were studied.

Predictions

I. Cross-language priming effects:

1. Priming between L1 and a non-native language

a. Priming effects from L1 to a non-native language are expected to be stronger than priming effects from that non-native language to L1.

This is expected based on the assumption that L2 word-access relies on L1 word-access but L1 word-access does not rely on L2 word-access. The stronger lexical connections from L2 to L1 assumed, for example, in the revised hierarchical model, predict stronger priming effects from L1 primes to L2 targets than in the opposite direction. This asymmetry is expected based also on speed of lexical access, if faster lexical access is assumed for highly proficient languages than for less-proficient languages.

b. Priming effects from L1 to a non-native language are expected to be stronger when the target language is a less-proficient non-L1 than a more-proficient non-L1.

This is expected if the strength of connections between L1 words and non-L1 words changes with non-L1 proficiency in the direction of more independent non-L1 word-access with increase proficiency. (This prediction can be tested here across the two non-native languages and within the same non-native language with more- and less-proficient speakers.)

2. Priming between the two non-native languages

a. Priming effects are expected between the two non-native languages.

This is expected if there are lexical connections between two non-native languages (despite the fact that they may have been learned independently) and based on participants' self-report of interference between them. If, however, non-native languages are not part of the lexical memory, no priming effects are expected between them.

b. Priming effects from the more-proficient non-native language to the less-proficient non-native language are expected to be stronger than priming effects from the less-proficient non-L1 to the more-proficient non-L1.

This is expected based on previous results between L1 and a second language and if proficiency-related speed of lexical access affects priming effects (i.e., sufficient processing time is needed at lower levels of proficiency for priming to occur).

c. Priming effects between two low-proficiency non-native languages are expected to be stronger than the priming effects between two non-native languages of very different levels of proficiency.

This is expected if stronger lexical connections exist between two non-native languages of lower proficiency than between two non-L1 languages when one is highly proficient and the other is not, as suggested by interference patterns reported by multilingual speakers as well as processing-time differences.

II. Within-language priming effects:

3. Within-language priming effects are expected in related conditions (identity priming) as compared to the unrelated conditions.

This is expected based on previous within-language results and current priming theories.

Chapter 2: Methods

Participants

Seventy-nine participants were included in this study.[4] They all were native speakers of Hebrew who had at least basic proficiency in both English and Arabic. Participants' proficiencies in their two non-native languages varied. Proficiency of each participant in each language was determined using the following measures (their outcome is outlined in Proficiency Measures Results below):

1. Latencies and accuracy levels in a simple lexical decision task (LDT) administered as a post-test. Response times and accuracy rates have been found to reflect proficiency, with longer latencies and higher error rates associated with lower proficiency (e.g., de Groot & Hoeks, 1995; van Hell, 1998).

2. Ratings on a self-rated 7-point scale measuring speaking, comprehension, reading, vocabulary, writing, and overall skills (administered as part of a background questionnaire, see below). The 7-point scale ranged from 1 = native-like proficiency to 7 = minimal knowledge.

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[4] While the experiment was administered to 85 participants, data from six participants were excluded from the study. Two participants were excluded because they were exposed to English from birth or early in childhood, two participants were not born in Israel and did not acquire Hebrew until after age 5, and two participants were excluded because they evidenced more than 50% errors on the Arabic LDT.

Information about manner of acquisition and language use was obtained via a detailed questionnaire (see Appendix A). All participants included in the study lived in Israel and had Hebrew as their first and dominant language. All had learned their additional languages at school (formally, not by immersion), starting after the age of 7. All had been further exposed to English in their studies, on television, and some via the Internet, and to Arabic as part of their studies or work, and to a lesser degree, on television.

Amount of English use at the time of the experiment varied from every day to several hours a week for reading and comprehension, and to once a month or less for writing and speaking. Amount of Arabic use varied from every day to almost never (for participants who had used the language more in the past). Four participants reported having lived in an English-speaking country for one to two years, all after the age of 20. None of the participants had lived outside of Israel in an Arabic-speaking country but several participants reported that they had family members who spoke Arabic and that they had been exposed to the language on occasions such as family gatherings.

Age of participants ranged from 19 to 52 with a mean age of 27. Participants' education ranged from 12 years to 19 years[5] with a mean of 14.5 years. There were 49 women and 30 men. Pertinent participant information is presented in Table 1.

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[5] Though one person reported 21 years of education, that person appears to have recorded years of university enrollment, rather than full academic years.

Participants were recruited from the north and center of Israel, by posting signs calling for volunteers. All participants were paid for their participation.

Table 1

Participants' Data

Age (in years)		Gender		Education (in years)		Age English-learning began		Age Arabic-learning began	
range	mean	women	men	Range	mean	range	mean	range	Mean
19-52	27.20	49	30	12-19	14.50	7-12	9	8-24	13

Task

The experimental task employed in the study was a primed LDT, using within-language and cross-language masked priming. A prime word was presented visually on a computer screen for a brief time, followed by the target word. Participants were asked to decide for each target word whether it was a real word or a non-word. In the (forward) masked priming paradigm, the mask, for example a sequence of # signs (as in the current experiment), is presented before the prime, which is presented for a very brief time, and then replaced by the target. The presentation of the prime is thus masked and is not consciously perceived by the participants (see Procedure).

Stimuli

Triads of translation equivalents of the three languages – Hebrew, Arabic (written Arabic), and English – were used as the experimental stimulus set. To select adequate translation equivalents, the following procedure was employed. Common, familiar, predominantly concrete words were compiled using dictionaries and language-learning books (frequency tables were not available for all three languages); 126 triads were initially selected. Adequate translation equivalency of the translation equivalents in each pair of languages was determined using bilingual raters as follows. Lists of words were given to bilingual speakers to translate from one language to the other (e.g., a list of English words was to be translated into Hebrew and Hebrew words into English by English-Hebrew bilinguals). Only pairs for which at least three of four raters produced identical translations, in both translation directions, were selected.

None of the translation pairs were cognates, that is, identical or similar in phonological form (e.g., English *telephone* and Hebrew טלפון; Arabic كلب and Hebrew כלב *dog*). Nor were any pairs "false friends", that is, pairs that have identical or similar phonological form (e.g., English *peel* and Hebrew פיל *elephant*; Arabic لحم *meat* and Hebrew לחם *bread*). Crucially, none of the Arabic-Hebrew translation pairs were related in form or shared a common root. The many words that sound and/or mean the same in the two languages – both being Semitic languages – were systematically avoided. Furthermore, each of the three languages uses a different orthographic system, thus there were no translation-equivalent pairs that were identical or similar in orthographic form. Average letter length did not differ overall across the target words across the three languages.

The selected words appeared as primes or targets in the various priming conditions of the experimental task (see Table 2) but such that each word appeared once in each of two counter-balanced versions. (For the complete stimulus list see Appendix B.) Thus, each participant saw each word only once. There were 14 items in each condition: 14 pairs of translation equivalents were used in each of the related cross-language conditions (e.g., *fork* priming מזלג, the Hebrew word for *fork*) and 14 pairs of repeated words were used for each of the related within-language conditions (e.g., *fork* priming *fork*). Similarly, 14 pairs of unrelated words were used in each of the unrelated conditions (e.g., נר, the Hebrew word for *candle* priming *fork* in the cross-language unrelated condition or *candle* priming *fork* in the within-language unrelated condition). An additional 126 words, 42 words in each language, were selected based on the same procedure without the rating for translation equivalency, to serve as the primes in the unrelated conditions.

An equal number of pseudo-words (word-like non-words) was constructed by changing two graphemes (and also two phonemes to the extent possible) from an existent word in the corresponding language (e.g. for an English non-word, *camdo*). Native speakers of each language confirmed the non-word status of these items and their distance from existing words. All non-words were orthographically and morpho-phonologically legal in their respective language and did not constitute real words in the other two languages. Half of the non-words were primed by real words and half were primed by the same non-word (as in repetition priming).

Table 2

Examples of Prime-Target Pairs in each of the Three Lists

Hebrew-Target List	Hebrew-Hebrew	English-Hebrew	Arabic-Hebrew
Related	פרח - פרח	sand - חול	פרה - بقرة
Unrelated	ארנק - אוהל	bread - שפם	מיטה - محرك
English-Target List	**Hebrew-English**	**English-English**	**Arabic-English**
Related	מסרק - comb	boat - boat	طفل - baby
Unrelated	זהב - towel	match - cake	لعبة - tree
Arabic-Target List	**Hebrew-Arabic**	**English-Arabic**	**Arabic-Arabic**
Related	برميل - חבית	stone - حجر	سمكة - سمكة
Unrelated	حائط - כובע	coin - زهرة	غيمة - صخرة

To approximate a monolingual language mode, that is, a context within which one language is clearly the target language of a given task (cf. Grosjean, 1997), the prime-target pairs were organized in three lists – one for each target language (Hebrew, English, Arabic) – of 168 items each. Each of the three lists contained targets in one language preceded by related and unrelated primes in each of the three languages. Two items were added in the beginning of each list but were not considered for analysis. In addition, each participant received 12 practice items (in Hebrew).

The words used as primes and as targets in the experimental LDT served as the items in the post-test simple LDT. The simple LDT served two goals. Accuracy and response times in each of the two non-native languages, as compared to performance on L1, were used as proficiency measures. In addition, accuracy results on this test were used as a selection criterion for individual items on the experimental LDT. Specifically, only words that were correctly identified by a given participant in the simple LDT were included in the analysis of that participant's experimental LDT.

That is, for each participant, the experimental data reported included only items for which the participant knew both the prime and the target, as evidenced by that individual's performance on the later simple LDT. The assumption here was that priming effects are not expected from or to a word that was not known by a given participant. It is likely that some words, even known by a certain participant, received a "no" response by mistake (due to the speeded response required in the task); erring in this direction was deemed preferable to erring in the other direction (i.e., including items not known by participants).

Procedure

The overall procedure comprised a brief screening, the experimental LDT, a detailed language-background questionnaire, and the post-test LDT, as follows.

1. A short phone screening was administered, before a test session was scheduled, to verify that participants met the basic criteria: being between the ages

of 18 and 50,[6] being native speakers of Hebrew, and having at least basic reading skills in both English and (written) Arabic.[7]

2. The experimental LDT consisted of three lists, one for each target language. Each list contained six types of prime-target combinations (related and unrelated prime-target pairs, within-language and cross-language; see examples in Table 2), presented in a counter-balanced pseudo-randomized order.

Each participant was tested individually. Participants were asked to sit in front of a computer screen (Ascentia 810N Notebook) and decide for each string of letters they saw whether it was a word in the target (pre-specified) language or not. For each item, presentation was as follows: a forward mask serving also as a fixation point (#########) presented for 500 ms, which was replaced by the prime stimulus presented for 60 ms, which was replaced in turn by the target stimulus, presented until a response was made.[8] The two shift keys on the notebook keyboard were used for "word" and "non-word" responses.

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[6] Several studies have reported decline in lexical access with increased age, with some changes found for participants in their 50s (e.g., Nicholas, Obler, Albert, & Goodglass, 1985; Ramsay, Nicholas, Au, Obler, & Albert, 1999). To allow generalizability of the results but to avoid age-related variability, the target population for the present study was adults between the ages of 18 and 50. However, two participants, a 51-year-old and a 52-year old, were among the people tested. Their data did not appear to differ from those of the other participants and thus they were included in the sample.

[7] Due to the diglossic situation of Arabic, its speakers may know the spoken variety only, the "higher" mostly written variety, or both. Because the task was a written-word recognition and for the purpose of word choice, it was important to establish that participants had at least a basic knowledge of the written variety of the language.

3. Questionnaire: A detailed language-background questionnaire (in Hebrew), eliciting information about age and manner of language learning, language use, and self-rating of proficiency was administered. Participants filled out the questionnaire on their own; if any of the information was missing or unclear, they were asked about it before the end of the session.

4. Proficiency test: A simple LDT was administered in each of the three languages. The words used in the experimental LDT were used as the target words in the post-test LDT.[9] Each stimulus was preceded by a fixation point (#########) for 500 ms; the target items remained on the screen until response. Words were presented in each of the three languages separately, in a pseudo-randomized order counter-balanced across participants.

Participants signed consent forms (in Hebrew) at the beginning of the session. They were paid and debriefed at the end of the session.

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[8] The sequence of presentation used here was similar to the one used in a number of masked priming studies (e.g., Forster & Davis 1984; Gollan et al., 1997). I originally intended to allow additional time for the prime word to be processed but pilot data revealed that the altered sequence may not be reliable and the previously used sequence was adopted. Presentation-sequence variables will be addressed in the Discussion below.

[9] Because the words that were used in this task were the same items that appeared in the experimental LDT, this measure did not provide a pure baseline RT. However, if an episodic-priming type of effect occurred, it would have affected all three languages. At most, the less-proficient language might be expected to benefit more from this episodic effect, such that participants appeared more proficient than they really were. However, relative proficiency levels were considered here and thus this effect was not expected to interact significantly with the results.

Proficiency Measures Results

Simple LDT

Mean response time (RT) to the Hebrew words in the simple LDT was obtained for each participant. As a measure of proficiency in the non-native languages, mean RT to the English words and mean RT to the Arabic words in the simple LDT were obtained for each participant. To account for RT variation among participants in their L1, the differences (in milliseconds) between participants' Hebrew mean RT and English mean RT and between the Hebrew mean RT and the Arabic mean RT were then calculated. This difference in RT, measuring the speed of participants' RT in English and in Arabic relative to their Hebrew RT, served as one measure of English and Arabic proficiencies (see Tables 3 and 4, the values represent ranges and means for the 79 participants included in the study).

Mean RT in the Hebrew simple LDT ranged from 430 ms to 1069 ms, with a mean of 652. Mean RT in the English simple LDT ranged from 573 ms to 1369 ms with a mean of 789. Mean RT in the Arabic simple LDT ranged from 650 ms to 1967 ms, with a mean of 1107. The difference between mean RT in Hebrew and English on the simple LDT (henceforth, English-RT-Difference) ranged from 8 ms to 512 ms with a mean of 136.[10]

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[10] The difference of 512 ms was subsequently identified as an outlier and was excluded from analyses, leaving the highest difference 304 and a mean of 132.

The difference between mean RT in Hebrew and Arabic in the simple LDT (henceforth, Arabic-RT-Difference) ranged from 130 ms to 1189 ms, with a mean of 455.

A second measure of proficiency was participants' error rates in the simple English and Arabic LDT (see Tables 3 and 4). Mean error rate in Hebrew was 1%, ranging from 0% to 6% (96% of the participants ranged between 0% and 3%). Error rates in Hebrew were not taken as an indication of proficiency; all participants included in the study reported Hebrew to be their first and most dominant language and given the high familiarity of the Hebrew items, errors were assumed to be a by-product of the task rather than an indication of proficiency. Mean error rate in the simple English LDT (henceforth, English-Error-Rate) was 4%; error rates ranged from 0% to 30% (most participants, 94%, ranged between 0% and 8%). Mean error rate in the Arabic simple LDT (henceforth, Arabic-Error-Rate) was 12%, ranging from 1% to 27%.

Table 3

Participant Performance on English Proficiency Measures

Proficiency Measures	Range	Mean (Standard Deviation)
English-RT-Difference (ms)	8-512	136 (80.49)
English-Error-Rate (%)	0-30	4.16 (4.57)
English-Mean-Self-Rate (1 native-like – 7)	1.17-5.17	2.87 (.76)

Table 4

Participant Performance on Arabic Proficiency Measures

Proficiency Measures	Range	Mean (SD)
Arabic-RT-Difference (ms)	130-1189	455 (275)
Arabic-Error-Rate (%)	1.0-27.33	11.58 (6.88)
Arabic-Mean-Self-Rate (1 native-like – 7)	1.50-5.83	3.48 (1.14)

Self-Rating of Language Proficiency

As an additional measure of proficiency, participants rated their speaking, reading, vocabulary, writing, comprehension, and overall skills in English and in Arabic on 7-point scales. Ratings in each of these linguistic areas as well as the overall ratings in English and in Arabic were tabulated and the mean of the self-rated skills was calculated for each participant (see Tables 5 and 6).

Mean self-rated scores (i.e., the mean of the individual self-rating in the various linguistic areas) in English (henceforth, English-Mean-Self-Rate) ranged from 1.2 to 5.2 with a group mean of 2.9 (see Table 5). The ratings of the different skills intercorrelated highly; the "overall" subset of the self-rating correlated highly with the English-Mean-Self-Rate ($r = .908, p < .001$).

Mean self-rated scores in Arabic (henceforth, Arabic-Mean-Self-Rate) ranged from 1.5 to 5.8 with a group mean of 3.5 (see Table 6). The ratings of the different

Arabic skills intercorrelated highly and the "overall" subset of the self-rating correlated highly with the Arabic-Mean-Self-Rate ($r = .919, p < .001$).

Table 5

English Self-Ratings

Language Skill	Range (1 native-like – 7)	Mean (SD)
Overall	1-5	2.76 (.89)
Vocabulary	1-5	3.04 (.93)
Reading	1-5	2.67 (.87)
Writing	1-6	3.13 (1.02)
Speaking	1-6	2.99 (1.01)
Comprehension	1-5	2.64 (.91)
Mean-Self-Rate	1.17-5.17	2.87 (.76)

Table 6

Arabic Self-Ratings

Language Skill	Range (1 native-like – 7)	Mean (SD)
Overall	1-6	3.48 (1.24)
Vocabulary	2-6	3.37 (1.10)
Reading	1-6	3.05 (1.27)
Writing	1-7	3.43 (1.51)
Speaking	1-7	4.30 (1.51)
Comprehension	1-7	3.25 (1.19)
Mean-Self-Rate	1.50-5.83	3.48 (1.14)

As a group, participants showed higher overall English proficiency than Arabic proficiency, particularly as seen in the mean Error-Rate and mean RT-Difference.

Correlations among Proficiency Measures

The relations among the various measures of proficiency employed in this study were analyzed for each non-native language using Pearson correlations (see Tables 7 and 8).

English-RT-Difference (recall, the difference in RT between Hebrew and English) correlated significantly with English-Error-Rate: $r = .230, p = .042$; with Overall-Self-Rate: $r = .265, p = .018$; with the Mean-Self-Rate: $r = .286, p = .011$ (see Figures 10 and 11); and with self-rating on individual language skills (e.g., with the Vocabulary-Self-Rate $r = .236, p = .036$). The English-Error-Rate correlated with several self-ratings on individual skill as well as with the mean self-rating: English-Error-Rate and English-Mean-Self-Rate: $r = .358, p = .001$

The Arabic-RT-Difference measure of proficiency correlated significantly with the Arabic-Error-Rate measure: $r = .717, p < .001$, and with the various self-ratings, including the Arabic-Mean-Self-Rate: $r = .400, p < .001$ (see Figures 12 and 13). The Arabic-Error-Rate also correlated with the Arabic-Mean-Self-Rate: $r = .447, p < .001$ as well as with self-ratings on individual skills.

Table 7

Correlations among Proficiency Measures in English

Measure	Vocabulary Self-Rate	Reading Self-Rate	Overall Self-Rate	Mean Self-Rate	E-RT-Difference
Vocabulary Self-Rate					
Reading Self-Rate	.733 **				
Overall Self-Rate	.711 **	.652 **			
Mean Self-Rate	.846 **	.801 **	.908 **		
English-RT-Difference	.236 *	.311 **	.265 *	.286 *	
English-Error-Rate	.231 *	.194 (p=.06)	.370 **	.358 **	.230 *

Table 8

Correlations among Proficiency Measures in Arabic

Measure	Vocabulary Self-Rate	Reading Self-Rate	Overall Self-Rate	Mean Self-Rate	A-RT-Difference
Vocabulary Self-Rate					
Reading Self-Rate	.748 **				
Overall Self-Rate	.819 **	.758 **			
Mean Self-Rate	.891 **	.881 **	.919 **		
Arabic-RT-Difference	.381 **	.362 **	.427 **	.400 **	
Arabic-Error-Rate	.371 **	.336 **	.506 **	.447 **	.717 **

* Correlation significant at the .05 level
** Correlation significant at the .01 level

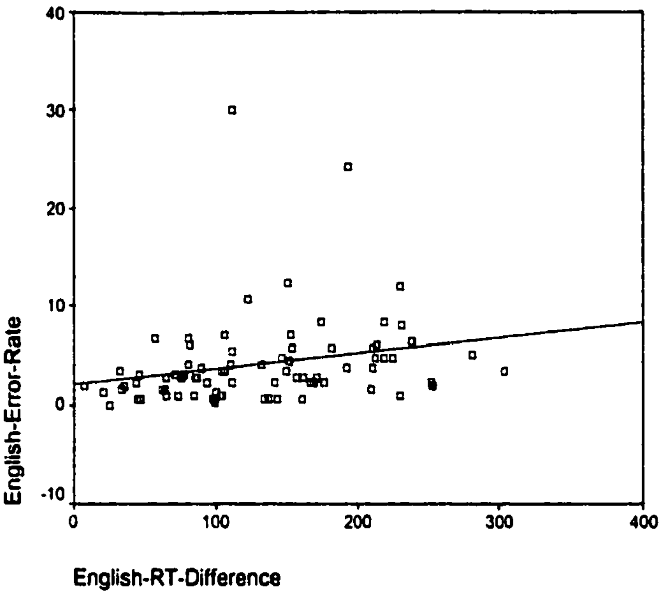

Figure 10. Correlation between English-RT-Difference and English-Error-Rate

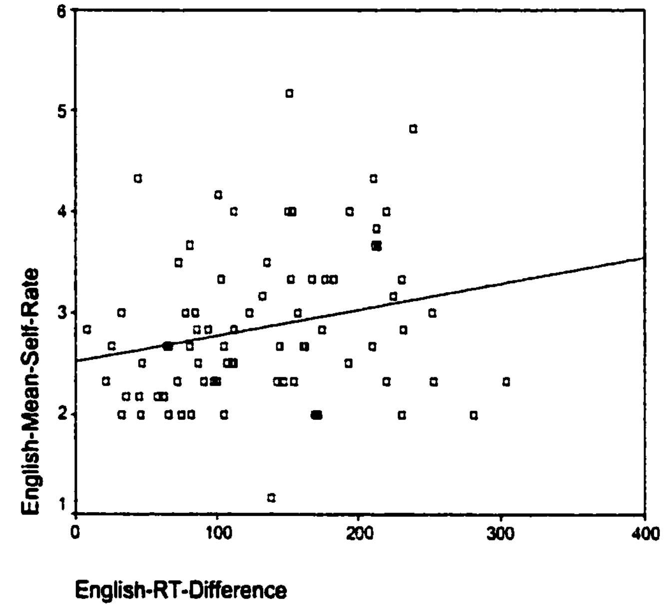

Figure 11. Correlation between English-RT-Difference and English-Mean-Self-Rate

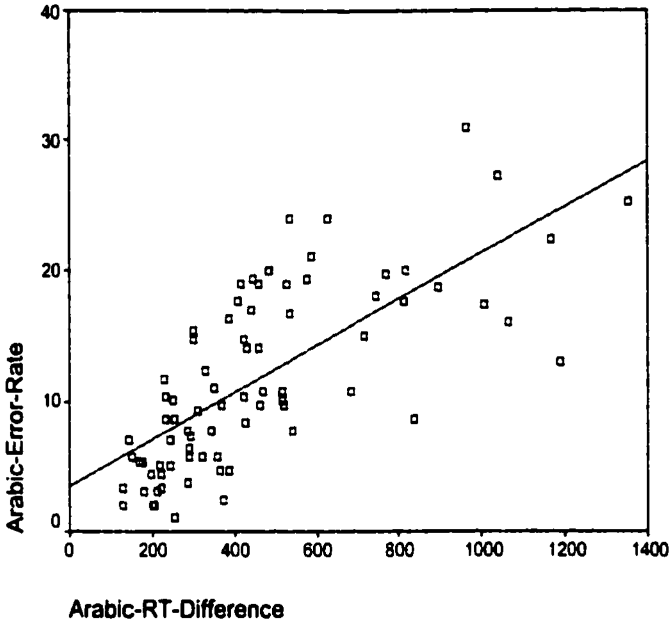

Figure 12. Correlation between Arabic-RT-Difference and Arabic-Error-Rate

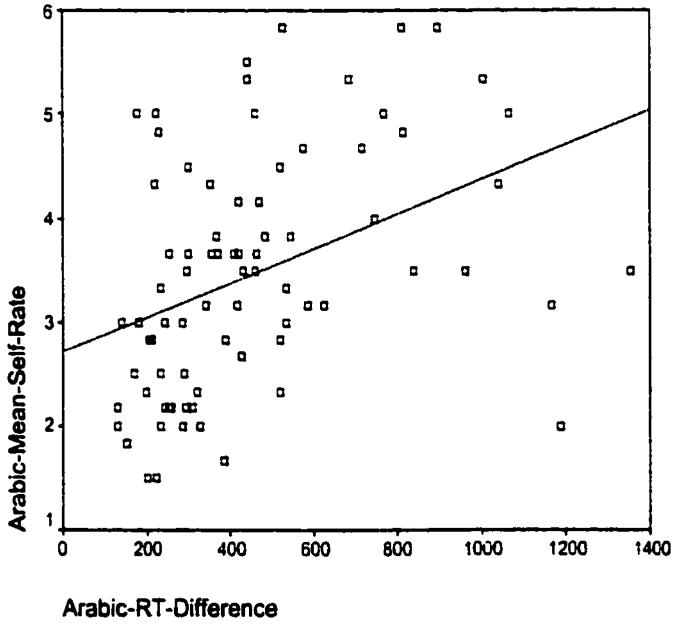

Figure 13. Correlation between Arabic-RT-Difference and Arabic-Mean-Self-Rate

In summary, significant positive correlations were found among the proficiency measures for participants as a group. While correlations between objective and subjective proficiency measures were significant in both English and Arabic measures, the values obtained did not suggest complete colinearity of the two types of measures. These results are consistent with previous studies that found significant correlations but not complete consistency between objective and subjective measures of L2 proficiency (Delgado, Guerrero, Goggin, & Ellis, 1999; Jared & Kroll, 2001; Lemmon & Goggin, 1989). Jared and Kroll (2001) found that the self-reported proficiency in their study was consistent with on-line picture-naming scores for their more- and less-proficient groups in one experiment but not in another. In addition, Delgado et al. found that self-assessment can be influenced by attitude and feedback variables. These issues were not directly assessed in the present study but the results of the self-assessment are interpreted with caution.

