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Short Communication

Semantic processing in native and second language: Evidence from hemispheric differences in fine and coarse semantic coding

Miriam Faust [a], Elisheva Ben-Artzi [b,*], Nili Vardi [c]

[a] Department of Psychology and Gonda Brain-Research Center, Bar-Ilan University, Israel
[b] Department of Psychology, Kinneret College, Tzemach, Israel
[c] Department of Psychology, Bar-Ilan University, Israel

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ABSTRACT

Previous studies suggest that whereas the left hemisphere (LH) is involved in fine semantic processing, the right hemisphere (RH) is uniquely engaged in coarse semantic coding including the comprehension of distinct types of language such as figurative language, lexical ambiguity and verbal humor (e.g., Chiarello, 2003; Faust, 2012). The present study examined the patterns of hemispheric involvement in fine/coarse semantic processing in native and non-native languages using a split visual field priming paradigm. Thirty native Hebrew speaking students made lexical decision judgments of Hebrew and English target words preceded by strongly, weakly, or unrelated primes. Results indicated that whereas for Hebrew pairs, priming effect for the weakly-related word pairs was obtained only for RH presented target words, for English pairs, no priming effect for the weakly-related pairs emerged for either LH or RH presented targets, suggesting that coarse semantic coding is much weaker for a non-native than native language.

1. Introduction

Much previous research suggests that the comprehension of figurative language, as well as other distinct types of language, such as lexical ambiguity and verbal humor, involves the unique semantic processing mechanisms of the right cerebral hemisphere (RH) (e.g., Beeman, 1998; Chiarello, 2003; Faust, 2012; Faust & Mashal, 2007; Federmeier, Wlotko, & Meyer, 2008; Jung-Beeman, 2005; Mashal, Faust, & Hendler, 2005). Thus, although traditionally the left cerebral hemisphere (LH) has been shown to be dominant for language processing, it has been suggested that the unique coarse semantic coding in the RH enables the processing of specific types of language that require the activation and/or maintenance of multiple meanings, including more distant and unusual meanings (e.g., Beeman, 1998; Jung-Beeman, 2005). However, the neural basis for fine and coarse semantic coding and, specifically, the unique ability of the RH to engage in coarse semantic coding was studied, to the best of our knowledge, only in native language speakers. Therefore, the aim of the present study was to directly examine LH and RH involvement in fine versus coarse semantic processing in non-native, second language, using native speakers of Hebrew who are also highly proficient in English, their second language. The findings could contribute to our understanding of the neural basis of bilingualism as well as of some of the differences in semantic processing between native and non-native language.

According to the Fine/Coarse semantic coding theory (FCT, Beeman, 1998; Jung-Beeman, 2005), semantic processing by the two cerebral hemispheres is qualitatively different (for reviews see e.g., Chiarello, 2003; Faust, 2012). Thus, the involvement of the RH in processing specific types of language, such as non-literal expressions, may not be particular to metaphors, idioms, etc., but rather may be one aspect of the unique semantic coding of this hemisphere, characterized by high sensitivity to distant semantic relations. The FCT postulates that immediately after encountering a word, the LH engages in relatively fine semantic coding, strongly activating closely related word meanings or semantic features, whereas the RH engages in coarse semantic coding, weakly and diffusely activating large semantic fields containing multiple alternative meanings and more distant associates. According to the FCT, coarse semantic coding by the RH facilitates the comprehension of specific types of language that may require activation and maintenance of distantly related meanings, such as metaphoric expressions, lexical ambiguity, verbal humor, insight problem solving and poetry. With regard to metaphoric language, for example, since the metaphorical meaning of a word is usually more semantically distant than its literal meaning, RH coarse semantic coding abilities will be needed for understanding metaphoric expressions.

Efficient language processing thus seems to depend on the ability to engage in both fine and coarse semantic coding, in line with the current linguistic, cognitive and social circumstances.

* Corresponding author.
E-mail address: elibenartzi@gmail.com (E. Ben-Artzi).

