

Cross-language lexical connections in the mental lexicon: Evidence from a case of trilingual aphasia

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Abstract

Despite anecdotal data on lexical interference among the languages of multilingual speakers, little research evidence about the lexical connections among multilinguals' languages exists to date. In the present paper, two experiments with a multilingual speaker who had suffered aphasia are reported. The first experiment provides data about inter-language activation during natural conversations; the second experiment examines performance on a word-translation task. Asymmetric patterns of inter-language interference and translation are evident. These patterns are influenced by age of language learning, degree of language recovery and use, and prevalence of shared lexical items. We conclude that whereas age of language learning plays a role in language recovery following aphasia, the degrees of language use prior to the aphasia onset and of shared vocabulary determine the ease with which words are accessed. The findings emphasize the importance of patterns of language use and the relations between the language pair under investigation in understanding lexical connections among languages in bilinguals and multilinguals.

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1. Introduction

When multilingual speakers experience difficulty producing a word they know during a conversation in one of their languages, they are often able to retrieve that target word in the “wrong” language. More often than not, the interfering language is *not* their first, most dominant, language. Rather, cross-language lexical interference is most often reported between two non-native languages. The unique status of one's native language, L1, has been identified in numerous studies and the distinction between the first-acquired language and later-learned languages has been emphasized (e.g., Birdsong, 1999; Gass & Selinker,

1992; Vaid, 1986). Indeed, research studies concerning the bilingual lexicon have explored the connections formed between L1 and L2 words and have addressed the hypothesis that L2 words are learned via the corresponding L1 words, rather than via direct links to the conceptual system. However, researchers have only recently begun to address analogous issues concerning the multilingual lexicon (e.g., de Bot, 2004; Goral & Obler, *in press*), and the lexical relations between two (or more) non-native languages have not been sufficiently examined. In this paper we report on a case study that provided us with the unique opportunity to investigate factors that determine cross-language lexical connections among words in the multilingual lexicon. We briefly review current models of lexical representation in bilingualism and outline the limitations of the data available thus far in answering questions about

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how lexical connections are formed in the mental lexicon of speakers of more than two languages. We then present two experiments we conducted with a multilingual speaker who had suffered aphasia and discuss how our data contribute to the understanding of multilingual language processing.

Extensive data from experiments conducted with bilingual speakers in the last few decades have led to the development of two competing models of how the bilingual lexicon is organized. The Revised Hierarchical Model (RHM), developed by Kroll and her colleagues, assumes separate but interconnected lexical representation of the first (L1) and the second (L2) languages (e.g., Kroll & Stewart, 1994). Crucially, the RHM captures the bidirectional and asymmetric relations between the two lexicons. That is, word forms in L1 are connected to their respective meanings from the time these words are first acquired. By contrast, word forms in L2 are first learned via their translation equivalents in L1; only with increased proficiency, are stronger connections between L2 words and conceptual representations formed. In this model, the connections in the direction from L1 words to L2 words are not as strong as those from L2 words to L1 words; such connections may develop over time. The RHM allows for dynamic, changing connections among the words of the first and second languages. The model does not specify a priori whether words from additional non-native languages, learned after L2, are connected in the lexicon via the L1 words or L2 words.

An alternative model of the bilingual lexicon, developed by Dijkstra and his colleagues, is based on a connectionist model of lexical representation (e.g., Dijkstra & van Heuven, 1998). In the Bilingual Interactive Activation (BIA) model, words are inter-connected within and across the two languages, with excitatory and inhibitory bidirectional connections between the word level and the letter level, as well as between the word level and the language level. As in the monolingual version of the model that serves as the basis for the bilingual model, the BIA represents word-recognition processes. In the BIA, lexical access is assumed to be language-non-selective and thus the integrated lexicon contains words from both languages. Indeed, Dijkstra and others have demonstrated in a series of studies that both languages are active during lexical access, even when only one of them is explicitly required by the task demands (e.g., Dijkstra, Timmermans, & Schriefers, 2000; Dijkstra & van Hell, 2003). Furthermore, Dijkstra has argued that the BIA can be extended to more than two languages (Dijkstra, 2003). He has developed the Multilingual Interactive Activation model (MIA) (Dijkstra, 2003; Dijkstra & van Hell, 2003), applying the same mechanisms and architecture that are assumed in the bilingual model. Dijkstra (2003) has acknowledged that increasing the lexicon size, by virtue of learning additional languages, leads to increased competition and neighborhood effects in the multilingual lexicon. He has demonstrated, however, that the number of neighbors that would be added to any given word by adding words from an additional language to

the existing representation should not significantly slow processes of visual lexical access.

A single, complex system of bilingual lexical representation has also been assumed in Kirsnet, Lalor, and Hird (1993). In this approach, the boundaries in the lexical system are not determined by language per se but by similarities of form and meaning among words. Thus one might expect more interlinking among lexical items of pairs of languages (such as English and French) that share many features (e.g., cognate words, orthographic system) than in pairs that share fewer (e.g., Hebrew and English).

The research evidence that has contributed to these models includes data from studies employing lexical-decision tasks, priming paradigms, and translation tasks. Translation tasks have received considerable attention in the literature on the bilingual lexicon and have yielded two main generalizations: Firstly, it has been demonstrated repeatedly that most speakers experience directional asymmetry in translation latency and that this asymmetry is associated with language proficiency. That is, translating from the more proficient language to the less proficient language is slower than translating to the more proficient language. Secondly, these latency differences decrease with increasing L2 proficiency (e.g., de Groot, Dannenburg, & van Hell, 1994; de Groot & Poot, 1997; Kroll & Dijkstra, 2002; Kroll & Stewart, 1994).

In addition, there is evidence suggesting that certain characteristics of stimulus words affect translation latency and accuracy. One group of words that have been extensively studied comprises cognates (i.e., translation-equivalent words that have similar form and meaning in two languages, such as *coffee* in English and *café* in Spanish). Cognates usually yield faster and more accurate responses than translation equivalents that are not cognates, that is, words that share their meaning but differ in form (such as *bread* in English and *pan* in Spanish) (e.g., de Groot, 1992). Another characteristic that affects performance pertains to specific semantic features of the word: concrete words are typically translated faster than abstract words. Furthermore, words that have more than one translation equivalent in the other language take longer to translate than words that have a unique translation equivalent (e.g., de Groot et al., 1994; van Hell & de Groot, 1998). Moreover, these two last findings are related in that for most language pairs, more concrete than abstract words have unique translation equivalents across the languages.