Considering the type of proficiency that was required for the experimental task, the objective measures of RT-Difference and Error-Rate in the simple LDT were taken as the more meaningful measures for this study. It should be noted, however, that in English, the Error-Rate measure showed a markedly reduced range, which may have contributed to its relatively low correlation with other measures.

Chapter 3: Results

The analyses used in the study and their results are presented in this section. A description of the data preparation is followed by the results from the cross-language priming in the experimental lexical decision task (LDT) and their relations to participants' proficiency in their two non-native languages. Finally, results from the within-language conditions are reported, followed by an overall summary of the results.

To assess the relations between language proficiency and the priming results, three lines of analysis were conducted: correlational analyses between priming effects and non-native language proficiency for participants as a group; repeated-measures analyses of variance (ANOVAs), covaried for non-native language proficiency for participants as a group; and comparisons among proficiency-based sub-groups of participants. Results from each analysis are reported considering effects between L1 and each of the non-native languages and between the two non-native languages.

Recall that the 79 participants included in the analyses were proficient speakers of Hebrew, which was their first (L1) and most dominant language, but varied in degrees of proficiency in their two non-native languages: English and Arabic. Their individual scores on the various proficiency measures used in this study were first calculated and tabulated for each of the two non-native languages (see Methods chapter). Three measures of non-L1 proficiency were considered for the analyses: RT-

Difference (i.e., the difference in milliseconds between mean response times in L1 and the non-native language in the simple LDT), Error-Rate (i.e., the error rate in the non-native language in the simple LDT), and Mean-Self-Rate (i.e., the mean of the self-rated linguistic skills in the non-native language).

For each participant, response times (RT) (in milliseconds) for all correct responses to the real words in each condition of the experimental LDT were tabulated and the means of RT and of number of errors were calculated. Thus, RT and error rates were obtained in each of the nine related conditions and nine unrelated conditions, i.e., the three within-language Hebrew-Hebrew, English-English, and Arabic-Arabic, related (i.e., identity) and the three within-language unrelated conditions; the six cross-language Hebrew-English, English-Hebrew, Hebrew-Arabic, Arabic-Hebrew, English-Arabic, and Arabic-English related (i.e., translation-equivalent) and the six cross-language unrelated conditions. Outliers of RT greater than two standard deviations above any participant's overall mean were excluded individually, as necessary, for each participant. Speed and accuracy of responses to the non-word items were also collected. Overall, RT to non-words was found to be significantly longer than RT to real words, as has been consistently reported in LDT studies. Moreover, the RT to the non-words did not differ in the different priming conditions (all *p*s $> .05$). The non-words served predominantly as fillers for the LDT and were not included in further analyses.

The items from the post-test simple LDT corresponding to each item in the experimental conditions were then tabulated for each participant and participants' RT and error rates were calculated. Non-L1 words that were not recognized by a given participant in the simple LDT (i.e., real words that were judged as non-words) were excluded from that participant's means in the experimental LDT, thus ensuring that for each participant, only items for which the participant knew both the prime and the target were included in that participant's means. Mean items excluded as "unknown" in each condition (not including the Hebrew-to-Hebrew conditions, where there were none) ranged from 2% to 20% with a mean of 7% in the related conditions, and from 2% to 27% with a mean of 7% in the unrelated conditions. The means of RT in the experimental LDT after excluding unknown items based on the simple LDT are referred to as "known items" RT.

Standard deviations (SD) were calculated for RT of each participant in each condition, and items that yielded RT of two SD above and below the condition mean were noted as outliers for that participant. Mean outliers ranged from 2% to 5% with a mean of 4% in the related conditions, and from 2% to 6% with a mean of 4% in the unrelated conditions. The means of RT were then re-calculated with these outlier items excluded. The means without the outliers in each condition are referred to as "w/o outliers" RT.

Mean RT of "known items" and "w/o outliers" and mean error rates in each related and unrelated condition were then calculated across participants (see Tables 9-12). RT priming effects (i.e., the difference between RT in the unrelated and related conditions) and error-rate priming effects (i.e., the difference between error-rates in the unrelated and related conditions) in each of the nine within- and cross-language condition pairs were obtained. When the mean RT in a related condition was smaller than the mean RT in the corresponding unrelated condition, the term *facilitation* *priming effect* or simply *priming effect* is used; when the mean RT in the related condition was larger than the mean RT in the corresponding unrelated condition, the effect is referred to as *inhibition priming* (for further discussion of this issue see Introduction and Discussion chapters).

Table 9

Mean LDT RT to Real-Word Targets (in ms) and Error Rate (and SD) in the Related and Unrelated Cross-Language Conditions

Condition	"Known Items" Related	"Known Items" Unrelated	"W/o Outliers" Related	"W/o Outliers" Unrelated	Number of Errors Related	Number of Errors Unrelated
Hebrew-to-English	833 (183)	913 (224)	799 (182)	859 (221)	.5 (.8)	1.3 (1.2)
Hebrew-to-Arabic	1269 (353)	1251 (369)	1231 (356)	1209 (377)	2.6 (2.2)	2.3 (1.9)
English-to-Hebrew	671 (102)	678 (115)	653 (102)	661 (110)	.1 (.4)	.2 (.5)
English-to-Arabic	1279 (394)	1235 (350)	1241 (397)	1202 (356)	2.3 (2.2)	2.4 (2.2)
Arabic-to-Hebrew	675 (98)	666 (106)	660 (96)	652 (105)	.2 (.4)	.1 (.2)
Arabic-to-English	835 (163)	836 (177)	798 (158)	797 (162)	.5 (.9)	.5 (.8)

Note: Hebrew-to-English refers to conditions in which Hebrew words primed English targets, English-to-Hebrew refers to conditions in which English words primed Hebrew targets, etc.

Table 10

Mean LDT RT to Real-Word Targets (in ms) and Error Rate (and SD) in the Hebrew-Target Within-Language and Cross-Language Conditions

Condition	"Known Items" Related	"Known Items" Unrelated	"W/o Outliers" Related	"W/o Outliers" Unrelated	Number of Errors Related	Number of Errors Unrelated
Hebrew-to-Hebrew	679 (97)	683 (110)	662 (100)	664 (108)	.2 (.6)	.1 (.4)
English-to-Hebrew	671 (102)	678 (115)	653 (102)	661 (110)	.1 (.4)	.2 (.5)
Arabic-to-Hebrew	675 (98)	666 (106)	660 (96)	652 (105)	.2 (.4)	.1 (.2)

Table 11

Mean LDT RT to Real-Word Targets (in ms) and Error Rate (and SD) in the English-Target Within-Language and Cross-Language Conditions

Condition	"Known Items" Related	"Known Items" Unrelated	"W/o Outliers" Related	"W/o Outliers" Unrelated	Number of Errors Related	Number of Errors Unrelated
English-to-English	938 (221)	878 (208)	884 (209)	837 (202)	1 (1)	1 (1)
Hebrew-to-English	832 (183)	913 (224)	799 (182)	859 (221)	.5 (.8)	1 (1)
Arabic-to-English	835 (163)	836 (177)	798 (158)	797 (162)	.5 (.9)	.5 (.8)

Note: The within-English results demonstrated longer RT in the related than in the unrelated conditions. This unexpected pattern of within-language inhibition effects is addressed in the Discussion Chapter.

Table 12

Mean LDT RT to Real-Word Targets (in ms) and Error Rate (and SD) in the Arabic-Target Within-Language and Cross-Language Conditions

Condition	"Known Items" Related	"Known Items" Unrelated	"W/o Outliers" Related	"W/o Outliers" Unrelated	Number of Errors Related	Number of Errors Unrelated
Arabic-to-Arabic	1318 (381)	1383 (398)	1288 (390)	1353 (404)	3 (2)	3 (3)
Hebrew-to-Arabic	1269 (353)	1251 (369)	1231 (356)	1209 (377)	3 (2)	2 (2)
English-to-Arabic	1279 (394)	1235 (350)	1241 (397)	1202 (356)	2 (2)	2 (2)

These overall results were subjected to a 3 (prime language: Hebrew, English, Arabic) by 3 (target language: Hebrew, English, Arabic) by 2 (condition: related, unrelated) repeated-measures ANOVA. ANOVAs were conducted separately for the "known items" RT data, the "w/o outliers" RT data, and the error-rate priming data. Extreme RT-priming values of more than three standard deviations above and below the group mean in each condition (1.30% of all responses) were not included in the analyses.

The analyses revealed a significant main effect of target language, for all three data sets: $F(2,66) = 196.50$ for "known items" RT, $F(2,63) = 167.67$ for "w/o outliers" RT, and $F(2,76) = 116.36$ for error rate, all $ps < .001$. There was also a significant main effect of prime language for the "known items" RT data: $F(2,66) = 4.33, p = .015$ and for the "w/o outliers" RT data: $F(2,63) = 7.36, p = .001$, but not for the error-rate data: $F(2,76) = 1.11, p > .1$. That is, overall there were differences in the priming effects found in the various prime-target language pairs.

While there was no main effect of condition: $F < 1$ in all data sets, the condition variable interacted with the prime and/or the target variables. Moreover, the 3-way interaction prime language by target language by condition was significant in all the analyses: $F(4,64) = 9.17$ for "known items" RT, $F(4,61) = 4.60$ for "w/o outliers" RT, and $F(4,74) = 6.35$ for the error-rate data, all $ps < .001$. The significant 3-way interactions suggest that the differences in priming effects between the related and unrelated conditions depended on the specific prime-target language pairs (see ANOVA Table, Appendix C).

When contrasting individual pairs of related and unrelated conditions, the only comparisons that reached statistical significance were the Hebrew-to-English and the English-to-English related versus unrelated conditions (both $ps < .01$).

Cross-Language Priming Effects

Correlations between Cross-Language Priming Effects and Non-L1 Proficiency

Mean RT- and error-rate-priming effects across participants as a group were correlated with their performance on the various proficiency measures. Effects in the Hebrew-to-English and English-to-Hebrew priming conditions were correlated with English proficiency and effects in the Hebrew-to-Arabic and Arabic-to-Hebrew priming conditions were correlated with Arabic proficiency. Effects between the two non-native languages were correlated with proficiency in both languages: English-to-Arabic and Arabic-to-English effects were correlated with both English proficiency and Arabic proficiency. Pearson product-moment correlations (2-tailed) were performed.

Effects between L1 and a Non-Native Language

Hebrew-to-English effects (H-E)

As can be seen in Table 13 and Figures 14-16, there was a significant negative correlation between RT priming effects, as well as error-rate priming effects, and English proficiency as measured by English-RT-Difference ($r = -.237$, $p = .038$ for H-E "known items" RT; $r = -.276$, $p = .016$ for H-E "w/o outliers" RT; and $r = -.244$, $p = .031$ for H-E error-rate priming). The correlation was in the direction of weaker priming effects for participants with higher L2 proficiency. The correlation with English proficiency as measured by English-Error-Rate was weaker and did not reach significance ($r = -.211$, $p = .063$ for H-E "known items" RT; $r = -.159$, $p = .163$ for H-E error-rate priming). Similarly, the correlation with English proficiency as measured by the Mean-Self-Rate measure did not reach significance (e.g., $r = -.178$, $p = .12$ for H-E "known items" RT).

Table 13

Correlation Coefficients between Hebrew-to-English Priming and English Proficiency

Priming/Proficiency	English-RT-Difference	English-Error-Rate	English-Mean-Self-Rate
"Known Items" RT Priming	-.237 *	-.211 (p=.063)	-.178
"W/o Outliers" RT Priming	-.276 *	-.119	-.155
Error-Rate Priming	-.244 *	-.159	-.070

* Correlation significant at the .05 level

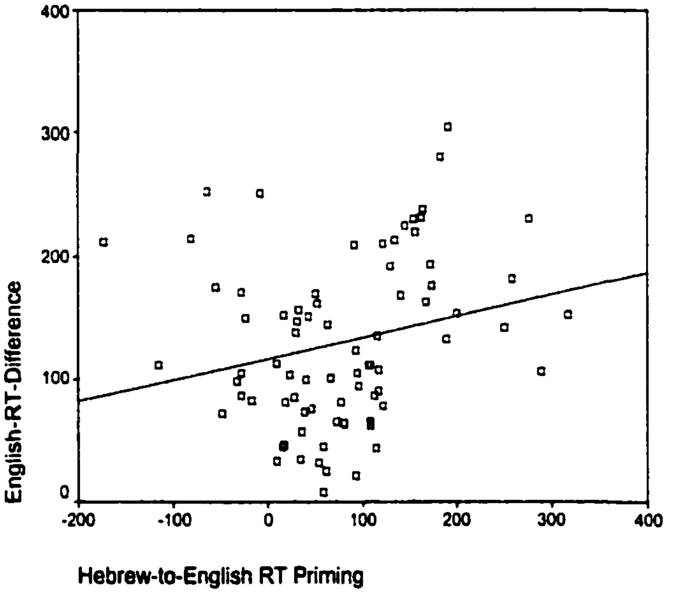

Figure 14. Correlation between Hebrew-to-English RT Priming and English Proficiency

It should be noted that a few participants demonstrated inhibition rather than facilitation effects from Hebrew to English at low levels of English proficiency. This finding led to a curvilinear, rather than linear, fit of the relation between these two variables (see Figure 15).

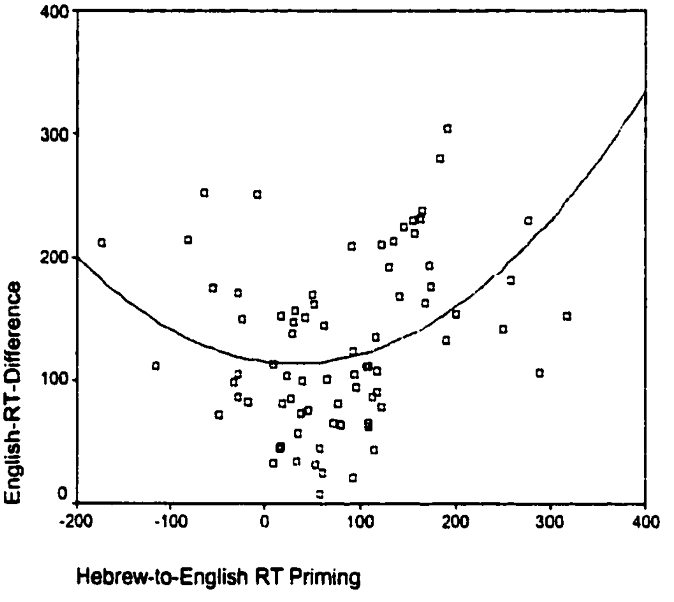

Figure 15. Correlation between Hebrew-to-English RT Priming and English Proficiency (curvilinear line fit)

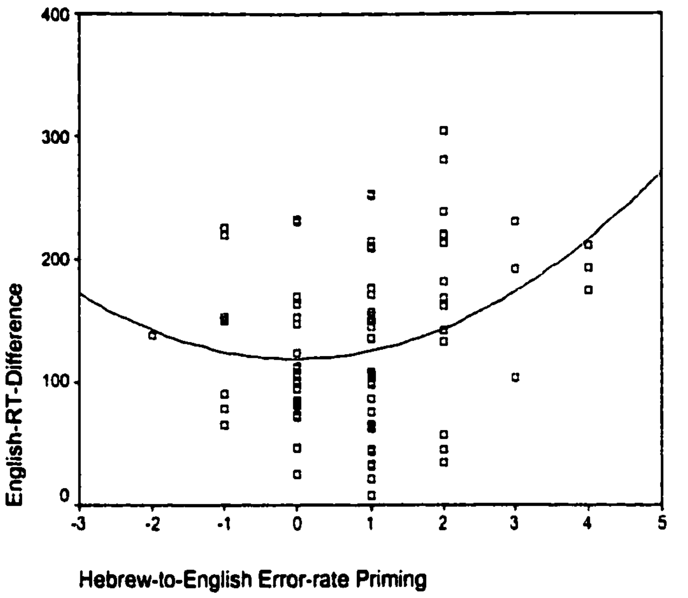

Figure 16. Correlation between Hebrew-to-English Error-rate Priming and English Proficiency

English-to-Hebrew effects (E-H)

As can be seen in Table 14 and Figure 17, there was a significant negative correlation between E-H priming effects and English proficiency (r = -.285, p = .012 for English-RT-Difference and H-E "known items" RT, r = -.272, p = .017 for English-RT-Difference and H-E "w/o outliers" RT). The significant correlation was in the direction of smaller priming effects from English to Hebrew with increased English proficiency.

Table 14

Correlation Coefficients between English-to-Hebrew Priming and English Proficiency

Priming/Proficiency	English-RT-Difference	English-Error-Rate	English-Mean-Self-Rate
"Known Items" RT Priming	-.285 *	.023	.123
"W/o Outliers" RT Priming	-.272 *	-.059	.140

* Correlation significant at the .05 level

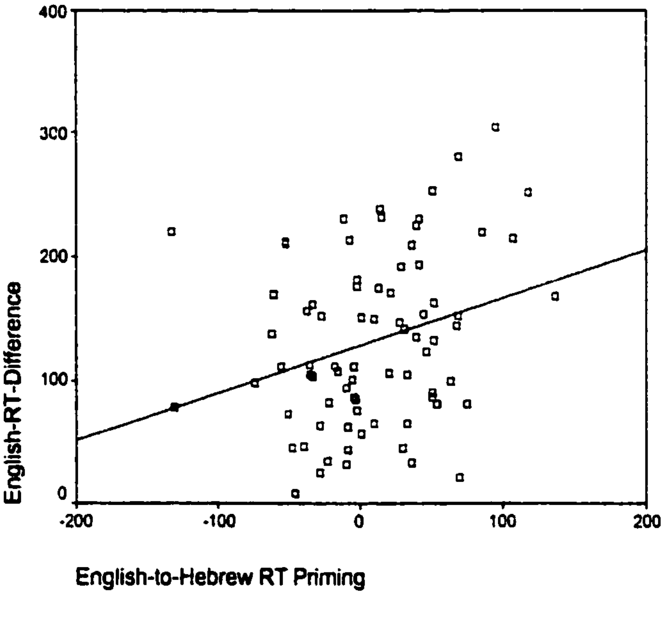

Figure 17. Correlation between English-to-Hebrew RT Priming and English Proficiency

Hebrew-to-Arabic effects (H-A)

As can be seen in Table 15 and Figures 18 and 19, there was no correlation between H-A RT or error-rate priming effects and Arabic proficiency.

Table 15

Correlation Coefficients between Hebrew-to-Arabic Priming and Arabic Proficiency

Priming/Proficiency	Arabic-RT-Difference	Arabic-Error-Rate	Arabic-Mean Self-Rate
"Known Items" RT Priming	-.078	.005	-.030
"W/o Outliers" RT Priming	- .087	.036	.036
Error-Rate Priming	.043	.070	.169

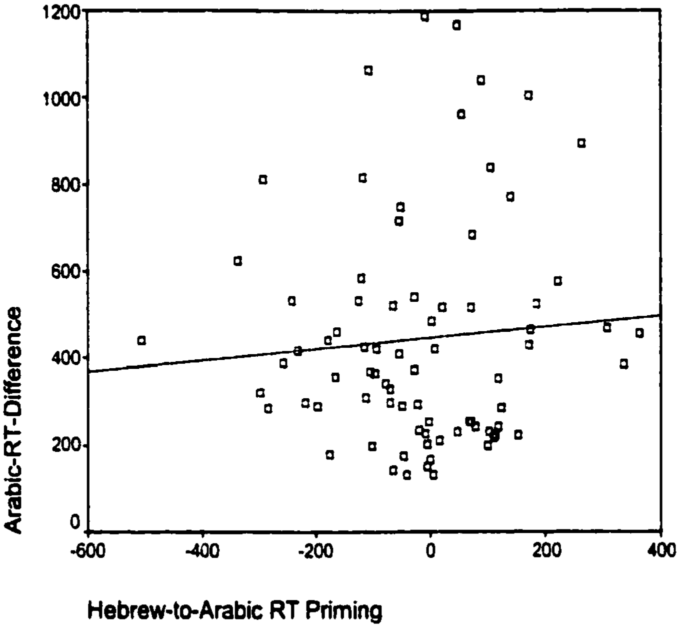

Figure 18. Correlation between Hebrew-to-Arabic RT Priming and Arabic Proficiency

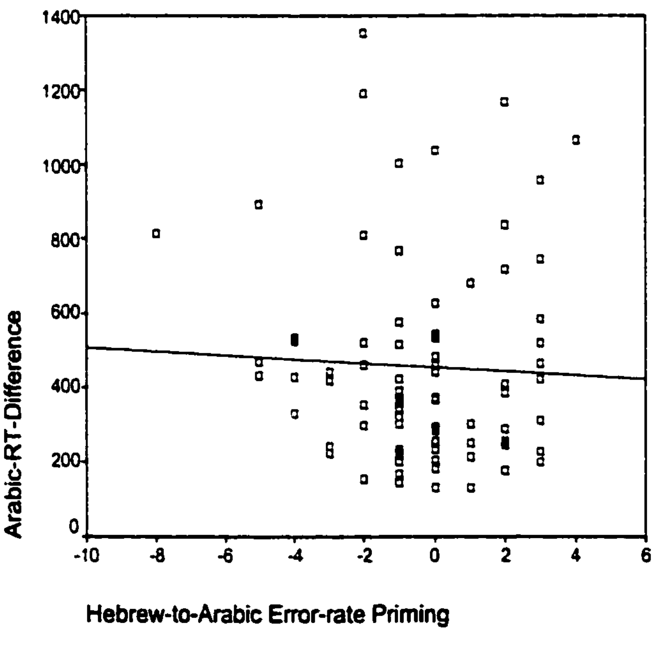

Figure 19. Correlation between Hebrew-to-Arabic Error-Rate Priming and Arabic Proficiency

Arabic-to-Hebrew effects (A-H)

There was no correlation between A-H priming and Arabic proficiency (e.g., $r = -.011$ for Arabic-RT-Difference and A-H "known items" RT; see Table 16).

