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Cross-language influences: translation status affects intraword sense relatedness

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Abstract Many words have more than one meaning, and these meanings vary in their degree of relatedness. In the present experiment, we examined whether this degree of relatedness is influenced by whether or not the two meanings share a translation in a bilingual's other language. Native English speakers with Spanish as a second language (i.e., English-Spanish bilinguals) and native Spanish speakers with English as a second language (i.e., Spanish-English bilinguals) were presented with pairs of phrases instantiating different senses of ambiguous English words (e.g., *dinner date–expiration date*) and were asked to decide whether the two senses were related in meaning. Critically, for some pairs of phrases, a single Spanish translation encompassed both meanings of the ambiguous word (*joint-translation condition*; e.g., *mercado* in Spanish refers to both a flea market and the housing market), but for others, each sense corresponded to a different Spanish translation (*split-translation condition*; e.g., *cita* in Spanish refers to a dinner date, but *fecha* refers to an expiration date). The proportions of "yes" (related) responses revealed that, relative to monolingual English speakers, Spanish–English bilinguals consider joint-translation senses to be less related than split-translation senses. These findings exemplify semantic cross-language influences from a first to a second language and reveal the semantic structure of the bilingual lexicon.

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Words are notoriously ambiguous in meaning. A single word can refer to several slightly different referents, or even to completely different referents, in different contexts. The word *beam* for instance, refers to a wooden beam in the context of carpentry, but to a laser beam in the context of physics. The different senses of words may be more or less related in meaning, and may share many or no semantic features. For instance, both senses of the polysemous word *beam* encompass a referent with a straight line. In other cases, a word can encompass two unrelated meanings, for which it is more difficult to identify a shared set of semantic features (e.g., the homonym *bark*, referring to the sound a dog makes or to the outer layer of a tree). Such homonyms are typically thought to have been accidently created in the language, such that two separate lexical entries happen to share form (e.g., Klein & Murphy, 2001, 2002).

Words therefore vary in the degree of relatedness of their different nuances of meaning, which we will refer to as *intraword sense relatedness*. In the present experiment, we examined whether this degree of relatedness is influenced by whether or not the two meanings share a translation in a bilingual's other language. In particular, we examined whether the two senses of an ambiguous word are more (or less) related when a single word in a bilingual's other language also captures these two senses. For example, the Spanish word *operación* refers to both the military and the mathematical senses of the English word *operation*. In contrast, each sense of the English word *ring* is translated into a different word in Spanish; *anillo* corresponds to the jewelry, whereas *timbre* corresponds to the sound. Here, we asked whether two senses with a shared translation in Spanish (*joint-translation condition*) are more or less related than two senses with independent translations in Spanish (*split-translation condition*) for bilinguals of Spanish and English, as compared with monolingual English speakers (see Fig. 1).

This issue is important to examine for several reasons. First, such cross-language influences, and especially those from a second (L2) to a first (L1) language, highlight the dynamic nature of the bilingual lexicon and exemplify the interconnectivity between the languages of multilingual speakers (see, e.g., Degani, Prior, & Tokowicz, 2011). Second, as reviewed below, the relatedness of the meanings of ambiguous words influences how ambiguous words are processed both in and out of context. Thus, if knowledge of another language exerts an influence on the degree of meaning relatedness, bilinguals may not process ambiguous words in the same way as monolingual speakers.

In the remainder of the introduction we first discuss semantic cross-language influences in the bilingual lexicon. We consider different inhibitory and facilitative processes that may be at play due to indirect mappings across translations. We then briefly review how semantic ambiguity influences language processing, focusing on the importance of the semantic relatedness among intraword senses. Finally, we consider inhibition and facilitation in the connections among intraword senses before outlining the predictions for the present experiment.

Cross-language influences: the shared-translation effect

In the present study, we explore whether intraword sense relatedness changes as a function of learning. Specifically,

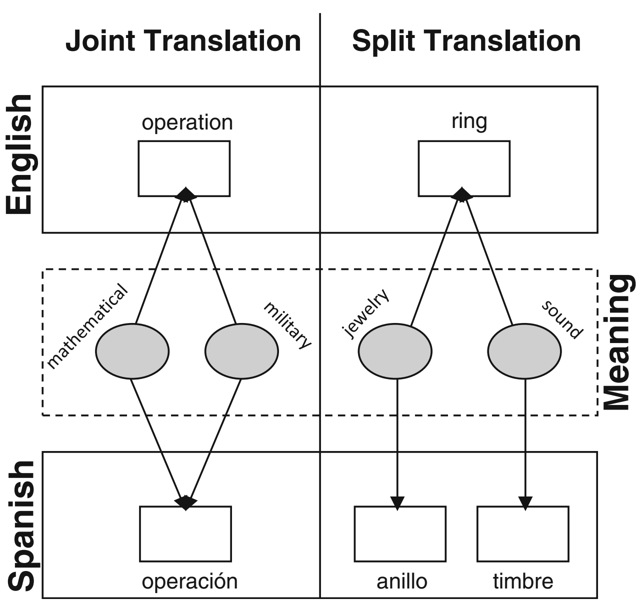

Fig. 1 Schematic representation of the joint-translation and split-translation conditions in the mapping of words to meaning in the bilingual lexicon

we ask whether the translation status of a word in a bilingual's other language increases or decreases the semantic relatedness of different senses. The potential for such semantic cross-language influences are suggested by recent studies examining the effect of a shared translation.

In a study with Hebrew–English and English–Hebrew bilinguals, Degani et al. (2011) examined the semantic relatedness of English word pairs that shared a translation in Hebrew (e.g., *tool* and *dish* share the Hebrew translation *kli*). In comparison to English pairs with different Hebrew translations, and to ratings by monolingual English speakers, bilinguals rated shared-translation pairs as more related in meaning (the *shared-translation effect*). Critically, this shared-translation effect was demonstrated not only for Hebrew–English bilinguals who learned English as an L2, but also for English–Hebrew bilinguals who learned Hebrew as an L2. Thus, for these bilinguals, a later-learned L2 influenced the semantic relatedness ratings of L1 word pairs. Furthermore, Degani et al. (2011) extended the investigation of this issue beyond related word pairs (e.g., *home–house*; e.g., Jiang, 2002, 2004) to unrelated word pairs (e.g., *tool–dish*). The shared-translation effect was present, and of similar magnitude, for both types of items, suggesting that even relatively unrelated words became more similar in meaning for bilingual speakers due to a shared translation.

Increased relatedness for shared-translation words across different levels of baseline semantic relatedness, and for both L1 and L2, might be due to coactivation in the interconnected bilingual lexicon. The *coactivation account* postulates that when bilinguals encounter a shared-translation word (e.g., the Hebrew word *kli* corresponding to both *tool* and *dish* in English), its two meanings are activated (e.g., Elston-Güttler & Friederici, 2005; Onifer & Swinney, 1981). Likewise, its two translations are also likely to be activated (e.g., Schwartz & Arêas da Luz Fontes, 2008) because both languages of bilingual speakers tend to be activated even in a single-language context (e.g., van Hell & Dijkstra, 2002). Based on Hebbian principles (Hebb, 1949), this coactivation of the two meanings and two translations of the shared-translation word leads to increased connections between them. The semantic relatedness of the two words is therefore increased, giving rise to the shared-translation effect.

