Bilingualism: Language and Cognition: page 1 of 20 © Cambridge University Press 2017 doi:10.1017/S1366728917000645

Target accessibility contributes to asymmetric priming in translation and cross- language semantic priming in unbalanced bilinguals*

YISRAEL SMITH
Bar Ilan University
JOEL WALTERS
Bar Ilan University
ANAT PRIOR
University of Haifa

(Received: June 30, 2016; final revision received: October 23, 2017; accepted: November 02, 2017)

The current study examined within- and cross-language connectivity in four priming conditions: repetition, translation, within-language semantic and cross-language semantic priming. Unbalanced Hebrew–English bilinguals (N = 89) completed a lexical decision task in one of the four conditions in both languages. Priming effects were significantly larger from L1 to L2 for translation priming and marginally so for cross-language semantic priming. Priming effects were comparable for L1 and L2 in repetition and within-language semantic priming. These results support the notion that L1 words are more effective primes but also that L2 targets benefit more from priming. This pattern of results suggests that the lower frequency of use of L2 lexical items in unbalanced bilinguals contributes to asymmetrical cross-language priming via lower resting-level activation of targets and not only via less efficient lexical activation of primes, as highlighted by the BIA+ model.

Keywords: priming, frequency, BIA, RHM, cross-language, within-language

Introduction

The bilingual lexicon maps concepts onto words in both languages, creating a complex structure of conceptual and lexical links within and between the first language (L1) and the second language (L2). Although much research has investigated directionality of connections BETWEEN bilinguals' two languages (Kroll, Van Hell, Tokowicz & Green, 2010; Basnight-Brown, 2014), less research has compared the INTERNAL connectivity of each of the two languages. The current study examines cross-language directionality and within language-connectivity using repetition, translation and semantic priming.

The two languages of proficient bilinguals rely on shared resources and representations (e.g., French & Jacquet, 2004; Kroll & Tokowicz, 2005). Numerous studies have shown that conceptual representations are likely shared across the two languages (Duñabeitia, Perea & Carreiras, 2010; Francis, 2005), though in the early stages of L2 acquisition L2 lexical items might have weaker connectivity to this shared semantic information (Jiang, 2000, 2002; Grainger, Midgley & Holcomb 2010). However, what still remains unclear is the degree to which both languages of proficient bilinguals might access conceptual representations in a parallel manner. Specifically, does the interconnectivity of L1 words and meanings mirror that of their L2 translation equivalents, or are there unique aspects of connectivity for each language? Further, a bilingual's languages might differ not only in the pattern of connectivity, but also in the strength of inter-item links. For example, reduced frequency of use for the less dominant L2 in unbalanced bilinguals might lead to weaker links between words in L2 in comparison to links between words in L1 (Gollan, Montoya, Cera & Sandoval, 2008). In empirical terms, these questions can be investigated using priming methods. Specifically, would semantically related primes in L1 and L2 be equally effective at activating a given target word? Based on previous research and the weaker links hypothesis (Gollan et al., 2008), it is possible that due to the lower frequency of L2 use, prime words in L2 might lead to lower activation of related words in L2.

Current models of the bilingual lexico-semantic system approach this issue from different perspectives. According to the Revised Hierarchical Model (RHM, Kroll & Stewart, 1994; see also Kroll et al., 2010), L2 words have weaker connections to concepts than do L1 words. In low proficiency bilinguals, conceptual access for L2 words might be mediated through L1 words. In contrast,

* The authors thank Andrei Markus for programming assistance and Nachshon Korem for help in data collection and coding. The research was supported by EU-FP7 Grant IRG-249163 to AP, and by the Edmond J. Safra Center for the Study of Learning Disabilities at the University of Haifa.

Address for correspondence:
Anat Prior, Edmond J. Safra Brain Research Center, Faculty of Education, University of Haifa, Mount Carmel, Haifa, Israel
aprior@edu.haifa.ac.il

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

according to the Bilingual Interactive Activation model (BIA+, Dijkstra & van Heuven, 2002), a model of bilingual visual word recognition, word frequency is the primary underlying processing mechanism. Information is passed up the model, with each node and level being activated on the basis of the frequency of its input. Frequency of use directly affects and determines resting-level activation levels such that less frequently used words have lower resting-level activation than more frequently used words (McClelland & Rumelhart, 1981). Since unbalanced bilinguals use the L2 less frequently, input coming from L2 takes longer to activate the low resting-level activation nodes. Dijkstra and van Heuven (2002) refer to this as the temporal delay hypothesis. Lexical access for L2 would then be slower not because the L2 word accesses meaning through the L1, as suggested in the original RHM (Kroll & Stewart, 1994), but rather because the L2 word has a lower resting-level activation (see also Gollan et al., 2008; Gollan, Slattery, Goldenberg, Van Assche, Duyck & Rayner, 2011).

Frequency has also been shown to affect resting-level activation of target words in classic priming studies with monolinguals. Specifically, lower frequency target words benefited more from priming than higher frequency targets (Becker, 1979; Stone & Van Orden, 1992). In the current study we explore whether this idea could be extended to the mechanisms of the BIA+ model.

Lexical priming experiments have shown support for both the RHM and the BIA+ models. Gollan, Forster, and Frost (1997) in a study with Hebrew–English bilinguals, found greater translation priming effects from L1 to L2 than in the reverse direction, despite the marked difference in the orthographies of the two languages. The authors state that these results fit well with the RHM, as the L1-L2 direction is conceptually mediated, which allows for full activation of the concept by the L1 prime, thus providing strong priming for the L2 target. The L2-L1 direction, on the other hand, does not produce strong priming because the L2 prime only partially activates conceptual representations of the word.

Basnight-Brown and Altarriba (2007) also found greater translation priming in the L1-L2 direction. In addition, they examined cross-language semantic priming, and found priming only in the L1-L2 direction, and even this disappeared under masked conditions. This finding would seem to indicate that L2 words might activate conceptual representation only to a limited degree, which is insufficiently strong to activate semantically related words across languages. These results were largely replicated by Schoonbaert, Duyck, Brysbaert and Hartsuiker (2009) who reported significant translation and semantic priming in both directions in Dutch–English bilinguals; though semantic priming effects were weaker. In both cases, priming was asymmetric (stronger from L1 to L2 than the reverse), leading the authors to conclude that these differences were of a quantitative and not a qualitative nature. As such, the authors suggest that the Distributed Representation Model (DRM) model (van Hell & de Groot, 1998) best explains the results of their study. The DRM accounts for greater facilitation in translation priming than in semantic priming by specifying a spreading activation mechanism together with shared nodes between prime and target. Translation equivalent primes share more conceptual nodes with the target than do semantically related primes, and as a result translation priming is stronger. The difference in directionality is explained by the proposal that L1 activates more conceptual nodes than does L2 due to its greater integration in the conceptual store, as suggested by the RHM.

Finkbeiner, Forster, Nicol and Nakamura (2004) further explored this issue, and demonstrated that L2 primes produced significant within-language repetition priming for identical L2 targets. This implies that although L2 words may not activate semantic information strongly enough to consistently prime across languages, they nevertheless have strong enough representations to prime within their own language. However, since the study used repetition priming, it could be argued that facilitation was a result of word form priming and did not necessarily involve semantic activation.

Summarizing, the studies of cross-language priming, reviewed above, report stronger priming from L1 to L2 than from L2 to L1. The explanations for this finding have largely focused on the claim that L1 primes are processed more efficiently than L2 primes and can thus contribute more to the processing of a related target. This increased efficiency of L1 primes has been ascribed either to conceptual links, as in the RHM, or to more efficient lexical access mediated by higher resting-level activation, as in the BIA+.

However, lower frequency of use of the L2 could also impact priming results in two ways. When L2 words act as primes, their lower resting-level activation could cause slower lexical access and reduced priming efficiency. At the same time, this lower resting-level activation when L2 words act as targets may result in a higher potential benefit from a preceding prime. The interplay and relative contribution of resting-level activation in primes and targets can be explored by comparing cross-language priming with within-language repetition and semantic priming. Specifically, if processing efficiency of the prime is the driving force as described in previous studies (Gollan et al., 1997; Jiang, 1999), we would expect greater within-language priming in L1 than in L2, due to higher accessibility of L1 over L2 primes. Alternatively, if target resting-level activation also contributes to the results of previous studies (Gollan et al., 1997; Jiang, 1999; Basnight-Brown & Altarriba, 2007; Schoonbaert et al., 2009), we would expect within-language L2 priming to be equal to or possibly even greater than

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

within-language L1 priming. Importantly, both the prime and the target resting-level activation contribute to the observed asymmetry in cross-language priming – greater L1-L2 priming (strong prime, highly primeable target) than L2-L1 priming (weak prime, less primeable target). The current study directly compares within-language priming in L1 vs. L2 in order to identify the relative contributions of prime and target resting-level activation and address previous findings of asymmetrical cross-language priming.