Table 16

Correlation Coefficients between Arabic-to-Hebrew Priming and Arabic Proficiency

Priming/Proficiency	Arabic-RT-Difference	Arabic-Error-Rate	Arabic-Mean-Self-Rate
"Known Items" RT Priming	-.011	.019	.038
"W/o Outliers" RT Priming	-.062	-.039	-.002

Effects between the Two Non-Native Languages

English-to-Arabic effects (E-A)

Priming effects from English primes to Arabic targets were correlated with both Arabic and English proficiency measures (see Tables 17 and 18). The analyses revealed no significant correlation with English proficiency on any of the measures (e.g., $r = -.085$, $p = .463$ for English-RT-Difference and E-A RT priming). The correlation with Arabic proficiency, on the other hand, approached or reached significance on several measures: $r = .201$, $p = .080$ for Arabic-RT-Difference and E-A "known items" RT priming; $r = .275, p = .014$ for Arabic-Mean-Self-Rate and E-A error-rate priming. The direction of the correlation with the Arabic proficiency measures demonstrated larger priming effects with increased Arabic proficiency.

Table 17

Correlation Coefficients between English-to-Arabic Priming and English Proficiency

Priming/Proficiency	English-RT-Difference	English-Error-Rate	English-Mean-Self-Rate
"Known Items" RT Priming	-.085	-.043	-.025
"W/o Outliers" RT Priming	-.147	-.060	-.039
Error-Rate Priming	-.003	.126	.138

Table 18

Correlation Coefficients between English-to-Arabic Priming and Arabic Proficiency

Priming/Proficiency	Arabic-RT-Difference	Arabic-Error-Rate	Arabic-Mean-Self-Rate
"Known Items" RT Priming	.201 (p=.080)	.138	.131
"W/o Outliers" RT Priming	.164	.124	.075
Error-Rate Priming	.011	.157	.275 *

* Correlation significant at the .05 level

When the proficiency of each non-native language was correlated independently, i.e., correlating E-A priming and English proficiency while partialling for Arabic proficiency and correlating E-A priming and Arabic proficiency while partialling for English proficiency, a stronger pattern of results emerged (see Tables 19 and 20). Namely, E-A priming effects correlated with both English and Arabic proficiencies, with overall stronger correlations between the priming effects and the Arabic-proficiency measures. Specifically, when partialling for Arabic-RT-Difference, a negative correlation with English proficiency was obtained: $r = -.241$, $p = .037$ for English-RT-Difference and E-A "w/o outliers" RT priming; $r = -.182$, $p = .12$ for English-RT-Difference and E-A "known items" RT priming. Moreover, when partialling for English-RT-Difference, a significant positive correlation between E-A priming effects and Arabic proficiency was obtained: $r = .253$, $p = .028$ for Arabic-RT-Difference and E-A "w/o outliers" RT priming; $r = .243$, $p = .035$ for Arabic-RT-Difference and E-A "known items" RT priming. No correlation was obtained between E-A error-rate priming and either English or Arabic proficiency measures.

Crucially, the relation with English proficiency was in the direction of smaller effects with increased English proficiency; in contrast, the pattern that was seen for the unpartialled correlation with the Arabic proficiency remained (in the partialled correlation) in the direction of larger priming effects with increased Arabic proficiency.

Thus, for E-A RT priming, larger effects were found for participants with lower proficiency levels in English and higher proficiency levels in Arabic. This pattern was most evident when the correlation with the E-A priming effects was assessed with each non-L1 proficiency while partialling for the other non-L1 proficiency. Given the overall higher levels of English proficiency as compared to Arabic proficiency among the participants (see Method Chapter), these results reflect larger priming effects when English and Arabic proficiency levels were less different from each other. These findings can be further accounted for by the role of the *relative* proficiency of both non-native languages within participants and will be discussed below.

Table 19

Correlation Coefficients between English-to-Arabic Priming and English Proficiency, Partialling for Arabic Proficiency

Priming/Proficiency	English-RT-Difference	English-Error-Rate	English-Mean-Self-Rate
"Known Items" RT Priming	-.182	-.064	-.017
"W/o Outliers" RT Priming	-.241 *	-.071	-.016
Error-Rate Priming	.022	.016	.059

* Correlation significant at the .05 level

Table 20

Correlation Coefficients between English-to-Arabic Priming and Arabic Proficiency, Partialling for English Proficiency

Priming/Proficiency	Arabic-RT-Difference	Arabic-Error-Rate	Arabic-Mean-Self-Rate
"Known Items" RT Priming	.243 *	.152	.102
"W/o Outliers" RT Priming	.253 *	.167	.063
Error-Rate Priming	-.097	.099	.219 (p=.059)

* Correlation significant at the .05 level

Arabic-to-English effects (A-E)

As can be seen in Tables 21-24, no significant correlations were obtained between priming effects from Arabic primes to English targets and English nor Arabic proficiency measures. This pattern of results was not modified when partialling for English or Arabic proficiency. While there was a trend toward a correlation between A-E error-rate priming and Arabic proficiency ($r = .203$, $p = .072$), in the direction of increased priming with increased Arabic (the prime language) proficiency, this correlation weakened when partialling for English proficiency ($r = .141$).

Table 21

Correlation Coefficients between Arabic-to-English Priming and English Proficiency

Priming/Proficiency	English-RT-Difference	English-Error-Rate	English-Mean-Self-Rate
"Known Items" RT Priming	-.168	-.112	-.036
"W/o Outliers" RT Priming	-.124	-.131	.081
Error-Rate Priming	.162	.202	-.122

Table 22

Correlation Coefficients between Arabic-to-English Priming and Arabic Proficiency

Priming/Proficiency	Arabic-RT-Difference	Arabic-Error-Rate	Arabic-Mean-Self-Rate
"Known Items" RT Priming	-.073	-.159	-.001
"W/o Outliers" RT Priming	-.057	-.139	.042
Error-Rate Priming	.203	.125	-.150

Table 23

Correlation Coefficients between Arabic-to-English Priming and English Proficiency, Partialling for Arabic Proficiency

Priming/Proficiency	English-RT-Difference	English-Error-Rate	English-Mean-Self-Rate
"Known Items" RT Priming	-.108	.084	.020
"W/o Outliers" RT Priming	-.071	.062	-.026
Error-Rate Priming	.067	-.026	-.196

Table 24

Correlation Coefficients between Arabic-to-English Priming and Arabic Proficiency, Partialling for English Proficiency

Priming/Proficiency	Arabic-RT-Difference	Arabic-Error-Rate	Arabic-Mean-Self-Rate
"Known Items" RT Priming	-.044	-.095	-.048
"W/o Outliers" RT Priming	-.030	-.078	.011
Error-Rate Priming	.141	.033	-.175

To summarize, a significant negative correlation was found between Hebrew-to-English priming effects and English proficiency and between English-to-Hebrew priming effects and English proficiency, with smaller effects (in both priming directions) with increased English proficiency. In contrast, correlation was not found between Hebrew-to-Arabic priming effects and Arabic proficiency nor between Arabic-to-Hebrew priming effects and Arabic proficiency.

As for the relations between the two non-native languages, negative correlations were obtained between English-to-Arabic priming and English proficiency, while positive correlations were found between English-to-Arabic priming effects and Arabic proficiency. That is, larger effects were seen for lower levels of English (the prime language) proficiency and higher levels of Arabic (the target language) proficiency. Thus, priming between the two non-native languages appeared to be affected by the relative proficiency levels of the two languages. In contrast to the findings in the English-to-Arabic direction, no significant correlations were obtained in the Arabic-to-English priming direction. This may be accounted for by participants' overall lower proficiency levels in Arabic (the prime language) as compared to English (the target language).

The correlation results between L1 and non-native languages demonstrated that while at very low levels of non-L1 proficiency no priming effects were observed from L1 primes to Arabic targets, priming effects were found between L1 and English (the stronger non-L1). Moreover, priming effects decreased again at the highest levels of non-L1 proficiency. Similarly, the correlation results between the two non-native languages demonstrated that priming effects decreased when proficiency was high in the prime language and low in the target language. Indeed, inhibition rather than facilitation effects were evident between the two non-native languages when the prime language was of higher proficiency than the target language; these patterns of priming effects will be further discussed below.

Repeated-Measures Analyses, Covarying for Non-L1 Proficiencies

Overall Effects

Based on the complete design of the experiment, an overall 3 (prime language) by 3 (target language) by 2 (condition) repeated-measures ANCOVA was administered with three levels for two of the within-participants variables: prime language (Hebrew, English, Arabic) and target Language (Hebrew, English, Arabic), and two levels for the third within-participants variable: condition (related, unrelated), covarying for English and Arabic proficiencies. The "known items" RT analysis revealed a significant main effect of target language: $F(2,64) = 6.73$, $p = .002$, but not of prime language: $F(2.64) < 1$, nor an effect of condition: $F(1,65) < 1$. There was a significant 2-way interaction between target language and both English and Arabic proficiencies: $F(2,64) = 23.73$ for target language by English proficiency, and $F(2,64) = 239.03$ for target language by Arabic proficiency, both ps $< .001$. This can be taken as evidence for the effect of the target-language proficiency on the priming effects. While the 2-way interactions between prime language and condition and target language and condition were not significant, nor was the 3-way interaction among prime language, target language and condition, the 4-way interaction of prime language by target language by condition by English (but not Arabic) proficiency was significant: $F(4,62) = 3.23, p = .013$. The 3-way interaction among the three main variables can be interpreted as unequal differences between the related and unrelated conditions in the nine different prime-target language pairs. The 4-way interaction suggests that the covariates, at least the English-proficiency variables, further modified the relations among the main variables (see ANOVA Table, Appendix D). From the regression equation of the ANCOVA it appears that, as expected, English and Arabic proficiencies affected some conditions but not others (see Tables 25 and 26). For example, the English-proficiency covariate was significant in the Hebrew-English conditions ($\beta = 1.5$ and 1.65 for the related and unrelated respectively, both $ps < .001$) and the English-Hebrew conditions ($\beta = .40, p < .05$ and $\beta = .61, p < .01$) but not in the Hebrew and Arabic conditions. English proficiency significantly contributed in the Arabic-to-English conditions and the within English conditions (see Table 25).

Similarly, Arabic proficiency played a significant role when Arabic was the target language in the Hebrew-to-Arabic conditions and the English-to-Arabic but not for the Arabic-to-Hebrew nor the Arabic-to-English conditions. In addition, Arabic proficiency affected the results of the within-Arabic conditions (see Table 26).

Table 25

β Values and Significance Levels for the English-Proficiency Covariate

Condition	β	t	p
Hebrew-English Related	1.5	6.5	< .01
Hebrew-English Unrelated	1.6	5.6	< .01
English-Hebrew Related	.40	2.0	< .05
English-Hebrew Unrelated	.61	2.9	< .01
English-Arabic Related	.31	.76	> .1
English-Arabic Unrelated	.79	2.4	< .05
Arabic-English Related	1.6	6.5	< .01
Arabic-English Unrelated	1.8	6.5	< .01
English-English Related	2.1	6.9	< .01
English-English Unrelated	1.5	5.4	< .01

For the "w/o outliers" data, a similar pattern of results emerged, with a significant main effect of target language $F(2,61) = 4.51$, $p = .013$, but not of prime language $F(2,61) < 1$. Target language interacted with both English and Arabic proficiencies: $F(2,61) = 17.50$, $F(1,61) = 235.45$, respectively, both $ps < .001$, and there were no other significant interactions.

Table 26

β Values and Significance Levels for the Arabic-Proficiency Covariate

Condition	β	t	p
Hebrew-Arabic Related	1.1	11.8	< .01
Hebrew-Arabic Unrelated	1.1	11.4	< .01
Arabic-Hebrew Related	< 1	.05	> .10
Arabic-Hebrew Unrelated	< 1	.04	> .10
English-Arabic Related	1.2	10.4	< .01
English-Arabic Unrelated	1.0	10.7	< .01
Arabic-English Related	< 1	-.99	> .10
Arabic-English Unrelated	< 1	.32	> .10
Arabic-Arabic Related	1.2	9.3	< .01
Arabic-Arabic Unrelated	1.2	9.9	< .01

In the error-rate data, while none of the main effects was significant, the 2-way target language by condition interaction was significant and the target language by prime language interaction approached significance: $F((2,73) = 3.85$, $p = .023$ for target language by condition, and $F(4,71) = 3.10$, $p = .016$ for prime language by target language.

Effects between L1 and Non-Native Languages

Mean RT and error rates in the Hebrew-and-English and Hebrew-and-Arabic cross-language conditions were subjected to a repeated-measures ANCOVA with two within-participant variables: priming direction (from L1 to non-L1, from non-L1 to L1) and condition (related, unrelated), covarying for non-L1 proficiency. (The two levels of the priming-direction variable combined effects between Hebrew and English and Hebrew and Arabic.)

The analysis for "known items" RT revealed a significant main effect of priming direction $F(1,146) = 5.18, p = .024$, and an interaction between priming direction and Arabic proficiency: $F(1,146) = 35.69, p < .001$. There was no main effect of condition nor a significant interaction between priming direction and condition. That is, there was a difference between the priming effects obtained in the two priming directions (from L1 and to L1) but no overall significant differences between the related and unrelated conditions. Similar results obtained for the "w/o outliers" RT data, although the main effect for priming direction did not reach significance. Likewise, the effect of priming direction was not significant in the error-rate data, but the interaction priming direction by Arabic proficiency was significant: $F(1,151) = 26.98, p < .001$, suggesting that the difference between the two priming directions for Arabic was modulated based on proficiency in Arabic (see Appendix E).

It should be noted that the interaction between priming direction and condition was significant when a repeated-measures ANOVA was run on this data set without covarying for proficiency: $F(1,146) = 8.36, p = .004$. That is, irrespective of proficiency, the differences between the related and unrelated conditions were affected by the priming direction (larger priming effects were obtained from L1 to non-native languages than in the opposite direction).

To evaluate whether these latter results were affected by collapsing the two components of the priming-direction variable (from L1 to English, from L1 to Arabic; from English to L1, from Arabic to L1), the analysis was conducted with the direction variable (from L1, to L1) divided into its two components (i.e., an analysis for the Hebrew and English data and an analysis for the Hebrew and Arabic data). The same pattern of results emerged, that is, for "known items" RT, a significant main effect of priming direction: $F(1,67) = 3.37, p = .023$, significant interactions between priming direction and non-L1 proficiencies ($p < .001$ for both English and Arabic proficiency), and no significant main effect of condition nor an interaction direction by condition: $F(1,69) < 1$.

For "w/o outliers" RT, the main effect of direction did not reach significance: $F(1,66) = 2.146, p = .103$, but the interactions between direction and non-L1 proficiencies were significant: $F(1,66) = 12.04$ for English and $F(1,66) = 80.55$ for Arabic, both $ps < .001$; the error-rate data yielded similar results.

Effects between the Two Non-Native Languages

Mean RT and error rates in the English and Arabic cross-language priming conditions were subjected to a repeated-measures ANCOVA with two within-participant variables: priming direction (from English to Arabic, from Arabic to English) and condition (related, unrelated), covarying for English and Arabic proficiency.

The analysis revealed a significant main effect of priming direction: $F(1,73) = 4.12, p < .05$ for "known items" RT, although not for "w/o outliers" RT: $F(1,73) = 1.91, p = .171$ nor for error rate: $F(1,75) < 1$, suggesting that when non-L1 proficiency was considered, the effects in the two priming directions differed, at least in the "known items" data. There was no significant main effect of condition nor a significant 2-way interaction between priming direction and condition. The interaction between condition and Non-L1-proficiency approached significance for both English and Arabic for "known items" RT: $F(1,73) = 3.6, p = .062$ for condition by English proficiency, $F(1,73) = 3.132, p = .081$ for condition by Arabic proficiency, and similarly for "w/o outliers" RT: $F(1,73) = 4.75, p = .033$ for condition by English and $F(1,73) = 3.45, p = .067$ for condition by Arabic; these interactions were not significant for the error-rate data with $F(1,75) < 1$. The 2-way interactions between condition and non-L1 proficiency suggested that differences between the related and unrelated conditions were modulated based on participants' proficiency in their non-native languages. The only other interaction that reached significance was the 3-way interaction priming direction by condition by Arabic proficiency (for both "known items" and "w/o outliers" RT data, but not the error-rate data), providing evidence for the influence of Arabic proficiency on the priming effects between English and Arabic (see ANOVA Table, Appendix F).

To summarize the ANCOVA results, significant effects were consistently found for priming direction. That is, overall and considering non-native language proficiency, there were differences in the priming effects as a function of the prime-target language pair. This is consistent with the overall differences between priming effects obtained in the different cross-language conditions. Moreover, the effects of priming direction interacted with the proficiency of the non-native languages, suggesting that the size of cross-language priming effects for a given language pair varied based on the proficiency of languages in question. On the other hand, there were no significant effects of condition, consistent with the finding of no overall differences between the related and unrelated conditions (i.e., no overall priming effects) for participants as a group.

Comparisons among Sub-Groups of Participants

In addition to the across-participants correlational and ANCOVA analyses, priming effects in the various cross-language conditions were assessed by examining the specific patterns obtained in different levels of non-L1 proficiency. Specifically, participants were divided into sub-groups on the basis of their proficiency in each of their non-native languages as well as their relative proficiencies in both non-native languages.

The Relations between L1 and Non-Native Languages

To specifically assess the relations between L1 and non-native languages as they are determined by participants' proficiency in the two non-native languages, participants were divided into groups by proficiency. To evaluate the relations between Hebrew and English, participants were grouped based on their English proficiency; to evaluate the relations between Hebrew and Arabic, participants were re-grouped based on their Arabic proficiency. Thus, two independent categorizations of three sub-groups each were formed: 1. English proficiency: a) participants with high English skills; b) participants with moderate English skills; c) participants with low English skills; and 2. Arabic proficiency: a) participants with high Arabic skills; b) participants with moderate Arabic skills; c) participants with low Arabic skills.

Participants were assigned to each of the three proficiency groups (in each of the two non-native languages) using the following procedure. The scores of the two objective proficiency measures: RT-difference (as well as RT-Percent-Difference) and Error-Rate were listed in ascending order. The top 20, the bottom 20, and the middle 20 of the score continuum were identified. Fifteen participants whose scores fell in the top 20 on both measures were selected for the high-skill group, 15 whose scores fell in the bottom 20 on both measures were selected for the low-skill group, and 15 whose scores fell in the middle range were selected for the moderate-skill group. Participants who did not meet these criteria (i.e., whose scores fell outside the selected ranges) were excluded from the current analysis. The same procedure was used for English skills and Arabic skills, independently. As noted in the Proficiency Measures Results above, the English scores for the participants as a group were higher than the Arabic scores. Consequently, the scores selected for the English-skill groups were overall higher than those selected for the Arabic-skill groups.

Effects between Hebrew and English

As can be seen in Tables 27 and 28, mean RT and error rates were obtained for the high-, moderate- and low-English groups, in the Hebrew-to-English and English-to-Hebrew priming conditions. An overall 2 (RT-priming direction: Hebrew-to-English, English-to-Hebrew) by 2 (condition: related, unrelated) repeated-measures ANOVA revealed a significant main effect of priming direction: $F(1,40) = 144.128$, $p < .001$ and of condition: $F(1,40) = 27.76$, $p < .001$, as well as a significant 2-way interaction priming direction by condition: $F(1,40) = 23.26$, $p < .001$. The between-participants variable (group: high, moderate, low) yielded a significant effect: $F(2,40) = 11.49$, $p < .001$. The differences among the groups were further explored in each of the two priming conditions.

Hebrew-to-English Effects

Larger Hebrew-to-English RT priming effects were seen for the group of low English proficiency than for the group of moderate English, which were in turn larger than the effects found for the group of highest English proficiency. Post-hoc comparisons (Tukey HSD) revealed a significant difference between the high-proficiency group and the low-proficiency group ($p < .001$) as well as between the high and the moderate English-proficiency groups ($p = .001$), but not between the moderate- and low-proficiency groups. These findings are consistent with the significant negative correlation between English proficiency and Hebrew-to-English priming effects reported above for participants as a group.

Table 27

Hebrew-to-English Priming: RT (in ms) and Error-Rate (and SD)

Group/ Condition	"Known Items" Priming	"W/o Outliers" Priming	Error-Rate Priming
High English	51 (42)	37 (41)	.7 (.8)
Mod. English	86 (102)	51 (89)	.5 (.9)
Low English	108 (121)	96 (114)	1 (1)

English-to-Hebrew Effects

Larger English-to-Hebrew RT priming effects were observed for the moderate-proficiency English group than the high-proficiency English group, but the difference should be viewed with caution due to the great inter-group variability and the small differences among the groups. Post-hoc comparisons confirmed that the differences among the groups were not statistically significant.

Table 28

English-to-Hebrew Priming: RT (in ms) and Error-Rate (and SD)

Group/ Condition	"Known Items" Priming	"W/o Outliers" Priming
High English	-7 (38)	-10 (39)
Mod. English	18 (33)	21 (40)
Low English	12 (68)	11 (63)

Effects between Hebrew and Arabic

As can be seen in Tables 29 and 30, mean RT and error rates were obtained for the high-, moderate-, and low-Arabic proficiency groups in the Hebrew-to-Arabic and Arabic-to-Hebrew priming conditions. A 2 (RT-priming direction: Hebrew-to-Arabic, Arabic-to-Hebrew) by 2 (condition: related, unrelated) repeated-measures ANOVA yielded a significant main effect of priming direction: $F(1,36) = 236.09$, $p < .001$, but not of condition, nor for the interaction priming direction by condition: $F(1,36) < 1$ in both cases. The between-participants variable (group: high, moderate, low) yielded a significant effect: $F(2,36) = 22.41$, $p < .001$. The differences among the groups in the two priming directions were then assessed.

Hebrew-to-Arabic Effects

As can be seen in Table 29, the groups with lower Arabic skills showed Hebrew-to-Arabic inhibition priming effects in contrast to the group of high Arabic. There was also greater within-group variability among the low-proficiency participants. Post-hoc comparisons (Tukey HSD) revealed a significant difference between the "w/o outliers" RT priming for the high-Arabic and the low-Arabic proficiency groups ($p < .001$) and for the moderate-Arabic and low-Arabic proficiency groups ($p < .001$).