Alternatively, an inhibitory mechanism may be at play, such that two words that share a translation become *less* related because they tend to serve as lexical competitors in many contexts. For instance, when one talks about the wonderful weather in the spring, the seasonal meaning of *spring* is appropriate, whereas the mechanical/coil meaning of *spring* is not (Chwilla & Kolk, 2003). By extension, only the translation corresponding to the appropriate meaning is relevant (i.e., *primavera* and not *resorte*, in Spanish). The two meanings (and translations) are therefore mutually exclusive and may develop inhibitory connections.

This inhibition account was proposed to explain reduced priming between two English words that map to a shared homonymous German translation. In particular, in an all English task, Elston-Güttler, Paulmann, and Kotz (2005) presented participants with target words (e.g., *jaw*) for lexical decision following either a shared-translation prime (e.g., *pine–jaw*, both corresponding to *Kiefer* in German) or an unrelated prime (e.g., *oak–jaw*). They recorded both behavioral measures (response times and accuracy) and event-related potentials (ERPs) while less- and more-proficient German–English bilinguals performed the task. For less-proficient bilinguals, reversed priming was observed in that they took longer to indicate lexicality for the target word when it was preceded by a sentence ending in a shared-translation word (e.g., *The beautiful table was made of solid pine . . . jaw*), as compared with control items. Reversed priming was also observed in the N200 component, with a larger N200 following shared-translation primes relative to control items. Thus, less-proficient bilinguals (but not more-proficient bilinguals) exhibited what seems to be inhibition between the two meanings of a shared L1 homonym when these were presented in context. The authors suggested that lexical-level inhibitory connections develop between the two translations of homonyms, because these serve as lexical competitors in many contexts (e.g., Chwilla & Kolk, 2003).

Thus, two mechanisms may be at play when two meanings (or translations) share a label (see Fig. 2). Increased relatedness or facilitation has been observed in isolation (Degani et al., 2011; Jiang, 2002, 2004; see also Morford, Wilkinson, Villwock, Piñar, & Kroll, 2011; Thierry & Wu, 2007; Wu & Thierry, 2010; Zhang, van Heuven, & Conklin, 2011) and in sentence context (Elston-Güttler & Williams, 2008), and when the shared-translation words were related in meaning (e.g., *home–house*, Degani et al., 2011; Elston-Güttler & Williams, 2008; Jiang, 2002, 2004; Morford et al., 2011; Thierry & Wu, 2007) and unrelated in meaning (e.g., *tool–dish*; Degani et al., 2011; Morford et al., 2011; Thierry & Wu, 2007; Wu & Thierry, 2010; Zhang et al., 2011). Inhibition has nonetheless been observed for unrelated shared-translation words in sentence context (Elston-Güttler et al., 2005).

The findings reviewed thus far may be taken to suggest semantic cross-language influences between a bilingual's two languages. Rather than examining the relation between different words, in the present study, we examine such influences on the relatedness of different senses of the same ambiguous word. In other words, we test whether the semantic relatedness of intraword senses differ in the bilingual lexicon as a function of whether the different senses share a translation in a bilingual's other language.

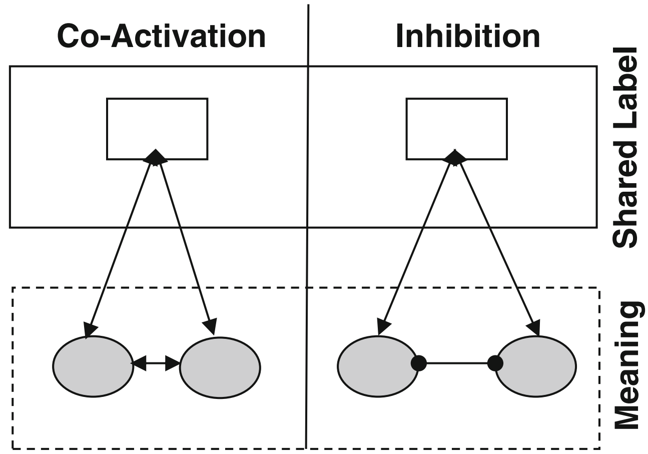

Fig. 2 Processes at play when two meanings share a label. The pointed arrows indicate facilitative connections, whereas the rounded arrows represent inhibitory connections. The two meanings are pulled together, due to coactivation, or pulled apart, due to inhibition

Semantic relatedness effects in ambiguity processing

A key finding that has emerged from extensive research on semantic ambiguity (e.g., Gorfein, 2001), is a difference in processing between ambiguous and unambiguous words across a variety of tasks (e.g., lexical decision, naming, and semantic categorization—Hino, Lupker, & Pexman, 2002; reading of connected text—Duffy, Morris, & Rayner, 1988). Ambiguous words were initially found to be processed more quickly than unambiguous words in lexical decision tasks (e.g., Kellas, Ferraro, & Simpson, 1988). However, more recent studies have highlighted the relevance of the degree of relatedness of the different senses/meanings of ambiguous words, and have claimed that this dimension had been overlooked in most previous research (e.g., Rodd, Gaskell, & Marslen-Wilson, 2002; see also Beretta, Fiorentino, & Poeppel, 2005; Klepousniotou & Baum, 2007). In particular, Rodd and colleagues showed that lexical decisions to words with fewer senses are slower than decisions to words with multiple related senses, but are faster than to words with multiple unrelated meanings (see also Armstrong & Plaut, 2008; Klepousniotou & Baum, 2007; see Beretta et al., 2005, for converging MEG results). Rodd et al. further showed that relatedness of senses accounted for unique variance in the processing of ambiguous words, such that ambiguous words were processed more quickly as the relatedness of their senses increased.

The relevance of intraword sense relatedness was further highlighted in a recent study by Rodd et al. (2012) in which monolingual participants were trained with fictitious new meanings for unambiguous English words. Critically, these new meanings were either semantically related or unrelated to the previously known meaning. In a cued recall test, participants were more accurate in their memory of related than unrelated meanings. Furthermore, when sufficient training took place (Exp. 3), the relatedness effect was manifested in a lexical decision task, such that words for which new related meanings were trained were responded to more quickly than words for which new unrelated meanings were trained.

Together, the empirical evidence clearly shows a processing difference as a function of the degree of semantic relatedness of intraword senses. The question asked in the present investigation is whether changes to the semantic relatedness of senses occur as a function of the mapping of words to meanings in another language, such that bilinguals differ from monolinguals in their processing of ambiguous words.

Inhibition and facilitation among intraword senses

The extensive literature on ambiguity processing suggests that the two meanings of ambiguous words are initially coactivated (though this activation is partially a function of meaning dominance and contextual constraint; e.g., Simpson, 1981). This initial coactivation may lead to increased relatedness of the different meanings of ambiguous words. This is especially likely for polysemous words, for which multiple senses could be relevant in the same context. For example, in the sentence *Your book is not only badly written, it is too heavy*, both the physical sense of the word book and the novel meaning are relevant (for a discussion, see Klein & Murphy, 2001, p. 273).

Following this initial coactivation, the meaning that is appropriate in the context is selected, but the fate of the inappropriate meaning is in question. Its activation may simply decay to baseline or it may be actively suppressed or inhibited below baseline. If the latter is true, then inhibitory connections may develop between the two alternative meanings of the ambiguous word.