The current study sought to further investigate the nature of intra-language and inter-language connections in each of a bilingual's two languages. Because studies of concreteness in cross-language priming have produced mixed results (Jin, 1990; Finkbeiner et al., 2004; Schoonbaert et al., 2009; Barber, Otten, Kousta & Vigliocco, 2013), we included this variable in the current design. Van Hell and de Groot (1998) found that concrete words produced more similar associations across languages in bilinguals than did abstract words, leading them to propose the Distributed Representation Model (DRM) of conceptual representation, which claims that concrete translation pairs will share more representational nodes than abstract pairs.

Concreteness effects have been reported in additional studies. Jin (1990) reported larger priming effects in both translation and cross-language semantic priming for concrete than for abstract words. The author attributed this to greater mediation across languages due to a 'shared imagery system' in concrete word pairs, similar to the argument put forth in the DRM. An additional study of within-language L2-L2 repetition priming and L2-L1 translation priming in Japanese–English bilinguals (Finkbeiner et al., 2004) found a main effect for concreteness, but no difference in priming. In contrast, two recent studies did not find significant concreteness effects, using translation and cross-language semantic priming (Chen, Liang, Cui & Dunlap, 2014; Schoonbaert et al., 2009). In light of these mixed findings, concreteness was included as a factor in our experimental design to further investigate possible effects of this variable on within- and across-language connectivity.

Finally, studies of translation and cross-language semantic priming in bilinguals have used both unmasked (e.g., Basnight-Brown & Altarriba, 2007; Kiran & Lebel, 2007) and, more prominently, masked priming methodologies (e.g., Duñabeitia et al., 2010; Dimitripoulou, Duñabeitia & Carreiras, 2011; Schoonbaert et al., 2009). Because our main goal in the present study was to compare cross-language and within-language priming, we opted to use unmasked priming, to increase the probability of eliciting both types of priming. Specifically, participants in the current study were unbalanced bilinguals immersed in an L1 environment, and some previous masked priming studies have failed to find L2-L1 priming for such bilinguals (Basnight-Brown & Altarriba, 2007). Indeed, in a recent meta-analysis of masked translation priming, Wen and Van Heuven (2016) show that only 11 out of 23 studies found priming in the L2-L1 direction that was significantly different from zero, although the overall effect size was significant. Further, the unbalanced bilingual participants in the current study spoke Hebrew and English, languages which use different scripts, further reducing the likelihood of achieving significant masked priming effects (e.g., Nakayama, Ida & Lupker, 2016, though see Gollan et al., 1997). A further consideration was our wish to focus on the contribution of target resting-level activation to any observed priming patterns – and thus we wanted to give sufficient processing opportunities to primes in both L1 and L2.

Importantly, we followed the guidelines recommended by Altarriba and Basnight-Brown (2007) in their methodological review paper to reduce expectancy strategies. Thus, the SOA was limited to 200 ms, and there was a low proportion of related pairs (0.3), and a 0.5 nonword proportion. Finally, none of the primes or targets was repeated for any of the participants.

The present study

The current study therefore offers a broad examination of within- and cross-language connectivity using two within-language priming experiments (repetition, semantic) and two cross-language priming experiments (translation, semantic). All experiments made use of a single set of items, and were performed on targets in both the L1 and the L2, by unbalanced bilingual speakers of Hebrew (L1) and English (L2).

In consonance with most previous research (Gollan et al., 1997; Jiang, 1999; Basnight-Brown & Altarriba, 2007; Schoonbaert et al., 2009; Wen & van Heuven, 2016), we expect to find asymmetric priming in the cross-language experiments (translation, semantic). The within-language priming experiments will allow us to probe the relative importance of prime vs. target resting-level activation: If prime resting-level activation has a stronger impact, we would expect greater priming in the L1-L1 within-language conditions, whereas if resting-level activation of the target largely determines priming effects, we would expect greater priming in the L2-L2 within-language conditions. Because a single set of stimuli was used across all four experiments, we describe the procedure of stimulus selection before describing the individual experiments.

Materials selection

The process for compiling the English stimuli is described first, followed by the Hebrew set. An initial set of concrete

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

Table 1. *Examples of related and unrelated stimuli with English primes.*

Condition	Repetition		Translation		Within-language semantic		Cross-language semantic	
Concreteness	Conc	Abs	Conc	Abs	Conc	Abs	Conc	Abs
Prime	*leaf*	*poetry*	*leaf*	*poetry*	*leaf*	*poetry*	*leaf*	*poetry*
Related Target	*leaf*	*poetry*	עלה *aleh (leaf)*	שירה *shira (poetry)*	*cabbage*	*story*	כרוב *kruv (cabbage)*	סיפור *sipur (story)*
Unrelated Target	*baby*	*age*	תינוק *tinok (baby)*	גיל *gil (age)*	*baby*	*Age*	תינוק *tinok (baby)*	גיל *gil (age)*

and abstract words in English was selected using the MRC psycholinguistic database (Coltheart, 1981). Concrete items were selected from a rating of 451–695 (M = 557, SD 50.1); abstract items were selected with a rating from 210–450 (M = 337, SD 54.8). In a two-tailed t-test, concrete and abstract stimuli differed significantly on concreteness, ($p<.001$). Next, semantically related pairs for these words were identified using association strength as a measure for semantic relatedness, based on the University of South Florida Free Association Norms (Nelson, McEvoy & Schreiber, 2004). Following Lucas (2000), average association strengths were kept low (forward strength <0.10) in order to ensure that the connections between words in the pairs were primarily semantic rather than associative.

These words were then used as stimuli for a norming study to generate their Hebrew translations. Unbalanced Hebrew–English bilinguals with the same language profile as participants in the priming experiment were given lists of 334 English words and asked to provide the first Hebrew translation that came to mind for each item. Each English word was translated by at least 10 bilinguals. The resulting Hebrew lists were given to a second set of at least 10 bilinguals who translated the words back into English. In an effort to control for translation ambiguity, which has been shown to interact with concreteness (Tokowicz & Kroll, 2007; Prior, MacWhinney & Kroll, 2007), only translation pairs with high levels of agreement (>70%) in both directions of translation were selected for this study. No cognates or interlingual homophones were used as stimuli, following the recommendations of Altarriba and Basnight-Brown (2007). Following this norming procedure, we selected a final set of 72 abstract and 72 concrete target words in English and their translations in Hebrew, as well as a set of semantically related primes for each target word, again in both languages. Unrelated prime-target pairs were created by randomly pairing primes with other targets from the list.

Abstract and concrete primes and targets were matched for frequency in English (>8 Log per million, Balota, Yap, Cortese, Hutchison, Kessler, Loftis, Neely, Nelson, Simpson & Treiman, 2007). As a further check of relatedness, the critically related pairs were run through Latent Semantic Analysis (Landauer, Foltz & Laham, 1998) to derive a similarity score (ranging from -1 to 1) for each pair. The concrete pairs had an average similarity score of 0.32 and the abstract pairs stimuli an average similarity score of 0.33, and they did not differ significantly ($p=.84$).

Table 1 presents an example of related and unrelated stimuli with English primes.

Lexical information such as word frequency, association strengths, and concreteness is generally lacking for Hebrew words. Therefore, we relied on the values generated for the English words. Because Hebrew is written without explicit representation for vowels, word length as measured by number of letters is on average significantly shorter than in English (Frost, Katz & Bentin, 1987). To compensate for this difference, we matched the stimuli across languages for number of phonemes as a measure of word length (Frost, 1995; 1998) (see Table 2 for stimulus characteristics). Primes and targets did not differ significantly from each other in length in phonemes or in frequency (all Ps $>.11$), for both L1 and L2. Further, targets in L1 and L2 were matched to each other on length in phonemes, and primes in L1 and L2 were also matched to each other on this variable (both $t<1$).

English non-words were generated using the ARC non-word database (Rastle, Harrington & Coltheart, 2002) and were selected to match English words for orthographic length, number of phonemes, and morphological complexity. Because there is no comparable database of non-words in Hebrew, Hebrew non-words were generated to match the Hebrew words for length in letters, number of phonemes, and morphological structure. Non-words in both languages were phonotactically acceptable for that language and were not real words in the other language. Non-word targets in all experimental conditions were always paired with real words as primes.