The rich data obtained thus far on bilingual word processing, therefore, have led researchers to hypothesize that the two lexicons of a bilingual speaker are interconnected and are both active, at least during word recognition. Furthermore, lexical, structural, and typological similarities or differences between language pairs influence representation and processing (e.g., Birdsong & Molis, 2001; Grosjean, 1998; Kirsnet et al., 1993). The BIA, for example, is based predominantly on data from speakers of Dutch and English, two languages that developed historically from the same language family and share many vocabulary items, as well as

orthography. Other research studies have examined co-activation of two languages of different typology and orthography (e.g., English and Hebrew in Gollan, Forster, & Frost, 1997; English and Chinese in Keatley, Spinks, & de Gelder, 1994). At least with respect to the relations between age of acquisition and later achieved level of proficiency, Birdsong and Molis (2001) have demonstrated substantial differences among matched groups of Spanish–English and Korean–Chinese speakers. The degree to which variables such as age of L2 learning, level of language proficiency, and patterns of language use influence bilingual processing, however, remains undetermined.

Examining the languages of multilingual speakers provides the opportunity to compare and contrast lexical connections between different pairs of languages in the same individuals, as well as to better understand connections among more than two languages. Yet, relatively little is known to date about lexical connections among three or more languages learned and used by multilingual speakers. In addition to anecdotal data on linguistic interference among non-native languages, a few research studies have begun to examine these relations (Goral, 2001; Lemhöfer, Dijkstra, & Michel, 2004). Both studies found initial evidence for direct lexical connections between two non-native languages; Lemhöfer and her colleagues for cognate activation during word recognition and Goral for non-cognate activation, which was modified by relative language proficiency.

In the present study, we utilized a unique opportunity to examine lexical relations among three languages of a multilingual speaker with aphasia via data from his performance in conversation and translation tasks.

2. The case

Our multilingual speaker, EC, a 46-year-old right-handed man, was born in the US but was exposed mostly to Hebrew in the three years prior to the time his family moved back to Israel, where Hebrew became his primary language. He learned English starting at age 10, in school, and started learning French on his own at age 16, from books and tapes. He spent one year studying in the United States prior to completing his doctoral work and earned his Ph.D. in physics in Israel. At age 25 he moved to Boston and completed post-doctorate work there, during which time he became fluent in spoken and written English. At age 27, he moved to Geneva and then to France, where he became fluent in spoken and written French. He reported that learning foreign languages was a hobby: in his twenties he studied German, Spanish, and Italian. At age 32, he started up a successful computer-animation business and at age 39, he moved to the United States with his family. At that time, he was fluent in English (spoken at work and in the community), French (spoken at home with his wife and daughters), and Hebrew (spoken occasionally with family and friends in Israel), and had functional knowledge of Spanish, German, and Italian.

At age 42, EC sustained a left MCA CVA following a left internal carotid artery dissection. Findings of a CT scan performed five days post onset were consistent with a left fronto-temporo-parietal infarct. At 11 months post onset (MPO), a speech-language evaluation revealed impairments in all language abilities, with language production more impaired than language comprehension skills. At 16 MPO, re-evaluation revealed non-fluent aphasia with good comprehension, moderate word-finding difficulty, and agrammatic language output. EC reported that his language ability was most impaired in French, less so in English, and Hebrew was the language that recovered first and showed the greatest improvement. Whereas his speech was only mildly agrammatic at the time we tested him (four years post the aphasia onset), it was slow and effortful, with much self-monitoring and self-correction (see evaluation below).

In the years post the aphasia onset, EC has continued to use French with his immediate family and English and Hebrew with friends. In addition to some months of speech-language therapy (mostly in English), he has spent many hours a day working with grammar books and dictionaries in a self-initiated program to improve his three languages. His relative impairment has remained greater in French than in English and Hebrew.

2.1. Language evaluation

A brief evaluation of EC's skills in each of the three languages was administered prior to the first study. Language evaluations were conducted in each language by native speakers. Portions of the Bilingual Aphasia Test (Paradis, 1987) were employed and the following subtests were administered: (I) Auditory comprehension: the examiner presents a sentence and the participant is asked to point to a picture (out of an array of 3 or 4) that matches the sentence (e.g., "The boy is holding the girl"). (II) Antonym selection: the examiner presents one word followed by a series of words (array of 3 or 4). The participant is asked to repeat the word that is the exact opposite of the target word (e.g., "young": "tall, old, green, small"). (III) Word and nonword repetition and lexical decision: the examiner presented a word (or a pseudo-word) and the participant is asked to repeat it and then judge whether it was a real word or a nonword (e.g., "ball", "flup"). (IV) Sentence repetition: the examiner presents a sentence and the participant is asked to repeat it. (V) Confrontation naming: the participant is presented with pictures of objects and actions and is asked to name them (e.g., "fork", "pray").¹ (VI) Sentence reading: the participant is asked to read sentences (e.g., "It is the truck that pulls the car"). (VII) Word translation: the examiner presents words in one language and the participant is asked to provide their translation equivalent in another (pre-specified) language. (VIII) Sentence

¹ We used pictures from the BDAE III for the naming subtest.

translation: the examiner presents sentences in one language and the participant is asked to provide their translation in another (pre-specified) language.

2.2. Evaluation results

EC's performance revealed mild impairment in Hebrew and English and mild-to-moderate impairment in French. Accuracy was generally good, but longer response latencies were noted when he experienced difficulty producing a response and especially during production of French. His output was characterized by frequent false starts, hesitations, and fillers, and by paraphasias and grammatical errors that were usually self-corrected. In French, auditory comprehension of syntax, sentence repetition, and confrontation naming yielded errors. In Hebrew and English, minor errors were noted on antonym recognition and confrontation naming (see Table 1).