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According to the FCT, the two cerebral hemispheres of the intact brain constitute complementary semantic systems that enable successful coping with the full range of linguistic forms characterizing the human language, including non-literal language and lexical ambiguity (e.g., Atchley, Grimshaw, Schuster, & Gibson, 2011; Jung-Beeman, 2005; Burgess & Simpson, 1988; Chiarello, 2003). However, although the FCT is a central, highly influential model supported by much empirical evidence (e.g., Anaki, Faust, & Kravetz, 1998; Atchley, Burgess, & Keeney, 1999; Chiarello & Richards, 1992; Coulson & Williams, 2005; Faust, 2012; Faust, Ben-Artzi, & Harel, 2008; Gold, Faust, & Ben-Artzi, 2011; Schmidt, DeBuse, & Seger, 2007), previous research has focused on fine versus coarse semantic processing by the two cerebral hemispheres in native language, while to the best of our knowledge there are no data on differences in fine versus coarse semantic processing by the two cerebral hemispheres in a foreign, non-native language.

The cerebral basis of bilingualism has been drawing much interest in recent years. In our increasingly globalizing modern society, learning and mastering a second language has become a basic requirement, thus a large proportion of the world population is either bilingual or even multilingual. Since the pressure posed by modern society to master a foreign language is increasing tremendously, it is of great importance that foreign language learners achieve high levels of linguistic and communicative functioning in their second language. This in turn may depend on their ability to use the full range of semantic abilities including both fine and coarse semantic coding. Although bilingual persons may acquire full mastery of their non-native language, both everyday experience and research findings strongly suggest that the comprehension of specific types of language, such as non-literal language, tends to be much more difficult in a second, non-native language, even for persons with a high degree of proficiency in this language (e.g., Cacciari, 1993; Charteris-Black, 2002; Cieslicka & Heredia, 2011; Irujo, 1993; Moon, 1997; Zughoul, 1991). Given the abundance and high significance of metaphoric language, that permits the efficient expression of ideas that would otherwise be awkward to explain literally (Glucksberg, 2001), the difficulty in processing non-literal expressions in a non-native language could interfere with successful linguistic and communicative functioning in this language. Similarly, difficulties of non-native speakers in comprehending linguistic ambiguity and humor as well as other types of language that require some degree of coping with the multifaceted nature of word meaning, could become a major obstacle in fully mastering a second language.

The differences between native and second language in processing specific types of language, including non-literal language, may be just one manifestation of different semantic processing mechanisms in native and non-native languages. According to this claim, the neural basis for the specific difficulties in semantic processing experienced in a second language may be related to the different neural representations of the two languages (for a review see e.g., Dijkstra & van Heuven, 2012) and specifically to a reduced ability of the RH to engage in coarse semantic coding in a non-native language. Recent findings support this claim indicating hemispheric asymmetries in figurative language processing, such that whereas the LH manifests similar patterns of activation for both native and non-native languages, the RH shows only figurative facilitation in native languages and only literal facilitation in non-native languages (Cieslicka & Heredia, 2011).

Semantic processing by the two cerebral hemispheres has been studied mainly with an experimental paradigm combining split visual field presentation with central or lateral semantic priming. The semantic priming effect has been used to investigate how word meanings are accessed, comprehended and integrated within larger contexts and thus serves as a rich source of information about semantic processing. In semantic priming, a target word is responded to more quickly after presentation of a related prime word than after presentation of an unrelated prime. Two types of word pairs widely used in previous priming research as well as in the present study are semantically (e.g., sharing category membership) and associatively related pairs (for a review see Hutchison, 2003). It has generally been found that semantic priming occurs even without association and that strongly associated word pairs can lead to a "boost" of priming over and above the effect of semantic relationship alone (for review see Lucas, 2000). Thus, word pairs that are both semantically and associatively related lead to strong priming effects, although weaker priming effects have been also found for word pairs that are semantically, but not associatively, related.