Several studies provide evidence relevant to this issue. For example, Chwilla and Kolk (2003) examined the relationship between intraword meanings/senses by using an ERP double word priming procedure. Specifically, they compared priming for conditions in which a target word was preceded by one related prime and one unrelated prime (e.g., *kidney–soda–organ*) to a condition in which the target was preceded by two primes that were related to different meanings of the target but unrelated to each other (e.g., *kidney–piano–organ*). Results from a lexical decision task showed additive effects for the two related primes in both response time and N400 mean amplitude, suggesting neither inhibition nor facilitation between the two meanings of the ambiguous word. In a relatedness judgment task of the prime(s) to the target, however, the results showed underadditive priming of the two related primes. This indicates that one or both primes produced less facilitation than when presented alone, suggesting inhibition between the different meanings of the ambiguous words.

It is important to note that this inhibition between multiple meanings of ambiguous words was observed when the task required meaning selection (i.e., in the relatedness judgment task) but was absent in the lexical decision task (see also Balota & Paul, 1996). It is therefore not clear whether such inhibition leads to stable changes in semantic representation of the type we investigate here. Furthermore, these studies presumably focused on ambiguous words with unrelated meanings, but the degree of relatedness of the different meanings was not specifically examined.

Evidence regarding facilitation and inhibition between different senses of polysemous words also comes from one of the experiments in a study by Klein and Murphy (2001, Exp. 5). Using a sensicality judgment task (i.e., judging whether an expression makes sense) and focusing on polysemous words only, they contrasted same-sense repetitions (*daily paper–liberal paper*) and different-sense repetitions (*wrapping paper–liberal paper*) with a neutral condition (____ *paper–liberal paper*). Their results provided support for both facilitation of same-sense repetition and inhibition of different-sense repetitions, in that the neutral condition elicited slower and less accurate decisions than the same-sense repetitions, but faster and more accurate decisions than different-sense repetitions. Notably, however, Klepousniotou, Titone, and Romero (2008) did not observe inhibition for different-sense repetitions using a similar paradigm with a slightly different neutral condition (**** *paper*) (see also Masson & Freedman, 1990, for no evidence of inhibition in a lexical decision task).

To summarize, it is generally agreed that both meanings of ambiguous words receive initial activation when encountered, even in context (for a review, see, e.g., Gorfein, 2001). However, whether this coactivation is followed by inhibition between different senses/meanings of ambiguous words is still an open question.

The present experiment

In the present experiment, we examined ambiguous words that varied in the relatedness of their senses, as determined by the ratings of monolingual English speakers (see Appendix A). Thus, rather than dichotomizing homonyms and polysemes (e.g., by counting the number of entries that a word corresponds to in a dictionary), we chose to rely on the psychological relatedness of the different senses/meanings (for a discussion of the consistency of these two measures, see Rodd et al., 2002). Previous researchers have pointed out the difficulty in clearly distinguishing homonyms from polysemes, and some have similarly adopted a continuous measure to capture intraword sense relatedness (e.g., Klepousniotou et al., 2008; Rodd et al., 2002).

Each ambiguous word was embedded in two expressions, such that each expression highlighted a different sense of the ambiguous word (e.g., *expiration date–dinner date*). These pairs of expressions were then presented together, and participants were asked to make a timed relatedness judgment ("yes" or "no") to each pair. Critically, some pairs of expressions instantiated two senses that are captured by one word in Spanish (*joint-translation condition*) and some pairs instantiated senses that correspond to different Spanish translations of the ambiguous word (*split-translation condition*). For each language group (i.e., monolingual English, English–Spanish bilinguals, and Spanish–English bilinguals) we compared relatedness judgments to joint- and split-translation expressions.

For all participant groups, relatedness ratings are predicted to influence online relatedness judgments (e.g., Jiang, 2002). Specifically, pairs of expressions that were rated in a norming task as more similar in meaning should be more likely to elicit a related ("yes") response in the online judgment task. Furthermore, for trials in which a "yes" response is made, decisions should be faster for more-related pairs than less-related pairs (e.g., Thierry & Wu, 2007). Conversely, for trials in which an unrelated ("no") response is made, decision times should be slower for more-related pairs than less-related pairs (e.g., Morford et al., 2011).

Of particular interest is the difference between joint- and split-translation expressions for bilinguals and monolinguals. Two alternative predictions can be contrasted for this effect on the basis of the coactivation and inhibition accounts. Increased relatedness for joint-translation expressions would be expected if one assumes that a shared label leads to increased connectivity between the senses due to their coactivation (Degani et al., 2011). Senses in the split-translation condition are linked to a shared label in English only, whereas senses in the joint-translation condition are linked to a shared label in Spanish as well. Thus, in the split-translation condition the two senses will be coactivated only when the English word is encountered, but in the joint-translation condition the two senses will be coactivated whenever either the English word or the Spanish word is encountered. The coactivation account was suggested to apply to shared-translation words regardless of their baseline semantic relatedness (Degani et al., 2011). By extension, two senses will grow more similar in meaning by their shared Spanish translation, irrespective of their initial relatedness (i.e., for homonymous and polysemous words alike).

Alternatively, two concepts or words that share a label may be *less* related in meaning because of inhibition. In particular, because the two meanings of an ambiguous word are mutually exclusive in most contexts (e.g., the river edge meaning of *bank* is inappropriate in a financial context), they could inhibit each other, such that the activation of one meaning would reduce activation of the other meaning. As we reviewed above, the empirical evidence regarding such intraword sense/meaning inhibition is inconsistent. Moreover, inhibition might be hypothesized to play a role for unrelated meanings (of homonyms; e.g., Elston-Güttler et al., 2005), but it is less clear why related senses (e.g., of polysemes) would inhibit each other, given that they sometimes fit the same context (for discussion, see Degani et al., 2011; Klein & Murphy, 2001). Here, the inhibition account predicts that two senses that share a label in English and in Spanish (i.e., joint-translation condition) would be less related than two senses that share a label in English but correspond to two translations in Spanish (i.e., split-translation condition), especially if the two senses are unrelated in meaning.

Of interest, the facilitation (coactivation) and inhibition (competition) mechanisms may both be at play, but their interaction may vary with language-processing time course and as a function of the bilingual proficiency in the two languages. The present study allows only limited evidence regarding time-course modulations, but directly examines how these processes vary as a function of language proficiency. Indeed, experience with the languages may alter the operation of these processes (e.g., Kellerman, 1982). Thus, because it takes time for L2 learners to fully grasp the nuances of L2 word meanings, we may observe a different balance of inhibition and facilitation for less- and more-proficient bilinguals. For instance, less-proficient speakers may be hesitant to assume that an ambiguous word in their L1 is captured by a single word in L2 (Kellerman, 1982), under the assumption that homonyms were accidentally created (e.g., Klein & Murphy, 2001, 2002). This *exaggerated caution* may lead them to experience difficulty in the joint-translation condition, in which both languages capture two senses with a single label.[1] Furthermore, when less-proficient bilinguals learn that two words in L1 share a label in L2, they may experience increases in semantic relatedness that go beyond what would be expected had the two words shared a label in the L1 from the start. We have termed this the *exaggerated shared-translation* account. Thus, the manifestation of semantic cross-language influences may vary as a function of language proficiency (e.g., Elston-Güttler et al., 2005). We return to the exaggerated caution and exaggerated shared-translation explanations in the Discussion section.

To examine these issues, we compared semantic relatedness judgments of English–Spanish and Spanish–English bilinguals and English monolinguals to pairs of expressions containing an ambiguous word (e.g., *diamond ring–loud ring*) that either share a Spanish translation (joint-translation condition) or correspond to two different Spanish translations (split-

[1] We thank an anonymous reviewer for raising this interesting suggestion.

translation condition). We further examine this as a function of bilingual proficiency.