EC demonstrated relatively greater difficulty on the translation subtests of the BAT, in all translation directions. On the word-translation subtests, he translated most concepts but often produced the incorrect part of speech, mostly adjectives instead of the target nouns (e.g., *brave* for *courage*, *beautiful* for *beauty*). Several of the items that yielded errors when EC was translating from one language to another (e.g., from English to French) yielded similar errors when he was translating between another pair of languages (e.g., from French to Hebrew). In the sentence-translation task, difficulty was noted in all translation directions; errors were predominantly grammatical, such as the use of incorrect tense, an active instead of passive sentence construction, and pronoun gender errors. Literal, word-by-word translation also contributed to grammatical and lexical errors in the translated-to language.

3. The studies

3.1. Study 1: Lexical interference in discourse

The first experiment we report was designed to examine patterns of lexical interference among EC's three languages during conversation. Identifying patterns of inter-language

Table 1
Evaluation results: Experiment 1

Subtest	French	English	Hebrew
Auditory comprehension	20/22 (91%)	22/22 (100%)	22/22 (100%)
Antonym selection	9/10 (90%)	9/10 (90%)	8/10 (80%)
Word/nonword repetition	12/12 (100%)	11/12 (92%)	12/12 (100%)
Lexical decision	11/12 (92%)	10/12 (83%)	12/12 (100%)
Sentence repetition	5/7 (71%)	7/7 (100%)	7/7 (100%)
Confrontation naming	25/30 (83%)	29/30 (97%)	27/30 (90%)
Sentence reading	9/10 (90%)	10/10 (100%)	9/10 (90%)
Word translation	E → F 6/10 H → F 7/10	F → E 8/10 H → E 8/10	F → H 6/10 E → H 10/10
Sentence translation	E → F 1/6 H → F 4/6	F → E 2/6 H → E 3/6	F → H 3/6 E → H 3/6

interference can help determine whether all languages of multilingual speakers are active during production in one target language.

3.1.1. Procedure

To systematically explore EC's inter-language interference patterns, we conducted 12 one-hour sessions of naturalistic conversation. Four one-hour sessions comprised conversations in French with a native speaker of French,² four were one-hour sessions in English with a native speaker of English, and four were one-hour sessions in Hebrew with a native speaker of Hebrew. Conversations were matched for the topics they addressed and included one topic that was English-biased, one French-biased, one Hebrew-biased (each of the three topics focused on events that happened to EC while being immersed in each of the three languages, respectively; see, for example, Schrauf & Rubin, 2000), and one topic that was assumed to have been well-rehearsed in all the languages (i.e., the history of EC's illness). The conversations were conducted in a pseudo-randomized order such that there were no two consecutive hours in the same language nor on the same topic. EC was instructed to not ignore or try to suppress any inter-language activation he might experience but rather to produce those words in the non-target language if they "came to mind" instead of the target word. The conversations were tape-recorded and subsequently transcribed. All instances of overt production in the non-target language, whether produced with or without EC's awareness, were tabulated. EC's awareness of instances of non-target production was determined in the following manner. If EC commented on his non-target production and/or proceeded to produce the target word, it was determined that he was aware of the interference. If, by contrast, he continued speaking without commenting on the interference or without correcting himself, it was determined that he was unaware of the interference. We note that EC generally was very aware of his language production, his word-finding difficulty, and the activation of words in the non-target language. His insights informed us throughout the experiments.

3.1.2. Interference results

Systematic tabulation of instances of interference revealed the following patterns (see Table 2 and Fig. 1; means are rounded to integers). Because of the relatively small number of interference errors, only descriptive results are included here. When collapsed across all conversations, English was most often the source of interference (accounting for 75.5% of all instances), French followed (with 17.6%), and Hebrew was the source of interference least often (with 6.9%). We then assessed the source of interference during the conversations in each of the three languages.

² The native speaker of French was an early bilingual, who was surrounded by French and English from infancy.

Table 2
Frequency of interference among the three languages

	Language of conversation			
	Hebrew	English	French	Total
# of instances of interference	14	18	70	102
<i>Language of interference</i>				
Hebrew		2 (11%)	5 (7%)	7 (6.9%)
Cognates		0 (0%)	0 (0%)	
Aware		2 (100%)	5 (100%)	
Eventually produced		1 (50%)	4 (80%)	
English	12 (86%)		65 (93%)	77 (75.5%)
Cognates	0 (0%)		41 (48%)	
Aware	11 (92%)		59 (91%)	
Eventually produced	8 (57%)		54 (83%)	
French	2 (14%)	16 (89%)		18 (17.6%)
Cognates	0 (0%)	1 (6%)		
Aware	1 (50%)	15 (94%)		
Eventually produced	1 (50%)	12 (75%)		

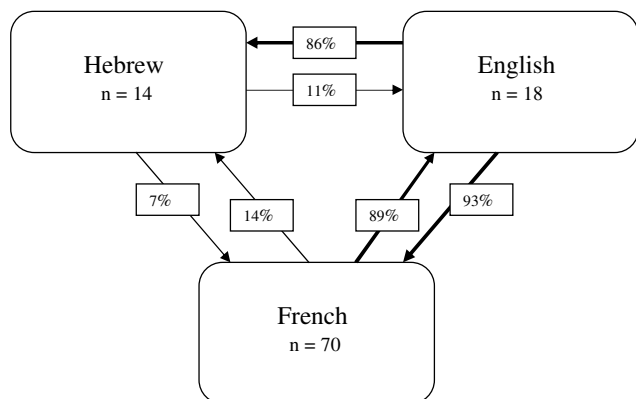


Fig. 1. Percent instances of interference between each language pair.

3.1.2.1. Conversations in French. When conversing in French, EC experienced a great deal of interference and inter-language activation (the mean number of instances per hour was 23, with a range of 21–25 and a total of 70). For example, he produced *translation* for *traduction*; *small* for *petit*; *sometimes* for *parfois*; *between* for *entre*; *basic words* for *mots basiques*. EC was usually aware of the interference (91% of the time) and in all but 17% of the tabulated instances, the target word was eventually produced. Ninety-three percent of the instances of inter-language activation were English words and only 7% of the time was the inter-language activation from Hebrew. Of the English interference instances, 48% were cognate words (e.g., *hôpital*–*hospital*).