In all priming experiments, participants performed a lexical decision task on target words in L1 and in L2 (order counterbalanced across participants). Each language block included 216 word pairs: 36 concrete targets (18 with a related prime and 18 with an unrelated

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

Table 2. *Prime and Target characteristics, Mean (SD), in L1 and L2.*

	Length in Letters	Length in Phonemes	Log Frequency*
L1 Targets** (all experiments, n =144)	4.1 (1.0)	5.0 (1.3)	–
L2 Targets*** (all experiments, n =144)	6.2 (1.7)	5.1 (1.7)	10.0 (1.4)
L1 Primes (within- and across-language semantic priming, n = 144)	4.2 (1.0)	5.2 (1.4)	–
L2 Primes (within- and across-language semantic priming, n = 144)	6.4 (1.8)	5.1 (1.7)	9.7 (1.4)

*Reliable frequency counts were unavailable for Hebrew words.
**L1 targets served as their own primes in the repetition priming experiment, and as primes for L2 targets in the translation priming experiment.
***L2 targets served as their own primes in the repetition priming experiment, and as primes for L1 targets in the translation priming experiment.

Table 3. *Participant characteristics by Experiment, Mean (SD)**.

Priming Condition	Age	L2 AOA	L2 Percent Use	L1 proficiency**	L2 proficiency**
Exp 1: Repetition (n =22)	25.2 (3.2)	6.5 (3.3)	21 (14.6)	9.5 (0.7)	8.0 (1.3)
Exp 2: Translation (n =22)	23.1 (2.7)	8.1 (1.8)	19 (16.6)	9.6 (0.8)	8.0 (1.0)
Exp 3: Within-Language Semantic (n =23)	26.0 (4.2)	7.7 (2.5)	23 (20.2)	9.7 (0.4)	7.9 (1.0)
Exp 4: Cross-Language Semantic (n =23)	25.5 (3.7)	7.2 (2.4)	23 (10.0)	9.7 (0.5)	8.1 (0.8)

*Across all experiments, three participants who spoke a language other than Hebrew as L1 or had lived for over 2 years in an English speaking country were excluded from the study. Three additional participants with accuracy rates below 90% were also excluded from the study, resulting in a final sample of 89 participants.
**Proficiency was based on self-rating on a 1–10 scale averaged across speaking, listening and reading.

prime), 36 abstract targets (18 related, 18 unrelated), 36 filler pairs (presented with unrelated primes); and 108 pairs with non-word targets. Thus, stimulus lists had a low relatedness proportion of 0.33 and a non-word ratio of 0.50, both of these to discourage participants from developing strategic processing of the critical stimuli (Altarriba & Basnight-Brown, 2007).

Importantly, each participant saw each target word or its translation only once across the entire experiment. Four lists were created for each experiment, such that across participants each target word was presented to half of the participants in each language (L1 and L2), and within each language half of the participants saw the target with a related prime and half with an unrelated prime.

Experiment 1: Repetition priming

Participants

Twenty-two students at Bar Ilan University and the University of Haifa (mean age 25.2) participated in the study. The study was approved by the university ethics board at both institutions, and all participants gave informed consent for their participation

All participants were native speakers of Hebrew who had learned English as a foreign language in school. Participants completed a Hebrew adaptation of the language experience and proficiency questionnaire (LEAP-Q, Marian, Blumenfeld & Kaushanskaya, 2007). Participants were L1-dominant, using Hebrew an average of 79% of the time in their day-to-day life, with occasional use of English for media consumption and for academic reading. The average age of initial acquisition of English was 6;5. All participants had normal or corrected vision and were right handed. Participants reported no diagnosed learning disabilities. See Table 3 for full participant characteristics.

Stimuli and procedure

In the repetition priming experiment, target words in the related conditions (36 items per language) were preceded by an identical prime word, in the same language. Target words in the unrelated conditions (36 items per language) were preceded by an unrelated prime word in the same language.

Experimental scripts were controlled by E-Prime 2 (Schneider, Eschman & Zuccolotto, 2012), and experimental sessions were conducted in a sound attenuated room. Participants completed both language conditions (Hebrew-L1 and English-L2) in a single session with a short break between language conditions. The order of the languages was counterbalanced across participants. Stimuli in each list were presented in random order to each of the participants. Participants were seated approximately 50cm in front of a 17 inch computer screen and were instructed to complete a lexical decision task on the second word (target) for every word pair

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

presented. Participants responded using a serial response box, pressing a button marked ‘Yes’ with their right index finger if the target was a word in the target language and a button marked ‘No’ with their left index finger if the target was not a word in the target language. Participants were instructed to make their decision as quickly and as accurately as possible.

Each trial began with the display of a fixation point in the center of the screen for 500 milliseconds. This was immediately followed by the prime word, which remained on the screen for 150 milliseconds, followed by a blank screen for 50 milliseconds and then by the target word which remained on the screen until the participant responded or for a maximum of 3 seconds. The resulting stimulus onset asynchrony (SOA) was 200 milliseconds. Primes and targets were presented using different fonts to avoid visual repetition. Font size was 14 point Times New Roman black on a white background for the prime and 14 point Arial black on white for the target. Each language block began with 12 practice items followed by an experimental block of 216 trials. There were two breaks in the course of the experiment. The experiment lasted approximately 20 minutes.

Results

Reaction times for correct responses to critical word targets on the lexical decision task were analyzed. Outlier RTs that deviated from each participant’s mean in each condition by 2 standard deviations or more were removed (4.4% of the data). Task performance was highly accurate in all conditions (average 95%), and so accuracy rates are not further analyzed.

Initially, RTs to word targets were submitted to a three-way repeated-measures ANOVA. Within-subject factors were language (Hebrew, English), relatedness (related, unrelated) and concreteness (abstract, concrete). Results for concreteness yielded no main effect for this factor and no significant interactions. Therefore, all further statistical analyses were conducted on data collapsed across concrete and abstract targets[1]. The lack of results for concreteness is addressed in the general discussion.

Reaction times were then submitted to a repeated measures ANOVA with target language (L1, L2) and relatedness (Related, Unrelated) as within participant variables over participants (F_1). A parallel analyses was conducted over items, in which Language was a between items factor, and relatedness a within items factor (F_2). The effect of language was significant, with significantly faster RTs to L1 targets than to L2 targets, $F_1(1,21) = 15.3$, $p < .001$, $\eta^2 = .42$, $F_2(1,285) = 163$, $p < .001$, $n^2 = .36$. In addition, RTs were significantly faster to targets preceded by a repetition prime than to targets following an unrelated prime, $F_1(1,21) = 62.6$, $p < .001$, $\eta^2 = .75$; $F_2(1,285) = 92.3$, $p < .001$, $n^2 = .25$. The interaction between language and relatedness was not significant, $F_1(1,21) = 1.70$, $p = .21$, $\eta^2 = .08$, $F_2(1,285) = 1.63$, $p = .2$, $n^2 = .01$, though priming for L2 targets was numerically larger (see Table 4 and Figure 1).

[1] This pattern was replicated across all four experiments, and thus all further analyses did not include concreteness as a factor.

Table 4. *Mean RTs (SD) for related and unrelated primes and priming effects, by target language, in Experiment 1 Repetition priming.*

	Condition		
Target Language	*Related*	*Unrelated*	Priming effect
L1	462 (89)	563 (132)	101
L2	631 (307)	761 (261)	130

Discussion

The results demonstrate significant repetition priming effects, of similar magnitude, in both languages. Focusing on the contribution of the prime to the priming effect, these results are puzzling. According to the RHM and the BIA+, L1 primes are both activated faster and are more strongly linked to conceptual representations. Therefore, the L1 primes should have produced greater priming effects than the L2 primes. However, when focusing on the contribution of targets – in particular the lower resting-level activation of the L2 targets – the result here is more explicable. This lower resting-level activation renders the L2 targets more ‘primeable,’ since the RTs have greater room for improvement. Thus, it seems that the current results can best be understood by the suggestion that the two mechanisms balance each other, such that the magnitude of priming is equivalent across the two languages. This finding supports the notion that the lower resting-level activation of L2 targets might be contributing to the asymmetry generally found in cross-language priming conditions.

Experiment 2: Translation priming

Participants

Twenty-two participants from the same population described above completed the translation priming experiment (see Table 3).