Method

Participants

Thirty monolingual English speakers, 30 English–Spanish bilinguals, and 30 Spanish–English bilinguals took part in this experiment. See Table 1 for background information on the final set of 90 participants. The monolingual English speakers (ME) participated for class credit. All were native English speakers who were not exposed to other languages before age 10 (with the exception of one who reported having some exposure at age 7), and were exposed to English at least 80 % of the time at the time of testing. None had studied Spanish.

The English–Spanish (ES) bilinguals were native English speakers who had studied Spanish as an L2 and were not exposed to Spanish at home during childhood. They were at least moderately proficient in Spanish. The Spanish–English (SE) bilinguals were native Spanish speakers who learned English as an L2 and were not exposed to English at home during childhood. They were at least moderately proficient in English. Two participants had indicated that English had become their dominant language.[2,3] All bilinguals were paid for their participation.

Materials

Initially, a set of 185 ambiguous English words were selected from available research on within-language ambiguity (e.g., Klepousniotou et al., 2008; Nelson, McEvoy, Walling, & Wheeler, 1980; Twilley, Dixon, Taylor, & Clark, 1994); 84 of them have a single translation in Spanish that captures both meanings/senses of the English word (joint-translation condition), and 101 have two Spanish translations (split-translation condition, each encompassing one of the senses/meanings of the English word). Translations in Spanish were initially determined by two highly proficient Spanish–English bilinguals, and were confirmed with translation overlap norms (details below).

Two modifiers were selected for each ambiguous word, each highlighting a different sense or meaning of the word, for example, *human body–administrative body*. These pairs of expressions were presented to a separate group of 20 monolingual English speakers who rated the meaning similarity of the two senses on a scale from 1 (*completely different*) to 7 (*exactly the same*) (see Appendix A). Two versions were created such that the order of presentation of the modified expressions was altered from one version to the next. These data indicate that the meanings of ambiguous English words vary in their semantic relatedness (M=2.7, range=1.1–5.7). These relatedness ratings were used as a predictor in the model analyzing the experimental data to ensure that differences between the joint-translation and split-translation conditions are not due to baseline differences in English meaning relatedness.

Two versions of the experimental stimuli were used, such that the order of the expressions within each pair was switched between versions. Approximately half of the participants in each group completed each version (i.e., Version 1–Version 2 splits of 16–13 for ME, 13–16 for ES, and 15–15 for SE). Each participant saw each ambiguous word in only one pair of expressions.

Translation-overlap norm rating

The norms are available at http://plumlab.pitt.edu/norms/. All 185 expression pairs were presented to participants in the main experiment, but additional procedures were followed to allow a more informed item selection procedure for the analysis. In particular, to verify that the Spanish translations adhered to our expectations, we asked the bilinguals who participated in the main experiment to translate the English expressions into Spanish approximately 9 months after their initial participation.

Participants A group of 24 bilinguals completed the translation task in one of two versions (see below; 13 in version A, and 11 in version B). Data from two participants were not used to maintain an equal number of participants in each version of the norms. The final set of participants therefore consisted of 22 participants, 12 English–Spanish bilinguals and 10 Spanish–English bilinguals. Each version was completed by half of the participants in each bilingual group.

Stimuli Expression pairs were divided into individual expressions, such that one expression from each pair was assigned to version A (e.g., *wood beam*) and the other expression was assigned to version B (e.g., *laser beam*). Each participant completed one version, and therefore translated only one expression from each pair. Order of presentation was initially randomized, and then kept constant in the two versions.

[2] The data from an additional 32 participants were replaced because they did not meet the language background criteria (six MEs who had learned Spanish, as well as five ESs who were not native speakers of English, were exposed to Spanish during childhood, or were not moderately proficient in Spanish), had difficulty following instructions on multiple tasks (one SE), or had poor performance on a preceding reading task, reported elsewhere (Degani, 2011; nine ME, seven ES, four SE).

[3] No significant differences emerged between the three groups in intelligence, as measured by a computerized version of Raven's Progressive Matrices (Raven, 1960). The SE group scored lower in operation–word working memory span (Turner & Engle, 1989), but this difference should be interpreted with caution, because the groups also differed in age.

Table 1 Participant characteristics as a function of group

Measure	Linguistic Background Group		
	Spanish–English Bilinguals	English–Spanish Bilinguals	English Monolinguals
Number of participants (gender)	30 (8 males)	30 (4 males)	30 (11 males)
L1	Spanish	English	English
Age (in years)	33.63 (11.84)$_a$	23.83 (8.35)$_b$	19.83 (2.69)$_b$
Age began learning L2 (in years)	10.98 (6.13)$_a$	12.10 (3.09)$_a$	n/a
Time studied L2 (in years)	13.20 (7.44)$_a$	9.15 (5.03)$_b$	n/a
L2 immersion (in years)	6.98 (8.44)$_a$	0.33 (0.58)$_b$	n/a
L1 proficiency	9.75 (0.53)$_a$	9.91 (0.23)$_a$	9.77 (0.48)$_a$
L2 proficiency	8.06 (1.36)$_a$	7.79 (0.79)$_a$	n/a
L1 current use	5.19 (2.12)$_a$	8.61 (1.33)$_b$	9.75 (0.63)$_c$
L2 current use	7.89 (1.30)$_a$	4.03 (1.68)$_b$	n/a
Nonverbal intelligence	5.96 (3.24)$_a$	6.96 (3.53)$_a$	6.89 (3.77) $_a$
Working memory span	.87 (.10)$_a$	.93 (.08)$_{a,b}$	.93 (.06)$_b$

Standard deviations of the measures appear in parentheses. Proficiency scores are the averages of reading, writing, conversational, and speech comprehension ability ratings on a 10-point scale, on which 1 indicated the lowest level of ability. The current-use scores are the averages of speaking, writing, reading, listening-to-the-radio, and watching-TV ratings on a 10-point scale on which 1 indicated the lowest level of current use. Nonverbal intelligence was estimated using a computerized abbreviated version (18 items) of Raven's Progressive Matrices (Raven, 1960). Working memory span was estimated using the weighted mean (PCU; see Conway et al., 2005) of the operation–word working memory span task (Turner & Engle, 1989). See Degani (2011) for details. Means in the same row that do not share subscripts differ at the $p<.05$ level in a t test with Bonferroni correction for multiple comparisons. L1, first language; L2, second language

Procedure Participants completed the task on their own time outside of the lab by providing the first Spanish translation they thought of for each English expression. They were instructed not to use the dictionary, but simply to guess or indicate "no" if they did not know the translation. They were further encouraged to translate the expressions in the order provided and to refrain from changing previous answers or going back.

Coding To examine translation overlap across the two expressions in each pair, we examined the Spanish translations given to the ambiguous word itself (i.e., the repeated word in each pair; e.g., "beam" in "wood beam" and "laser beam"). For each pair of expressions, translation overlap was computed as the number of times the same Spanish translation was given in both expressions to the ambiguous English word (range 0–11).

Furthermore, for each expression we counted the number of omitted or incorrect responses (range 0–11), as well as the number of different correct responses given to each word (word variability) and each modifier (modifier variability) in the expression. Lastly, a proficient English–Spanish bilingual noted whether one of the Spanish translations given to the critical word was a cognate (cognate present).