3.1.2.2. Conversations in English. When conversing in English, EC experienced little interference (the mean number of instances per hour was 4.5, with a range of 2–8 and a total of 18). Eighty-nine percent of the instances were French words and only 11% of the time was the inter-language activation from Hebrew. In several instances, a French inter-language activation was followed by a Hebrew one.

Examples include *lit* for *bed*; *sale* for *dirty*; *seul* for *alone*; *c'est tout* for *that's all*. Of the instances of English activation, only one was a cognate of the target word (*butcher*–*boucher*). The target word (or phrase) was eventually produced in 75% of the instances and EC was usually aware of the interference (94% of the time).

3.1.2.3. Conversations in Hebrew. When conversing in Hebrew, EC experienced very little interference (the mean instances per hour was 3.5, with a range of 2–5 and a total of 14). More than 86% of the instances of inter-language activation were English words and 14% (2 instances) were French. For example, he produced *bridge* for *גשר* [gesher]; *great* for *עצום* [atsom]; *but* for *אבל* [aval]. EC was aware of all instances except two (the English *no* for the Hebrew *לא* [lo] and the French *non* for the Hebrew *לא* [lo]). The target Hebrew word was eventually produced 50% of the time. None of the interfering words was a cognate of the target word.³

The pattern of interference we found (depicted in Fig. 1) demonstrated that, whereas in normal conversation, EC was usually able to voluntarily inhibit production in a language that would not be appropriate in the conversational context, when asked to not inhibit inter-language activations he experienced instances of translation-equivalent activation in the non-target languages. Evidence for inter-language activation was found most often when speaking in the least recovered language, French, and least in the most recovered languages, Hebrew and English. During conversations in French, English was the most activated language whereas during the English conversations, predominantly French, but also Hebrew, were activated. During the Hebrew conversations, inter-language activation was predominantly from English. The frequency of interference did not appear to be affected by the topic of the conversation (with the exception of a discussion of French food that yielded relatively more instances of French interference during Hebrew and English production). Inter-language activations were mostly nouns, adjectives, and to a lesser degree, adverbs and function words; only a few verbs were activated in a non-target language. Over 90% of the instances were single words but a few phrases were also activated. The small number of instances in Hebrew and English precluded a comparison of the distribution of different word types among non-target words in the three languages.

It is interesting to note that while inter-language activation accompanied instances of word-finding difficulties, it did not usually correspond to a lack of knowledge of (or

³ Though cognates between Hebrew and English and Hebrew and French do exist, they are rarer than cognates between English and French and include primarily relatively recent borrowing (e.g., *television*–*טלוויזיה* [televizia]). There are also cognates that are words that were borrowed into Hebrew as well as into French and English from another source, for example in the early Middle Ages from Arabic or Greek (e.g., *algebra*, *dogma*).

permanent inability to access) a target word. Evidence for this can be found in examples such as the activation of *petit* from French during English conversation and *little* from English during French conversation, as well as the activation of highly common words that are clearly in EC's recovered lexicon (e.g., the Hebrew אַבָּל [aval] for *but* and the French *et* for *and*). This is, of course, not surprising, given the hypothesis that it is access to language production, not language knowledge, that is impaired in non-fluent aphasia.

3.1.3. Discussion

The first experiment was designed to assess spontaneous inter-language activation during production in the three languages of a multilingual speaker who had acquired aphasia. Instances of inter-language activation were examined during conversations in each of EC's three dominant languages. Words that EC produced in a non-target language rather than in the target language, as well as those he produced while searching for the target word (during a word-finding pause) were counted. These inter-language interference errors were taken as evidence for activation of the equivalent word in a non-target language and, indirectly, as evidence for the strength of lexical connections among the three languages. Examining the frequency and language source of inter-language interference during language production, we found that most instances of inter-language interference occurred during production in the language that recovered least. That is, while speaking French, the language in which production was still difficult for EC, the other two languages were active.

Moreover, whereas both English and Hebrew were better recovered than French, the majority of the instances of inter-language interference during French production were from English words. That interference from English was more frequent than interference from Hebrew during French production can be attributed to at least three variables. One is the relatively larger vocabulary English and French share. Secondly, whereas Hebrew was EC's first-acquired language, both English and French were learned formally and later in childhood (except for minimal exposure to English at a very young age). Furthermore, English and French were spoken daily at the time of the aphasia onset, whereas Hebrew was used only infrequently at that time.

In addition, such cross-language activation during conversation can occur intentionally or unintentionally. It can reflect a strategy that the speaker may use to cope with word-finding difficulty, consciously accessing equivalent words in other languages in an attempt to facilitate the production of the target word. This is consistent with EC's self-report of using word translation as a deliberate strategy to resolve instances of word-finding problems. We examine this possibility and EC's translation skills further in the second experiment we report below. By contrast, words in the non-target language(s) can be activated unintentionally and automatically. Activated non-target words

may then fail to be inhibited, leading to cross-language interference. This is consistent with the non-selective language access found in recognition tasks (e.g., Dijkstra et al., 2000) and with patterns of unintentional code-switching during language production (e.g., Zentella, 1997), especially when the interlocutors are not monolinguals. Indeed, EC was aware of the fact that his interlocutors were bilinguals and knew what languages each of his interlocutors understood (e.g., the French interlocutor did not understand Hebrew).

During Hebrew production, most of the non-target words produced were English words. We might expect more frequent interference from English than from French during Hebrew production because English was better recovered than French. By contrast, recovery level cannot explain why during English production, the majority of inter-language interferences were from French, not from Hebrew. We will return to this interaction between level of recovery and the shared lexical items or non-first-language status in Section 4.

Because we counted only overt inter-language interference and because of the metalinguistic nature of the task, we postulate that the number of instances of inter-language activation (whether resulting in overt production or not) is likely underestimated in our results.⁴ Moreover, in the present protocol we were able to take advantage of observing inter-language activation during natural conversation, but we were unable to control for the materials (e.g., comparability among the three languages, word characteristics) or to unequivocally determine what the target item intended by EC was in each instance. In the second experiment, reported below, we employed a word-translation test that enabled us to control the stimuli across the three languages and obtain objective measures of accuracy and response latency.