The difference between these two types of priming has been used to study fine and coarse semantic coding by the two cerebral hemispheres. This research has shown that words presented to either hemisphere are primed by related primes, although not necessarily under the same conditions. Two major factors that differentially modulate priming effects obtained in the LH and RH are the nature of prime–target semantic relation and the time course of meaning activation (e.g., Chiarello, 2003). Thus, although the findings are not entirely consistent, strong priming for categorical associates was generally found in the LH across a range of prime–target intervals (SOAs). Priming for more weakly related words, such as non-associated category members, has been reported to diminish at longer intervals, particularly in the LH, and this may indicate the decay or suppression of more distant meanings in this hemisphere when there is no supportive context requiring their maintenance. However, RH priming for weakly related meanings has shown a delayed onset but was maintained across longer intervals during which the LH may no longer have access to distant meanings (e.g., Anaki et al., 1998; Chiarello, 2003; cf. Coney, 2002). The general picture emerging from the split visual field priming studies thus suggest much less robust hemispheric asymmetries when the words are strongly related and share many semantic features. In contrast, words with less semantic similarity appear to show a more distinctly asymmetrical pattern across hemispheres, and over time. Thus, whereas priming within the LH dissipates rapidly, RH priming is maintained across longer intervals. As mentioned above, this unique RH coarse semantic coding may support the processing of distinct types of languages, allowing access to the rich resources provided by native speakers' linguistic capacity.

In order to study fine and coarse semantic coding in a non-native language, we applied the same paradigm combining split visual field presentation with central priming using both native and second, non-native linguistic stimuli. We used categorical associate pairs for the strong, fine coding condition and non-associated category members for the relatively weak, coarse semantic coding condition, in addition to unrelated pairs. A relatively long time interval of 750 ms was used.

If the differential pattern of semantic coarse/fine processing by the LH and RH, respectively, reported in native language, is repeated in non-native language, this may support the notion of similar patterns of lateralization for semantic processing, at least in late bilinguals with high level of proficiency in their second language. If, however, the FCT does not generalize to semantic processing in a non-native language, then the findings may lend some support to the claim that hemispheric involvement in semantic processing is different for native and non-native languages. This difference may result in a different representation of word meanings in native as compared to non-native languages.

2. Results

For each participant, mean reaction times in milliseconds for correct responses and percent correct responses for target words were computed. Data were analyzed by visual field (left, right), semantic relationship (strong, weak, unrelated) and language (Hebrew, English). Pearson correlations between RTs for correct responses and percent correct responses, conducted separately by language and hemisphere, revealed no accuracy–speed trade-off both for Hebrew and English: In Hebrew, RTs and percent correct responses correlations were nonsignificant both for the RVF/LH and LVF/RH, and in English they were significantly negative both for RVF/LH, $r = -.50$, $p < .001$, and LVF/RH, $r = -.48$, $p < .001$.