Stimuli and procedure

In the translation priming experiment, target words in the related conditions (36 items per language) were preceded by their translation equivalent in the other language. Target words in the unrelated conditions (36 items per language),

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

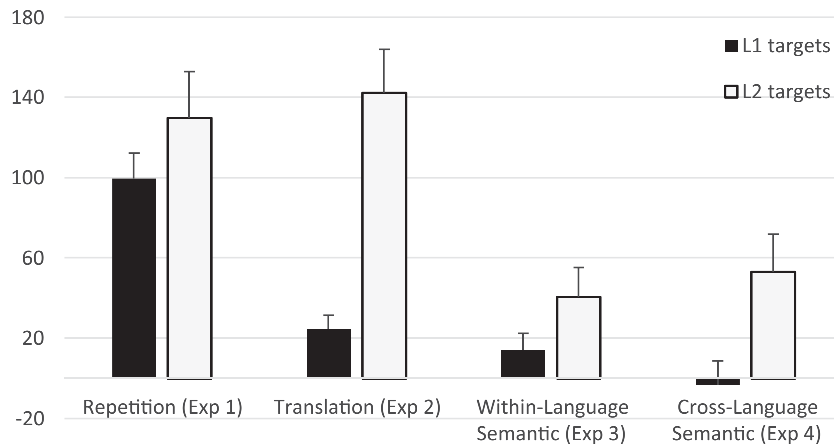

Figure 1. Mean priming effects in milliseconds (SEM) for Hebrew (L1) and English (L2) targets, by priming condition

were preceded by a different prime word, in the other language. All other details of the procedure were identical to those described for Experiment 1.

Results

Data trimming and analyses procedures are as described in Experiment 1. Outlier RTs that deviated from each participant's mean in each condition by 2 standard deviations or more were removed (4.3% of the data). Task performance was highly accurate in all conditions (93%), and so accuracy rates are not further analyzed.

RTs for correct responses to word targets were analyzed using a repeated measures ANOVA with target language (L1, L2) and relatedness (Related, Unrelated) as within participant variables over participants (F_1). A parallel analysis was conducted over items, in which Language was a between items factor and relatedness a within items factor (F_2). RTs for L1 targets were significantly faster than for L2 targets, $F_1(1,21) = 20.6$, $p < .001$, $\eta^2 = .50$, $F_2(1,285) = 120.5$, $p < .001$, $\eta^2 = .29$. Targets preceded by a translation prime were responded to faster than targets following an unrelated prime, $F_1(1,21) = 48.9$, $p < .001$, $\eta^2 = .70$; $F_2(1,286) = 87.8$, $p < .001$, $\eta^2 = .24$. In addition, the interaction between language and relatedness was also significant, $F_1(1,21) = 32.26$, $p < .001$, $\eta^2 = .61$ and $F_2(1,286) = 42.5$, $p < .001$, $\eta^2 = .13$. Follow up comparisons demonstrated that priming effects in English were larger than in Hebrew, $t_1(21) = 5.7$, $p < .001$; $t_2(286) = 6.52$, $p < .001$ (see Table 5 and Figure 1).

Table 5. *Mean RTs (SD) for related and unrelated primes and priming effects, by target language, in Experiment 2 Translation priming.*

	Condition		
Target Language	*Related*	*Unrelated*	Priming effect
L1	533 (139)	558 (142)	25
L2	608 (184)	750 (235)	142

Discussion

The current results replicate the findings of many previous studies (Gollan et al., 1997; Jiang & Forster, 2001; Finkbeiner et al., 2004; Basnight-Brown & Altarriba, 2007; Schoonbaert et al., 2009). Namely, we found significant translation priming in both directions, from L1-L2 and from L2-L1, with significantly larger priming effects in the L1-L2 direction.

These findings fit well with predictions focusing on the resting-level activations of both the primes and the targets. In the L1-L2 condition, a strong prime with its higher resting-level activation acts more effectively to prime the L2 target, which has a lower resting-level activation and thus stands to benefit to a larger extent from the prime. This consequently results in a large prime effect. On the other hand, in the reverse condition in the L2-L1, the weaker L2 prime with its lower resting-level activation is less effective in priming the less primeable L1 target with its higher resting-level activation.

Experiment 3: Within-Language Semantic Priming

Participants

Twenty-three participants from the same population described above completed the within-language semantic priming experiment (see Table 3).

Stimuli and procedure

In the within-language semantic priming experiment, target words in the related conditions (36 items per language) were preceded by a semantically related word

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

Table 6. *Mean RTs (SD) for related and unrelated primes and priming effects, by target language, in Experiment 3 Within-Language Semantic priming.*

	Condition		
Target Language	*Related*	*Unrelated*	Priming effect
L1	544 (108)	558 (108)	14
L2	655 (98)	696 (139)	41

in the same language. Target words in the unrelated conditions (36 items per language), were preceded by a semantically unrelated prime word, in the same language. All other details of the procedure were identical to those described for Experiment 1.

Results

Data trimming and analyses procedures are as described in Experiment 1. Outlier RTs that deviated from each participant's mean in each condition by 2 standard deviations or more were removed (4.5% of the data). Task performance was highly accurate in all conditions (94%), and so accuracy rates are not further analyzed.

RTs for correct responses to word targets were analyzed using a repeated measures ANOVA with target language (L1, L2) and relatedness (Related, Unrelated) as within participants variables over participants (F_1). A parallel analysis was conducted over items, in which language was a between items factor, and relatedness a within items factor (F_2). RTs to L1 targets were significantly shorter than to L2 targets, $F_1(1,22) = 60.5$, $p < .001$, $\eta^2 = .73$, $F_2(1,285) = 198$, $p < .001$, $n^2 = .41$. Targets preceded by a semantically related prime in the same language were responded to significantly faster than targets following a semantically unrelated prime, $F_1(1,22) = 9.4$, $p = .006$, $\eta^2 = .30$, $F_2(1,286) = 9.90$, $p = .021$, $n^2 = .03$. The interaction between language and relatedness was not significant for either participants, $F_1(1,22) = 2.86$, $p = .1$, $\eta^2 = .12$ or items, $F_2(1,286) = 1.20$, $p = .27$, $n^2 = .004$, but numerically the effect was much larger for L2 targets (see Table 6 and Figure 1). Because of our specific interest in the priming effect in each language, we conducted follow up analyses despite the marginally significant interaction in the analysis by participants. These analyses revealed that whereas the priming effect in L2 was significantly different from zero $t_1(22) = 2.7$, $p<.05$; $t_2(143) = 2.451$, $p<0.05$, the priming effect in L1 was not, $t_1(22) = 1.7$, $p = .1$; $t_2(143) = 2.045$, $p<0.05$.

Discussion

Experiment 3 tested an additional element of intra-language connectivity. Whereas Experiment 1 (repetition priming) examined the extent to which a word can prime itself, this experiment examined the strength of within-language connectivity in each of the two languages of the bilingual participants. Here again, there was a main effect for target language: reaction times to L1 targets were faster, thus showing greater ease in processing L1 over L2. Within-language semantic priming was significant overall, with the suggestion that this effect was driven mostly by L2 targets.

The fact that the difference between the priming effects of the two languages was not significant (though numerically 3 times larger in L2) sheds further light on the possible role of higher resting-level activation of L1 primes versus lower level resting activation of L2 targets. If the priming effect were solely attributable to features of the prime, we would expect priming within L1 to be significantly larger than within L2. However, the overall statistical analysis did not find a significant difference between the two languages, and the planned comparisons in fact demonstrated the opposite pattern, namely stronger priming within L2 than within L1, despite the presence of a prime that is processed less efficiently. Thus, similarly to the results of Experiment 1 (repetition priming) this experiment also supports the importance of resting-level activation of targets for understanding bilingual priming effects.

Experiment 4: Cross-language semantic priming

Participants

Twenty-two participants from the same population described above completed the translation priming experiment (see Table 3).

Stimuli and procedure

In the cross-language semantic priming experiment, target words in the related conditions (36 items per language) were preceded by a semantically related word in the other language. Target words in the unrelated conditions (36 items per language), were preceded by a semantically unrelated prime word, in the other language as well. All other details of the procedure were identical to those described for Experiment 1.

Results

Data trimming and analyses procedures are as described in Experiment 1. Outlier RTs that deviated from each participant's mean in each condition by 2 standard deviations or more were removed (4.5% of the data). Task performance was highly accurate in all conditions (96%), and so accuracy rates are not further analyzed.