3.2. Study 2: Word translation

The second study⁵ focused on lexical-retrieval performance during a word-translation task. Accuracy and response latency served as measures of the relative activation and inhibition of inter-language translation equivalents. On the basis of previous findings with neurologically healthy bilinguals we expected that differential recovery levels might be reflected in asymmetric translation performance between pairs of languages. We also predicted that if lexical representation did not change following the onset of aphasia, EC would demonstrate the differential performance by stimulus type found with neurologically healthy individuals.

⁴ Indeed, EC reported that in the more difficult French conversations, because interference occurred so frequently, he may have missed reporting some instances to convey what he wanted to express.

⁵ The translation study was administered approximately eight months after the conversation study. EC reported no substantial change in his relative language abilities in the interim nor did we observe any.

3.2.1. Stimuli and procedure

A list of single words was presented blocked by language pairs in six translation conditions: Hebrew-to-English, English-to-Hebrew, Hebrew-to-French, French-to-Hebrew, English-to-French, and French-to-English. In each translation direction, three stimulus-type comparisons were included as follows: The first comparison comprised concrete versus abstract words (e.g., *hammer*—פטיש [patish] versus *truth*—*vérité*; or *memory*—זיכרון [zikaron]); the second consisted of cognates (e.g., *palace*—*palais*; *student*—סטודנט [student]) versus non-cognate (concrete) words; the third comprised words that have a unique translation equivalent in the target language versus words that have multiple translation equivalents in the target language (e.g., *nail*—ongle/clou; *airplane*—מטוס\אווירון [matos/aviron]). Cognate words were defined as two words from two languages that had similar meaning and shared at least 70% of their phonological form (measured by syllables) (see Roberts & Deslauriers, 1999). Stimulus type was determined by one of the authors (MG) and was independently judged by another author (EL). The two stimulus sets in each comparison were matched for word frequency using the English frequency per million values from the CELEX written frequency list. For the complete list of the stimuli, see Appendix A.

Each word was presented visually at the center of a computer screen. EC was instructed to say aloud a single-word translation for each stimulus as quickly and accurately as he could. (A single word was accepted as a correct response even for stimulus words that had more than one translation equivalent). There were 12 blocks, two 32-word blocks in each source-target language pair. Before each block, the examiner reminded EC of the target language for that block and reiterated the instructions in that language, in an attempt to establish the language set. As in the first study, the language blocks of the experiment were administered by the native speaker of the target language. All responses were tape-recorded and digitized.

3.2.2. Results

Accuracy and latency of translation were tabulated for each item in each sub-list. An accurate response was defined as an acceptable translation of the presented word (judged by the bilingual examiner and verified in a dictionary when needed). Response latencies were measured (in milliseconds) using the computer software Sound Forge (Sony). An independent judge, blind to the predictions of the experiment, measured the duration between the presentation of the written word (marked by a tone on the sound file) and the onset of EC's response. Only latencies for correct responses and responses that were produced without circumlocutions or self-corrections were measured. To examine the effects of translation direction and stimulus type on response accuracy and response times (RT), we conducted non-parametric (Mann–Whitney rank test) analyses.

3.2.2.1. Accuracy. Overall accuracy was high (mean accuracy = 88%) in all translation directions for all stimulus types (see Table 3). A Mann–Whitney test revealed no significant differences for the translation direction in each language pair nor for any of the stimulus-type comparisons (all p 's > .1).

3.2.2.2. Response time

3.2.2.2.1. Translation direction. The comparison between the two translation directions for each language pair revealed RT differences when translating from Hebrew to English versus from English to Hebrew (see Fig. 2) as well as when translating from Hebrew to French versus from French to Hebrew (see Fig. 3), and no differences between translating from English to French and French to English (see Fig. 4). A Mann–Whitney rank test revealed longer RTs for translating from Hebrew to English than from English to Hebrew for cognate words ($n = 15$, $m = 14$, $Z = -2.95$, $p = .04$) and for words with multiple translation equivalents ($n = 14$, $m = 12$, $Z = -2.16$, $p = .03$). The pattern held for concrete words, as well, but did not reach statistical significance. Translating from Hebrew to French appeared to be slower than translating from French to Hebrew for all stimulus types; the difference was statistically significant for words with multiple translation equivalents ($n = 13$, $m = 12$, $Z = -2.28$, $p = .02$). There were no significant differences between translation from English to French or from French to English.

3.2.2.2.2. Stimulus type. Whereas the abstract words yielded longer RTs in most translation directions (see

Table 3
Percent accuracy in the six translation directions and four stimulus types

	Abstract (%)	Concrete (%)	Cognates (%)	Multiple translation equivalents (%)
Hebrew to English	73	100	94	93
English to Hebrew	93	100	88	80
Hebrew to French	60	100	100	81
French to Hebrew	87	100	100	75
English to French	87	87	87	73
French to English	87	87	93	80

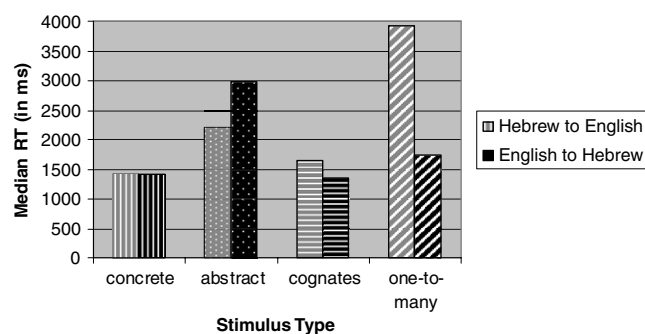


Fig. 2. Translating from Hebrew to English versus from English to Hebrew.