Table 29

Hebrew-to-Arabic Priming: RT (in ms) and Error-Rate (and SD)

Group/ Condition	"Known Items" Priming	"W/o Outliers" Priming	Error-Rate Priming
High Arabic	6 (91)	14 (96)	-.1 (2)
Mod. Arabic	-20 (165)	-38 (179)	-.1 (3)
Low Arabic	-28 (185)	-41 (186)	-.1 (3)

Arabic-to-Hebrew Effects

No clear difference could be observed for the Arabic-to-Hebrew priming effects among the three proficiency groups.

Table 30

Arabic-to-Hebrew Priming: RT (in ms) and Error-Rate (and SD)

Group/ Condition	"Known Items" Priming	"W/o Outliers" Priming
High Arabic	2 (48)	2 (48)
Mod. Arabic	-7 (47)	-16 (47)
Low Arabic	4 (47)	15 (62)

To summarize, consistent with the results from the correlational analyses, differences among the three English-proficiency groups were found when priming effects between Hebrew and English were compared, with smaller effects for more proficient participants. When effects between Hebrew and Arabic were compared among the three Arabic-proficiency groups, a pattern of inhibition effects was found for participants with lower Arabic proficiency in the Hebrew-to-Arabic condition. While the overall correlation between Hebrew-to-Arabic priming and Arabic proficiency was not found for participants as a group, the pattern of inhibition at low non-L1 proficiency levels is consistent with the findings between the non-native languages and will be discussed below.

Effects between the Two Non-Native Languages

To assess the relations between the two non-native languages, four sub-groups of participants were defined based on participants' proficiency levels in both English and Arabic, using relative cut-off values for the two languages. In a similar procedure used for the six sub-groups of English and Arabic proficiency described above, participants' scores were divided into the top 20, bottom 20, and middle 20 scores. Only participants whose scores fell within the selected ranges (for both RT-Differences and Error-Rate proficiency measures) in both languages were assigned to one of four groups, as follows. Six participants were identified as high-English/high-Arabic, 10 participants were identified as low-English/low-Arabic, four participants as high-English/low-Arabic, and three participants as low-English/high-Arabic.[11]

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[11] When the criteria for inclusion were relaxed to include even participants whose score in only one of the two measures fell in the designated range, the number of participants in each of the four groups was larger. Specifically, 15 participants were identified as high-English/high-Arabic, 13 participants were identified as low-English/low-Arabic, nine participants were categorized as high-English/low-Arabic, and nine participants were identified as low-English/high-Arabic. The mean RT and error-rate priming effects of these groups in the English-to-Arabic and Arabic-to-English conditions are presented in Tables 33 and 34, respectively, in Appendix G. The pattern of results obtained was similar, though weaker.

The mean RT and error-rate priming effects of the groups in the English-to-Arabic and Arabic-to-English priming conditions are presented in Tables 31 and 32, respectively.

Table 31

English-to-Arabic Priming: RT (in ms) and Error-Rate (and SD) for the Four Participant Sub-Groups

Group/Condition	"Known Items" Priming	"W/o Outliers" Priming	Error-Rate Priming
High E/High A (n=6)	-24 (105)	-27 (115)	-.3 (.5)
Low E/Low A (n=10)	30 (230)	59 (221)	-.7 (3)
High E/Low A (n=4)	-148 (125)	-169 (104)	1 (1)
Low E/High A (n=3)	100 (110)	90 (69)	-.1 (1)

Table 32

Arabic-to-English Priming: RT (in ms) and Error-Rate (and SD) for the Four Participant Sub-Groups

Group/Condition	"Known Items" Priming	"W/o Outliers" Priming	Error-Rate Priming
High E/High A (n=6)	-30 (44)	-33 (49)	-.5 (.1)
Low E/Low A (n=10)	53 (168)	57 (174)	-1 (1)
High E/Low A (n=4)	46 (47)	36 (48)	.5 (.1)
Low E/High A (n=3)	-50 (78)	-39 (69)	.0 (.0)

English-to-Arabic Effects

Comparing the four sub-groups on the English-to-Arabic priming effects, a clear difference was evident between the strong inhibition effects found for the High-English/Low-Arabic group and the small effects found for the other groups. Moreover, for the group of Low-English/Low-Arabic, as well as for the group of Low-English/High-Arabic, facilitation effects were observed. In other words, when the target language was of lower proficiency than the prime language, inhibition effects were observed, whereas when the two languages were of equally low proficiency, or when the target language was better than the prime language, a trend toward facilitation priming was observed. A trend toward inhibition effects was also evident for the group with high proficiency in both languages.

Arabic-to-English Effects

Consistent with what was found in the English-to-Arabic direction, a trend toward facilitation effects was observed for the groups of low proficiency in both languages and when the target language was of higher proficiency than the prime language, for the groups of unequal proficiency. Inhibition effects were evident when the prime language was stronger than the target language, as well as for the sub-group with high proficiency in both languages.

Thus, patterns of facilitation and inhibition effects were found to be determined by the relative proficiency of the target and the prime non-native languages, with most notable inhibition effects from a stronger non-L1 to a weaker non-L1.

Within-Language Priming Effects

Within-Hebrew Priming Effects

As can be seen in Table 10 above, the priming effect between the RT in the within-Hebrew repetition priming and the unrelated conditions was small (679 and 683 ms, respectively). This difference was not reliable statistically. When the within-Hebrew priming effect (RT in the repetition condition subtracted from the unrelated condition) was correlated with RT in the Hebrew simple LDT task, a significant correlation was observed in the direction of increased priming effects with increased response time: $r = .311$, $p = .006$ for "known items" and $r = .272$, $p = .016$ for "w/o outliers". When only the 12 slowest participants (i.e., participants with Hebrew RT of more than 1SD above the group mean) were considered, their mean RT in the Hebrew repetition priming and unrelated conditions were 798 and 851, respectively. This difference did not reach statistical significance, possibly due to the small number of participants.

Within-English Priming Effects

The within-English related and unrelated conditions yielded a mean RT of 938 and 878 ms, respectively (see Table 11). A post-hoc analysis based on the post-test simple LDT revealed that the items of the related condition yielded longer response times and higher error rates overall across participants than the items of the unrelated condition (811 ms and 766 ms in the related and unrelated conditions, respectively; a t-test showed that the difference between the two means approached statistical significance $p = .07$). This (unintended) difference may have contributed to the unexpected pattern of inhibition observed when comparing the unrelated and related within-English conditions.

When the measures of English proficiency were correlated with the within-English priming effect, a significant correlation was observed between English-RT-Difference and priming effects for "known items": $r = .307$, $p = .007$, with a trend toward a correlation between RT-Difference and "w/o outliers": $r = .213$, $p = .063$. In addition, a significant correlation was obtained for the Error-Rate measure of proficiency and the error-rate priming effect: $r = .235$, $p = .037$. The correlation was in the direction of increased priming effects with increased English proficiency.

These results may be taken as evidence for an unbalanced distribution of the English items in the two conditions, a problem that affected participants who were less proficient in English but not those who were highly proficient English speakers.

Within-Arabic Priming Effects

As can be seen in Table 12, the means for the "known items" RT in the related and unrelated Arabic-Arabic conditions were 1318 and 1383 ms, respectively. The difference was not statistically significant, possibly due to the large inter-participant variability.

Summary

The three lines of analysis – the various correlation analyses, the ANCOVA, and the proficiency-group comparisons – converged in their findings that the proficiency level of the non-native language(s) influenced priming effects between L1 and non-native languages as well as between two non-native languages.

The strong overall effect of proficiency on the target language was evident in the ANCOVA results, with significant effects of the priming-direction variables, particularly the target-language variable, as well as in the finding that the effects obtained in the analyses interacted with the non-L1 proficiency measures.

When I assessed the effects between Hebrew (L1) and the two non-native languages, employing correlational analysis across participants as well as group comparisons, smaller priming effects were found between Hebrew and English with increased English proficiency. Reduced cross-language priming at high levels of proficiency can be taken as evidence for increasingly independent non-native language-processing at high levels of proficiency. While a similar pattern was not found for effects between Hebrew and Arabic, it was noted that participants' overall proficiency in Arabic appeared to be lower than their overall proficiency in English. Indeed, inhibitory effects of priming from Hebrew to Arabic were observed at low levels of Arabic proficiency. This suggests that in translation-equivalent priming, at low levels of target-language proficiency, the prime word inhibits, rather than facilitates, accessing the target word. Further support for this hypothesis was found in the inhibition effects observed between the two non-native languages at low levels of target-language proficiency. In contrast, facilitation effects between two non-native languages were evident when both languages were of equally low proficiency. This was consistent with the positive correlation obtained between English-to-Arabic priming effects and Arabic proficiency, and the negative correlation between English-to-Arabic priming effects and English proficiency.

The results of this study demonstrate that proficiency levels determine the pattern of translation-equivalent cross-language priming effects. The findings, and the lexical relations between the first language and any additional language and between two non-native languages that may be assumed based on these findings, will be addressed in the following chapter.

Chapter 4: Discussion

As described at greater length in Chapter 1, issues concerning lexical representation and lexical access processes of bilingual people have been thoroughly studied using various tasks, stimuli, and language combinations (e.g., de Groot & Kroll, 1997; Harris, 1992; Schreuder & Weltens, 1993). In recent decades, several models of the bilingual lexicon have been proposed and several realizations about the study of bilingualism have emerged. Attention has been paid to the effects that variables such as task characteristics and demands, stimulus type, and the relations between the two languages in question have on the observed results (e.g., Dijkstra & Van Heuven, 1998; Grosjean, 1997). Moreover, the need to distinguish between lexical levels and semantic or conceptual levels of representation and processing, originally addressed in Weinreich's early discussion of sign and meaning units in bilingual lexical representation (Weinreich, 1953), has resurfaced (de Bot et al., 1995; de Groot & Kroll, 1997; Potter et al., 1984). In addition, the degree of proficiency in the second language has been found to have an effect on the results of studies examining the bilingual lexicon (e.g., Chen & Leung, 1989; de Groot, Dannenburg, & van Hell, 1994; Kroll, 1993), although complex patterns of results have left questions regarding specific proficiency effects unanswered.

In contrast to the extensive research on the bilingual lexicon, only a few studies expanded the investigation and explored the relations among the three or more languages of multilingual speakers. While a growing number of recent studies have addressed issues concerning trilingual and multilingual speakers (e.g., Cenoz & Genesee, 1998; Hoffmann, 1999; Klein, 1995), only a few addressed aspects of lexical access (Abunuwara, 1992; de Groot & Hoeks, 1995). The nature of lexical relations among the first language and various additional languages, of the relations among two or more non-native languages, and the effect of language proficiency on these relations, are not well understood. In addition to the interest in the little-explored lexical organization of trilingual and multilingual speakers per se, studying lexical representation among multilinguals can dissociate two aspects of second-language representation that are usually confounded in bilingual studies: the status of L2 as a lexical system learned after the first system has been established and the status of L2 as a language with proficiency that is lower than the proficiency of the dominant L1. Moreover, variables such as language proficiency and specific language-combinations can be studied within participants rather than between participants to avoid between-group variability.

This study was designed to explore the relations among the three languages of trilingual speakers and the effects that the proficiency in the two non-native languages have on these relations. A cross-language translation-equivalent priming paradigm was used in a lexical-decision task (LDT) to investigate processes of lexical access and cross-language lexical activation. Participants were native speakers of Hebrew who had varying levels of proficiency in their two non-native languages, English and Arabic. Each participant performed an LDT in each of the three languages. Various prime-target pairs appeared (in a pseudo-randomized order) such that target words in each language were primed by words from the same language: by related words (repetition priming) and by unrelated words, and by words from each of the other two languages, again by related words (translation equivalents) and by unrelated words. Response times (RT) and error-rates in each of the priming conditions were collected. Means per participant and across the group were calculated and priming effects, i.e., the differences between the means in the related and the unrelated conditions, were calculated. The results were analyzed for participants as a group and then further evaluated with respect to proficiency in the non-native languages. The findings of the study support the existence of cross-language semantic word associations and non-selective, automatic, lexical activation processes that are dependent on the relative levels of proficiency in the three languages. This study provides evidence for the hypothesis that processes of lexical access of non-native languages change with changes in language proficiency.

Specifically, facilitation and inhibition priming effects were found in the various cross-language priming conditions (facilitation refers to faster RT in the related versus the unrelated conditions, inhibition refers to slower RT in the related versus the unrelated conditions; see below). Facilitation effects between Hebrew (L1) and a non-native language were found for participants overall when Hebrew words primed English words but not when Hebrew words primed Arabic words. Overall priming effects from the non-native languages to L1 were not observed, nor were overall effects between the two non-native languages for the group of participants. However, the findings revealed significant effects of language proficiency on the pattern of the priming results between L1 and the non-native languages, as well as between the two non-native languages, as follows: Priming effects from Hebrew primes to English targets correlated with levels of English proficiency in the predicted direction of decreased facilitation effects with increased English proficiency. While priming effects from Hebrew primes to Arabic targets did not correlate with Arabic proficiency, inhibition priming effects were found at very low levels of Arabic proficiency. Priming effects between the two non-native languages correlated with both English and Arabic proficiencies in the direction of increased facilitation effects from English to Arabic with increased Arabic proficiency and decreased English proficiency, and larger inhibition effects from English primes to Arabic targets were found at lower levels of Arabic proficiency. The pattern of results evident in the correlation analyses was further revealed when sub-groups of participants, defined based on non-native language proficiency, were compared. Furthermore, in assessing the priming effects between the two non-native languages, different patterns emerged, depending on the relative proficiency in the two languages.

Subsequently, two main patterns of findings were identified. One, priming effects depend on the proficiency of the target language and appear to progress along the target-language proficiency continuum: Inhibition priming effects were found for a low-proficiency target language, facilitation effects were found for a proficient target language, and decreased facilitation effects were found for a highly proficient target language. The other, priming effects between two non-native languages depend on the relative proficiency in the two languages (the target language and the prime language): Facilitation priming effects were found between primes and targets from two non-native languages that were similar in proficiency (but not highly proficient) and when the target language was of higher proficiency than the prime language, while inhibition priming effects were found between two non-native languages when the prime language was of higher proficiency than the target language.

The results summarized above will be detailed and discussed with respect to previous findings, the predictions outlined in the Introduction, and existing models of the bilingual lexicon. A preliminary theory of multilingual lexical organization will then be proposed. Finally, various factors that should be considered in interpreting the results will be reviewed, and unresolved issues will be outlined for future research.

The Relations between L1 and Non-Native Languages

Effects between Hebrew (L1) and English (non-L1)

In accordance with previous findings and with prediction 1a, significant priming effects from Hebrew primes to English targets were found for participants overall while no significant effects were found from English primes to Hebrew targets overall. These findings are consistent with asymmetric lexical connections between L1 and a non-proficient non-native language and with the hypothesis that L2 word-access processes occur via L1 word-access but that L1 access does not rely on L2 access (Kroll & Stewart, 1994). Based on the lexical connections assumed in Kroll and Stewart's revised hierarchical model (RHM), when L2 words are initially learned, associations to the equivalent L1 words are formed. However, associations in the other direction, from L1 words to their L2 equivalents, are not expected, as L1 word access can be accomplished independently of the new words learned. The asymmetry that is captured in the RHM (see Figure 7) and that has been found in various studies (Gollan et al., 1997; Keatley et al., 1994; Kroll & Sholl, 1992) was thus further demonstrated in this study in the overall priming effects between Hebrew and English. (Additional accounts for the directional asymmetry have been proposed and will be addressed below.)

Crucially, the priming results between Hebrew and English in this study were found to be affected by the proficiency levels of the non-native English. As predicted in prediction 1b, stronger priming effects from Hebrew primes to English targets were found for participants whose proficiency in English was lower than for participants whose proficiency in English was high. It should be noted that the relation between the priming effects from Hebrew primes to English targets and English proficiency was not strictly linear. Indeed, a curvilinear line was found to be a better fit for the data (see Figure 15), with inhibition effects at lowest levels of English proficiency. The overall negative correlation between the priming effects and English proficiency is consistent with the hypothesis that the lexical connections between L1 and a non-native language change as the non-L1 proficiency increases, and specifically, that the reliance of L2 word access on L1 words decreases with increased L2 proficiency.

This assumption is incorporated in the developmental aspect of the RHM, according to which L2 lexical-access processes become more independent of L1 lexical access with increased L2 proficiency. In the RHM, the decrease in reliance on L1 words coincides with increased direct L2 access to the conceptual or semantic representation; indeed, Kroll and her colleagues found support for increased direct access to concept representation with increased L2 proficiency (e.g., Kroll & de Groot, 1997). The priming results reported here do not directly address the question of concept mediation in lexical access but do relate to semantic access, as will be discussed below.

In the bilingual interactive activation (BIA) model presented by Dijkstra and Van Heuven (1998), an integrated representation of both languages is assumed. Shared representation is postulated at the lexical level and at the semantic level while language-specific word nodes and letter nodes are assumed to be separate but connected in the lexical network (see Figure 9). According to the BIA, when participants are presented with a string of letters and are asked to make a lexical decision, the process of word recognition is initially language independent. Then, language-specific features trigger specific word activation and inhibition of non-target competitors. The duration of the recognition process depends on various factors, including what is referred to in the interactive activation framework as resting-level activation. High-frequency words, for example, are assumed to have a higher resting-level activation. In the bilingual model, words from a less-proficient language are assumed to have lower frequency and thus lower resting-level activation.

Based on this model, bi-directional priming effects may be expected when the inter-connected lexicon is accessed. However, less activation is expected for words of lower frequency, including words from the less-proficient language. As a result, L1 words are expected to be recognized faster and to thus prime non-L1 words, but the recognition of non-L1 word primes would take longer and they may not influence L1 word access. The BIA model, then (like the RHM), would predict that with increased L2 proficiency (as words gain higher resting-activation levels), priming effects from non-L1 words to L1 words would increase. The opposite pattern was found here.

There is one issue that is not directly addressed in the BIA model but is crucial to the present study. The BIA was developed based on Dutch-English bilinguals; it is unclear whether a non-selective visual recognition process can be assumed for two languages with different orthographic systems, when a language decision is likely to precede any subsequent lexical decision. The role of orthography in visual word recognition and particularly in cross-language priming will be addressed below.

The finding of decreasing priming effects with increased English proficiency found for priming from Hebrew to English was also evident for priming from English to Hebrew. Thus, in both priming directions (from Hebrew primes to English targets and from English primes to Hebrew targets), the priming effects decreased with increased non-L1 (English) proficiency. This is consistent with the assumption that the independence of the two languages (L1 and a non-L1) increases with increased non-L1 proficiency. The decreased effects from non-L1 primes to L1 targets with increased non-L1 proficiency is not, however, completely compatible with the predictions of the RHM nor the BIA model. That is, the present results suggest that when the non-native language is not highly proficient, there is automatic cross-language activation in both directions; not only does access of L1 words facilitate access of non-L1 words, but also access of non-L1 words may facilitate access of L1 words. Such mutual activation during L1 word access is not assumed in the connections defined in the RHM and may not be expected in the framework of the BIA model if the non-L1 words have low resting-level activation. Yet, based on the current findings it could be hypothesized that even though non-L1 access is not necessary to L1 access, strong bi-directional associations do exist between the two languages and automatic cross-language activation does occur in both directions (but is dependent on the proficiency level of the non-native language).

Indeed, cross-language priming effects in both directions, from L1 to L2 and from L2 to L1 were found in a few studies. For example, Keatley, Spinks, and de Gelder (1994) found translation-equivalent priming effects in both priming directions in a study with Dutch-French bilinguals (native speakers of Dutch with high proficiency of French), although the priming effects were larger in the direction from L1 primes to L2 targets than from L2 primes to L1 targets. The lack of overall priming effects from non-L1 English primes to L1 Hebrew targets in the present study, in contrast to the effects found in Keatley et al., can be explained by differences between the paradigms used in the two studies (e.g., masked vs. unmasked prime presentation, stimulus characteristics, orthographic differences between the two languages used), by the amount of inter-participant variability, and by differences in participants' non-native language proficiency. It should be noted that while a few studies found priming in both directions (Keatley et al., 1994; Williams, 1994) other studies that used cross-language priming did not find reliable priming effects from L2 primes to L1 targets (e.g., de Groot & Nas, 1991; Gollan et al., 1997; Jiang, 1999).

Several accounts for the absence of priming from the second language to the more proficient first language have been discussed. These include differences in the type of representation of L1 and L2 (Jiang & Forster, 2001), differences in speed of lexical processing in L1 and L2 (e.g., Jiang, 1999), and differences in levels of L1 and L2 language activation (e.g., Green, 1998).

Jiang and Forster (2001) observed that while no priming effects from L2 primes to L1 targets were found in an LDT, significant priming effects emerged in this direction (from L2 primes to L1 targets) in an episodic-memory task of old-new decision (i.e., when participants were presented with a list of words in a study phase and were later asked to decide whether words presented in the test phase were part of the study phase or not). Moreover, they identified a double dissociation: the effects from L1 primes to L2 targets were significant only in the LDT but not in the episodic task. These results led Jiang and Forster to hypothesize that the representation of L2 in memory is not lexical in nature. Rather, episodic associations are established between L1 meanings and L2 words when the latter are learned (particularly when L2 is learned later in childhood or in adulthood). That is, while L1 words are represented in a lexical memory storage, when L2 words are learned they are stored as non-lexical memory associations to L1 concepts, and thus their associations to the lexical representation of L1 words is indirect. Accordingly, priming effects from L2 to L1 are assumed to be a result of episodic, non-lexical connections between words in the two languages and not due to direct activation of lexical representation (which would explain the lack of L2-to-L1 priming effects in an LDT).

Jiang (1999) assessed the suggestion that processing-time differences between the two languages account for the directional asymmetry in cross-language priming. In a series of experiments with Chinese-English speakers, he manipulated the stimulus-presentation sequence and the duration of the prime. The results showed that the directional asymmetry persisted even when the primes in L2 were presented for relatively longer times or with longer SOA. Moreover, in one condition (Experiment 5), both languages were mixed in the stimulus list to encourage activation of both languages, but weak L2-to-L1 effects – as compared to significant L1-to-L2 effects – were still evident. Jiang concluded that mere processing time or activation levels differences between L1 and L2 are not sufficient to account for the priming asymmetry.

It should be noted, however, that a relatively small increase of duration was used in Jiang's study, which may have not been sufficient for complete processing of the prime (relative to the speed of processing the L1 target). Indeed, increased time for prime processing was found to produce L2-to-L1 priming effects in the experiments reported in Williams (1994; see below). Thus, further evidence is needed before timing accounts for weak priming effects from L2 primes to L1 targets could be dismissed.

Similarly, presenting both languages in the stimulus list (Jiang, 1999, Experiment 5) may have not been sufficient to change the inherent higher activation levels of the more-proficient language (cf. Green, 1998; see below). Issues concerning levels of language activation were further addressed by Dijkstra and his colleagues. Evidence for non-selective lexical access was found in a number of experiments (e.g., de Groot et al., 2000; Dijkstra et al., 2000), supporting the BIA hypothesis that at early stages of lexical access, representation levels that include both languages are activated. The BIA then further hypothesizes that only when language-specific nodes are reinforced, such that words from one of the two languages receive further activation, are language-specific items activated or selected. As mentioned above, the BIA model treats proficiency-related levels of activation as frequency-related activation levels. Thus, even when both languages are active in a given task, the specific activation levels of the two languages may be different due to their different proficiency levels.