Item selection

Item selection followed several criteria. First, 47 expression pairs that elicited seven or more omitted or incorrect responses (possible range: 0–22) were excluded. Second, with respect to translation overlap, items in the split-translation condition were retained only if they never elicited a shared Spanish translation in the norms. Items in the joint-translation condition were retained if they elicited a shared translation at least six (of 11) times. On the basis of these criteria, 94 expression pairs were selected (see Table 2 for the item characteristics and Appendix A for the full list of items). The remaining 91 items served as fillers in the analysis. Additional dimensions on which the items in the joint-translation condition differed from items in the split-translation condition were entered as covariates in the statistical analysis (see Results section).

Procedure

The semantic relatedness task was embedded within a larger study described elsewhere (Degani, 2011). This task was administered following a 45-min eyetracking session in which participants silently read English sentences that varied in their semantic anomaly. The semantic relatedness task described here was administered individually in a quiet room. On each trial, participants were presented with a pair of expressions, each including an ambiguous English word along with a modifier of its meaning or sense, all at once (e.g., *kitchen cabinet–presidential cabinet*). They were asked to decide whether the two senses described in these

Table 2 Example stimuli and experimental item characteristics as a function of condition

Measure	Condition	
	Joint-translation	Split-translation
Number of items	50	44
Example	housing market–flea market	expiration date–dinner date
Spanish translation(s)	*mercado*	*cita–fecha*
Translation overlap (0–11)*	8.02 (1.79)	0 (0)
Semantic relatedness rating (1–7 scale)*	3.63 (1.21)	2.08 (0.80)
Average length (in letters)*	6.46 (2.27)	4.41 (0.87)
Average frequency (Kučera–Francis)	122.56 (126.25)	131.89 (197.80)
Average concreteness	471.98 (113.37)	476.23 (100.99)
Average modifier's length	6.79 (2.09)	6.35 (1.90)
Cognate present*	.54 (.50)	.23 (.42)
Average omitted/incorrect word responses*	2.34 (1.69)	3.27 (1.89)
Average omitted/incorrect modifier responses±	2.94 (2.21)	3.68 (2.03)
Average word translation variability*	1.55 (0.65)	2.48 (0.95)
Average modifier translation variability±	1.47 (1.10)	1.84 (1.02)
Same part of speech in the two expressions*	.90 (.30)	.43 (.50)

Standard deviations appear in parentheses. Asterisks mark significant differences between the conditions at the $p<.05$ level; ±s mark marginally significant differences between the conditions at the $p<.1$ level. Word Kučera–Francis frequencies and word concreteness (range 100–700) were taken from the MRC database (Wilson, 1988)

expressions were related in meaning, by pressing "yes" or "no" as quickly and accurately as possible; "yes" responses were always made with the dominant hand. Participants were informed that this was not a test of their knowledge but rather that we were interested in their intuitions. Each trial began with a fixation cross in the center of the screen for 1,500 ms followed by the pair of expressions, until a response was made or 10 s had elapsed. Two examples were provided in the instructions and five practice trials were presented to allow participants to become comfortable with the task. Because we were interested in participants' subjective judgments of relatedness, feedback was never provided. A total of 185 experimental trials were presented in a different randomized order for each participant (E-Prime software; Psychology Software Tools, Pittsburgh, PA), interleaved with three short breaks.

Following this task, participants completed proficiency tests in English and (for bilinguals) Spanish (including lexical decision and picture naming tasks), as well as working memory and nonverbal intelligence tasks. Before debriefing they completed a language history questionnaire and a brief posttest related to the eyetracking experiment.

Results

Data analysis

The data from two participants were lost; analyses were therefore performed on a final set of 88 participants (29 ME, 29 ES, and 30 SE). Analyses were performed using linear mixed effects models, as implemented in the lme4 library in R (Baayen, Davidson, & Bates, 2008; R Development Core Team, 2007). The models included random effects of participants and items, and fixed effects of group, condition, and the interaction between them. For the effect of group, ME speakers were established as the reference, such that we examined the difference between ES bilinguals and ME speakers and the difference between SE bilinguals and ME speakers. In addition, participant age and item characteristics were included as covariates. The item characteristics include word length, word log Kučera–Francis frequency (taken from the MRC Psycholinguistic Database; Wilson, 1988), log word concreteness ratings (MRC database; Wilson, 1988), length of first and second modifiers and their position within the expression, and whether the two expressions instantiated the ambiguous word in the same part of speech (e.g., *white lie* and *lie down* instantiate different parts of speech). Importantly, semantic similarity ratings of the expressions obtained from a different group of monolingual English speakers in a norming experiment were included in the model to account for any baseline differences between the split- and joint-translation conditions. Furthermore, on the basis of the translation-overlap norms described above, the average number of missing word translations, the variability in word translation, and the availability of a cognate translation in the norms were entered into the model, to account for baseline differences between the joint- and split-translation conditions. Prior to analyses, covariates were centered and the semantic similarity ratings of the expressions were log transformed to reduce skewness.

A model including main effects was fit first, followed by a model that included the theoretically important interaction between condition and group. To examine whether changes in intraword sense relatedness are modulated by baseline differences in semantic relatedness (i.e., differ for homonyms and polysemes), a second set of models was tested, in which relatedness was allowed to interact with condition and group. A model including two-way interactions was followed up by a model including the three-way interaction among condition, group, and relatedness. Model comparisons using the log-likelihood ratio test reveal that a model including the two-way interactions should be favored; Table 3 presents the coefficient estimates from this model, and Table 4 presents estimated mean performance by group, condition, and relatedness. In what follows, we report only fixed effects that were significant (at $p<.05$) or marginally significant (at $p<.1$).

Response probability

To determine whether the probability of responding "yes" is influenced by relatedness, group, and condition, a logistic regression model with the above predictors was fit to the data. As expected, the results show that as the relatedness of the expressions increased (based on the ME speaker norms), the probability of responding "yes" increased. Furthermore, the probability of responding "yes" marginally decreased as participant age increased.

Critically, the interaction between condition and group was significant, such that the SE bilinguals, but not the ES or ME participants, were more likely to respond "yes" for expressions in the split-translation condition than the joint-translation condition (see Fig. 3). These findings, along with the significant positive slope of the relatedness judgments for this measure, suggest that SE bilinguals consider the two meanings of English ambiguous words to be *less* similar in meaning when both are captured by a single Spanish translation.

The effect of relatedness interacted with the effect of group (see Table 5), such that, in comparison to the ME baseline group, the relatedness effect was stronger for the ES group but weaker for the SE group.