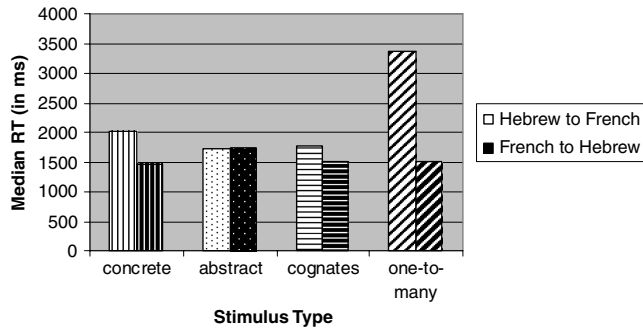


Fig. 3. Translating from Hebrew to French versus from French to Hebrew.

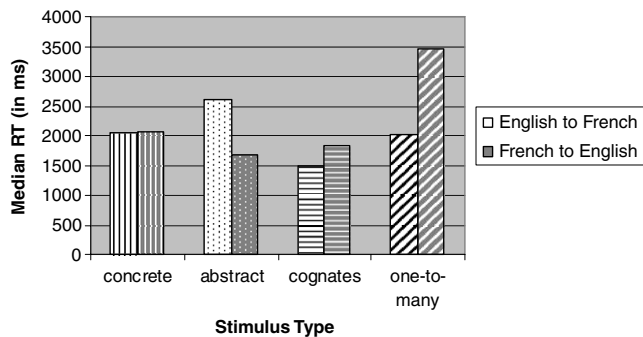


Fig. 4. Translating from English to French versus from French to English.

Fig. 5), a Mann–Whitney test revealed that the difference between concrete and abstract was only significant in the English-to-Hebrew translation direction ($n = 14, m = 15, Z = -2.18, p = .029$). The RT difference between cognate and non-cognate (see Fig. 6) was not significant in any translation direction for any language pair. The difference between words that had one translation equivalent and those that had multiple translation equivalents (see Fig. 7) was marginally significant only for translating from Hebrew to French ($n = 10, m = 13, Z = -1.92, p = .055$).

3.2.3. Discussion

In the second experiment, response accuracy and latency in a word-translation task were examined. The task included six translation-direction conditions (translating between

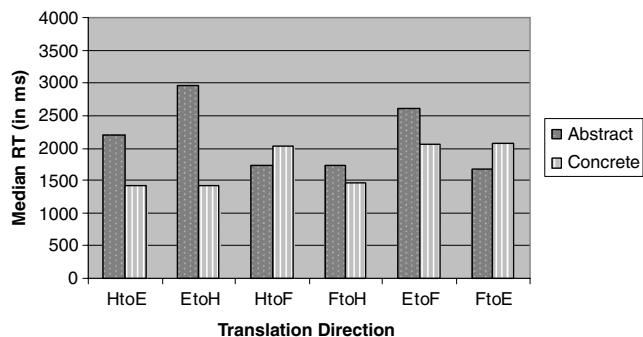


Fig. 5. Translating abstract versus concrete words.

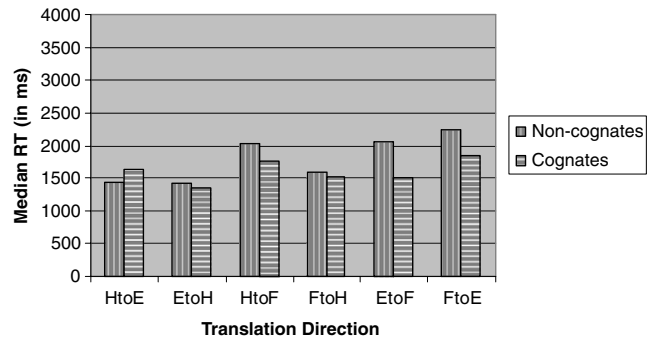


Fig. 6. Translating cognate versus non-cognate words.

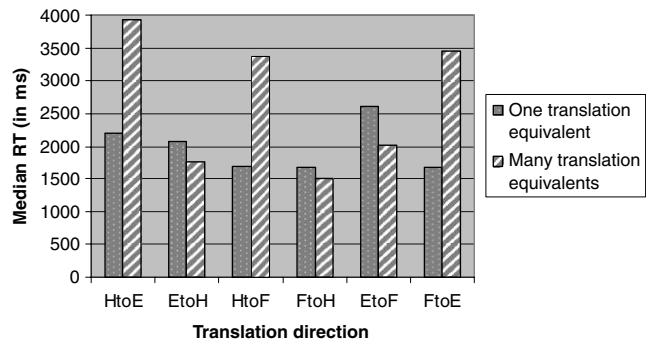


Fig. 7. Translating words with one versus multiple translation equivalents.

words in each language pair) and the stimuli allowed for three comparisons (concrete versus abstract words, cognates versus non-cognate words, and one versus multiple translation equivalents). Accuracy was high overall and significant differences were not observed but differential response latencies were obtained depending on the translation direction and the stimulus type.

3.2.3.1. Translation direction. When we compared response latencies between each language pair, we found that EC demonstrated longer RTs when translating from Hebrew to French than in the reverse direction, from French to Hebrew. This was consistent with the fact that, according to both the language evaluation and EC’s self-report, French was his least-recovered language (as one would predict that translating into a better-recovered language should be easier than translating into a less-recovered language). On the basis of this differential degree of recovery, however, we would have also expected longer RTs when EC translated from English to French than from French to English. Instead, we found comparable RTs in these two translation directions. Also unexpected was the finding of asymmetric latencies between Hebrew and English, because both languages showed virtually comparable recovery levels.

3.2.3.2. Stimulus type. We found that stimulus type interacted with the response-latency performance on this

translation task. First we examine the comparison between cognate and non-cognate words. Cognate words have been previously found to behave differently from non-cognates in bilinguals' performance on primed and unprimed lexical-decision and naming tasks (e.g., Costa, Caramazza, & Sebastian-Galles, 2000; Kirsnet et al., 1993; Van Hell & Dijkstra, 2002), as well as on translation tasks (e.g., de Groot et al., 1994). One hypothesis is that cognates are represented differently from non-cognates in the lexicons of bilingual speakers. We found that cognate words yielded relatively short translation latencies, but not shorter than concrete non-cognate words did. It should be noted vis-à-vis our stimulus set that cognate words have quite a special status among the specific languages used in the study. Namely, cognate words among Hebrew, French, and English are often of Latin or Greek origin and of high register. Comparing cognate effects between language-pairs that do and do not share cognates in their core vocabularies would help disentangle these effects.