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

Table 7. *Mean RTs (SD) for related and unrelated primes and priming effects by target language, in Experiment 4 Cross-Language Semantic Priming.*

	Condition		
Target Language	*Related*	*Unrelated*	Priming effect
L1	597 (151)	594 (135)	-3
L2	735 (237)	788 (239)	53

RTs for correct responses to word targets were analyzed using a repeated measures ANOVA with target language (L1, L2) and relatedness (Related, Unrelated) as within participants variables over participants (F_1). A parallel analysis was conducted over items, in which language was a between items factor, and relatedness a within items factor (F_2). Reaction times for L1 targets were significantly faster than for L2 targets, $F_1(1{,}21) = 14.5$ $p = .0015$, $\eta^2 = .41$; $F_2(1{,}285) = 122.1$, $p < .001$, $n^2 = .3$. Targets preceded by a semantically related cross-language prime were responded to significantly faster than targets following unrelated primes in the participant analysis, $F_1(1{,}21) = 4.9$, $p = .038$, $\eta^2 = .19$, but not in the item analysis $F_2(1{,}285) = 1.71$, $p = .19$, $n^2 = .006$. The interaction between language and relatedness was significant in the participant analysis, $F_1(1{,}21) = 6.9$, $p < .015$, $\eta^2 = .25$, and follow up comparisons demonstrated significant priming in the L1-L2 language condition ($p_1 < .01$), but not in the L2-L1 condition ($p_1 = .79$). However, the interaction was not significant in the item analysis $F_2(1{,}285) = 1.92$, $p = .17$, $n^2 = .007$, and follow up comparisons showed no significant priming in either language condition (both ps>.133 – see Table 7 and Figure 1).

Discussion

The results of this experiment align to a certain degree with the results of the translation priming experiment (Experiment 2). Specifically, in the participant analysis we found evidence for asymmetric priming, such that priming was larger in the L1-L2 direction than in the L2-L1 direction, and planned comparisons demonstrated that in fact there was no significant priming in the L2-L1 direction. This stronger priming in the L1-L2 direction can be attributed to both the higher resting-level activation of the prime and the lower resting-level activation of the target. In the opposite direction, L2-L1, the combined effects of a lower resting-level activation of the prime and a higher resting-level activation of the target in fact resulted in the absence of any facilitation, as has been reported in several previous studies (e.g., Basnight-Brown & Altarriba, 2007).

In comparison to the results of the translation priming experiment, the overall cross-language semantic priming effect was much weaker, and in fact failed to reach significance in the item analysis. Similar findings have been reported in several previous studies, which failed to demonstrate significant cross-language semantic priming (e.g., Basnight-Brown & Altarriba, 2007; deGroot & Nas, 1991). This finding can be understood by the fact that meaning overlap is necessarily smaller and more variable in semantically related pairs than in translation pairs, leading to reduced effects in the item analyses[2]. Thus, given that the overall priming effect was not significant in the item analysis, it is not surprising that we found no difference between L1 and L2 targets in this analysis.

Therefore, the results of Experiment 4 support previous findings of asymmetry in cross-language priming, though not as strongly as the results of the translation priming experiment.

Comparison across experiments

To compare the results across the four experiments, we calculated a priming effect (PE) for each participant for each language by subtracting RTs to targets preceded by related primes from RTs to targets preceded by unrelated primes (see Figure 1). These data were then submitted to a two-way repeated measures ANOVA with Experiment (repetition, translation, within-language semantic, cross-language semantic) as a between-subjects factor and Language (L1, L2) as a within-subjects factor.

Overall, priming effects were larger for L2 than for L1 targets, showing a main effect of target language, $F(1{,}85) = 32.3, p < .001, \eta^2 = .28$. The main effect for experiment was also significant, $F(3{,}83) = 14.0$, $p < .001$, $\eta^2 = .33$, indicating significant differences in the magnitude of priming effects across the four experiments. Finally, the interaction between language and experiment was also significant $F(3{,}85) = 4.30$, $p = .007$, $\eta^2 = .13$.

Tukey HSD Post hoc analyses showed that PEs in repetition and translation priming conditions did not differ significantly from each other ($p = .253$), but were larger than priming effects in the within- and cross-language semantic experiments (all ps $< .01$), which again did not differ significantly from each other ($p = .99$). In order to directly compare within-language and cross-language priming for the two target languages, we compared translation with repetition priming and within-language and cross-language semantic priming, for each target language separately. Tukey HSD Post hoc analyses showed that English targets were equally primed by within- and cross-language semantic primes (p = .969),

[2] As argued by Schoonbaert et al. (2009), testing a larger number of participants might have resulted in a more stable effect across items as well.

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

and repetition and translation primes (p = .968). Hebrew targets were also equally primed by within- and cross-language semantic primes (p = .645), but were more strongly primed by repetition than by translation primes (p < 0.001).

General discussion

The present study examined directionality and connectivity in the bilingual mental lexicon of Hebrew–English bilinguals in four priming experiments (repetition, translation, within-language semantic and cross-language semantic). As expected, the participants, who were unbalanced bilinguals, responded faster in L1 than in L2. Additionally, all priming conditions were effective in facilitating performance, but to various degrees (cross-language semantic priming was notably weak). Of particular note was the fact that despite the faster response times overall for L1 targets, the priming effects were generally larger for L2 targets.

The current results align well with previous findings of asymmetric cross-language priming, namely greater facilitation in the L1-L2 direction than in the L2-L1 direction in both translation priming (Gollan et al., 1997; Jiang & Forster, 2001; Finkbeiner et al., 2004; Basnight-Brown & Altarriba, 2007; Schoonbaert et al., 2009; Wen & van Heuven, 2016) and cross-language semantic priming (e.g., Duyck, 2005; Basnight-Brown & Altarriba, 2007; Schoonbaert et al., 2009). Thus, in the current study priming effects were significantly larger from L1/Hebrew to L2/English in translation priming and more weakly so in cross-language semantic priming. As presented in the introduction, two converging mechanisms have been put forth to explain this pattern, both of which refer to the reduced efficiency of L2 primes. The RHM (Kroll & Stewart, 1994; see also Kroll et al., 2010) cites less efficient conceptual access from L2 primes as the reason for reduced priming in the L2-L1 direction. The BIA+ model (Dijkstra & van Heuven, 2002) describes the temporal lag in lexical access for L2 primes, due to their lower frequency of exposure resulting in lower resting-level activation, which would again lead to reduced L2-L1 priming.

In the current study, we wished to examine the possibility that lower resting activation of L2 TARGETS might contribute to asymmetric cross-language priming as well. This mechanism is partly motivated by a comparison with the monolingual priming literature, in which low frequency words have been shown to benefit more from priming than high frequency words (Becker, 1979; Stone & Van Orden, 1992). The participants in the current study were unbalanced bilinguals, who reported using their L2 significantly less often than their L1, leading to a lower resting-level activation for L2 lexical items compared to L1 items (see Gollan et al., 2008). Thus, L2 target words stand to benefit more from priming than L1 target words, given their overall lower resting-level activation. However, in cross-language priming, both the larger effectiveness of L1 primes and the higher 'primeability' of L2 targets influence performance in the same direction – namely, stronger priming in the L1-L2 direction than in the L2-L1 direction.

Because both prime and target differences in resting-level activation between L1 and L2 predict asymmetric priming in cross-language conditions, we made use of within-language priming in an attempt to better differentiate between them. The most straightforward way to describe the prediction that lower resting-level activation of L2 TARGET words will lead to greater priming is because L2 targets leave more room to benefit from priming. Specifically, if lower TARGET resting activation contributes to enhanced L1-L2 priming, we should also see stronger L2-L2 than L1-L1 priming. Alternatively, if the main factor which drives asymmetric priming in cross-language conditions is more efficient lexical access of L1 primes due to higher resting-level activation, as suggested by the BIA+ model, we would expect stronger priming effects within L1 than within L2, namely in priming conditions with L1 primes.

The results of the current study do not align easily with either prediction, because priming of L1 and L2 targets did not differ significantly in repetition priming, and only marginally so in within-language semantic priming. However, in both cases priming for L2 targets was numerically larger, and in the case of within-language semantic priming, follow-up comparisons demonstrated significant priming in L2, but not in L1. This pattern strongly suggests that it is not only the strength of L1 primes that is responsible for the asymmetry in cross-language priming results. Thus, we suggest that resting-level activation of both the prime and the target are at play and can be argued to concurrently influence performance, leading to similar priming effects within L1 and L2 and asymmetric priming in cross-language conditions.

The current study also allowed us to compare connections between lexical items within and across languages by focusing on the two semantic priming conditions. We tested the hypothesis claiming that within-language connections might be stronger than cross-language connections. Using a specific example to illustrate, if within-language connections were stronger, we would expect a within-language prime such as *table-chair* (L2-L2) to produce greater priming than a cross-language prime, *shulxan-chair* (L1-L2). The same would be true for L1 targets, namely, we would expect a within-language prime *shulxan-kisei* (L1-L1) to produce greater priming than a cross-language prime *table-kisei* (L2-L1). However, the results show that in the current study, within-language and cross-language semantically related primes were equally effective in priming targets in both L1 and L2.