Response times

Response times (RTs) shorter than 200 ms were removed, constituting less than 1 % of the data. Significance was estimated on the basis of 10,000 Markov-chain Monte Carlo samples of the posterior distribution of the parameters (pMCMC; Baayen, 2008). RTs were log-transformed prior to the analyses. Analyses were first performed with response type (i.e., yes/no) as a predictor in the model, to examine

Table 3 Coefficient estimates for the semantic relatedness judgment task

	"yes" Probability	"yes" RT	"no" RT
Intercept	–1.175**	8.118**	7.987**
Participants' age	–0.016$^{\pm}$	0.009**	0.006*
Word length (in letters)	0.018	0.013$^{\pm}$	0.013$^{\pm}$
Word KF frequency (log)	0.042	–0.021	–0.016
Word concreteness ratings (log)	0.369	0.016	–0.127*
Same part of speech	0.318	–0.001	–0.052$^{\pm}$
1st modifier's length	0.015	0.008*	0.011**
2nd modifier's length	0.033	0.008*	0.011**
1st modifier's location [after]	–0.086	0.088**	0.027
2nd modifier's location [after]	–0.036	0.005	–0.059*
Average word translation unknown	0.027	–0.004	–0.006
Average word translation variability	0.121	0.005	–0.007
Cognate translation present	–0.039	0.042	–0.009
Relatedness ratings (log)	4.024**	–0.253**	0.145**
Group [ES]	–0.004	–0.155*	–0.081
Group[SE]	0.240	0.054	0.142*
Condition [split]	–0.316	–0.013	–0.014
Condition [split]: Relatedness ratings	–0.280	0.232**	0.001
Group [ES]: Relatedness ratings	0.519*	–0.015	0.041
Group [SE]: Relatedness ratings	–0.804**	0.054	–0.008
Group [ES]: Condition [split]	0.128	0.020	–0.009
Group [SE] : Condition [split]	0.415*	0.012	0.022

Coefficients for the probability of "yes" responses were estimated with a logistic regression. For the RT analyses, coefficients were estimated on the log-transformed data, and significance was based on Markov-chain Monte Carlo samples of the posterior distribution.
$^{*}p<.05$, $^{**}p<.001$, $^{\pm}p<.10$

Table 4 Estimated mean performance as a function of group, condition, and relatedness

Condition	Relatedness	Measure and Group								
		Percent "yes" responses			"yes" RT			"no" RT		
		SE	ES	ME	SE	ES	ME	SE	ES	ME
Joint-translation	High	63.98	72.12	67.07	3,091.93	2,393.10	2,822.25	3,487.32	2,817.88	3,030.35
	Mean	28.19	23.53	23.60	3,304.84	2,618.16	3,071.99	3,295.05	2,609.37	2,854.33
	Low	7.99	3.53	4.47	3,532.40	2,864.39	3,343.82	3,113.38	2,416.28	2,688.54
Split-translation	High	63.25	65.29	56.58	3,618.08	2,823.39	3,262.79	3,515.76	2,754.97	2,989.48
	Mean	30.26	20.32	18.39	3,578.04	2,857.94	3,285.94	3,321.10	2,550.48	2,815.14
	Low	9.86	3.34	3.75	3,538.45	2,892.92	3,309.26	3,137.22	2,361.17	2,650.97

Means are estimated from the model presented in Table 3 when other covariates are at their mean. High and low relatedness values are based on one standard deviation above and below the mean relatedness, respectively

whether it influenced the speed of response. Because response type was a significant predictor of the latency data, $F(1, 8206)=19.16$, $p<.001$, and interacted with condition, $F(1, 8206)=23.73$, $p<.001$, it was important to examine the effects of condition and group on "yes" responses separately from "no" responses.

In the analyses of "yes" responses, response times increased with participant age and modifier length. Furthermore, shorter RTs were associated with expressions in which the first modifier appeared before the ambiguous word rather than following it. RTs also marginally increased with word length. ES bilinguals responded more quickly overall than ME speakers. As expected, response times decreased as the semantic relatedness of the two expressions increased. Relatedness interacted with condition, such that RT decreased with relatedness for joint-translation items but not for split-translation items (see Fig. 4). Critically, there were no significant interactions between group and condition.

In the analysis of "no" responses, response times increased as participant age increased, as word concreteness

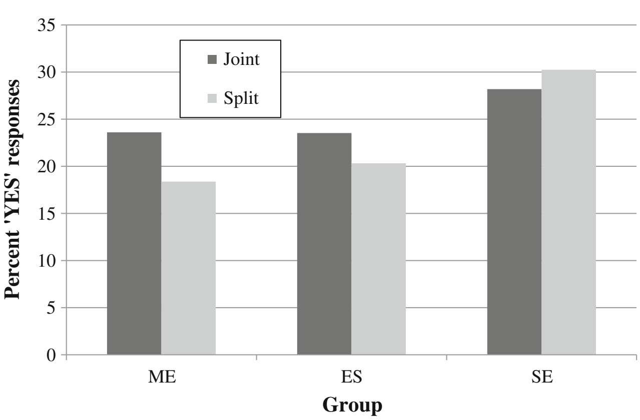

Fig. 3 Percentages of "yes" responses as a function of condition and group (ME, monolingual English speakers; ES, English–Spanish bilinguals; SE, Spanish–English bilinguals)

decreased, and as modifier length increased. Furthermore, RTs marginally increased as word length increased. Pairs of expressions instantiating the same part of speech were associated with marginally shorter RTs. Shorter RTs were also associated with expressions in which the second modifier appeared after the ambiguous word (e.g., *white lie–lie down*). ES bilinguals made "no" responses significantly more quickly overall than ME speakers. As expected, time to make a "no" response increased as the semantic relatedness of the two expressions increased. There were no significant effects of condition or group, and no interaction between them.

Language proficiency

To examine whether cross-language influences, as reflected by the difference between split-translation versus joint-translation items, are modulated by L2 language proficiency, we conducted an additional analysis within each group of bilinguals, and examined whether the effect of condition was modulated by L2 proficiency.[4] Proficiency scores were composite measures derived via a principal-component analysis (see Appendix B for the details). For ES bilinguals we included a Spanish proficiency score, on which participants' accuracy and RT on Spanish lexical decision and picture naming tasks, as well as participant's self-rated Spanish proficiency loaded most strongly. For SE bilinguals we included an English proficiency score on which participants' accuracy and RT in English lexical decision and picture naming tasks and their self-rated English proficiency and use loaded most strongly. The same covariates were included as in the original model with all participants, with the added covariate of the age at which participants began to learn the L2. Coefficient estimates are presented in Table 6.

[4] Because L2 proficiency scores apply only to bilinguals, this analysis was conducted as a secondary analysis with bilinguals only.

Table 5 Percentages of "yes" responses as a function of group and relatedness

	ME	ES	SE
Low relatedness	4.18	3.46	8.72
Mean relatedness	21.44	22.26	28.26
High relatedness	63.02	69.56	62.30

Relatedness was treated as a continuous variable in the model. For presentation purposes, three levels were estimated, with low reflecting one standard deviation below the mean, and high reflecting one standard deviation above the mean

We focus the description below on the effects of L2 proficiency.

ES bilinguals The probability of making a "yes" response increased as L2 (Spanish) proficiency increased. Critically, L2 proficiency did not interact with the effect of condition in any of the measures.

SE bilinguals The probability of "yes" responses was significantly higher when the two expressions instantiated the same part of speech. In addition, time to make a "no" response decreased as L2 (English) proficiency increased. Furthermore, the effect of English proficiency interacted with the effect of condition in two of the three measures. In particular, the pattern we observed in our original model with split-translation items eliciting higher proportions of "yes" responses than joint-translation items for SE bilinguals, appears to be driven by less-proficient participants (see Fig. 5). With increased proficiency, the difference between split-translation and joint-translation items is more similar to the pattern observed for ME (and ES) speakers. The interpretation that less-proficient SE bilinguals consider split-translation items more related than joint-translation items gains support from the latency data for "no" responses, in that again less-proficient SE bilinguals take longer to make a "no" response for split- than joint-translation items (see Fig. 6). Higher proficiency is associated with a pattern more similar to ME (and ES) speakers.