In contrast to previous studies with neurologically intact bilinguals (e.g., de Groot & Hoeks, 1995), we did not observe significant difference in response times to concrete versus abstract words. Although the same pattern of longer response times to abstract than to concrete words held in all six translation directions, the difference was significant only in one (from English to Hebrew). This could be the consequence of our selection of abstract words that had unique translation equivalents. It has been hypothesized that the reason for longer RTs obtained for abstract words can be, at least in part, due to the tendency of abstract words to not be completely equivalent across languages (e.g., Kroll & Tokowicz, 2001). When the number of translation equivalents was controlled in this stimulus set (and there were no differences between the abstract and concrete words in word frequency or length), no RT difference between abstract and concrete words was obtained. Consistent with this account, we found that the effect of multiple translation equivalents was significant at least in one translation direction (from Hebrew to French, arguably one of the most difficult conditions for EC).

We turn now to a discussion of the factors that may have contributed to the pattern of results of the two experiments and their relevance to multilingual lexical processing.

4. General discussion

Reports of cross-language interference among the non-native languages of multilingual speakers suggest complex lexical connections among them. Yet, to date, there is little research evidence for the nature of these relations and the variables that influence them. In a unique opportunity to study lexical interference and word translation in a highly proficient multilingual speaker who had suffered aphasia, we examined the effects of four variables on the lexical connections between words in the multilingual lexicon. We considered the influence of age of language learning, degree

of language recovery, lexical similarities, and language use on the degree of inter-language activation during language production (Study 1) as well as on the ease of translating words from one language to another (Study 2). Recall that our speaker acquired Hebrew as his first language and learned English and French later in childhood (with minimal early exposure to English in early childhood and daily exposure to both non-native languages in adulthood). In adulthood, he had suffered a stroke, resulting in aphasia that affected his three languages. At the time of his aphasia onset, EC's proficiency was reportedly very high and comparable in all three languages; English and French were used daily, whereas Hebrew was used rarely. We discuss below the degree to which each variable alone and their interaction account for our data.

4.1. Age of language learning

On the basis of the age of language learning, one would predict better performance in Hebrew, EC's first language, than in the other two languages. This was indeed the case when we compared the translation latencies from Hebrew to English or French versus from English or French into Hebrew. That is, translating to Hebrew yielded faster RTs than translating from Hebrew. (We assume that this is the result of the production effort in the target language, rather than of difficulty processing the source language. This assumption is also supported by the small number of instances of inter-language activation during Hebrew production found in Study 1.) Also consistent with an age-of-learning explanation, at the early stages of language recovery, EC's Hebrew skills appeared to be improving to a greater extent than his English and French skills, despite the fact that Hebrew was used rarely in the years before the aphasia onset.

The first-language advantage observed in the present case is predicted by Ribot's (1882) "rule", that the language that was learned first was less likely to be affected in aphasia. This is in contrast to Pitres, (1985) prediction, that it is the language most used at the time of the aphasia onset that is less likely to be affected. Support for Pitres' "rule" was found in the pattern evidenced in bilingual and polyglot individuals with aphasia described in Obler and Albert (1977). Obler and Albert demonstrated that across 106 cases reported previously in the literature, virtually all of which reported differential recovery of the two or more languages, it was the language that had been used most around the time of the aphasia onset that had greater than chance likelihood of being less impaired and better recovered. EC's results do not conform to this pattern. It may be that the unusual cases in which an L1 did not recover first (or faster) were more striking and thus selectively published, accounting for the Obler and Albert results. Only examining a series of unselected, consecutive cases of bilingual aphasia would tell us whether EC's pattern of recovery is, indeed, unusual or not.

4.2. Degree of language recovery

In addition to having Hebrew as his first language, EC's relatively good recovery in Hebrew could in itself account for his relative ease in translating from English and French into Hebrew. Degree of recovery could also account for the pattern of inter-language activation obtained during Hebrew production, whereby there were more instances of interference from English, the better recovered of the two non-native languages, than from French. However, on the basis of degree of recovery, one might have also predicted symmetric translation latencies between the two better-recovered languages, Hebrew and English, and asymmetric latencies between English and French. This is clearly not the pattern of translation performance we found in this study. We therefore conclude that the degree of recovery can account for some, but not all, of our results.

4.3. Lexical similarities and language use

Among the three languages of our speaker, two—English and French—share a sizeable vocabulary, whereas the third language, Hebrew, is of a different language family and shares only few words with the other two languages, mostly as a result of borrowings. The symmetric response latencies for translating words from English to French and from French to English, as well as the tendency for inter-language activations between these two languages, point to robust lexical connections between the two languages. Stronger lexical connections between two languages that share portions of their vocabularies may have been what determined the activation of French, not Hebrew, during English production, and the symmetry in the translation latencies between English and French despite their different recovery levels.

Alternatively, these patterns of results between French and English can be accounted for by the facts that these two languages were learned formally and had been the ones used regularly before the time of the aphasia onset. The relative contribution of these three factors—the amount of use of English and French, their being both non-L1 languages learned initially in a formal fashion, and the degree of lexical similarity between them—to the lexical connections between the languages cannot be determined on the basis of the current data.

4.4. The multilingual lexicon

What, then, can we conclude concerning the lexical connections between the first language and two additional languages in the multilingual lexicon? Whereas there were fewer instances of inter-language activation during English production than during French production (consistent with degree of recovery), the inter-activation between these two languages was stronger than the inter-activation between each of these two non-native languages and Hebrew,

EC's L1. Resilient lexical connections between two non-native languages that share orthography and vocabulary were manifested in both experiments: there was more interference from French to English than from Hebrew to English and there were symmetric translation patterns between English and French.