2.1. Reaction times for correct responses

Descriptive statistic for RTs is presented in Table 3. A 2 (Visual field: left, right) × 3 (Relationship type: strong, weak, unrelated) × 2 (Language: Hebrew, English) repeated measures ANOVA was conducted on RTs for correct responses, with both participants ($F1$) and items ($F2$) as random effects. The analyses revealed no significant effect of visual field, $F1 < 1$; $F2(1,197) = 1.93$, $p = .17$, a significant effect of relationship type, $F1(2,28) = 15.55$, $p < .001$, $\eta_p^2 = .53$; $F2(2,197) = 5.67$, $p = .004$, $\eta_p^2 = .05$, and a significant effect of language, $F1(1,29) = 20.25$, $p < .001$, $\eta_p^2 = .41$; $F2(1,197) = 23.77$, $p < .001$, $\eta_p^2 = .11$, reflecting faster responses for Hebrew than for English. There was also a significant Visual field × Language interaction, $F1(1,29) = 20.09$, $p < .001$, $\eta_p^2 = .40$; $F2(1,197) = 11.56$, $p < .001$, $\eta_p^2 = .06$. More importantly, the interaction between visual field, relationship type, and language was significant by subjects and marginally significant by items, $F1(2,28) = 4.08$, $p = .028$, $\eta_p^2 = .23$; $F2(2,197) = 2.39$, $p = .089$. Planned comparisons indicated that for English, both the RVF/LH and the LVF/RH showed a priming effect for the strong condition (shorter RTs for the strong as compared to the unrelated condition), ($p = .009$ and $p = .001$ for the RVF/LH and LVF/RH by subjects, and $p = .017$ and $p = .015$ for the RVF/LH and LVF/RH by items), but not for the weak condition, ($p = .21$ and $p = 1.00$ for the RVF/LH and LVF/RH by subjects, and $p = .20$ and $p = .94$ for the RVF/LH and LVF/RH by items). For Hebrew a different hemispheric pattern emerged: Whereas the RVF/LH showed a priming effect for the strong condition ($p = .003$ by subjects and $p = .02$ by items) but not for the weak condition ($p = .59$ by subjects and $p = .58$ by items), the LVF/RH did not show a priming effect for the strong condition ($p = .65$ by subjects and $p = .57$ by items) but did show a priming effect for the weak condition by subjects, $p = .026$. Analysis by items for the LVF/RH showed the same pattern of results, i.e., a larger difference between the weakly and unrelated conditions (613 ms vs. 632 ms) than between the strongly and unrelated conditions (640 vs. 649 ms), although the priming effect for the weak condition did not reach statistical significance, $p = .25$. As can be seen in Fig. 1, priming size for the LH, for both the strong and weak pairs, was almost identical for Hebrew and English.

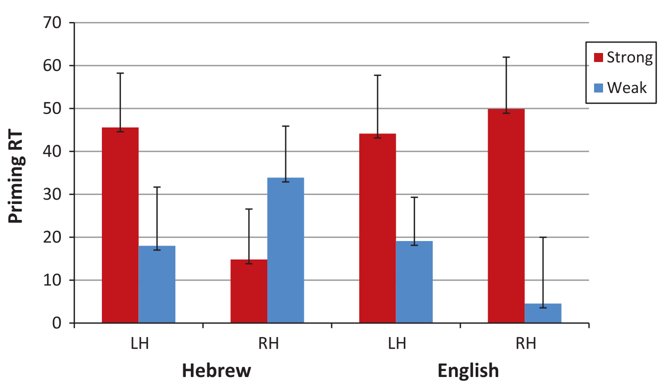

Fig. 1. Means and SEs of priming RT (strong/weak-unrelated conditions difference) by language, hemisphere and relationship type.

2.2. Correct responses

Descriptive statistic for correct responses is presented in Table 4. A 2 (Visual field: left, right) × 3 (Relationship type: strong, weak, unrelated) × 2 (Language: Hebrew, English) repeated measures ANOVA was conducted on percent correct responses, with both participants ($F1$) and items ($F2$) as random effects. The analysis revealed that the visual field effect was not significant by subjects, $F1(1,29) = 2.51$, $p = .12$, but was marginally significant by items, $F2(1,197) = 3.82$, $p = .052$. There were significant effects of relationship type, $F1(2,28) = 20.25$, $p < .001$, $\eta_p^2 = .59$; $F2(2,197) = 6.01$, $p = .003$, $\eta_p^2 = .06$ and language, $F1(1,29) = 29.72$, $p < .001$, $\eta_p^2 = .51$; $F2(1,197) = 26.16$, $p < .001$, $\eta_p^2 = .12$, such that, as expected, percent of correct responses was higher for Hebrew than for English. Moreover, there was a significant Visual field × Language interaction, $F1(1,29) = 9.92$, $p = .004$, $\eta_p^2 = .26$; $F2(1,197) = 8.33$, $p = .004$, $\eta_p^2 = .04$. Bonferroni tests indicated that whereas no hemispheric difference emerged for Hebrew, $p = .11$ by subjects and $p = .34$ by items, for English, there was an accuracy advantage for the RVF/LH over the LVF/RH, $p = .009$ by subjects and $p = .003$ by items.