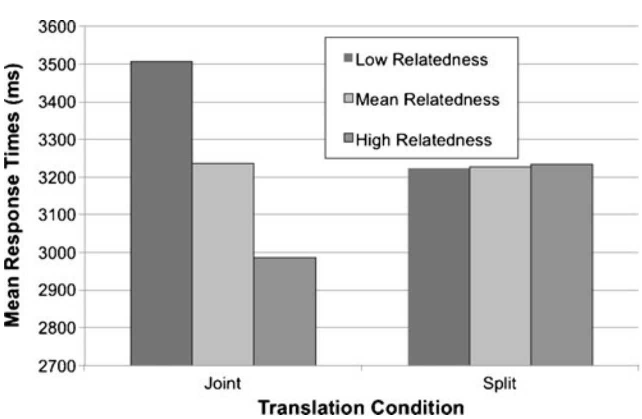

Fig. 4 Response times (in milliseconds) on "yes" trials as a function of condition and relatedness

Discussion

The results of the present experiment show that translation status influences bilinguals' relatedness judgments for intraword senses. In particular, SE bilinguals judged joint-translation items, which instantiate two senses of an ambiguous English word that are captured by a single Spanish translation, to be *less* related than split-translation items, which instantiate senses that correspond to separate Spanish words. This cross-language influence was evident in the proportion of "yes" responses, such that joint-translation items were judged as related less often than split-translation items by SE bilinguals, in comparison to ME speakers.

The idea that this task reflects participants' semantic processes is supported by monolingual English relatedness ratings predicting performance in all three dependent measures. First, pairs that were rated as more related in meaning in the norming experiment by ME speakers were more likely to be judged as related in this task. This effect was somewhat enhanced for ES bilinguals, and attenuated for SE bilinguals. Second, relatedness ratings also significantly predicted response times. In particular, higher ratings were associated with speeded responses on related trials (although only for joint-translation items), and with slowed responses on unrelated trials, such that participants were faster to indicate that a pair was related and slower to indicate that it was unrelated when it received a higher rating in the norms. These converging findings support the idea that the task is semantic in nature.

The present data further suggest that expressions having the same part of speech tend to elicit shorter latencies in the semantic relatedness task, as reflected by a marginal effect for "no" response latencies. In addition, SE bilinguals were more likely to judge pairs instantiating the same part of speech as related. This sensitivity to part-of-speech alignment is consistent with previous findings of second-language learners' sensitivity to grammatical class (e.g., Sunderman & Kroll, 2006).

The main goal of the present experiment was to examine how translation status affects intraword sense relatedness. We found reduced relatedness ratings for joint-translation senses as compared with split-translation senses for SE bilinguals. This finding is consistent with the inhibition account, by which two senses that share a label come to inhibit each other because only one is appropriate in any given context (e.g., Chwilla & Kolk, 2003; Elston-Güttler et al., 2005). Presumably, the shared label in Spanish led to suppression between the two meanings, such that SE bilinguals considered them to be less related than two meanings that did not share a Spanish lexical form.

As mentioned in the introduction, it is more conceivable to assume that two unrelated meanings of homonyms inhibit each other than it is to assume that two related senses of polysemous words inhibit each other, because only the former

Table 6 Coefficient estimates for semantic relatedness judgments, including L2 proficiency, as a function of group

	Spanish–English Bilinguals			English–Spanish Bilinguals		
	"yes" Probability	"yes" RT	"no" RT	"yes" Probability	"yes" RT	"no" RT
Intercept	–1.427**	8.175**	8.086**	–0.577	7.979**	7.937**
Participants' age	–0.016	0.013*	0.003	–0.044*	0.012	0.009
Word length (in letters)	0.027	–0.006	0.007	0.029	0.021*	0.013
Word KF frequency (log)	0.026	–0.026	–0.014	0.127	–0.043*	0.005
Word concreteness ratings (log)	0.449	0.019	–0.144±	1.044±	–0.083	–0.147±
Same part of speech	0.913**	–0.052	–0.027	0.062	–0.016	–0.044
1st modifier's length	0.013	0.013*	0.010±	–0.007	0.006	0.004
2nd modifier's length	0.017	0.007	0.011*	0.051	0.007	0.003
1st modifier's location [after]	0.198	0.104*	0.027	0.187	0.041	0.049
2nd modifier's location [after]	–0.073	–0.016	–0.041	–0.287	–0.007	–0.053
Average word translation unknown	0.035	–0.006	–0.005	0.010	–0.015±	–0.001
Average word translation variability	0.091	–0.004	–0.0207	0.214	0.0153	–0.012
Cognate translation present	–0.211	0.083*	0.018	0.020	0.034	–0.019
Relatedness ratings (log)	3.259**	–0.121*	0.148**	4.500**	–0.229**	0.194**
Age begun L2 learning	–0.017	–0.001	0.001	–0.090	–0.015	–0.020
L2 proficiency	–0.159	0.032	–0.085*	0.567*	0.077	0.100
Condition [split]	0.123	0.001	0.011	–0.331	0.074	–0.050
Condition [split]: L2 proficiency	–0.447**	0.024	–0.041*	–0.010	0.032	–0.003

Coefficients for "yes" probability were estimated with a logistic regression. For the RT analyses, coefficients were estimated on the log-transformed data, and significance was based on Markov-chain Monte Carlo samples of the posterior distribution. KF, Kučera–Francis; L2, second language. * p<.05, ** p<.001, ± p<.10

are likely to be mutually exclusive in a vast majority of possible contexts (for a discussion, see Degani et al., 2011; Klein & Murphy, 2001). Nonetheless, there is some evidence to suggest that even related senses of polysemous words may inhibit each other (Klein & Murphy, 2001; Pylkkänen, Llinás, & Murphy, 2006). For instance, Klein and Murphy (2001) found that sensicality judgments to polysemous words were slower and less accurate when the same word had been presented previously with a different sense than when it had been presented previously in a neutral context (but see Klepousniotou et al., 2008, for a different pattern). In the present experiment, these effects were not consistently modulated by baseline relatedness. A more sensitive measure may be better suited to tap such relatedness modulation in the time course of the effect, or in the mechanism underlying this inhibition (see also Pylkkänen et al., 2006).

An alternative explanation for the difference between joint- and split-translation items relies on the learning history of these items for SE bilinguals. In particular, a Spanish speaker who learns English as an L2 learns to map two words (e.g., *anillo* and *timbre*, corresponding to jewelry and a sound) to a

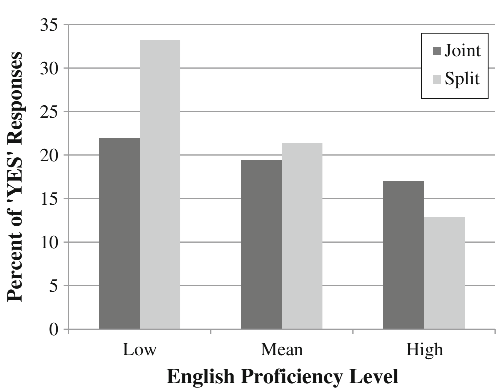

Fig. 5 Percentages of "yes" responses for Spanish–English bilinguals as a function of condition and English proficiency