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

Taken together, this pattern does not seem to support the notion that within-language connections are necessarily stronger than cross-language connections in bilingual lexical priming. Instead, the current results can be better understood by the mechanism of resting-level activation – namely, that L1 PRIMES are processed more efficiently due to higher resting-level activation, and that L2 TARGETS stand to benefit more from priming, due to lower resting-level activation. To summarize, the current results show that the lower resting-level activation of L2 lexical items in unbalanced bilinguals contributes to asymmetrical cross-language priming via lower resting-level activation of targets and not only via less efficient lexical activation of primes, as highlighted by the BIA+ model.

An interesting direction for future research would be an attempt to parcel out the relative contributions of resting-level activation of targets versus primes by directly manipulating the lexical frequency of the stimuli. For instance, an investigation of L1-L2 priming pairs where the L1 prime is of lower frequency than the L2 target and/or L2-L1 priming pairs where the L2 prime is of higher frequency than the L1 target, would allow us to evaluate the relative contribution of prime versus target accessibility. A similar comparison could be made for within-language priming pairs, where again the L1-L1 pairs are of lower frequency than the L2-L2 pairs.

Finally, the current study was initially designed to investigate the possible impact of concreteness on within- and cross-language priming patterns, but results of this manipulation were not as instructive. Although we did find a main effect for concreteness across experiments, it was qualified by an interaction with language. Specifically, whereas for L2 there was no difference in processing of concrete and abstract targets, in L1 the effect of concreteness was reversed – abstract words were recognized faster than concrete words. Further, concreteness did not interact with any of the priming manipulations, and the magnitude of priming was equal for concrete and abstract items. At the very least, the current results echo those of several recent studies (e.g., Chen et al., 2014) and suggest that concreteness effects may be less stable and pervasive than has previously been assumed in the literature on lexical decisions in visual word processing, both monolingual (e.g., Yap & Balota, 2015) and bilingual (e.g., Jin, 1990).

Conclusion

The current study investigated within and between language connectivity and directionality in bilingual lexical representation by implementing a comprehensive design including repetition, translation, within-language semantic, and cross-language semantic priming. The study mostly replicated previous findings of asymmetric priming in cross-language conditions, while at the same time demonstrating similar within-language priming in L1 and L2, with some indication of stronger effects within L2. This pattern of results supports our novel hypothesis that lower resting-level activation of L2 targets in unbalanced bilinguals might be an additional mechanism contributing to asymmetric cross-language priming. Further, within-language semantic connections were comparable for L1 and L2. Taken together, the results align well with the BIA+ model, by demonstrating that frequency-driven resting-level activation is a critical mechanism for understanding bilingual lexical representation and processing. Importantly, the current study identifies the unique importance of L1-L2 differences in TARGET resting-level activation, whereas most previous literature focused on effects stemming from L1-L2 differences in PRIME resting-level activation.

Appendix A: Full list of stimuli for the four experiments

Critical Stimuli

Concrete/ Abstract	English Target (Translation Prime)	Hebrew Target (Translation Prime)	English Semantic Prime (within- / cross-language)	Hebrew Semantic Prime (within- / cross-language)
abstract	ability	יכולת	talent	כישרון
abstract	answer	תשובה	guess	ניחוש
abstract	anxiety	חרדה	depression	דיכאון
abstract	area	אזור	location	מיקום
abstract	autumn	סתיו	season	עונה
abstract	background	רקע	past	עבר
abstract	beauty	יופי	art	אמנות

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

abstract	center	מרכז	middle	אמצע
abstract	challenge	אתגר	risk	סיכון
abstract	commerce	מסחר	business	עסקים
abstract	community	קהילה	population	אוכלוסיה
abstract	compliment	מחמאה	insult	עלבון
abstract	control	שליטה	management	ניהול
abstract	crime	פשע	murder	רצח
abstract	culture	תרבות	tradition	מסורת
abstract	damage	נזק	insurance	ביטוח
abstract	debt	חוב	taxes	מסים
abstract	decision	החלטה	choice	בחירה
abstract	devil	שטן	hell	גיהינום
abstract	discovery	תגלית	science	מדע
abstract	discussion	דיון	group	קבוצה
abstract	distance	מרחק	length	אורך
abstract	dream	ניסיון	expert	מומחה
abstract	effect	השפעה	reaction	תגובה
abstract	emergency	חירום	crisis	משבר
abstract	end	סוף	death	מוות
abstract	eternity	נצח	universe	יקום
abstract	experience	חלום	hope	תקווה
abstract	expression	ביטוי	feeling	הרגשה
abstract	fact	עובדה	report	דווח
abstract	faith	אמונה	religion	דת
abstract	fear	פחד	guilt	אשמה
abstract	freedom	חופש	peace	שלום
abstract	fun	כיף	adventure	הרפתקה
abstract	genius	גאון	average	ממוצע
abstract	health	בריאות	happiness	אושר
abstract	illusion	אשליה	magic	קסם
abstract	judgment	שיפוט	criticism	ביקורת
abstract	justice	צדק	law	חוק
abstract	language	שפה	grammar	דקדוק
abstract	learning	למידה	thinking	חשיבה
abstract	loan	הלוואה	mortgage	משכנתא
abstract	majority	רוב	minority	מיעוט
abstract	memory	זכרון	thought	מחשבה
abstract	mess	בלגן	confusion	בלבול
abstract	minute	דקה	moment	רגע
abstract	mistake	בעיה	problem	טעות
abstract	need	צורך	addiction	התמכרות
abstract	number	מספר	quantity	כמות
abstract	pain	כאב	comfort	נוחות
abstract	passion	תשוקה	lover	מאהב
abstract	period	תקופה	month	חודש
abstract	pity	רחמים	regret	חרטה
abstract	poetry	שירה	story	סיפור
abstract	power	כוח	leadership	מנהיגות
abstract	reality	מציאות	life	חיים

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

abstract	result	תוצאה	election	בחירות
abstract	service	שירות	work	עבודה
abstract	shame	בושה	pride	גאווה
abstract	shock	הלם	surprise	הפתעה
abstract	society	חברה	economy	כלכלה
abstract	south	דרום	direction	כיוון
abstract	suggestion	הצעה	advice	עצה
abstract	system	מערכת	process	תהליך
abstract	time	זמן	future	עתיד
abstract	topic	נושא	idea	רעיון
abstract	trust	אמון	promise	הבטחה
abstract	truth	אמת	rumor	שמועה
abstract	welfare	רווחה	poverty	עוני
abstract	wisdom	חוכמה	age	גיל
abstract	year	שנה	week	שבוע
abstract	youth	נעורים	innocence	תמימות
concrete	animal	חיה	goat	עז
concrete	banana	בננה	apple	תפוח
concrete	blanket	שמיכה	towel	מגבת
concrete	blood	דם	mosquito	יתוש
concrete	bottle	בקבוק	wine	יין
concrete	bracelet	צמיד	necklace	שרשרת
concrete	builder	בנאי	engineer	מהנדס
concrete	carpet	שטיח	floor	רצפה
concrete	chair	כסא	furniture	רהיט
concrete	city	עיר	people	אנשים
concrete	club	מועדון	dancer	רקדן
concrete	contract	חוזה	document	מסמך
concrete	country	ארץ	citizen	אזרח
concrete	customer	לקוח	buyer	קונה
concrete	diamond	יהלום	earring	עגיל
concrete	doctor	רופא	medicine	תרופה
concrete	dress	שמלה	sleeve	שרוול
concrete	drug	סם	injection	זריקה
concrete	ear	אוזן	elephant	פיל
concrete	entrance	כניסה	door	דלת
concrete	envelope	מעטפה	package	חבילה
concrete	fabric	בד	silk	משי
concrete	face	פנים	mirror	מראה
concrete	father	אב	adult	מבוגר
concrete	feather	נוצה	pillow	כרית
concrete	flower	פרח	butterfly	פרפר
concrete	food	אוכל	freezer	מקפיא
concrete	horse	סוס	straw	קש
concrete	house	בית	neighbor	שכן
concrete	industry	תעשיה	factory	מפעל
concrete	leaf	עלה	cabbage	כרוב
concrete	library	ספריה	literature	ספרות
concrete	mail	דואר	address	כתובת