3. Discussion

In addition to processing the core semantic features of words, native speakers can easily and naturally deal with understanding semantic ambiguity, metaphoric language and humor, which are all manifestations of the more flexible and creative aspects of word meanings. These linguistic types require the access to more distant, unusual and even seemingly unrelated semantic features of words. According the FCT, whereas the core semantic features of words are processed by the LH that specializes in fine coding, the more distant and peripheral meaning of words are activated and maintained by the RH by coarse semantic mechanisms.

The findings of the present study support this pattern of hemispheric specialization in native language by showing that priming effects for strongly-related target words were larger for RVF/LH than for LVF/RH presented target words. A similar pattern was found for accuracy of responses. Furthermore, as predicted by the FCT, priming effects for weakly-related target were larger for LVF/RH than for RVF/LH presented target words.

This pattern was not replicated in a non-native language: When native Hebrew speaking participants were asked to respond to strongly and weakly related English target words, priming effects were found only for strongly related target words. These effects were similar for target words presented to the RVF/LH and LVF/RH. Furthermore, the almost identical priming effects in Hebrew and English for the RVF/LH presented strongly-related target words support the participants' high proficiency in fine semantic coding in their non-native language.

These findings suggest that coarse semantic coding is much weaker for a non-native than native language. Thus, it seems the unique role of the RH in activating and maintaining a larger range of word meaning and semantic features may be limited to native language, and does not fully extend to later acquired non-native languages. This suggest that the meaning representations of words might be much richer and wider in a native language and may explain the difficulties in appreciating the more flexible creative aspects of words, including ambiguity, metaphoric expressions, humor and insight problem solving in non-native language (for a review see Faust, 2012). The findings of a recent study (Cieslicka & Heredia, 2011) that used a similar group of bilingual subjects support the claim that RH does not engage in the comprehension of figurative language, i.e., in coarse semantic coding, in a non-native language.

The findings of the present study point to a serious limitations of semantic processing in a foreign language which may have significant implications for linguistic and social functioning. Thus, special emphasis should be put on developing coarse semantic coding during the process of acquiring foreign language in order to achieve full mastery of such languages.

Although not directly addressed by the present study, the findings may have interesting implications for two major controversies regarding the bilingual brain. One relates to the pattern of lateralization for native and non-native languages, emphasizing the critical periods for language acquisition as well as the typical differences in acquisition circumstances (e.g., age of acquisition, natural versus formal learning), degree of proficiency and level of exposure (for reviews see Abutalebi & Della Rosa, 2012; Dijkstra & van Heuven, 2012; for meta-analytic reviews see e.g., Hull & Vaid, 2007; Sebastian, Laird, & Kiran, 2011).

The other central question concerns the level of representation, i.e., whether native and non-native languages share common conceptual representations (for reviews see Abutalebi & Della Rosa, 2012; Kroll, Guo, & Misra, 2012). According to some models (e.g., Kroll & Tokowicz, 2005), separate lexical memory systems contain words for each of the two languages, whereas concepts are stored in an abstract memory system common to both languages. Other models emphasize differences in semantic representation between different languages (e.g., van Hell & De Groot, 1998; for reviews see De Groot, 2012; Dijkstra & van Heuven, 2012). Our findings suggest that the division of labor between the hemispheres during semantic processing is different in native and non-native languages. Furthermore, the findings also suggest that the conceptual representation of word meaning may differ in a native and non-native language such that meanings are fuller and richer in a native language, including a wider range of semantic features and associations, even for relatively proficient foreign language speakers.