Related issues of speakers' control over activation and inhibition of their two languages are central to Green's approach to bilingual processing (e.g., Green, 1993, 1998). The ability to inhibit the prime word and successfully switch to the language of the target word may depend on control over both languages. Increased automatic activation on the one hand, and increased controlled inhibition on the other, are expected with increased levels of language proficiency. Thus, automatic speeded activation of words from L1 is expected to yield priming effects from L1 primes to L2 targets and speeded inhibition of L1 prime words will further allow processing of the L2 target word. When the primes are words from L2, more automatic activation of the prime words is expected at higher levels of L2 proficiency. Thus L2-to-L1 priming effects may be expected for participants whose L2 is proficient enough to allow automatic L2 activation. While further study of the factors that influence the presence and absence of priming effects from L2 primes to L1 targets is warranted, timing and activation factors should be further considered to account for the lack of cross-language priming between L1 and a low-proficiency non-L1, seen in the present study in the Hebrew and Arabic conditions.

Effects between Hebrew (L1) and Arabic (non-L1)

In contrast to the overall significant priming effect from Hebrew primes to English targets, no overall priming effect was found from Hebrew primes to Arabic targets. Two related factors may have contributed to this finding. One, great inter-participant variability was observed among participants' RT and error-rates in the Arabic-target conditions. Some participants showed the expected facilitation patterns while others did not; the overall standard deviations in these conditions were high, and it is likely that the lower Arabic proficiency of participants, as compared to their English proficiency (see Proficiency Measures Results above), has contributed to this variability. Indeed, the other contributing factor can be the pattern of inhibition priming found from Hebrew primes to Arabic targets at the lowest levels of Arabic proficiency. The inhibition effects from Hebrew primes to Arabic targets demonstrated by a number of participants may have influenced the overall Hebrew-to-Arabic results. Recall that a small number of participants with low levels of English proficiency showed inhibition effects from Hebrew primes to English targets but the few participants who showed the inhibition pattern did not affect the overall pattern of results. It should be noted that those participants who demonstrated facilitation priming effects had relatively high proficiency in Arabic, yet not all participants who can be identified as high in Arabic proficiency demonstrated the pattern. Further study, using various L1 and non-L1 combinations at low levels of non-L1 proficiency, would be needed to verify these accounts. The pattern of inhibition effects at low levels of proficiency was also obtained between the two non-native languages (indeed in most conditions at very low target-language proficiency) and will be further addressed below, as will additional studies that found cross-language inhibition effects.

Prediction 1b, then, was supported within the Hebrew-to-English priming results but not within the Hebrew-to-Arabic priming results. Nor was it supported when the effects from Hebrew to the overall more-proficient non-native language (English) were compared to the effects from Hebrew to the overall less-proficient non-native language (Arabic), across the trilingual participants as a group.

The lack of effects between L1 and a non-proficient non-L1 would not be expected based on the RHM, as strong reliance of L2 words on L1 words is assumed (based on the strong lexical connections from a non-proficient L2 to the proficient L1). The BIA model does not directly address bilingual representation at very low levels of L2 proficiency, but low resting-level activation of low-proficiency languages may result in a lack of cross-language effects. Green's model of controlled activation and inhibition processes may predict low activation levels for a low-proficiency L2 that may be further inhibited by the automatic activation of the L1 prime words. Additional aspects of inhibition processes will be discussed below. Alternative explanations for the lack of effects between Hebrew and Arabic may be related to degrees of language use (such issues will be briefly considered below) as well as to the overall lower familiarity of the participants with the Arabic font used in this paradigm (which may have reduced the automaticity of the reading process).

The Relations between English and Arabic, Two Non-Native Languages

Little study has been conducted on the relations between the lexicons of the non-native languages of multilingual speakers (Ecke, 1999) and there are no current models that I am aware of that address these relations. Ecke studied elicited tip-of-the-tongue states and assessed the frequency of L2 lexical activation during word-finding situations in L3. He found that the Spanish-English-German trilinguals he studied reported interference in L3 from L2 more often than they reported interference from L1. While Ecke (1999) found preliminary evidence for cross-language activation between two non-native languages, Abunuwara (1992) did not find Stroop-type interference between the two non-native languages of trilingual Arabic-Hebrew-English speakers. Several differences between the two studies (e.g., participants' proficiency in the non-native languages, the tasks used) can account for the seemingly contradictory results. Based on Ecke's findings and on multilinguals' self-report of interference between their two or more non-native languages, it has been hypothesized here that there are lexical connections between the words of non-native languages. For speakers who learned their non-native languages independently (of each other), accessing words from one of the non-native languages is not expected to rely on accessing words from the other non-native language; however, interconnected representation and cross-language spreading activation can be hypothesized. Such cross-language activation would yield cross-language priming effects between the two non-native languages.

If the BIA framework were to be extended to more than two languages and non-selective processes were still assumed, patterns of cross-language activation among all languages would be expected. These may depend on the relative frequency of the words from the various languages. The assumptions of the RHM, in contrast, do not lend themselves easily to specifying connections among several non-native languages. Notions of automatic and controlled activation and inhibition could be applied to the processing of more than two languages but further specification of these mechanisms would be needed.

In contrast to prediction 2a, significant priming effects between the two languages were not found for participants as a group. This finding is consistent with the Jiang and Forster (2001) hypothesis that the representation of a non-native language is not part of the lexical memory of L1. Based on their hypothesis, it would be predicted that while each additional language is associated with L1 words at the episodic memory storage, there is no independent lexical representation of non-L1 words. No cross-language lexical activation would thus be expected between two non-native languages. Yet, interesting patterns of facilitation and inhibition priming effects that were associated with participants' proficiency in the two languages were observed in the current study, which are not consistent with a completely independent representation of two non-native languages. Overall, priming effects from English primes to Arabic targets correlated with participants' proficiency in both Arabic and English: priming effects from English primes to Arabic targets increased with increased Arabic proficiency and with decreased English proficiency.

When the effects were evaluated based on the relative proficiency of the two languages, inhibition priming effects were found from English primes to Arabic targets for participants who had low levels of Arabic (the target language) proficiency and higher levels of English (the prime language) proficiency. In contrast to the prediction that stronger priming effects would be found from the more-proficient non-native language to the less-proficient non-native language (prediction 2b), strong inhibition priming effects were evident for participants who had higher proficiency in English, the prime language, than in the language of the target, Arabic. While this prediction was based on findings between L1 and a non-native language (e.g., the asymmetry in priming effects from the more-proficient L1 to the less-proficient non-L1), it appears that the relations between two non-native languages are different from the relations between the native language and a non-native language. This may be expected particularly when each of the non-native languages was learned in a formal setting and with no reference to the other non-native language.

In contrast to these inhibition effects and consistent with prediction 2c, a pattern of facilitation priming effects (albeit with great inter-participant variability) was observed when the prime and target languages had comparable (low) levels of proficiency. These patterns of inhibition and facilitation between the two non-native languages are based on small numbers of participants and further evidence is needed before conclusions can be drawn. However, support for the validity of these results comes from the finding that the patterns obtained in the Arabic-to-English priming conditions were very similar to the pattern of results obtained in the English-to-Arabic priming conditions.

Namely, when priming effects from Arabic primes to English targets were assessed, a possible pattern of inhibition was again evident for participants whose target-language English was of lower proficiency than their Arabic, the prime language. A pattern of facilitation effects, on the other hand, was observed for participants with comparable levels of proficiency in both languages and for participants with higher proficiency in the target language than in the prime language.

It thus appears that at very low levels of target-language proficiency, primes from another language do not facilitate lexical access, while at higher levels of proficiency, accessing words from another language does facilitate word recognition; at highest levels of target-language proficiency, other-language primes do not seem to facilitate lexical access of the target words. It can be hypothesized that at lower levels of target-language proficiency, the activation of the prime as well as of additional competitors from the prime language hinders the process of activating the target language and accessing the target word.

Moreover, if mechanisms of control over the language of the prime are not completely automatic, more time would be needed to appropriately inhibit the prime language and to activate the target language. Upon activation of the prime language, the other non-native language might be inhibited such that the short lag between the prime and the target is not sufficient for activating the target language. The finding of no inhibition between the two non-native languages when they do not differ in levels of proficiency provides further support for this hypothesis. Inhibition processes during lexical access will be further discussed in the priming-theories section below.

Cross-Language Priming and Language Proficiency

It is evident from several previous studies and from the results of this study that proficiency has a fundamental effect on language processing and on the language representation of multilingual speakers. Nevertheless, many studies that assessed lexical processing in bilingual speakers generalized their conclusions to bilinguals in general. Models that attempt to represent the relation between the two languages, however, are more effective if level of proficiency is explicitly incorporated into their assumptions. Moreover, certain contradictions in the literature may be resolved if proficiency level is considered. For example, the small cross-language priming effects found in several studies for non-cognate translation equivalents (e.g., de Groot & Nas, 1991; Keatley et al., 1994) may be explained by the fact that highly proficient bilinguals participated in these studies, and as suggested by the present results, cross-language priming effects may decrease at highest levels of non-L1 proficiency. Indeed, when Gollan et al. (1997) compared the priming effects found for participants who demonstrated faster RT in L2 to those obtained by participants who had slower RT in L2 (and recall, slower RT is associated with lower L2 proficiency), larger priming effects were evident for the participants with slower RT. Similarly, Kirsner et al. (1984), who did not find cross-language priming for translation equivalents in either direction, had as their participants highly proficient bilinguals, some working as professional translators.

While some theories of bilingual processing may be extended to more than two languages, for example, Green's theory of proficiency-related ability to activate and inhibit words can be applied beyond bilingualism, and similarly, the integrated lexical representation assumed in the BIA for the two languages of bilingual speakers could conceivably be assumed for more than two languages, there is no explicit model of multilingual lexical representation.

Based on the results obtained in the present study, I postulate that cross-language activation and inhibition processes occur not only between L1 and L2, but between the first language and any additional non-native language, as well as between any two non-native languages. I hypothesize that the relations between the languages change and progress along the proficiency continuum and that certain thresholds of proficiency must be reached for the relations between the languages to be adjusted. To that end, I propose the following continuum of lexical relation.

The Two-Threshold Hypothesis: Proficiency-Determined Cross-Language Relations

On the basis of the present results, a two-threshold hypothesis is proposed (see Figures 20 and 21). First, the relations between the native language and any additional non-native language will be considered, then the relations between two non-native languages will be addressed.

At low levels of non-native language proficiency, newly learned words are associated with their equivalent L1 words; the non-native lexical activation is weak, as are cross-language lexical connections. No cross-language priming effects are thus expected between the native language and a very low-proficiency non-native language.

This pattern of results was evident for Hebrew and Arabic in the current study; other studies have employed at least intermediate, and usually highly proficient, bilinguals.

With increased non-native proficiency, the activation of the non-native lexicon becomes stronger and once the first proficiency threshold is reached, stronger connections are expected between the two languages and evidence for cross-language lexical activation should be found. At this stage, processing the non-native words relies on L1 words more than processing L1 words relies on the non-native lexicon. This pattern can be seen in the cross-language priming effects found between Hebrew and English in the present study as well as in previous studies (e.g., Gollan et al., 1997).

When the second threshold is reached and speakers achieve high proficiency in their non-native language, the representation of the non-native language gains a certain independence, lexical processes rely less on equivalent L1 words, and weaker automatic cross-language activation is expected. This was evident in the negative correlation found between the amount of cross-language priming and language proficiency in the Hebrew-English conditions in the present study. The growing independence of the two languages is also consistent with increased control over activation and inhibition processes at higher levels of language proficiency and reduced interference between languages of high proficiency that have been reported by multilingual speakers. It can be further hypothesized that at the highest levels of proficiency, bilinguals are able to separate the processing of their different languages and experience no cross-language interference during selective processing in one of their languages.

Stage I. High-Proficiency L1, Low-Proficiency Non-L1:

Non-L1 dependency on L1; No cross-language activation

↓

Threshold I

Stage II. High-Proficiency L1, Medium-to-High-Proficiency Non-L1:

Non-L1 dependency on L1; Cross-language activation

↓

Threshold II

Stage III. High-Proficiency L1, High-Proficiency Non-L1:

No Non-L1 dependency on L1; No cross-language activation

Figure 20. The Two-Threshold Hypothesis: L1 and Non-L1

This progression of interlingual relations is similar to the one mentioned by de Bot and his colleagues. Considering various issues relevant to the results obtained from studies of lexical processing in bilinguals, de Bot, Cox, Ralston, Schaufeli, and Weltens (1995) addressed the effect of L2 proficiency on visual LDT. In some of the results they reported, larger cross-language effects were found for intermediate-level L2 learners than for highly proficient bilinguals. De Bot et al. advanced the hypothesis that the connections between the two languages become stronger at first but that at very high levels of proficiency there is independent processing of the two languages. In their review, however, they reported additional results that did not support this assumption and the hypothesis was not pursued. Supporting results were also not found for auditory LDT reported in their paper, but it is conceivable that different processes are involved in auditory as compared to visual lexical processing, as discussed by the authors.

A similar progression of proficiency-based performance has been proposed by Tzelgov and his colleagues (e.g., Tzelgov, Henik, & Leiser, 1990). Tzelgov et al. discussed the relation between L2 proficiency and the degree of interference demonstrated by their bilingual participants in a bilingual version of the Stoop test. They found that while at low levels of L2 proficiency cross-language interference was small, it increased with increased L2 proficiency. On the other hand, at the highest levels of L2 proficiency, participants were able to control and reduce the degree of cross-language interference when they were expecting words from the non-target language. Tzelgov et al. (1990) hypothesized a curvilinear relation between cross-language Stroop interference and L2 proficiency whereby interference increases with increased proficiency at lower levels of L2 proficiency but decreases with increased L2 proficiency at higher levels of L2 proficiency.

Together with the findings of the present study, it thus seems premature to abandon the notion of an inverted u-shape curve as depicting the changing relations between pairs of languages of bilinguals. Based on this model, the difference between the lexical relations found between Hebrew and English and Hebrew and Arabic can be attributed to the overall lower levels of Arabic proficiency demonstrated by the participants of this study. This progression of relations between two languages can be extended to any number of non-native languages and applied to trilingual as well as multilingual speakers.

When two non-native languages are considered, several types of relations are assumed, depending on the relative proficiency in the two languages (see Figure 21). Cross-language activation may be expected even at lower levels of proficiency if the representations of non-native languages are connected. In the present study, evidence for small facilitation-priming effects was obtained for participants who had low proficiency in both their non-native languages. Increased cross-language activation is expected as the proficiency levels in the two languages reach the first threshold. If, however, there is a proficiency difference between the two non-native languages, the relatively low activation of the weaker language appears to result in patterns of inhibition.

Stage I. Two Low-Proficiency Non-Native Languages:

Cross-language activation

↓

Threshold I

Stage II. Two Non-Native Languages of Unequal Proficiency:

Cross-language activation; Inhibition from the higher-proficiency one

↓

Threshold II

Stage III. Two High-Proficiency Non-Native Languages:

No cross-language activation

Figure 21. The Two-Threshold Hypothesis: Two Non-Native Languages

In the present study, inhibition priming effects were found from the more-proficient non-native language to the less-proficient non-native language but not when words from the less-proficient language primed words from the more-proficient non-native language. Finally, when both languages reach the second threshold at higher proficiency levels, independent lexical processing would be expected, with decreased cross-language activation and increased control over activation and inhibition levels of the languages.

Here too, these relations can be extended to any pair of non-native languages. The same non-native language may have one type of relation with one additional non-native language and another type of relation with another.

To further interpret the results of the present study, it would be useful to review the underlying lexical-access mechanisms that have been hypothesized to account for cross-language priming effects and the variables that may influence these effects. I review below relevant priming phenomena (masked priming, semantically related priming, and cross-language priming) and the theories that have been proposed to explain them, including processes of inhibition relevant to monolingual and multilingual lexical access.

Priming Theories

When a reader is asked to make a lexical decision about a string of letters, the process of visual word recognition is assumed to involve a search for a match in the mental lexicon. The metaphor commonly used in the literature is that of a network of linked nodes of lexical-representations; notions such as activation levels, recognition threshold, and elimination (or inhibition) of all the non-target activated candidates are used; word recognition occurs when an activated word reaches a selection threshold; word recognition is followed by a decision about the lexical status of the stimulus.

The context in which the string of letters is presented has been found to affect the latencies of the lexical decision process and has thus been assumed to affect the process of word recognition and selection. One such context is a preceding stimulus, presented immediately before the target string, as has been the structure of various priming paradigms. In primed LDT experiments, response times to target words in various priming conditions are compared and the effect of the prime on the process of target recognition is assessed.

Results from numerous studies concerning the specific effects of the prime word on the recognition of the target word as a function of the specific relations between the two words (e.g., whether they have similar forms, similar meaning, or both) led to the development of several theories of lexical network organization (e.g., Forster & Veres, 1998; Humphreys, Evett, Quinlan, & Besner, 1987; McNamara, 1992, 1994; Neely, 1991).

One of these theories, which gained support from a sizable number of studies using several different paradigms, involves the notion of spreading activation (Collins & Loftus, 1975; de Groot, 1983). In the automatic spreading activation framework, nodes of words in the memory network are connected and activation of one node spreads to all connected words. The spreading process is constrained by time and distance: activation spreads more to closely related words than to farther nodes and decays as time elapses. Facilitation of target-word recognition following the presentation of a related prime-word is explained by partial activation of the target word during the activation of the prime word.

Alternative theories have been proposed to account for priming effects (e.g., Klinger, Burton, & Pitts, 2000; McNamara, 1992; Neely, 1991), including variations on a compound-cue model. Here, priming effects are associated with the degree of familiarity of the two words as a compound cue; when the prime and target are related, the familiarity of the compound cue is higher than when the prime and target are unrelated. As in the spreading activation approach, in a compound-cue model, the effects are expected to decay over distance as less related prime-target pairs are associated with less familiar compound cues, but the distance – in meaning as well as in number of items presented between the prime and the target – may be different from the one expected in spreading activation accounts (McNamara, 1992; Ratcliff & McKoon, 1988).

A third approach focuses on expectations that participants may develop regarding the relations between the prime and the target (e.g., Neely, 1991). Specifically, if a target string of letters is identified as semantically related to the prime word, that string of letters is likely to constitute a real word; thus the lexical decision (although not necessarily the lexical search) is facilitated if a relation between the two words is identified. Participants are likely to develop strategies to look for relations between the prime and the target. Consequently, expectancy theories consider "post-lexical" (or post-access) stages of the lexical decision.

Expectation-based theories, however, cannot account for priming effects obtained when participants are not consciously aware of the primes, as is the case in masked-priming paradigms. Several studies compared priming effects obtained in masked versus unmasked prime presentations and assessed the interaction of the effects with various factors, including the frequency of the primes and of the targets and the proportion of related prime-target pairs in the stimulus lists (e.g., Forster & Davis, 1984; Forster & Veres, 1998; Humphreys et al., 1987). Forster (1998) reviewed the pros and cons of masked priming and concluded that the masked priming paradigm can be used to detect automatic lexical processing. Although his discussion addressed mostly form-related priming findings with words as well as non-words, the model he and his colleagues proposed – postulating a 2-filter search or an entry-opening process – accounts for a range of effects that have been reported in various studies. Crucial for the present study is the assumption that priming effects found with the use of a masked priming paradigm can be taken as evidence for automatic lexical processes.

Additional discussions of the priming phenomena focus on the process of the prime-word recognition (e.g., Forster & Veres, 1998). Addressing form-related priming effects in LDT (i.e., when the prime and target words are visually similar, or share most letters), Forster and his colleagues (e.g., Forster & Davis 1984, Forster & Veres, 1998) hypothesized that simultaneous activation of several lexical items during the prime presentation, prior to the moment of recognition of the prime, was crucial to the process of priming. That is, as long as the prime word was not fully identified, other words (i.e., other candidates or competitors) would be still active; if one of these competitors were then presented as the target word, its recognition would be facilitated. Once the identification of the prime is resolved, however, no priming effect should be observed. Forster and Veres (1998) found supporting evidence for their theory in form-related and identity priming in masked and unmasked paradigms. Questions concerning timing aspects of priming processes and whether a prime, once its recognition has been completed, can or cannot affect targets have been addressed in various studies (see McNamara, 1992). Various aspects of the prime-word recognition and its potential effect on the latencies of the target-word recognition may have played a role in the pattern of inhibition priming found in the current results (see below).

The findings obtained in the translation-equivalent priming paradigm employed in the present study, particularly with the three languages used (i.e., three languages that do not share orthography; see below), are most relevant to two types of processes: semantic priming and cross-language priming. I will address each of these two concepts in turn.

Semantically Related Priming

When the prime and the target words are semantically related, priming effects are associated with simultaneous activation of several lexical items and are assumed to occur during the process of identifying the prime word. That is, the target word is assumed to be activated upon processing of the preceding prime word. Priming effects from a prime word to a semantically related word have been found in many studies that used a primed LDT paradigm (e.g., Neely, 1977; de Groot, 1983).

Several researchers have pointed out the important distinction between prime-target pairs that are associated to each other and pairs that are semantically related but not strongly associated. Associations between words have been assessed by presenting participants with a word, for example, *bread*, and asking them to produce the first word that comes to mind; the word *butter* is likely to be produced due to the strong association between the two words. In contrast, the words *bread* and *cake* are semantically related but are less likely to be produced as associations of each other. Strong priming effects are usually found for association pairs (e.g., Meyer & Schvaneveldt, 1971; Neely, 1977) but less clear results have been reported for semantically related, unassociated pairs; it has been suggested that expectancy-related strategies, rather than automatic activation, are the source of the priming effects found for semantically related (but not associated) words (Neely, Keefe, & Ross, 1989; Shelton & Martin, 1992).

Shelton and Martin (1992) showed that automatic priming (in single-presentation style LDT)[12] was not found for semantically related words that were not

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[12] Three main paradigms have been used to assess the priming phenomenon. In episodic priming (e.g., Kirsner et al., 1984; Scarborough et al., 1977), words appear in a study phase and then are repeated, after an interval of 15 to 50 minutes, in the test phase. In pair-presentation, the prime word appears immediately prior to the target word, with intervals of 50 to 1000 ms, and usually a response to the prime is not required (Forster & Davis, 1984; Henik et al., 1983; Meyer & Schvanenveldt, 1971). In single presentation, words appear in a continuous sequence and response is required for each word; repeated or related words appear on the list at intervals of 300 to 1500 ms (Stern et al., 1991; Shelton & Martin, 1992).

associated and when the proportion of related pairs was low (that is, when strategies are less likely to be developed). They concluded that lexical organization is based on associations among words, not on shared semantic features.

In contrast, a recent ERP study (Stenberg, Lindgren, Johansson, Olsson, & Rosen, 2000) reported evidence for semantic processing of briefly presented, masked, written words. Stenberg et al. found that even when words were not consciously identified by participants, brain responses were different when the masked words belonged to a designated category from those evoked when the words were not of that category. These findings suggest the semantic processing of visually presented words occurs automatically, even when participants are not aware of the words. This is consistent with priming theories that are based on automatic activation of words and not on conscious strategies developed by participants based on expectations.

It should be noted, however, that the nature of automatic lexical processing as revealed by the use of LDT paradigms and priming paradigms may be still different from natural lexical processes that occur during everyday reading or lexical activity. Several researchers have attempted to understand these more natural processes, using brain-imaging techniques. For example, Brown and Hagoort (1993) used a primed LDT paradigm in an ERP study, comparing the N400 effects obtained during masked and unmasked semantically related priming. The N400 effect has been found to be related to the semantic relations between the word eliciting the effect and its preceding context. Brown and Hagoort found that the RT data yielded significant priming effects in both the masked and unmasked priming presentations but that the ERP analyses, by contrast, yielded a significant difference between related and unrelated pairs and a significant N400 effect for the unrelated words only in the unmasked presentation condition. No significant N400 effect or significant differences between the related and unrelated prime-target pairs were found in the masked presentation. These results confirm the dissociation between automatic lexical processing, detected in the masked priming paradigm, and processes that are influenced by the task, the context, and participants' awareness of the relations among the presented stimuli in the unmasked priming presentation.