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

concrete	monster	רעל	mushroom	פטריה
concrete	mother	אמא	baby	תינוק
concrete	mountain	הר	cliff	צוק
concrete	night	לילה	moon	ירח
concrete	nose	אף	mustache	שפם
concrete	ocean	אוקיינוס	whale	לוויתן
concrete	onion	בצל	garlic	שום
concrete	partner	שותף	friend	חבר
concrete	poison	מפלצת	vampire	ערפד
concrete	powder	אבקה	flour	קמח
concrete	printer	מדפסת	computer	מחשב
concrete	queen	מלכה	crown	כתר
concrete	rain	גשם	thunder	רעם
concrete	rectangle	מלבן	triangle	משולש
concrete	restaurant	מסעדה	waiter	מלצר
concrete	ring	טבעת	finger	אצבע
concrete	sandwich	כריך	bread	לחם
concrete	scissors	מספריים	paper	נייר
concrete	shirt	חולצה	stain	כתם
concrete	shower	מקלחת	soap	סבון
concrete	skeleton	שלד	bone	עצם
concrete	smell	ריח	fish	דג
concrete	soldier	חייל	army	צבא
concrete	spider	עכביש	snake	נחש
concrete	sweat	זיעה	fever	חום
concrete	sword	חרב	knife	סכין
concrete	table	שולחן	shelf	מדף
concrete	teacher	מורה	speaker	דובר
concrete	tongue	לשון	lizard	לטאה
concrete	tower	מגדל	castle	טירה
concrete	vegetable	ירק	fruit	פרי
concrete	vehicle	רכב	truck	משאית
concrete	village	כפר	town	עיר
concrete	voice	קול	singer	זמר
concrete	wedding	חתונה	bride	כלה
concrete	whistle	שריקה	train	רכבת
concrete	window	חלון	frame	מסגרת
concrete	woman	אישה	secretary	מזכירה
concrete	writing	כתיבה	paragraph	פסקה

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

Filler pairs:

Concrete/ Abstract	English Target	Hebrew Target	English Prime	Hebrew Prime
abstract	act	פעולה	despair	יאוש
abstract	affection	חיבה	interview	ראיון
abstract	call	תשלום	denial	הכחשה
abstract	cause	סיבה	amount	כמות
abstract	conference	כנס	behaviour	התנהגות
abstract	curve	עיגול	content	תוכן
abstract	danger	כלל	news	חדשות
abstract	envy	קנאה	lesson	שיעור
abstract	essence	מהות	reminder	תזכורת
abstract	evening	ערב	threat	איום
abstract	gender	מגדר	rumour	שמועה
abstract	grace	חן	protest	הפגנה
abstract	hatred	שנאה	fool	כסיל
abstract	intention	כוונה	joy	שמחה
abstract	item	פריט	clue	רמז
abstract	kind	סוג	robbery	גניבה
abstract	knowledge	ידיעה	situation	מצב
abstract	lie	שקר	calm	רוגע
abstract	look	מבט	protection	הגנה
abstract	measure	מדד	conflict	סכסוך
abstract	merit	זכות	rating	דרג
abstract	name	שם	half	חצי
abstract	oath	שבועה	budget	תקציב
abstract	payment	קריאה	crawl	זחילה
abstract	peer	עמית	break	שבר
abstract	praise	שבח	border	גבול
abstract	public	ציבורי	trouble	בעיה
abstract	punishment	עונש	enemy	אויב
abstract	retreat	נסיגה	benefit	תועלת
abstract	rotation	סבב	bet	הימור
abstract	rule	סכנה	term	מונח
abstract	slice	פרוסה	finance	מימון
abstract	subject	נושא	height	גובה
abstract	suspect	חשוד	cost	עלות
abstract	value	ערך	suspicion	חשד
abstract	work	עבודה	misery	אומללות
concrete	aunt	דודה	hunter	צייד
concrete	basket	סל	fence	גדר
concrete	brother	אח	brush	מברשת
concrete	camp	מחנה	witness	עד
concrete	clown	ליצן	square	מרובע
concrete	coach	מאמן	moisture	לחות
concrete	coral	אלמוג	cement	מלט
concrete	dairy	מחלבה	walk	הליכה
concrete	deer	צבי	parliament	כנסת
concrete	detective	בלש	choir	מקהלה

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

concrete	dove	יונה	quarter	רבע
concrete	drink	שתיה	observer	משקיף
concrete	duck	ברווז	test	מבחן
concrete	essay	מאמר	carbon	פחמן
concrete	flag	דגל	priest	כומר
concrete	flea	פרעוש	kick	בעיטה
concrete	fork	מזלג	dance	ריקוד
concrete	grave	קבר	fight	צרה
concrete	hair	שיער	guide	מדריך
concrete	institute	מכון	blue	כחול
concrete	leader	מנהיג	grass	דשא
concrete	lens	עדשה	land	אדמה
concrete	liquid	נוזל	rocket	טיל
concrete	marble	שיש	foundation	יסוד
concrete	olive	זית	ankle	קרסול
concrete	port	נמל	film	סרט
concrete	president	נשיא	prison	כלא
concrete	rust	חלודה	continent	יבשה
concrete	seed	זרַע	monkey	קוף
concrete	shadow	צל	bench	ספסל
concrete	shape	צורה	sunset	שקיעה
concrete	sheet	טעם	trumpet	חצוצרה
concrete	string	חוט	font	גופן
concrete	taste	סדין	material	חומר
concrete	thumb	בוהן	key	מפתח
concrete	worker	פועל	spark	ניצוץ

Non-word stimuli

English Target	Hebrew Target	English Prime	Hebrew Prime
acclintion	דוטה	generation	שומר
arube	תצגון	bubble	נביא
awuft	בח	prince	פתיחה
bault	כאה	kingdom	לידה
beraition	הסמגה	show	מנעול
blosh	הקפגה	guard	שטפון
blupe	המדקה	prayer	בועה
blurnt	בוזפן	scorpion	נחושת
boover	צישר	curse	מלחין
burgment	הגשקה	elephant	מוצר
canol	קפיג	tribe	מתנה
clourth	אן	assistance	משאבה
crage	מגבד	fall	עמק
crarsh	גולץ	heart	פיל
cropt	ציש	gift	שליח
crumption	הצשרה	addition	בטן

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

deater	דה	respect	מומחה
deave	תצבון	permission	גלגל
defond	סמג	burn	יצור
dincement	סחלה	college	לב
drange	בנלה	hunger	כויה
emmuny	שטס	sum	עיתון
errance	עלריד	cabin	עקרב
ethant	קצידה	greed	ברד
figgle	מילנה	fountain	דירה
filazion	מובד	cream	בקתה
frodin	נמיצה	root	ארנק
fruant	מסלרה	smile	מזרקה
frul	דסקנות	dough	תייר
geanority	מגקת	quality	קוץ
ghuition	גזיג	vein	מכללה
gike	חיד	fair	סרגל
glaffism	עס	composer	חצץ
gorb	הגלקה	violin	נסיך
hab	בפלה	harvest	שורש
hirm	הגשלה	band	עטלף
hoarant	נדץ	thorn	חנות
huse	הגקרה	burden	מיץ
indoment	מגץ	juice	סופר
irreany	משדב	plan	בלם
jad	ברלן	newspaper	צמר
jure	מקמדה	jump	וריד
kassen	זכבה	messenger	חלוץ
kimple	הגחור	finish	שבט
kir	מדסוק	birth	עיסה
lebment	שיגת	agreement	חיוך
leddle	גטילה	failure	קציר
liffy	ניז	lock	כלוב
lirth	מתשגה	blessing	בשר
lishertion	הראחה	pioneer	עשן
loeper	חליגה	wheel	להקה
meamer	אגצה	creature	בור
mesarone	סשגות	opening	כינור
misation	הפתזה	ruler	קצפת
moicer	חגת	decree	קפיצה
mourdness	ריג	opponent	קפיצה
nang	עה	copper	נס
nease	קשון	hero	נטל
noofenage	קצידה	echo	תוכנית
nubblebine	ראדה	cage	תאווה
odrian	שדיבה	state	חמדנות
ossen	כושום	product	יריד
phothle	זדרה	meat	מטרה
pirler	לוצה	conquest	נפילה
plibble	זאמה	purpose	כבוד

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

poulsion	הדקאה	apartment	גודל
pronk	מזלק	miracle	גזרה
psarn	קריל	wool	אסון
queadence	מליבות	belief	סיוע
rappenity	חטשה	unit	הסכם
reflam	דאל	charity	הופעה
regetion	גלנה	tourist	בדיחה
rimpseld	טשה	brake	סיכוי
rolve	החגפה	hail	צדקה
rond	גא	pleasure	חג
rulk	פלבה	title	כיבוש
scir	אגמקה	fashion	אנחה
scurkity	נשידות	bat	כותרת
shan	נליצות	diversity	התפרעות
shent	הדשוק	debate	גמר
silement	פיבה	prophet	יריב
slupper	לכיב	pit	איכות
spleafing	חשיגה	event	יחידה
spleeze	נשיז	smoke	ברכה
spruib	עדפט	valley	זוג
staggle	ליף	store	אופנה
swike	הדפאה	author	כישלון
thade	זא	sigh	סכום
thrumper	ניתה	disaster	רעב
thweet	מברול	gravel	תפילה
thwirl	רולק	lust	רשות
tresion	דטקן	pump	יתרון
troafity	חדיפה	deal	הפסד
trulersion	הלמגה	concept	אירוע
tudment	פיברון	specialist	הד
umbanship	רבה	loss	הנאה
unturam	הלשרה	opinion	גיבור
vard	פקיזה	pair	תוספת
vaubince	אחגה	flood	קללה
voliment	מימוף	way	מלכות
vontle	פעה	purse	אמונה
wealtment	טק	stomach	מושג
wesh	צממה	joke	מדינה
woffery	שלירה	riot	דעה
yag	רגיחה	holiday	גיוון
yelse	בנסן	chance	דרך
yurching	טרב	advantage	עסק
zerin	מבחות	size	ויכוח

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

References

Altarriba, J., & Basnight-Brown, D. M. (2007). Methodological considerations in performing semantic- and translation-priming experiments across languages. *Behavior Research Methods, 39,* 1–18.