Since behavioral as well as neuroimaging studies suggest that many of the qualitative differences between native and non-native speakers in lexico-semantic representations may depend on several factors such as age of acquisition, proficiency and exposure level (for a review see e.g., Abutalebi & Della Rosa, 2012) further studies comparing semantic processing by the two cerebral hemispheres in native and non-native speakers should focus on the effects of these factors.

4. Method

4.1. Participants

Thirty female students with a mean age of 22.32 ($SD = 1.5$) participated in the study. All were native Hebrew speakers who started studying English at school in 4th grade (age 9). All acquired a high level of proficiency in English as indicated both by their SAT English exemption scores, indicating that they were highly proficient in English and by self report. All participants yielded a laterality quotient of at least +80 on the Edinburgh Inventory, indicating strong right-handedness (Oldfield, 1971).

4.2. Stimuli

Word pairs used in the study were selected from two, Hebrew and English lists, each comprising of 284 same-category prime–target pairs of singular nouns, 2–7 and 3–8 letters long for Hebrew and English, respectively. The Hebrew word pairs were translated into English by two Hebrew–English bilingual students. The Hebrew and English prime–target lists were presented to forty students who did not participate in the experiment, but met the inclusion criteria used for the experiment sample. The judges rated the prime and target words for familiarity on a scale from *unfamiliar* (1) to *very familiar* (7), and concreteness on a scale from *not at all concrete* (1) to *very concrete* (7). In addition, judges rated the degree of meaning relatedness between word pairs, on a scale from *The words are not related in meaning* (1) to *The words are strongly related in meaning* (7). Language was counterbalanced among judges so that each judge rated each word and each word pair only once, either in Hebrew or English.

The fifty most strongly related word pairs (e.g., *palace–castle*) and fifty most weakly related pairs (e.g., *mouse–bird)* were selected for this study (see Appendix A for target word and word pair properties). Table 1 presents descriptive statistics of target words and word pairs by language and pair relationship. Target words familiarity did not differ between the strongly and weakly related pairs, both for Hebrew ($p = .20$) and English ($p = .60$). Target words concreteness did not differ between the strongly and weakly related pairs for Hebrew ($p = .37$) but was marginally higher for the weakly than strongly related pairs in English ($p = .07$). Nevertheless, the Language $\times$ Pair relationship interaction was not significant ($p = .52$). Target words were significantly longer for the strongly than weakly related pairs for Hebrew ($p = .04$) and marginally longer for English ($p = .08$). However, word length and pair relatedness affected RTs and accuracy is opposite directions. More importantly, prime–target semantic relatedness was significantly higher for the strongly than weakly related pairs, both for Hebrew and English ($ps < .001$).

One hundred unrelated prime–target pairs were generated by re-pairing the primes and targets of the strongly and weakly related word pairs. The unrelated pairs were each rated as "unrelated" by at least 80% of the raters. Finally, 75 Hebrew and 75 English word–pseudoword pairs were generated by pairing words from the initial list that were not selected for the strongly or weakly related pairs with Hebrew and English pseudoword targets. Pseudoword targets were created by replacing two letters in real

Table 1
Descriptive statistics of target words properties and relatedness ratings of word pairs by language and pair relationship.

	Hebrew				English			
	Strongly related		Weakly related		Strongly related		Weakly related	
	M	SD	*M*	SD	*M*	SD	*M*	SD
Familiarity	5.31	1.01	5.05	1.08	5.27	1.02	5.17	0.95
Concreteness	5.64	1.01	5.80	0.93	5.46	1.01	5.78	0.62
Word length	4.38	1.18	3.90	0.97	5.04	1.26	4.64	1.08
Relatedness rating	6.15	0.43	3.45	0.89	6.06	0.54	3.42	0.73

Table 2
Sample set of experimental prime and target stimuli.