Furthermore, in another recent ERP study, Brown, Hagoort, and Chwilla (2000) compared the N400 effects elicited in related, unrelated, and neutral priming conditions. They found that the amplitude of the N400 was larger to unrelated than to related words, both when participants were instructed to merely read the words silently and when they were asked to make an explicit lexical decision on the target words. Crucially, when participants were asked to simply silently read the stimulus words, the size of the N400 did not interact with the proportion of related pairs in the stimulus list. However, when participants were asked to complete an explicit LDT condition, the N400 was significantly larger when the proportion of related pairs was high than when it was low. These findings demonstrated that the relatedness effect obtained was specific to the LDT and suggest that expectancy-based processes, which may not be part of natural visual-word processing (or may be different in neutral processing), occur in the context of an LDT.

Cross-Language Priming

In a cross-language priming paradigm that uses translation equivalents, the prime and the target are inherently semantically related (as they share semantic features and meaning characteristics) but they do not necessarily constitute associatively related words. While a lexical-decision task per se may be assumed to address form levels of word recognition and not necessarily to require the activation of semantic levels, cross-language priming effects – similar to within-language semantic priming effects – would suggest that levels beyond surface-form representation are activated even during word-recognition tasks. It is not clear whether translation-equivalent priming effects can be assumed to be the result of spreading activation across lexical forms from the two languages or to be the result of activation of language-independent semantic levels of lexical representation that occurs in addition to the activation of language-specific form levels.

Yet, cross-language priming is expected if network connections and spreading activation processes are assumed to be language-independent and to include nodes of words from all languages known by an individual. As in within-language priming, both processes of activation of related words and inhibition of non-target competitors, including the inhibition of the activated prime, are necessary. Several factors are expected to affect cross-language priming processes. These include the relative speed of word recognition in each language and the relative ability to inhibit non-target competitors in each language. Both processes, activation and inhibition, have been suggested to be more automatic as well as more likely to be controlled in speakers' first and most dominant language than in a non-native, less proficient language (Green, 1998; Rafal & Henik, 1994).

The notion of inhibition as used here may refer to the diminishing of the activation of the prime over time or of non-target competitors that were activated upon the presentation of a related prime word. It can also refer to the reduced activation of words that are unrelated to the prime word (e.g., Neely, 1991). These interpretations, as well as additional ones, have been discussed in various studies of lexical access and lexical organization; some of the aspects more relevant to the notion of inhibition as referred to here are outlined below.

Inhibition Effects

One unexpected pattern of results found in the current data is inhibition priming effects – that is, longer latencies in the related than in the unrelated conditions – obtained under some circumstances. The concept of inhibition in lexical processes has been discussed in various contexts (Dagenbach & Carr, 1994; Neely, 1991; Peynircioğlu & Gökşen-Erelçin, 1988). Rafal and Henik (1994) discussed processes of inhibition, applying neurological principles to lexical processes. They outlined two examples of lexical processes that involve inhibition: Stroop effects and semantic priming. Tzelgov and his colleagues studied participants' ability to control the interference effect in both monolingual and bilingual versions of the Stroop test (e.g., Tzelgov, Henik, & Berger, 1992; Tzelgov, Henik, & Leiser, 1990). They found that while there was greater interference from a written word in participants' proficient language than from a written word in the less-proficient language, participants were more successful in exercising control over the amount of interference from the written word when the word was in their more-proficient language than in their less-proficient language. This is consistent with increased automatic activation, but also increased controlled inhibition, at higher levels of language proficiency.

The second task discussed by Rafal and Henik (1994) was semantic priming. In addition to the facilitation effects from related words reported in the literature, inhibition effects from unrelated words have been found in several experiments (Neely, 1991). Specifically, unrelated primes have been found to yield longer RT than neutral primes in various LDT experiments, suggesting that during word recognition, related words are activated but unrelated words are deactivated. Similarly, slower RT to targets that were unexpected based on task-specific instructions have been reported (Neely, 1977). Thus, for example, Neely demonstrated that when participants expected words from a certain category (e.g., *robin*, *sparrow*) to follow a certain (unrelated) category name (BODY), seeing a related but unexpected word (*arm*) resulted in slower RT. (This inhibition effect, however, was found only at long SOA, not at short SOA, suggesting that it was a result of controlled expectations, not automatic activation.)

Activation of one lexical item may result in the inhibition of related items that may be initially activated as candidates (or competitors) but then inhibited to allow for the selection of the target item. Inhibition effects from competing lexical items have been found in various production tasks such as word and picture naming (Blaxton & Bookheimer, 1993; Blaxton & Neely, 1983) and word generation (Roediger, 1973;

Peynircioğlu & Gökşen-Erelçin, 1988). For example, evidence for within-category inhibition processes was found both within language and across languages in picture naming and word translation (Kroll & Stewart, 1994) and in word-generation tasks (Peynircioğlu & Gökşen-Erelçin, 1988). Peynircioğlu and Gökşen-Erelçin (1988) used a word-generation task and found the previously reported within-language category-related interference (Roediger, 1973). That is, they found that when participants were asked to generate words from a given category, they produced fewer words when they performing the task while hearing words from the target category (i.e., possible target words) than when no words were heard. Furthermore, Peynircioğlu and Gökşen-Erelçin found that their bilingual Turkish-English participants experienced this interference when the words they heard were in the target language but also when the words were in their other language, not the language of the target production. Interestingly, when the participants were instructed to produce words in Turkish, their L1, they experienced more interference from Turkish words than from English L2 words (consistent with higher activation levels of a more proficient language); but when generating words in English, their L2, they experienced equal interference from English words and Turkish words. That is to say, the distracting cross-language words were more successfully inhibited when the production task was performed in the more proficient L1 than when the production was in the less-proficient L2.

These reports of stronger activation of words from the more-proficient language and weaker ability of controlled inhibition in a less-proficient language are consistent with the present findings of inhibition priming effects when the target language was of lower proficiency than the prime language. Inability to inhibit the activation of the prime and in turn to sufficiently activate the target word can account for the longer response times found in the related conditions for less-proficient non-native languages described above, specifically when the language of the prime was of higher proficiency than the language of the target (e.g., the inhibition effects found from English primes to Arabic targets when English was more proficient than Arabic).

It is interesting to note that inhibition effects were not found from primes in the first, most proficient language, except when the target language was of very low proficiency. Based on inhibition and activation theories, it is expected that proficient bilinguals will be able to inhibit the prime language and activate the target language sufficiently fast to benefit from the cross-language prime. Indeed, cross-language facilitation effects from the first language to a non-native language have been reported for relatively proficient bilinguals. In contrast, when participants perform an LDT in their less proficient languages, sufficient inhibition of the prime language and activation of the target language may not be completed. The resulting pattern will be expected to be slower response times to the target word when it follows a related prime from another language – as has been found in the present study between the two non-native languages – when participants were more, but not completely, proficient in the prime language.

Additional Considerations: Frequency, Orthography, and Stimulus Presentation

Word Frequency

The relative word-frequency of the prime and the target has been found to influence priming results. For example, larger priming effects were found for low-frequency targets than for high-frequency targets (Becker, 1979; Forster & Davis, 1984). Forster and Davis manipulated the prime presentation (masked or unmasked), task demands (response required for the primes or not), and the word frequency of the primes and the targets. They found that all these variables affected the results. However, word frequency was found to have a larger effect in unmasked-priming conditions than in masked-priming conditions. The authors took the results as evidence that word frequency effects may be related to episodic (or non-automatic) aspects of the priming processes rather than to the process of lexical access itself. Thus, while frequency effects influence priming results in some conditions, they have limited effects in certain paradigms.

In cross-language priming, it is expected that the words from the less-proficient language would behave like low-frequency words (e.g., Dijkstra & Van Heuven, 1998). Therefore, frequency may offer an additional account for the asymmetry of effects in processing from the more-proficient language and in the other direction, from the less-proficient language. If more-frequent words are activated faster than less-frequent words, larger priming effects from the more-proficient language to the less-proficient language may be expected. However, speed of lexical access per se can be viewed as a confounding factor. Namely, words from a less-proficient language are expected to take longer to recognize and the time for spreading activation from the prime presentation to the targets may be shorter or insufficient. When two non-proficient languages are used, both these variables may have markedly smaller influence, and priming effects that are independent of proficiency-related speed of access and relative frequency may be observed. Indeed, a pattern of facilitation priming was observed between the two non-native languages tested here when they were both of low proficiency.

Frequency considerations may account also for some of the within-language results observed in this study. In contrast to previous studies (Forster & Davis, 1994; Gollan et al., 1997), repetition priming effects were not found in the within-L1 conditions. One possible account for the lack of within-Hebrew facilitation may be related to the choice of stimuli in this study. As described in the Method section above, translation-equivalent triads were selected to serve as prime-target pairs in the related cross-language conditions. Common, concrete, highly familiar words were selected to assure that participants with various degrees of proficiency would be likely to know these words in their non-native languages. Moreover, the non-words that were created for the task were clearly not words, differing from real words by two phonemes.[13]

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[13] In most studies, non-words differ from real words by one grapheme (or one phoneme). Lexical decisions with such items, however, may be extremely difficult for low-proficiency non-native speakers of a language and thus, the non-words used in the present study were created to clearly differ from real words.

As a result, the lexical decision in Hebrew was quite easy for native speakers of the language; fast response times, perhaps a ceiling effect, resulted in both related and unrelated conditions, with no repetition priming effect evident. Support for this account comes from the finding that a subset of the participants who were particularly slow in their Hebrew RT overall showed the expected pattern of facilitation effects in the Hebrew repetition-priming condition. Comparing the results obtained here with comparable experiments with another set of stimuli (of less frequent, less common words) may be needed to verify this account.

Indeed, the within-Arabic repetition conditions yielded a pattern of facilitation, although great inter-participant variability was again evident and the facilitation effect did not reach statistical significance. While some participants with higher Arabic skills showed the expected pattern of facilitation, others showed no effect or inhibition effect.

The within-English conditions, on the other hand, yielded an inhibition effect, with faster response times overall in the unrelated than in the related conditions. While this finding was not expected on the basis of previous findings (e.g., Gollan et al., 1997), an artifact of the stimulus choice may account for the observed within-English results. Namely, post-hoc analysis revealed that, despite the random designation of English words to the two within-English conditions, the items that comprised the related conditions were found – post hoc – to be more difficult overall than those of the unrelated conditions (as was revealed by the significantly longer mean RT to the words that appeared in the related condition than to those that appeared in the unrelated condition in the post-test LDT). Other accounts may be given to this unexpected within-English inhibition effect; further study, using additional or alternative stimuli, is needed before conclusions can be drawn.

Orthography

The choice of three different languages with three different orthographic systems allowed controlling for orthography effects. Non-selective language activation processes (i.e., activation of all languages known by a participant, at least at initial stages of visual word recognition) that may be expected when orthography is shared (e.g., Dijkstra et al., 2000) were thus at least minimized and likely eliminated. Consequently, priming effects between pairs of languages with non-shared word forms can be taken as further evidence for (semantic) spreading activation processes, regardless of the degree of shared form-level representation. Furthermore, priming effects across orthographies lend additional support for the assumption that lexical-decision tasks can involve access of meaning in addition to access of lexical forms. As has been discussed above, priming effects between non-cognate translation equivalents have not always been found (e.g., de Groot & Nas, 1991; Keatley et al., 1994), but when obtained, they provide strong support for cross-language activation at levels beyond the lexical form (phonologically or orthographically). It is interesting to note that masked priming effects with non-cognates have been invariably found in studies that used two languages of different orthographies (e.g., Gollan et al., 1997; Jiang,

1999) but not when the two languages shared orthography (e.g., de Groot & Nas, 1991).

All three of the orthographic systems used in this study are alphabetic and represent grapheme-to-phoneme correspondence. While none of the three systems can be considered "shallow" orthography, that is, a system that has a one-to-one correspondence of graphemes to phonemes (see, for example, Frost, Katz, & Bentin, 1987), both the Hebrew and Arabic orthographies can be considered "deeper" than the English orthography, in that both Hebrew and Arabic orthographies (in the unvoweled versions used in the present study) represent mostly consonants; most vowels are not explicitly represented in the orthography and thus many letter strings are ambiguous, corresponding to more than one spoken word.

While the degree of phonological involvement in reading shallow and deep orthographies has been discussed in various studies using tasks such as word naming (i.e., reading single words aloud), the role of phonological access in word recognition tasks may be less critical, because participants are required to make a lexical decision and may not necessarily need to access the word's phonological form. Indeed, it has been proposed that word-recognition processes of highly irregularly spelled words and of words from languages with deep orthography involve processes of semantic access that precede the access of phonological forms (Bentin, Bargai, & Katz, 1984; Frost, 1998). On the other hand, cross-language neighborhood effects (that is, the number of words that differ from each other by only one letter and share most of their grapheme-to-phoneme correspondences) have been discussed in the framework of the BIA mentioned above (e.g., van Heuven, Dijkstra, & Grainger, 1998). These effects further support phonological activation during lexical access as well as non-selective lexical processes for bilingual speakers. Whether phonological processing accompanied word recognition in the present study should not affect the interpretation of the results because priming (of non-cognates) across orthographies suggests lexical relations beyond the form levels of word access (e.g., Forster, 1999; Gollan et al, 1997; Keatley et al., 1994).

Although the three languages used in this study differed equally in their orthographies, when structural characteristics such as word structure and various syntactic structures are considered, the two languages that belong to the same language-family, namely, Hebrew and Arabic, are more closely related to each other than to the third, non-Semitic language, English. The effect of this difference in the relation between Hebrew and Arabic on the one hand, and Hebrew and English and Arabic and English on the other, was minimized by two factors. One, by choosing the single-word level of language processing and using morphologically simple words, structural characteristics were virtually irrelevant to the task. In addition, care was taken to choose only words that did not share phonological features nor relate to equivalent roots in the two languages that share phonological and morphological elements (Hebrew and Arabic). With respect to direction of reading, the difference between the right-to-left Hebrew and Arabic and the left-to-right English is not expected to influence the results when words are presented one at a time and without any overt context.

Several studies assessed L2 reading skills and reading strategies while considering participants' L1 orthography and the relation between the orthographic systems of L1 and L2 in pairs of languages such as English and Japanese versus Chinese and Japanese (Chikamatsu, 1996) and Greek and English versus Chinese and English (Chitiri, Sun, Willows, & Taylor, 1992). Differences in types of orthographic systems were found to affect the process of learning to read in a second language but to be less influential at higher levels of L2 reading proficiency. Several researchers have suggested that with increased reading proficiency, the process of visual word recognition becomes more automatic in the non-native language (Chitiri et al., 1992; Segalowitz, Segalowitz, & Wood, 1998; Shimron & Sivan, 1994). It could be hypothesized that the Arabic reading skills of the participants reported in the present study did not reach automatic word-recognition processes, which may have contributed to the lack of facilitation effects between Arabic and the highly proficient first language, Hebrew.

Furthermore, Shimron and Sivan (1994) found evidence for differences in the rate of reading in different orthographies. They demonstrated that for equivalent texts, English text was read faster by native speakers of English than Hebrew text by native speakers of Hebrew; there was no difference between reading rates of Hebrew voweled and unvoweled texts. The authors acknowledged, and tried to control for, a number of differences between the orthographies and morphological structures of the two languages; indeed their English text, for example, had more words than the Hebrew one. While Shimron and Sivan's study focused on reading text in context (taken from introductory books in social sciences in Hebrew and in English, original as well as translated versions), it is possible that there are inherent differences in the speed of processing written words among different orthographies even at the single-word level.

However, no evidence of differences in rates of single-word reading or recognition in the three languages used here has been found in the literature. One measure that can be taken to control for such potential differences is comparing the results obtained in the present study to similar studies using different combinations of languages and orthographies (see below).

Timing

Various findings of cross-language priming and translation tasks have been associated with certain timing variables. For example, the lag between the target word and the prime, the lag between the two presentations of a repeated word or of translation pairs, and presentation-sequence variations including short versus long ISI and SOA, have been reported to influence the results (e.g., Forster, 1998; Keatley & de Gelder, 1992; Neely, 1991; Neely et al., 1998).

In addition, the timing differences associated with word recognition under different conditions are relevant to priming studies in general and to cross-language priming studies in particular. Several researchers have incorporated in their theories of lexical processing hypotheses regarding the time it takes to recognize a lexical item or to search the mental lexicon and how these timings are affected by prior context (e.g., Forster, 1999; Neely & Keefe, 1989). These issues are particularly relevant when two or more languages are concerned. Indeed, speed of lexical processing has been hypothesized to account for the directional asymmetry found in various bilingual tasks, as discussed above. For example, larger priming effects from L1 to a second, less proficient, language than in the opposite direction may be explained by differences in lexical-processing speed (e.g., Forster & Jiang, 2001; Gollan et al., 1997; Jiang & Forster, 2001). Namely, if participants are slower to process lexical items from their non-native language, the time for cross-language activation and priming processing may not be sufficient for facilitation in processing the target L1 words to take place. Differences in speed of lexical processing can thus account for differences in the priming effects observed in the two priming directions (when the more-proficient language primes the less-proficient languages as compared to when the less-proficient language primes the more-proficient language).

Several attempts to assess these timing differences have been reported in the literature (Jiang, 1999; Neely et al., 1998; Williams, 1994). While Jiang (1999), who manipulated the duration of the L2 prime and the SOA in order to increase the time to process the prime, did not find priming from L2 primes to L1 targets, Williams (1994) reported significant priming effects from L2 primes to L1 targets when allowing longer duration for L2 prime processing. There are several differences between the two studies that can account for the apparently contradictory results. Jiang used the masked priming paradigm described in Forster and Davis (1984), in which the prime duration is short (50 or 60 ms) and the SOA was manipulated by adding a backward mask. While the prime presentation was still brief, there was an additional 200 ms before the target appeared. Williams, on the other hand, manipulated prime duration by presenting the prime twice for a brief duration of 14.3 ms each, and in a sequence of masks and blanks yielding an overall SOA of 728 ms. In addition, the languages used in the two studies were different (English-Chinese in Jiang, 1999; a number of language pairs, e.g., English-French and English-Italian, in Williams, 1994), which could have contributed to the different results.

Two additional studies manipulated the duration of the prime presentation by presenting the word twice, both in a monolingual context (Balota & Paul, 1996; Neely et al., 1998). They found that the repetition of the prime did not increase the priming effect. Neely et al. (1998) found that response time to target words was faster when two words serving as primes were unrelated but the target was semantically related to the second prime than when the target was unrelated to the second prime. That is, regardless of the first prime word, the second prime – if identical or related to the target – facilitated the response to the target. However, when the first and second primes were the same word, no facilitation effect was evident when the two primes were related to the target (the first prime was masked, but the second was visible).

It is unclear whether related, rather than repeated, two-prime words would have yielded similarly reduced priming effects and whether masking both primes would have yielded different results, but current results suggest that repeating the prime word may not be a simple solution for increasing processing time of the prime in a non-native language. More evidence is needed to determine the effect of repeated prime presentation and of the time allowed for the prime to be processed, in particular when non-proficient participants are studied.

Assessing cross-language priming effects between two languages of similar proficiency can resolve the question whether speed of lexical processing accounts for the asymmetry of cross-language priming effects. The trend toward facilitation priming effects found in the present study between two non-native languages of similar proficiency can be taken as evidence that it is, at least in part, speed of lexical access that determines priming effects, but the small number of participants in this group of low-proficiency in both English and Arabic leaves the answer inconclusive. Moreover, the decreased priming effects with increased non-native proficiency found from English primes to L1 targets provides further support that the speed of lexical access cannot be considered the only reason for the directional asymmetry of cross-language priming effects. If less time is required for processing in a non-native language at higher proficiency, increased priming from the non-native language to L1 would have been expected with increased non-native proficiency (but the opposite pattern was found).

As mentioned above, the overall lack of priming effects between the two non-native languages could be taken as supporting evidence for Jiang and Forster's hypothesis that later-learned languages are episodically, not lexically, associated to L1. On the other hand, the lack of effects could also be accounted for by the varying degrees of proficiency of participants in the two non-native languages and the subsequent within-group variability; the inhibition effects between the two languages found for some participants suggest that there are cross-language activation and inhibition processes between the two languages. Additional research on the relations between two non-native languages is necessary.

Expectations and Language Mode

The effects of presenting participants with mixed lists of stimuli or language-specific lists have been studied in a number of experiments (e.g., Grainger & Dijkstra, 1992; Grosjean, 1998; Neely, 1991). In the present study, participants were presented with three stimulus lists. Each of the three lists contained one target language such that participants were encouraged to be in a monolingual language-set for the duration of each list. Because the primes were not visible for participants' conscious awareness, it is likely that as far as participants' awareness was concerned, they remained in a relatively monolingual mode. However, as each list contained primes in all three languages and at least some automatic levels of processing, all languages can be expected to have been active. The inclusion of all possible prime-target pair combinations was important to reduce any bias that might have been developed if each list of words presented to the participants was made of the same prime-target language pair or same type of prime-target relation. Theoretically, priming effects obtained in a masked priming paradigm with mixed prime-target pairs reflect automatic lexical processing that takes place during the process of lexical access and word recognition and thus reveal cross-language effects at these levels. Including the various pair combinations may have contributed to the variability of response times within each list and to the unreliable overall priming effects obtained in certain conditions. It might prove useful to compare cross-language effects obtained in mixed versus unmixed lists of prime-target pairs to further assess the effect of the internal structure of the stimulus list.

Furthermore, while several researchers used neutral primes in addition to related and unrelated primes and compared the response times obtained with related and unrelated primes to those obtained in the neutral prime (baseline) conditions (see Neely, 1991), others simply compared related to unrelated prime-target pairs. It is debatable whether the effect of the prime on the target when the two words are related should be compared to a condition with a prime that is unrelated to the target or to a prime that is determined to be neutral. This is particularly relevant for theories of priming that assume that activation of related items, but also inhibition of unrelated items, take place during the processing of the prime. The problem of neutral primes has been discussed regarding the repetition effect of a relatively meaningless prime such as *word* or *blank*, which have been used in several studies, and the non-word effects of strings such as "XXXXX," which have been used in other studies (e.g., de Groot, 1983; Neely, 1991). Most cross-language priming studies have focused on contrasting related and unrelated pairs (de Groot & Nas, 1991; Gollan et al., 1997) and this was the paradigm adopted in the current study.

There are additional variables, beyond task and stimulus characteristics, that affect the relations among languages of multilingual speakers and may have contributed to the results of the present study and specifically to some of the differences found between the two non-native languages used here. For instance, a number of participants had learned their Arabic considerably later than their English. Age-of-acquisition effects, which have been considered in neurolinguistic studies of bilinguals but less in psycholinguistic studies, may play an important role in language processing. Additionally, different levels of language use and exposure to written forms of the languages may have played a role in the differences observed between the two non-native languages. Specifically, most participants have had experience with English print on computer screens due to their exposure to the Internet, but minimal or no exposure to Arabic fonts, and no experience with the font used in the present experiment. For most native speakers of Hebrew, more English is heard in the Israeli environment generally, particularly on television and in movies, than Arabic. Most participants had reported at least some current use of Arabic, either in their occupation or their studies, but for some participants the daily experience with Arabic was rather limited. Findings from several studies suggest that current exposure to a language plays a role in bilingual performance (e.g., Dijkstra et al., 2000; Jared & Kroll, 2001). Further assessment of individual levels of language use as well the relation between the amount of daily use and the pattern of priming effects obtained is needed.