Balota, D. A., Yap, M. J., Cortese, M. J., Hutchison, K. A., Kessler, B., Loftis, B., Neely, J. H., Nelson, D. L., Simpson, G. B., & Treiman, R. (2007). The English lexicon project. *Behavior Research Methods, 39,* 445–59.

Barber, H. A., Otten, L. J., Kousta, S. T., & Vigliocco, G. (2013). Concreteness in word processing: ERP and behavioral effects in a lexical decision task. *Brain and Language, 125,* 47–53.

Basnight-Brown, D. M. (2014). Models of lexical access and bilingualism. In R. R. Heredia & J. Altarriba (eds.) *Foundations of bilingual memory*, pp. 85–110, New York: Springer.

Basnight-Brown, D. M., & Altarriba, J. (2007). Differences in semantic and translation priming across languages: The role of language direction and language dominance. *Memory & Cognition, 35,* 953–65.

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.

Chen, B., Liang, L., Cui, P., & Dunlap, S. (2014). The priming effect of translation equivalents across languages for concrete and abstract words. *Acta Psychologica, 153,* 147–152.

Coltheart, M. (1981). The MRC psycholinguistic database. *The Quarterly Journal of Experimental Psychology, 33,* 497–505.

Dijkstra, T., & van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition, 5,* 175–197.

Dimitripoulou, M., Duñabeitia, J.A., & Carreiras, M. (2011). Two words, one meaning: Evidence of automatic co-activation of translation equivalents. *Frontiers in Psychology*, https://doi.org/10.3389/fpsyg.2011.00188.

Duñabeitia, J. A., Perea, M., & Carreiras, M. (2010). Masked translation priming effects with highly proficient simultaneous bilinguals. *Experimental Psychology, 57,* 98–107.

Finkbeiner, M., Forster, K., Nicol, J., & Nakamura, K. (2004). The role of polysemy in masked semantic and translation priming. *Journal of Memory and Language, 51,* 1–22.

Francis, W. S. (2005). Bilingual semantic and conceptual representation. In J. F. Kroll & A. M. B. de Groot (eds.), *Handbook of bilingualism: Psycholinguistic approaches*, pp. 251–267. New York: Oxford University Press.

French, R. M., & Jacquet, M. (2004). Understanding bilingual memory: Models and data. *Trends in Cognitive Sciences, 8,* 87–93.

Frost, R. (1995). Phonological computation and missing vowels: Mapping lexical involvement in reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 398–408.

Frost, R. (1998). Toward a strong phonological theory of visual word recognition: True issues and false trails. *Psychological Bulletin, 123,* 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.

Gollan, T. H., Forster, K. I., & Frost, R. (1997). Translation priming with different scripts: masked priming with cognates and non-cognates in Hebrew-English bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23,* 1122–39.

Gollan, T. H., Montoya, R. I., Cera, C., & Sandoval, T. C. (2008). More use almost always means a smaller frequency effect: Aging, bilingualism, and the weaker links hypothesis. *Journal of Memory and Language, 58,* 787–814.

Gollan, T. H., Slattery, T. J., Goldenberg, D., Van Assche, E., Duyck, W., & Rayner, K. (2011). Frequency drives lexical access in reading but not in speaking: The frequency lag hypothesis. *Journal of Experimental Psychology: General, 140,* 186–209.

Grainger, J., Midgley, K., & Holcomb, P. J. (2010). Re-thinking the bilingual interactive-activation model from a developmental perspective (BIA-d). In M. Kail & M. Hickmann (eds.), *Language acquisition across linguistic and cognitive systems*, pp. 267–284. Philadelphia, PA: John Benjamins.

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. (2002). Form–meaning mapping in vocabulary acquisition in a second language. *Studies in Second Language Acquisition, 24,* 617–637.

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

Jin, Y. (1990). Effects of concreteness on cross-language priming in lexical decisions. *Perceptual and Motor Skills, 70,* 1139–1154.

Kiran, S., & Lebel, K.R. (2007). Crosslinguistic semantic and translation priming in normal bilingual individuals and bilingual aphasia. *Clinical Linguistics and Phonetics, 21,* 277–303.

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. (2005). Models of bilingual representation and processing: Looking back and to the future. In J. F. Kroll & A. M. B. De Groot (eds.), *Handbook of bilingualism: Psycholinguistic approaches*, pp. 531–533. Oxford, England: Oxford University Press.

Kroll, J. F., van Hell, J. G., Tokowicz, N., & Green, D. W. (2010). The revised Hierarchical model: A critical review and assessment. *Bilingualism: Language, and Cognition, 13,* 373–381.

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645

Landauer, T. K., Foltz, P. W., & Laham, D. (1998). An introduction to latent semantic analysis. *Discourse Processes, 25,* 259–284.

Lucas, M. (2000). Semantic priming without association: A meta-analytic review. *Psychonomic Bulletin & Review, 7,* 618–30.

Marian, V., Blumenfeld, H. K., & Kaushanskaya, M. (2007). The Language Experience and Proficiency Questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals. *The Journal of Speech, Language, and Hearing Research, 50,* 940–967.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: I. An account of basic findings. *Psychological Review, 88,* 375.

Nakayama, M., Ida, K., & Lupker, S.J. (2016). Cross-script L1-L1 noncognate translation priming in lexical decision depends on L2 proficiency: Evidence from Japanese-English bilinguals. *Bilingualism: Language and Cognition, 19,* 1001–1022.

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (2004). The University of South Florida free association, rhyme, and word fragment norms. *Behavior Research Methods, Instruments, & Computers, 36,* 402–407.

Prior, A., MacWhinney, B., & Kroll, J. F. (2007). Translation norms for English and Spanish: The role of lexical variables, word class, and L2 proficiency in negotiating translation ambiguity. *Behavior Research Methods, 39,* 1029–1038.

Rastle, K., Harrington, J., & Coltheart, M. (2002). 358,534 nonwords: The ARC Nonword Database. *Quarterly Journal of Experimental Psychology, 55,* 1339–1362.

Schneider, W., Eschman, A., & Zuccolotto, A. (2012). *E-Prime User's Guide*. Pittsburgh: Psychology Software Tools, Inc.

Schoonbaert, S., Duyck, W., Brysbaert, M., & Hartsuiker, R. J. (2009). Semantic and translation priming from a first language to a second and back: Making sense of the findings. *Memory & Cognition, 37,* 569–86.

Stone, G. O., & Van Orden, G. C. (1992). Resolving empirical inconsistencies concerning priming, frequency, and nonword foils in lexical decision. *Language and Speech, 35,* 295–324.

Tokowicz, N., & Kroll, J. F. (2007). Number of meanings and concreteness: Consequences of ambiguity within and across languages. *Language and Cognitive Processes, 22,* 727–779.

Van Hell, J. G., & De Groot, A. M. B. (1998). Conceptual representation in bilingual memory: Effects of concreteness and cognate status in word association. *Bilingualism: Language and Cognition, 1,* 193–211.

Wen, Y., & van Heuven, W.J.B. (2016). Non-cognate translation priming in masked priming lexical decision experiments: A meta-analysis. *Psychonomic Bulletin and Review*, doi:10.3758/s13423-016-1151-1

Yap, M. J., & Balota, D. A. (2015). Visual word recognition. In A. Pollatsek & R. Treiman (eds.), *The Oxford handbook of reading*, pp. 26–43. New York, NY: Oxford University Press

Downloaded from https://www.cambridge.org/core. University of Haifa, Library, on 20 Feb 2018 at 10:12:54, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1366728917000645