These results lead us to suggest that a third language (L3) may be learned in connection with a previously learned non-native language (L2), and thus develop strong lexical connections with that language. These connections can be detected even in the presence of a language deficit resulting from aphasia. As mentioned, we are unable, on the basis of the present case, to dissociate whether the strong connections between English and French are due to their status as non-native languages, their being used regularly at the time of the aphasia onset or their shared vocabulary. We can, however, posit that any or all of these factors contributed to sustained ties between words in the two languages. Presently, models of the bilingual (or multilingual) lexicon do not incorporate all of these factors in their assumptions. Whereas both the RHM and the BIA distinguish the representation of the first language and the second (non-L1) language of bilinguals, only the RHM explicitly considers language proficiency as a variable that determines lexical connections; our data suggest that proficiency contributes significantly to performance. Furthermore, the BIA and the assumption of language non-selective access are based predominantly on evidence from languages that share substantial vocabulary and orthography, but explicit predictions about more distant languages are not made; our data suggest that relative distance on these measures may play a role in trilingual lexical representation and processing. Finally, neither model directly addresses patterns of language use, nor the potential interaction among these variables. These considerations will likely shape future models of the multilingual lexicon. Furthermore, future neuroimaging research may help determine the interplay among the variables identified in the current study.

Although a thorough discussion of findings from neuroimaging studies with bilinguals and multilinguals is beyond the scope of this paper, we note that recent neuroimaging studies of bilinguals support overlapping language representations, at least for proficient bilinguals (for reviews see Abutalebi, Cappa, & Perani, 2001; Goral, Levy, & Obler, 2002; Vaid & Hull, 2002). However, translating from one language to another as well as switching from production in one language to another, have been found to require additional effort on the speakers' part, suggesting separate processing for the two languages at some level (Hernandez, Dapretto, Mazziotta, & Bookheimer, 2001; Price, Green, & von Studnitz, 1999). Only a few imaging studies have employed multilingual speakers (e.g., Yetkin, Yetkin, Haughton, & Cox, 1996) and their findings suggest that degree of language proficiency plays a role in language representation and processing in the brain.

4.5. *Lexical connections and multilingual aphasia*

One source of evidence that has been used to understand the degree of interconnection and separation of the languages of bilinguals and multilinguals is data from polyglot aphasia (Albert & Opler, 1978; Fabbro, 1999; Paradis, 2004; Vaid, 1986). Studies that examine the full range of language abilities of individuals with aphasia can explore the relative difficulty they experience in each of their languages, as compared to their pre-morbid language proficiency profile. In some instances, the difficulties in one language (or more) may not meet predictions based on pre-morbid proficiency. Such a discrepancy might suggest selective deficit of a particular language or set of languages. In a number of publications, Paradis has identified patterns of non-parallel language impairment of two or more languages that differed from what would be expected on the basis of the speaker's pre-onset skills (e.g., Paradis, 1977, 1993, 2004). The lexical relations among the languages of individuals with polyglot aphasia, however, have been the focus of fewer studies.

Those studies of aphasia that focused on lexical skills are of particular pertinence to our study. Several studies have demonstrated that bilingual individuals with aphasia perform better on cognate words than on non-cognates, similarly to healthy bilinguals. This was found in a lexical-decision task (Kohnert, 2004; Lalor & Kirsner, 2001) as well as in picture naming (Lalor & Kirsner, 2001; Roberts & Deslauriers, 1999). Furthermore, few studies with bilingual speakers who have acquired aphasia examined lexical performance via translation tasks. These studies have yielded conflicting results. On the one hand, increasing ability to translate into a language was found to be associated with increasing lexical-production ability in that language (Aglioti, Beltramello, Girardi, & Fabbro, 1996; see also Paradis, 1987). On the other hand, in at least one case study, an inverse relation between the ability to produce words in a language and the ability to translate into that language has been reported (Paradis, Goldblum, & Abidi, 1982). The individuals discussed in the two studies differed in several respects; for example, Aglioti et al.'s participant was a 68-year-old woman who spoke Venetan, the Veronese dialect of Italian, as her L1 and standard Italian as her L2. She suffered a stroke yielding a subcortical lesion (involving the basal ganglia) resulting in non-fluent aphasia. By contrast, the participant of Paradis et al. was a younger (48-year-old) right-handed woman whose L1 and L2 were more dissimilar languages (she was born in Morocco and acquired French as her L1, then learned Classical Arabic as L2 at age 10 and spoken Arabic at age 21). The two participants also differed in the etiology and type of their lesion: Paradis et al.'s participant suffered a moped accident, resulting in right temporo-parietal fracture. Thus, the relation between lexical access for naming and lexical access for translation remains unclear.

In addition, recent studies have examined the influence of the improvement of lexical-access processes in one

language on lexical-access processes in the other language in bilingual speakers with aphasia. Findings show that improving naming ability in L2 leads to improvement in naming ability in L1. Such transfer of skills, however, may not occur in the reverse direction, that is, improvement in lexical production in L1 may not transfer to improvement in L2 (Edmonds & Kiran, *in press*). This is consistent with the asymmetric lexical connections outlined in the RHM in that L2-to-L1 word connections are assumed to be stronger than the connections from L1 to L2 words. Again, however, stimulus type may have played a role in these results: Kohnert (2004) reported on treatment gains in each of the two languages of a bilingual person with non-fluent aphasia and the interaction between the generalization of treatment across languages and certain word characteristics. Specifically, when naming was the target of the treatment, generalization of improvement from L1 (Spanish) to L2 (English) was observed, but only for cognate words. Non-cognate translation equivalents did not show significant improvement in English following treatment in Spanish (in her study, generalization from L2 to L1 was not examined). These data further suggest the unique status of cognate words in the bilingual lexicon and are consistent with the language-non-selective processing posited in the BIA, possibly only for words that share both meaning and form features. In the present data, we found evidence for this special status of cognate words in Study 1 but not in the translation latencies in Study 2.

The data obtained in the present studies suggest the existence of lexical connections between non-native languages, independent of their connections to L1. Furthermore, multilingual lexical connections appear to be determined by language- and speaker-specific characteristics, including not only the often-considered age and manner of language learning, but also the less-addressed relative degree of shared vocabulary and recent language-use patterns. We conclude that pre-morbid patterns of inter-language lexical connection can remain potent in the presence of aphasia.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.bandl.2006.05.004.

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