Similarly, additional issues pertaining to participants' motivation and attitude toward the languages studied can be explored. Several studies found evidence for the effects of attitude toward non-native languages on language learning and on the ability to understand accented speech (e.g., Brown, 1992; Goral, Obler, & Galletta, 2000); we might expect, then, that attitude can influence the degree of non-native language activation. Such issues are beyond the scope of the present analyses but relevant data have been collected and these effects can be assessed in the future.

Future Research

Several aspects of the present findings remain inconclusive. These include the patterns of facilitation and inhibition effects found between the two non-native languages, predominantly due to the smaller number of participants that could be clearly identified for each trilingual-proficiency group. Larger numbers of participants in each of the four proficiency-combinations used in this study (low proficiency in both non-native languages, high-proficiency in both non-native languages, and one low-proficiency non-native language and one high-proficiency non-native language) should be used to assess the validity of the patterns of priming that emerged here. Yet, identifying the relative levels of proficiency in each of trilinguals' languages may not be a simple task. A thorough pre-test assessment may be required in order to classify participants into the appropriate proficiency groups, which can then be followed by the experimental testing.

Further, the contribution of the specific language-combination studied could be determined by studying several additional language combinations. That is, both groups of Arabic-English-Hebrew trilinguals who are native speakers of English and who are native speakers of Arabic could be compared to the group of native speakers of Hebrew used in this study. Moreover, additional combinations of three languages should be studied to explore the effects of two important variables, namely, linguistic relations and orthographic relations among the languages in question and their effects on cross-language activation. For example, results from three languages that all share linguistic relation as well as orthography, such as Italian, French, and Spanish; three languages that belong to three different language-families and have different orthographies, such as Hebrew, English, and Russian; and various combinations of a different L1 and two related non-native languages, such as, English (L1), Hebrew and Arabic (non-L1), and Arabic (L1), Italian and French (non-L1), could be compared.

Additional language-specific considerations, such as participants' attitude toward each of the languages in question and the importance of each of the languages in participants' language use can be crucial. Another variable that was not explored in the present study but has been found to be an influential one is manner of language acquisition. While, in this study, participants learned their two non-native languages in late childhood and in formal settings, some variation may still be found among the participants regarding the amount of exposure to the languages in natural settings (e.g., by contact with family members who speak the language) and the amount of non-formal acquisition that took place. Further assessment of various items on the background questionnaire used in the present study can contribute to understanding the pattern of results obtained here, particularly some of the inter-participant variability obtained. Moreover, future research can explicitly compare cross-language activation and evidence for multilingual representation while considering the age at which, as well as the way in which each of the languages of the trilingual speakers was learned. Of particular interest would be to compare the same language combinations learned at early versus late childhood and in formal versus informal settings while controlling for language proficiency to the extent possible.

To test the generalizability of the two-threshold hypotheses proposed above, further research is warranted. Specifically, assessing the patterns of cross-language activation with trilinguals who are proficient in both their non-native languages as well as careful comparisons of cross-language effects between a native language and a highly proficient non-native language can provide supporting or refuting evidence for the hypothesis of independent language processing at high levels of language proficiency proposed here. Similarly, thorough investigation of cross-language activation between two languages of low proficiency and comparisons with the activation between a native language and a low-proficiency non-native language is needed to verify the proposed relations between two languages when one or both are of very low proficiency, an area that has not been addressed in the bilingual literature.

Several other limitations of the present study could be addressed in future research. Namely, additional methods to assess level of language proficiency would validate the findings obtained and generalize them to trilingual speakers with various language experiences. Additional words can be used as primes and as targets, expanding the discussion, for example, to abstract words, morphologically complex words, and to translation equivalents that share more and less of their meanings (e.g., cognates, semi-cognates, false friends). The degree of meaning equivalency between pairs of translation equivalents varies from one language pair to another (based on linguistic relations, cultural differences, and other variables) and between a pair of translations to another, and has been found to influence bilingual lexical processing (e.g., Tokowicz & Kroll, in press).

Indeed, a detailed item analysis of the items used in the present study could reduce the effects of individual patterns that may have interacted with the results and would contribute to understanding the present findings. Additionally, it would be of interest to assess whether episodic priming effects can be detected in participants' performance on the items in the post-test LDT. It may be expected that differences in RT and error rate will be found between items that appeared as primes as compared to those that appeared as targets in the experimental LDT.

Finally, assessing cross-language activation and multilingual language representation with a variety of tasks tapping various aspects of multilingual lexical processing would broaden the realm of the present findings and provide converging evidence to substantiate the results obtained from the cross-language priming paradigm. For example, patterns of interference may be revealed during naming in each of the languages of multilingual speakers as well as during translating from one of the languages to another, collecting evidence such as false starts, participants' reports of tip-of-the-tongue state, and unintentional code switching.

Conclusion

In conclusion, the results of the present study reveal the dynamic relations that exist among the native language and the non-native languages of multilingual speakers and demonstrate that the complex lexical associations among the languages of multilingual speakers are determined by degrees of language proficiency. Future study will further our understanding of lexical representation and lexical processing in trilingual and multilingual speakers.

Appendix A

Language-Background Questionnaire (translated version)

The background questionnaire was administered in the middle of the testing session. The first 21 items were filled out by the examiner. Questions 22-34 were given to the participants to fill out for each of their non-native languages.

1. Participant number
2. Date of birth
3. Place of birth
4. Occupation
5. Number of years of education [specific details]
6. List all languages you speak/read
7. Language(s) spoken at your home today [details if more than one]
8. Language(s) spoken at home when you were growing up [if more than one, which predominantly?]
9. Language you predominantly use presently [overall, at home, outside home]
10. Language you predominantly used in the past five years [overall, at home, outside home]
11. Your mother's dominant language
12. Your father's dominant language
13. Your grandparents' dominant language

14. Other country(ies) you have lived in

each country: which, from age __ to age __ / for how long

number of years of education in another country in another language

15. Do you like learning foreign languages [mainly to rule out great difficulty learning foreign languages]?

16. Do you feel you have particular difficulty learning foreign languages?

17. Do you feel you have particular talent for learning foreign languages?

18. Known history of learning difficulty

speech? language? reading?

19. Known history of neurological deficit [Have you ever hit your head? had a head trauma? head operation? stroke?]

20. Which hand do you consider dominant?

21. Which hand would you use to throw a ball? to answer the phone? to strike a match?

Language: ________

22. Age began learning

23. Number years learned

24. Age current proficiency reached

25. Age began reading

26. Where learned: [to speak] [to read] [to understand]

	[to speak]	[to read]	[to understand]	
	_	_	_	a. at school (how many hours a week)
	_	_	_	b. at home
(check as many	_	_	_	c. an afternoon course (# hours a week)
as apply)	_	_	_	d. in a country where spoken (initially)
	_	_	_	e. in a country where spoken (in addition to a, b, or c)
	_	_	_	f. exposed to spoken by relatives (who, how often)
	_	_	_	g. exposed to spoken in neighborhood
	_	_	_	h. exposed to news, books, signs, at home
	_	_	_	i. exposed to news, books, signs, in neighborhood
	_	_	_	j. other

____

____

____

____

27. How learned: [to speak] [to read] [to understand]

(check as many as apply)

__ __ __ a. classroom, mostly conversation

__ __ __ b. classroom, mostly grammar

__ __ __ c. classroom, mostly translating from L1

__ __ __ d. classroom, mostly reading

__ __ __ e. classroom, all skills equally

__ __ __ f. by spending time in country where spoken

__ __ __ g. by being exposed to language at home

__ __ __ h. improved by reading

__ __ __ i. self-study

__ __ __ j. other ____________________

____

____

28. How often used: [speak] [understand] [read] [write]

(check one)

a. most of the day everyday

b. a few hours a day everyday

c. more then 6 hours a week

d. up to 6 hours a week

e. once a month

f. once every few months

g. once a year

h. hardly ever

i. other ____________________

____

29. Where used [speak] [understand] [read] [write]

(check as many as apply)

a. with parents

b. at home

c. with grandparents

d. with relatives

e. at school

f. with partner

g. with friends

h. at work

i. exposed to on TV

j. with native speakers

k. other ____________________

____

30. How often read

(circle as many as apply)

a. most of leisure reading [ask: how much is that]

b. about half of leisure reading

c. a small part of leisure reading

d. most of work/school reading (how much is that)

e. about half of work/school reading

f. a small part of work/school reading

g. hardly ever

h. can't read

i. other ______________________

____

31. Why learned

(circle as many as apply)

a. required at school

b. elective at school

c. for a job

d. interest

e. moved to another country

f. planned visit or trip

g. to be able to communicate with partner

h. to be able to communicate with friend(s)

i. to be able to communicate with relatives

j. to be able to read

k. for fun

l. other ______________________

____

32. Why being used (today)

(check as many as apply)

a. needed for work

b. for fun

c. planned visit or trip

d. to communicate with partner

e. to communicate with friend(s)

f. to not lose skill

g. other ______________________

____

33. Could use if needed to:

buy train tickets	yes	probably	barely	no
read road signs	yes	probably	barely	no
explain your job	yes	probably	barely	no
make small talk	yes	probably	barely	no
discuss news	yes	probably	barely	no
read newspaper	yes	probably	barely	no
discuss literature	yes	probably	barely	no
argue an opinion	yes	probably	barely	no

34. Self-rate scale:

Overall:

1	2	3	4	5	6	7
native-like knowledge	very proficient but not quite native- like	almost proficient	good knowledge but not proficient	basic knowledge	limited knowledge	very limited knowledge

Speaking:

1	2	3	4	5	6	7
native-like knowledge	very proficient but not quite native- like	almost proficient	good knowledge but not proficient	basic knowledge	limited knowledge	very limited knowledge

Vocabulary:

1	2	3	4	5	6	7
native-like knowledge	very proficient but not quite native- like	almost proficient	good knowledge but not proficient	basic knowledge	limited knowledge	very limited knowledge

Reading:

1	2	3	4	5	6	7
native-like knowledge	very proficient but not quite native- like	almost proficient	good knowledge but not proficient	basic knowledge	limited knowledge	very limited knowledge

Understanding:

1	2	3	4	5	6	7
native-like knowledge	very proficient but not quite native- like	almost proficient	good knowledge but not proficient	basic knowledge	limited knowledge	very limited knowledge

Writing:

1	2	3	4	5	6	7
native-like knowledge	very proficient but not quite native- like	almost proficient	good knowledge but not proficient	basic knowledge	limited knowledge	very limited knowledge

Appendix B

<u>Stimulus List (experimental words)</u>

English	Hebrew	Arabic
army	צבא	جيش
baby	תינוק	طفل
ball	כדור	كرة
barrel	חבית	برميل
battle	קרב	قتال
bed	מיטה	سرير
bee	דבורה	نحلة
bell	פעמון	جرس
bird	ציפור	عصفور
boat	סירה	زورق
bomb	פצצה	قنبلة
box	קופסה	علبة
bribe	שוחד	رشوة
broom	מטאטא	مكنسة
butter	חמאה	زبدة
butterfly	פרפר	فراشة
button	כפתור	زر
cabbage	כרוב	ملفوف
cake	עוגה	كعكة
camp	מחנה	معسكر
candle	נר	شمعة
car	מכונית	سيارة
carpet	שטיח	سجادة
ceiling	תקרה	سقف
chair	כסא	كرسي
closet	ארון	خزانة
cloud	ענן	غيمة
color	צבע	لون

comb	מסרק	مشط
cow	פרה	بقرة
crowd	קהל	جمهور
cucumber	מלפפון	خيار
darkness	חושך	ظلمة
dawn	שחר	فجر
dictionary	מילון	قاموس
dough	בצק	عجين
echo	הד	صدى
exit	יציאה	خروج
face	פנים	وجه
family	משפחה	عائلة
faucet	ברז	حنفية
feather	נוצה	ريشة
fish	דג	سمكة
flour	קמח	طحين
flower	פרח	زهرة
forest	יער	غابة
fork	מזלג	شوكة
fox	שועל	ثعلب
fruit	פרי	فاكهة
furniture	רהיטים	اثاث
garden	גן	حديقة
gift	מתנה	هدية
glasses	משקפיים	نظارات
groom	חתן	عريس
hammer	פטיש	مطرقة
heart	לב	قلب
hen	תרנגולת	دجاجة
honey	דבש	عسل
horse	סוס	حصان
hunger	רעב	جوع
icecream	גלידה	بوظة
judge	שופט	حاكم
juice	מיץ	عصير
kiss	נשיקה	قبلة
law	חוק	قانون

line	קו	خط
lion	אריה	اسد
lock	מנעול	قفل
magic	קסם	سحر
mail	דואר	بريد
meal	ארוחה	وجبة
missile	טיל	صاروخ
monkey	קוף	قرد
moon	ירח	قمر
mouse	עכבר	فار
mustache	שפם	شارب
neck	צוואר	رقبة
needle	מחט	ابرة
net	רשת	شبكة
newspaper	עיתון	جريدة
notebook	מחברת	دفتر
officer	קצין	ضابط
orange	תפוז	برتقالة
peel	קליפה	قشرة
picture	תמונה	صورة
pistol	אקדח	مسدس
pocket	כיס	جيب
prayer	תפילה	صلاة
restaurant	מסעדה	مطعم
ring	טבעת	خاتم
roof	גג	سطح
room	חדר	غرفة
sand	חול	رمل
scissors	מספריים	مقص
sea	ים	بحر
shoe	נעל	حذاء
side	צד	جانب
silk	משי	حرير
sink	כיור	مغسل
skin	עור	جلد
smile	חיוך	ابتسام
smoke	עשן	دخان

soldier	חייל	جندي
spider	עכביש	عنكبوت
station	תחנה	محطة
stone	אבן	حجر
street	רחוב	شارع
suit	חליפה	بدلة
table	שולחן	طاولة
tail	זנב	ذيل
thief	גנב	سارق
throat	גרון	حلق
towel	מגבת	منشفة
tower	מגדל	برج
train	רכבת	قطار
tree	עץ	شجرة
truck	משאית	شاحنة
umbrella	מטריה	مظلة
voice	קול	صوت
wall	קיר	حائط
war	מלחמה	حرب
wave	גל	موجة
weapon	נשק	سلاح
window	חלון	شباك
worm	תולעת	دودة
wound	פצע	جرح

Appendix C

Results of Analysis of Variance of Prime Language by Target Language by Condition (for "Known Items" RT Data)

Source	df	MS Error	F
Prime Language	2	40663.12	4.33*
Target Language	2	34006391.10	196.50**
Condition	1	88.51	.01
Prime Language x Target Language	4	270911.70	27.28**
Prime Language x Condition	2	79988.54	8.14**
Target Language x Condition	2	4140.48	.55
Prime Language x Target Language x Condition	4	81967.86	9.17**
Error	268	8941.68	

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

Appendix D

Results of Analysis of Variance of Prime Language by Target Language by Condition, Covarying for English Proficiency and Arabic Proficiency (for "Known Items" RT Data)

Source	df	MS Error	F
Prime Language	2	6627.59	.71
Prime Language x English Proficiency	2	15611.37	1.67
Prime Language x Arabic Proficiency	2	1982.39	.21
Target Language	2	237853.71	6.73**
Target Language x English Proficiency	2	839196.13	23.73**
Target Language x Arabic Proficiency	2	8454833.76	239.03**
Condition	1	116.85	.01
Condition x English Proficiency	1	926.44	.10
Condition x Arabic Proficiency	1	199.29	.02
Prime Language x Target Language	4	15461.44	1.55
Prime Language x Target Language x English Proficiency	4	9364.58	.94
Prime Language x Target Language x Arabic Proficiency	4	7296.08	.73

Prime Language x Condition	2	1948.06	.19
Prime Language x Condition x English Proficiency	2	2597.79	.26
Prime Language x Condition x Arabic Proficiency	2	18007.98	1.83
Target Language x Condition	2	2618.27	.35
Target Language x Condition x English Proficiency	2	3436.85	.46
Target Language x Condition x Arabic Proficiency	2	12746.12	1.7
Prime Language x Target Language x Condition	4	17266.90	1.98
Prime Language x Target Language x Condition x English Proficiency	4	28165.54	3.23*
Prime Language x Target Language x Condition x Arabic Proficiency	4	9988.45	1.15
Error	260	8710.22	

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

Appendix E

Results of Analysis of Variance of Direction (from-L1, to-L1) by Condition, Covarying for English Proficiency and Arabic Proficiency (for "Known Items" RT Data)

Source	df	MS Error	F
Direction	1	406073.96	5.18*
Direction x English Proficiency	1	78063.29	.99
Direction x Arabic Proficiency	1	2795900.54	35.69**
Condition	1	2139.39	.37
Condition x English Proficiency	1	7170.97	1.24
Condition x Arabic Proficiency	1	2252.03	.39
Direction x Condition	1	63.80	.01
Direction x Condition x English Proficiency	1	368.67	.07
Direction x Condition x Arabic Proficiency	2	4253.94	.85
Error	146	4975.74	

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

Appendix F

Results of Analysis of Variance of Direction (English-to-Arabic, Arabic-to-English) by Condition, Covarying for English Proficiency and Arabic Proficiency (for "Known Items" RT Data)

Source	df	MS Error	F
Direction	1	118077.73	4.12*
Direction x English Proficiency	1	431525.32	15.07**
Direction x Arabic Proficiency	1	5182401.86	181.02**
Condition	1	12622.35	1.34
Condition x English Proficiency	1	33912.04	3.59
Condition x Arabic Proficiency	1	29519.83	3.13
Direction x Condition	1	7.28	.00
Direction x Condition x English Proficiency	1	9085.00	.84
Direction x Condition x Arabic Proficiency	2	43119.69	3.99*
Error	146	10794.82	

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

Appendix G

Priming Effects between English and Arabic for Four Sub-Groups of Participants Using Inclusion Criteria as Described in Footnote 11

Table 33

English-to-Arabic Priming: RT (in ms) and Error-Rate (and SD) for the Four Participant Sub-Groups

Group/Condition	"Known Items" Priming	"W/o Outliers" Priming	Error-Rate Priming
High E/High A (n=15)	-14 (127)	-33 (117)	.2 (.8)
Low E/Low A (n=13)	-25 (224)	4 (213)	-.2 (2)
High E/Low A (n=9)	-80 (122)	-89 (118)	.2 (2)
Low E/High A (n=9)	-19 (125)	-11 (127)	.4 (2)

Table 34

Arabic-to-English LDT RT (in ms) and Error-Rate Priming (and SD) for the Four Participant Sub-Groups

Group/Condition	"Known Items" Priming	"W/o Outliers" Priming	Error-Rate Priming
High E/High A (n=15)	-16 (66)	-13 (78)	-.2 (1)
Low E/Low A (n=13)	61 (144)	56 (149)	-.7 (1)
High E/Low A (n=9)	39 (65)	30 (68)	.4 (.7)
Low E/High A (n=9)	-53 (126)	-47 (105)	.8 (1)

References

Abunuwara, E. 1992. The structure of the trilingual lexicon. *European Journal of Cognitive Psychology, 4* (4): 311-322.

Albert, M., & Obler, L. K. 1978. *The Bilingual Brain: Neuropsychological and Neurolinguistic Aspects of Bilingualism.* New York: Academic Press.

Altarriba, J. 1992. The representation of translation equivalents in bilingual memory. In R. J. Harris (Ed.) *Cognitive Processing in Bilinguals* (pp. 157-174). Amsterdam: Elsevier Science.

Balota, D. A., & Chumbley, J. I. 1984. Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage. *Journal of Experimental Psychology,* 10 (3), 340-357.

Balota, D. A., & Paul, S. T. 1996. Summation of association: Evidence from multiple primes that converge and diverge within semantic memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* 22, 827-845.

Basden, B. H., Bonilla-Meeks, J. L., & Basden, D. R. 1994. Cross-language priming in word-fragment completion. *Journal of Memory and Language,* 33, 69-82.

Beauvillain, C. 1992. Orthographic and lexical constraints in bilingual word recognition. In R. J. Harris (Ed.) *Cognitive Processing in Bilinguals* (pp. 221-235). Amsterdam: Elsevier Science.

Becker, C. A. 1979. Semantic context and word frequency effects in visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance,* 5, 252-259.

Bentin, S., Bargai, N., & Katz, L. 1984. Orthographic and phonemic coding for lexical access: Evidence from Hebrew. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* 10 (3), 353-368.

Blaxton, T. A., & Bookheimer, S. Y. 1993. Retrieval inhibition in anomia. *Brain and Language,* 44, 221-237.

Blaxton, T. A., & Neely, J. H. 1983. Inhibition from semantically related primes: Evidence for category-specific inhibition. *Memory and Cognition,* 11, 500-510.

Brown, C. M., & Hagoort, P. 1993. The processing nature of the N400: Evidence from masked priming. *Journal of Cognitive Neuroscience,* 5, 34-44.

Brown, C. M., Hagoort, P., & Chwilla, D. J. 2000. An event-related brain potential analysis of visual word priming effects. *Brain and Language*, 72, 158-190.

Cenoz, J., & Genesee, F. (Eds.) 1998. *Beyond Bilingualism: Multilingualism and Multilingual Education*. Clevedon: Multilingual Matters.

Charlton, M. H. 1964. Aphasia in bilingual and polyglot patients – A neurological and psychological study. *Journal of Speech and Hearing Disorders*, 29, 307-311.

Chee, M. W. L., Caplan, D., Soon, C. S., Sriram, N., Tan, E. W. L., & Weeks, B. Processing visually presented sentences in Mandarin and English with fMRI. *Neuron*, 23, 127-137.

Chee, M. W. L., Tan, E. W. L., & Thiel, T. 1999. Mandarin and English single word processing studied with functional magnetic resonance imaging. *The Journal of Neuroscence*, 19 (8) 3050-3055.

Chen, H-C. 1992. Lexical processing in bilingual or multilingual speakers. In R. J. Harris (Ed.) *Cognitive Processing in Bilinguals* (pp. 253-264). Amsterdam: Elsevier Science.

Chen, H-C., & Leung, Y-S. 1989. Patterns of lexical processing in a nonnative language. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 15 (2), 316-325.

Chen, H-C., & Ng, M-L. 1989. Semantic facilitation and translation priming effects in Chinese-English bilinguals. *Memory and Cognition*, 17, 454-462.

Chikamatsu, N. 1996. The effects of L1 orthography on L2 word recognition: A study of American and Chinese learners of Japanese. *SSLA*, 18, 403-432.

Chitiri, H-F., Sun, Y., Willows, D., & Taylor, I. 1992. Word recognition in second-language reading. In R. J. Harris (Ed.) *Cognitive Processing in Bilinguals* (pp. 283-297). Amsterdam: Elsevier Science.

Collins, A. M., & Loftus, E. F. 1975. A spreading activation theory of semantic processing. *Psychological Review*, 82, 407-428.