Relationship	Hebrew		English	
	Prime	Target	Prime	Target
Strongly related				
Phonetic transcription	/armon/	/tira/	Palace	Castle
Hebrew script	ארמון	טירה		
Weakly related				
Phonetic transcription	/gesher/	/migdal/	Bridge	Tower
Hebrew script	גשר	מגדל		
Unrelated				
Phonetic transcription	/sus/	/maalit/	Horse	Elevator
Hebrew script	סוס	מעלית		

Table 3
Descriptive statistics of RTs for correct responses by language, visual field, and pair relationship.

Relationship	Hebrew						English					
	RVF/LH			LVF/RH			RVF/LH			LVF/RH		
	M	SD	95% CI	*M*	SD	95% CI	*M*	SD	95% CI	*M*	SD	95% CI
Relationship	Hebrew						English					
Strong	609.74	151.19	553.29–666.20	621.42	174.72	556.19–686.67	673.20	121.18	627.95–718.45	691.63	141.95	638.63–744.64
Weak	637.31	145.27	583.07–691.56	602.35	127.12	554.89–649.83	698.23	113.13	655.99–740.48	736.97	136.62	687.83–786.12
Unrelated	655.32	158.40	596.18–714.48	636.24	136.59	585.24–687.25	717.34	117.76	673.38–761.32	741.52	137.29	690.25–792.79

Table 4
Descriptive statistics of percent correct responses by language, visual field, and pair relationship.

Relationship	Hebrew						English					
	RVF/LH			LVF/RH			RVF/LH			LVF/RH		
	M	SD	95% CI	*M*	SD	95% CI	*M*	SD	95% CI	*M*	SD	95% CI
Strong	98.1	0.4	96.5–99.6	96.5	0.7	93.7–99.3	96.5	0.7	93.9–99.1	90.7	1.0	87.1–94.3
Weak	93.9	0.8	90.8–96.9	96.8	0.6	94.6–98.9	90.3	0.9	86.8–93.8	89.0	1.1	84.9–93.2
Unrelated	93.5	0.9	90.1–96.8	96.0	0.4	94.5–97.5	90.8	0.7	88.1–93.5	87.2	1.0	83.3–91.1

Hebrew and real English words such that the resulting strings were pronounceable but nonexistent words in these languages. An example of a sample set of experimental prime and target stimuli is presented in Table 2.

In order for each participant to be tested with each word pair only once throughout the experiment, four sets of word pairs were created from the full word pairs lists. Each set included two blocks of word pairs, one in Hebrew and one in English. Each block comprised 25 strongly related, 25 weakly related, 50 unrelated prime–target, and 75 word–pseudoword pairs. Sets were created so that word pairs appeared within a set only once. Visual fields were counterbalanced across sets. Each participant was presented with one set of word pairs. In total, each participant was presented with 350 word pairs, half in Hebrew and half in English and saw each prime–target pair, either in Hebrew or in English, only once throughout the experiment.

4.3. Procedure

The presentation of the stimuli was conducted using the SuperLab-Pro 2.0 software that controlled the stimulus presentation and measured response times (RTs) in milliseconds. Each participant was tested individually in a single session conducted in a dim, quiet testing room. Stimuli were presented one word at a time on a 17″ SVGA monitor placed at a distance of approximately 60 cm from the participant. Each trial began with a presentation of a 2-mm black fixation point, presented centrally for 700 ms. Immediately following the fixation point, a prime word was presented centrally for 150 ms. After 600 ms the target word was presented for 180 ms. For each participant, half of the target words were randomly presented to the LVF and the other half to the RVF, such that the center of each word was 3.0° and the innermost edge of each word was 2.0° from the center of the monitor. Participants were asked to respond to the target as quickly and accurately as possible with a lexical decision judgment: i.e., they were to press "yes" with one response button if the target was a legal word or "no" with the other button if target was a non-word. Hand used to respond "yes" was counterbalanced across participants and lists. The participant's response initiated the next trial sequence with an ISI of 600 ms.

Word pairs within language blocks were presented randomly, differently for each participant, in bold Arial 42" font in black against a white background. A 20-trial practice block proceeded the experimental session.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.bandl.2012.09.007.

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