Dagenbach, D., & Carr, T. H. 1994. *Inhibitory Processes in Attention, Memory, and Language*. San Diego: Academic Press.

de Groot, A. M. B. 1983. The range of automatic spreading activation in word priming. *Journal of Verbal Learning and Verbal Behavior*, 22, 417-436.

de Groot, A. M. B. 1992. Determinants of word translation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18, 1001-1018.

de Groot, A. M. B. 1993. Word-type effects in bilingual processing tasks: Support for a mixed-representation system. In R. Schreuder & B. Weltens (Eds.) *The Bilingual Lexicon* (pp. 27-51). Amsterdam, Netherlands: John Benjamins Publishing Company.

de Groot, A. M. B., Dannenburg, L., & van Hell, J. G. 1994. Forward and backward translation by bilinguals. *Journal of Memory and Language*, 33, 600-629.

de Groot, A. M. B., Delmaar, P., & Lupker, S. J. 2000. The processing of interlexical homographs in translation recognition and lexical decision: Support for non-selective access to bilingual memory. *The Quarterly Journal of Experimental Psychology*, 53a, 397-4128.

de Groot, A. M. B., & Hoeks, J. C. J. 1995. The development of bilingual memory: Evidence from word translation by trilinguals. *Language Learning*, 45 (4), 683-724.

de Groot, A. M. B., & Nas, G. L. J. 1991. Lexical representation of cognates and noncognates in compound bilinguals. *Journal of Memory and Language*, 30, 90-123.

de Groot, A. M. B. & Poot, R. 1997. Word translation at three levels of proficiency in a second language: The ubiquitous involvement of conceptual memory. *Language Learning*, 47 (2), 215-264.

de Groot, A. M. B., & Kroll, J. F. (Eds.) 1997. *Tutorials in Bilingualism: Psycholinguistic Perspectives*. Mahwah, NJ: Lawrence Erlbaum Associates.

Dehaene, S., Dupoux, E., Mehler, J., Cohen, L., Paulesu, E., Perani, D., van de Moortele, P-F., Lehericy, S., & Le Bihan, D. 1997. Anatomical variability in the cortical representation of first and second language. *Neuroreport*, 8, 3809-3815.

Delgado, P., Guerrero, G., Goggin, J. P., & Ellis, B. 1999. Self-assessment of linguistic skills by bilingual Hispanics. *Hispanic Journal of Behavioral Sciences*, 21(1), 31-46.

Dijkstra, T., Timmermans, M., & Schriefers, H. 2000. On being blinded by your other language: Effects of task demands on interlingual homograph recognition. *Journal of Memory and Language*, 42, 445-464.

Dijkstra, T., & van Heuven, W. J. B. 1998. The BIA model and bilingual word recognition. In J. Grainger & A. M. Jacobs (Eds.) *Localist Connectionist Approaches to Human Cognition*. Mahwah, NJ: Lawrence Erlbaum Associates.

Dijkstra, T., Van Jaarsveld, H., & Brinke, S. 1998. Interlingual homograph recognition: Effects of task demands and language intermixing. *Bilingualism, Language and Cognition*, 1, 51-66.

Ecke, P. Lexical retrieval in a third language: Evidence from errors and tip-of-the-tongue states. September 1999. Paper presented at the International Conference on Third Language Acquisition and Trilingualism, Innsbruck, Austria.

Eisenstein, M. 1980. Childhood bilingualism and adult language learning aptitude. *International Review of Applied Psychology*, 29, 159-172.

Ervin, S. M., & Osgood, C. E. 1954. Second language learning and bilingualism. *Journal of Abnormal Social Psychology*, Supplement, 139-146.

Fabbro, F. 1999. *Neurolinguistics of Bilingualism*. Philadelphia, PA: Taylor & Francis, Inc.

Forster, K. I. 1985. Lexical acquisition and the modular lexicon. *Language and Cognitive Processes*, 1 (2), 87-108.

Forster, K. I. 1998. The pros and cons of masked priming. *Journal of Psycholinguistic Research*, 27 (2), 203-233.

Forster, K. I. 1999. The microgenesis of priming effects in lexical access. *Brain and Language*, 68, 5-15.

Forster, K. I., & Davis, C. 1984. Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning , Memory, and Cognition*, 10, 680-698.

Forster, K. I., Davis, C., Schoknecht, C., & Carter, R. 1987. Masked priming with graphically related forms: Repetition or activation? *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, 39, 211-251.

Forster, K. I., & Jiang, N. 2001. The nature of the bilingual lexicon: Experiments with the masked priming paradigm. In J. L. Nicol (Ed.) *One Mind, Two Languages: Bilingual Language Processing* (pp. 72-83). Malden, MA: Blackwell Publishers.

Forster, K. I., & Veres, C. 1998. The prime lexicality effect: Form priming as a function of prime awareness, lexical status, and discrimination difficulty. *Journal of Experimental Psychology: Language Memory and Cognition,* 24 (2), 498-514.

Fox, E. 1996. Cross-language priming from ignored words: Evidence for a common representational system in bilinguals. *Journal of Memory and Language,* 35, 353-370.

Frost, R. 1999. Toward a strong phonological theory of visual word recognition: True issues and false trails. *Psychological Bulletin,* 123 (1) 71-99.

Frost, R., Katz, L., & Bentin, S. 1987. Strategies for visual word recognition and orthographical depth: A multilingual comparison. *Journal of Experimental Psychology: Human Perception and Performance,* 13, 104-115.

Gollan, T. H., Forster, K. I., & Frost, R. 1997. Translation priming with different scripts: Masked priming with cognates and noncognates in Hebrew-English bilinguals. *Journal of Experimental Psychology: Learning, Memory and Cognition,* 23 (5), 1122-1139.

Gollan, T. H., & Kroll, J. F. 2000. Bilingual lexical access. In B. Rapp (Ed.) *The Handbook of Cognitive Neuropsychology: What Deficits Reveal about the Human Mind* (pp. 321-345). Philadelphia, PA: Psychology Press.

Goral, M. 2001. Aphasia in Hebrew speakers. *Journal of Neurolinguistics*, 14, 297-312.

Grainger, J. 1990. Word frequency and neighborhood frequency effects in lexical decision and naming. *Journal of Memory and Language,* 29, 228-244.

Grainger, J. & Dijkstra, T. 1992. On the representation and use of language information in bilinguals. In R. J. Harris (Ed.) *Cognitive Processing in Bilinguals*, 207-220. Amsterdam: Elsevier Science.

Green, D. W. 1993. Toward a model of L2 comprehension and production. In R. Schreuder & B. Weltens (Eds.) The Bilingual Lexicon. Amsterdam: John Benjamins.

Green, D. W. 1998. Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition,* 1, 67-81.

Grosjean, F. 1997. Processing mixed language: Issues, findings, and models. In A. M. B. de Groot & J. F. Kroll (Eds.) *Tutorials in Bilingualism: Psycholinguistics Perspectives*. Mahwah, NJ: Lawrence Erlbaum Associates.

Grosjean, F. 1998. Studying bilinguals: Methodological and conceptual issues. *Bilingualism: Language and Cognition,* 1 (2), 131-149.

Henik, A., Friedrich, F. J., & Kellogg, W. A. 1983. The dependence of semantic relatedness effects upon prime processing. *Memory and Cognition,* 11 (4), 366-373.

Hernandez, A. E., Martinez, A., & Kohnert, K. 2000. In search of the language switch: An fMRI study of picture naming in Spanish-English bilinguals. *Brain and Language,* 73, 421-431.

Hoffmann, C. 1999. Trilingual competence: Linguistic and cognitive issues. *Applied Linguistic Studies in Central Europe,* 3, 16-26.

Humphreys, G. W., Evett, L. J., & Quinlan, P. T. 1990. Orthographic processing in visual word identification. *Cognitive Psychology,* 22, 517-560.

Humphreys, G. W., Evett, L. J., Quinlan, P. T., & Besner, D. 1987. Orthographic priming : Qualitative differences between priming from identified and unidentified primes. In M. Coltheart (Ed.) *Attention and Performance XII* (pp. 201-219). Hillsdale, NJ: Erlbaum.

Illes, J., Francis, W. S., Desmond, J. E., Gabrieli, J. D. E., Glover, G. H., Poldrack, R., Lee, C. J., & Wagner, A. D. 1999. Convergent cortical representation of semantic processing in bilinguals. *Brain and Language,* 70, 347-363.

Jared, D., & Kroll, J. F. 2001. Do bilinguals activate phonological representations in one or both of their languages when naming words? *Journal of Memory and Language,* 44, 2-31.

Jessner, U. 1999. Metalinguistic awareness in multilinguals: Cognitive aspects of third language learning. *Language Awareness,* 8, 201-209.

Jiang, N. 1999. Testing processing explanations for the asymmetry in masked cross-language priming. *Bilingualism: Language and Cognition,* 2, 59-75.

Jiang, N. 2000. Lexical representation and development in a second language. *Applied Linguistics,* 21, 47-77.

Jiang, N., & Forster, K. I. 2001. Cross-language priming asymmetries in lexical decision and episodic recognition. *Journal of Memory and Language,* 44, 32-51.

Keatley, C. W. 1992. History of bilingualism research in cognitive psychology. In R. J. Harris (Ed.) *Cognitive Processing in Bilinguals.* Amsterdam: Elsevier Science.

Keatley, C. W. & de Gelder, B. 1992. The bilingual primed lexical decision task: Cross-language priming disappear with speeded responses. *European Journal of Cognitive Psychology,* 4 (4), 273-292.

Keatley, C. W., Spinks, J. A., & de Gelder, B. 1994. Asymmetrical cross-language priming effects. *Memory and Cognition,* 22, 70-84.

Kim, K. S., Relkin, N., Lee, K. M., & Hirsch, J. 1997. Distinct cortical areas associated with native and second languages. *Nature,* 388, 171-174.

Kintsch, W. 1972. Notes on the structure of semantic memory. In E. Tulving & W. Donaldson (Eds.) *Organization of Memory.* NY: Academic Press.

Kirsner, K., Brown, H., Abrol, S., Chadha, N. K., & Sharma, N. K. 1980. Bilingualism and lexical representation. *Quarterly Journal of Experimental Psychology,* 32, 585-594.

Kirsner, K., Smith, M. C., Lockhart, R. S., King, M. L., Jain, M. 1984. The bilingual lexicon: Language-specific units in an integrated network. *Journal of Verbal Learning and Verbal Behavior,* 23, 519-539.

Klein, E. C. 1995. Second versus third language acquisition: Is there a difference? *Language Learning,* 45 (3), 419-465.

Klein, D., Zatorre, R. J., Milner, B., Meyer, E., & Evans, A. C. 1995. The neural substrates of bilingual language processing: Evidence from positron emission tomography. In: M. Paradis (Ed.) *Aspects of Bilingual Aphasia* (pp. 23-36). Oxford: Pergamon Press.

Klinger, M. R., Burton, P. C., & Pitts, G. S. 2000. Mechanisms of unconscious priming: I. Response competition, not spreading activation. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* 26 (2), 441-455.

Kolers, P. A. 1966. Interlingual facilitation of short-term memory. *Journal of Verbal Learning and Verbal Behavior,* 5, 314-319.

Kolers, P. A. & Gonzalez, E. 1980. Memory for words, synonyms, and translations. *Journal of Experimental Psychology: Human Learning and Memory,* 6 (1), 53-65.

Kroll, J. F. 1993. Accessing conceptual representation for words in a second language. In R. Schreuder & B. Weltens (Eds.), *The Bilingual Lexicon* (pp. 53-81). Amsterdam/Philadelphia: John Benjamins.

Kroll, J. F. & Curley, J. 1988. Lexical memory in novice bilinguals: The role of concepts in retrieving second language words. In M. M. Grunberg, P. E. Morris, & R. N. Skyes (Eds.), *Practical Aspects of Memory: Current Research and Issues* (pp. 389-395). London: John Wiley.

Kroll, J. F., & de Groot, A. M. B. 1997. Lexical and conceptual memory in the bilingual: Mapping form to meaning in two languages. In A. M. B. de Groot & J. F. Kroll (Eds.) *Tutorials in Bilingualism: Psycholinguistic Perspectives* (chapter 6). Mahwah, NJ: Lawrence Erlbaum Associates.

Kroll, J. F., & Sholl, A. 1992. Lexical and conceptual memory in fluent and nonfluent bilinguals. In R. J. Harris (Ed.) *Cognitive Processing in Bilinguals* (pp. 191-204). Amsterdam: Elsevier Science.

Kroll, J. F., & Stewart, E. 1994. Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language*, 33, 149-174.

Kroll, J. F., & Tokowicz, N. 2001. The development of conceptual representation for words in a second language. In J. L. Nicol (Ed.) *One Mind, Two Languages: Bilingual Language Processing* (pp. 49-71). Malden, MA: Blackwell Publishers.

La Heij, W., Starreveld, P. A., & Steehouwer, L. C. 1993. Semantic interference and orthographic facilitation in definition naming. *Journal of Experimental Psychology: Learning Memory and Cognition*, 19 (2), 352-368.

Lemmon, C. R., & Goggin, J. P. 1989. The measurement of bilingualism and its relationship to cognitive ability. *Applied Psycholinguistics*, 10, 133-155.

Leung, I. V. 1998. Transfer between interlanguages. *Proceedings of the Annual Boston University Conference on Language Development*, 22, 477-487.

Magiste, E. 1984. Stroop tasks and dichotic translation: The development of interference patterns in bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 10, 304-315.

McNamara, T. P. 1992. Theories of priming: I. Associative distance and lag. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18 (6), 1173-1190.

McNamara, T. P. 1994. Theories of priming: II. Types of primes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 20 (3), 507-520.

Menn, L. & Obler, L. K. 1990. *Agrammatic Aphasia: A Cross-Language Narrative Sourcebook*. Amsterdam: John Benjamins Publishing Company.

Meyer, D. E., & Schvaneveldt, R. W. 1971. Facilitation in recognizing pairs of words: Evidence of a dependency between retrieval operations. *Journal of Experimental Psychology,* 90, 227-234.

Morton, J. 1969. Categories of interference: Verbal mediation and conflict in card sorting. *British Journal of Psychology,* 60, 329-346.

Neely, J. H. 1977. Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General,* 106, 226-254.

Neely, J. H. 1991. Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. W. Humphreys (Eds.) *Basic Processes in Reading: Visual word recognition* (pp. 264-336). Hillsdale, NJ: Lawrence Erlbaum.

Neely, J. H., & Keefe, D. E. 1989. Semantic context effects on visual word processing: A hybrid prospective/retrospective processing theory. In G. H. Bower (Ed.) *The Psychology of Learning and Motivation: Advances in Research and Theory.* New York: Academic Press.

Neely, J. H., Keefe, D. E., & Ross, K. 1989. Semantic priming in the lexical decision task: Roles of prospective prime-generated expectancies and retrospective semantic matching. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* 15, 1003-1019.

Neely, J. H., Verwys, A., & Kahan, T. A. 1998. Reading "glasses" will prime "vision" but reading a pair of "glasses" will not. *Memory and Cognition,* 26 (1), 34-39.

Nicholas, M., Obler, L. K., Albert, M., & Goodglass, H. 1985. Lexical retrieval in healthy aging. *Cortex,* 21, 595-606.

Nilipour, R., & Ashayeri, H. 1989. Alternating antagonism between two languages with successive recovery of a third in a trilingual aphasic patient. *Brain and Language,* 36, 23-48.

Norman, D. A. 1970. *Models of Human Memory.* New York: Academic Press.

Obler, L. K. 1984. The neuropsychology of bilingualism. In D. Caplan, A. R. Lecour, & A. Smith (Eds.) *Biological Perspectives on Language.* MIT Press.

Obler, L. K., & Albert, M. L. 1978. A monitor system for bilingual language processing. In M. Paradis (Ed.) *Aspects of Bilingualism* (pp. 156-164). Columbia, S.C: Hornbeam.

Obler, L. K., Levy, E., & Goral, M. In preparation. Neurolinguistic perspectives on mother tongue: Evidence from aphasia and brain imaging.

Ojemann, G. A., & Whitaker, H. A. 1978a. The bilingual brain. *Archives of Neurology*, 35, 409-412.

Ojemann, G. A., & Whitaker, H. A. 1978b. Language localization and variability. *Brain and Language*, 6, 239-260.

Paivio, A., & Desrochers, A. 1980. A dual-coding approach to bilingual memory. *Canadian Journal of Psychology*, 34, 388-401.

Paivio, A. & Lambert, W. 1981. Dual coding and bilingual memory. *Journal of Verbal Learning and Verbal Behavior*, 20, 532-539.

Paradis, M. 1977. Bilingualism and aphasia. In H. Whitaker & H. Whitaker (Eds.) *Studies in Neurolinguistics*, Vol. 3 (pp. 65-121). New York: Academic Press.

Paradis, M. 1983. *Readings on Aphasia in Bilingualism and Polyglots*. Montreal: Marcel Didier.

Paradis, M. 1989. Bilingual and polyglot aphasia. In F. Boller & J. Grafman (Eds.) *Handbook of Neuropsychology*, vol. 2 (pp. 117-140). Amsterdam: Elsevier.

Paradis, M. 2001. Manifestations of Aphasia Symptoms in Different Languages. Amsterdam: Pergamon.

Penfield, W., & Roberts, L. 1959. *Speech and Brain Mechanisms*. Princeton, NJ: Princeton University Press.

Perani, D., Dehaene S., Grassi, F., Cohen, L., Cappa, S. F., Dupoux, E., Fazio, F., & Mehler, J. 1996. Brain processing of native and foreign languages. *Neuroreport*, 7, 2439-2444.

Perani, D., Paulesu, E., Galles, N. S., Dupoux, E., Dehaene, S., Bettinardi, V., Cappa, S. F., Fazio, F., & Mehler, J. 1998. The bilingual brain: Proficiency and age of acquisition of the second language. *Brain*, 121, 1841-1852.

Peynircioğlu, Z., & Gökşen-Erelçin, F. 1988. Part-set cueing across languages: Evidence for both word- and concept-mediated inhibition depending on language dominance. *Acta Psychologica*, 67, 19-32.

Potter, M. C., So, K-F., von Eckardt, B., & Feldman, L. B. 1984. Lexical and conceptual representation in beginning and proficient bilinguals. *Journal of Verbal Learning and Verbal Behavior*, 23, 23-38.

Preston, M. S. & Lambert, W. E. 1969. Interlingual interference in a bilingual version of the Stroop color-word task. *Journal of Verbal Learning and Verbal Behavior*, 8, 295-301.

Rafal, R., & Henik, A. 1994. The neurology of inhibition: Integrating controlled and automatic processes. In: D. Dagenbach & T. H. Carr (Eds.) *Inhibitory Processes in Attention, Memory, and Language* (pp. 1-51). San Diego: Academic Press.

Ramsay, C. B., Nicholas, M., Au, R., Obler, L. K. & Albert, M. 1999. Verb naming in normal aging. *Applied Neuropsychology*, 6(2), 57-67.

Rapport, R. L., Tan, C. T., & Whitaker, H. A. 1983. Language function and dysfunction among Chinese- and English-speaking polyglots: Cortical stimulation, Wada testing, and clinical studies. *Brain and Language*, 18, 342-366.

Ratcliff, R., & McKoon, G. 1988. A retrieval theory of priming in memory. *Psychological Review*, 95, 385-408.

Roediger, H. L. 1973. Inhibition in recall from cueing with recall targets. *Journal of Verbal Learning and Verbal Behavior*, 12, 644-657.

Sanchez-Casas, R., Davis, C. W., and Garcia-Albea, T. E. 1992. Bilingual lexical processing: Exploring the cognate/noncognate distinction. *European Journal of Cognitive Psychology*, 4, 293-310.

Scarborough, D. L., Cortese, C., & Scarborough, H. S. 1977. Frequency and repetition effects in lexical memory. *Journal of Experimental Psychology: Human Perception and Performance*, 3, 1-17.

Schreuder, R., & Weltens, B. (Eds.) 1993. *The Bilingual Lexicon*. Amsterdam/Philadelphia: John Benjamins Publishing Company.

Schwanenflugel, P. J., & Rey, M. 1986. Interlingual semantic facilitation: Evidence for a common representational system in the bilingual lexicon. *Journal of Memory and Language*, 25, 605-618.

Segalowitz, S., Segalowitz, N., & Wood, A. 1998. Assessing the development of automaticity in second language word recognition. *Applied Psycholinguistics*, 19, 53-67.

Shelton, J. R., & Martin, R. C. 1992. How semantic is automatic semantic priming? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18, 1191-1210.

Shimron, J., & Sivan, T. 1994. Reading proficiency and orthography: Evidence from Hebrew and English. *Language Learning*, 44, 5-27.

Sholl, A., Sankaranarayanan, A., & Kroll, J. F. 1995 Transfer between picture naming and translation: A test of asymmetries in bilingual memory. *Psychological Science*, 6, 45-49.

Smith, M. C. 1997. How do bilingual access lexical information? In A. M. B. de Groot & J. F. Kroll (Eds.) *Tutorials in Bilingualism: Psycholinguistic Perspectives* (chapter 5). Mahwah, NJ: Lawrence Erlbaum Associates.

Soares, C., & Grosjean, F. 1984. Bilinguals in a monolingual and bilingual speech mode: The effect of lexical access. *Memory and Cognition*, 12, 380-386.

Stenberg, G., Lindgren, M., Johansson, M., Olsson, A., & Rosen, I. 2000. Semantic processing without conscious identification: Evidence from event-related potentials. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 26, 973-1004.

Stern, C., Prather, P., Swinney, D., & Zurif, E. The time course of automatic lexical access and aging. *Brain and Language*, 40, 359-372.

Stroop, J. R. 1935. Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 18, 643-662.

Thomas, J. 1992. Metalinguistic awareness in second- and third-language learning. In: R. J. Harris (Ed.) *Cognitive Processing in Bilinguals* (pp. 531-545). Amsterdam: Elsevier Science.

Tokowicz, N. 2000. *Meaning representation within and across languages*. Unpublished dissertation, The Pennsylvania State University, University Park, PA.

Tokowicz, N., & Kroll, J. F. 1998. When is meaning accessed for second language words? It depends on what you mean. Paper presented at the International Linguistic Association, April, New York, NY.

Tokowicz, N., & Kroll, J. F. In Press. Accessing meaning for words in two languages: The effects of concreteness and multiple translations in bilingual production.

Tulving, E. 1972. Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.) *Organization of Memory*. NY: Academic Press.

Tzelgov, J. & Eben-Ezra, S. 1992. Components of the between-language semantic priming effect. *The European Journal of Cognitive Psychology*, 4, 253-272.

Tzelgov, J., Henik, A., & Berger, J. 1992. Controlling Stroop effects by manipulating expectations for color words. *Memory and Cognition*, 20 (6), 727-735.

Tzelgov, J., Henik, A., & Leiser, D. 1990. Controlling Stroop interference: Evidence from a bilingual task. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 16, 760-771.

Tzelgov, J., Henik, A., Sneg, R., & Baruch, O. 1996. Unintentional word reading via the phonological route: The Stroop effect with cross-script homophones. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 22, 336-349.

van Hell, J. 1998. Cross-Language Processing and Bilingual Memory Organization. Amsterdam: Universiteit van Amsterdam.

van Hell, J., & Dijkstra, T. Submitted. Foreign language knowledge can influence native language performance: Evidence from trilinguals.

van Heuven, W. J. B., Dijkstra, T., & Grainger, J. 1998. Orthographic neighborhood effects in bilingual word recognition. *Journal of Memory and Language*, 39, 458-483.

Watamori, T., & Sasanuma, S. 1978. The recovery processes of two English-Japanese bilingual aphasics. *Brain and Language*, 6, 127-140.

Weinreich, U. 1953. *Languages in Contact*. New York: Linguistic Circle of New York.

Williams, J. N. 1994. The relationship between word meanings in the first and second languages: Evidence for a common, but not restricted, semantic code. *European Journal of Cognitive Psychology*, 6 (2), 195-220.