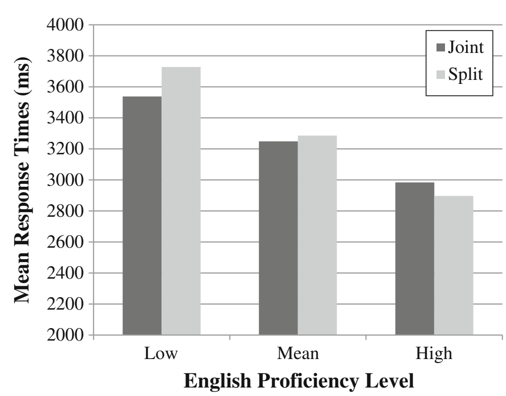

Fig. 6 Response times (in milliseconds) of "no" responses for Spanish–English bilinguals as a function of condition and English proficiency

single shared English lexical form (*ring*). Previous work has shown that two words that share a translation in a bilingual's other language become more related in meaning (e.g., Degani et al., 2011; Elston-Güttler & Williams, 2008; Jiang, 2002, 2004; but see Elston-Güttler et al., 2005). It is conceivable that this shared-translation effect in some way overshoots the target relatedness level, such that the two meanings become more related as a function of the L2 shared translation than they would have been had they shared a label in Spanish from the outset. In contrast, in the case of the joint condition, two meanings already share a label in Spanish, and no change occurs for these meanings as a function of learning an additional joint (L2) English label. Moreover, perhaps because these two senses share a label in their L1, speakers may have had the opportunity to notice the distinctive features of each sense and their commonalities, and thus a shared English label has little effect on the intraword senses of these items. Thus, split-translation meanings grow more similar as a function of a shared label in English, but joint-translation meanings do not undergo any change. As a result, SE bilinguals judge split-translation meanings to be more related than joint-translation meanings. We refer to this explanation as the exaggerated shared-translation effect. Our future work will employ a training paradigm to more directly examine how intraword sense relatedness changes as a function of learning.

The exaggerated shared-translation effect may be complemented by exaggerated caution on the part of L2 learners. Specifically, Kellerman (1982) observed that beginning L2 learners of English assume that not all senses of an L1 (Dutch) polysemous word are captured by the translation equivalent in L2 (e.g., *break–breken*). This extreme caution on the part of the learner gradually disappears as nuances of meaning in the target language are acquired. A similar cautiousness assumption is observed with respect to idioms, by which learners assume that idioms are language specific and thus cannot be translated literally to L2. In the context of the present study, this extreme caution will present itself as reduced relatedness for the joint-translation condition, because the availability of a shared label in the speaker's two languages contradicts the intuitive assumption that different senses are captured by different translations.

To the extent that exaggerated caution and an exaggerated shared-translation effect are more characteristics of beginner learners, we may expect to find language proficiency modulations of the difference between joint-translation and split-translation. We turn to this issue next.

Language proficiency

In the present experiment, ES bilinguals did not differ from ME speakers in their processing of joint and split-translation items, providing no support for the influence of learning on intraword sense relatedness, or for the possible influence of L2 on L1 processing. Nonetheless, such effects may surface with more proficient ES bilinguals, or with those who are immersed in an L2 (Spanish) environment. Indeed, the bidirectional pattern of L2 influence on L1 processing observed by Degani et al. (2011) was present for English–Hebrew bilinguals who had been immersed in their L2 (Hebrew) environment for 20 years on average. Within the range of L2 (Spanish) proficiency sampled in the present study, and in the absence of prolonged L2 immersion experience, we did not observe cross-language influences from L2 to L1 in this task, even when we considered L2 proficiency as a modulating factor. It is thus possible that intraword sense relatedness in L1 is less susceptible to change, or that the long latencies inherent to the present paradigm obscure such effects.

Interestingly, however, cross-language influences from L1 to L2 do seem to be modulated by L2 proficiency in this task. In particular, a significant interaction between condition and English proficiency emerged for SE bilinguals, such that lower English proficiency was associated with a higher probability of "yes" responses for split- than for joint-translation items, but higher English proficiency was associated with a reversed pattern (see Fig. 5). The results from the latency data to make an unrelated ("no") response converge with this in that only participants with lower English proficiency exhibited a latency difference in the responses to joint- versus split-translation items (see Fig. 6). Together, these results indicate that less-proficient SE bilinguals show reliably higher semantic relatedness for split than joint-translation items, but that this difference tends to disappear or change direction with increased English proficiency.

These findings are consistent with the results of Elston-Güttler et al. (2005, Exp. 2), who found a cross-language effect that was observed primarily for participants of lower L2 proficiency. In particular, as mentioned above, native German speakers who learned English as an L2 performed a primed lexical decision task to targets preceded by a sentence ending in a prime that either shared a translation with the target in German (e.g., *The beautiful table was made of solid pine… jaw*, where both *pine* and *jaw* are translated to German as *Kiefer*), or was unrelated. Less-proficient participants showed reversed priming for the shared translation condition as reflected in both RT and the N200. More-proficient participants did not show significant RT or ERP effects. The authors suggested that this might be due to the more-proficient group having increased control, which may have decreased cross-language influence.

Furthermore, in the present study, increased English proficiency was associated with faster "no" responses for SE bilinguals. Such reductions in RT may make it more difficult to identify differences between the joint- and split-translation conditions. This may further explain why ES bilinguals, who are highly proficient in English and were substantially faster than

SE bilinguals (2,835 vs. 3,642 ms), do not exhibit significant differences between conditions. Future variations in task parameters may make such condition differences more salient.

To the extent that these proficiency modulations reflect intrinsic properties of semantic representations, they could be explained within the exaggerated shared-translation and exaggerated caution accounts proposed above. In particular, when SE bilinguals learn that two meanings (and words) that do not share a label in Spanish in fact share a label in English (split-translation items), these meanings grow more similar due to their shared label in a way that may be exaggerated, as compared to a pair of meanings that already share a label in Spanish (i.e., joint-translation items). With increased L2 proficiency, however, bilinguals no longer attend to the similarity of these two meanings that share an L2 label, and their relatedness gradually decreases to resemble that of meanings that share a label in L1. Conversely, they may approach joint-translation items with exaggerated caution, assuming that it is unlikely that the two meanings of a word in their L1 are also encompassed by a single word in their L2 (Kellerman, 1982). This exaggerated caution with respect to joint-translation items decays as they learn that English too denotes the two senses of the ambiguous Spanish word with a single ambiguous English word (see also Kellerman, 1982). Such exaggerated caution may be related to the way they process ambiguous words. For instance, at lower proficiency, bilinguals may process expressions like *presidential cabinet* and *kitchen cabinet* as chunks, and thus the overlap operates as partial overlap (i.e., similar to a shared morpheme), and not as a full overlap of a shared label. With increased proficiency, bilinguals may adopt a more compositional approach. These hypotheses await further investigation.

The present study suggests that the operation of inhibition and facilitation among meanings that share a label may be, at least partly, a function of language proficiency. Indeed, in previous research facilitation was observed for highly proficient bilinguals (Degani et al., 2011), and inhibition was observed for lower-proficiency bilinguals (Elston-Güttler et al., 2005). Interestingly, the operation of these two mechanism may also vary with processing time course. Indeed, evidence for inhibition was initially detected early in processing as modulations in the N200 ERP component (Elston-Güttler et al., 2005). These early (lexical) processes may be complemented by facilitation at a later (semantic) time point. The present paradigm was not intended to differentiate these and employed measures that provide only the end result of a process. Ongoing research, using more time-sensitive measures (eyetracking, ERP), have the potential to shed light on this relevant issue.

The results of the present study may diverge from the expectation of increased relatedness of a shared-translation (Degani et al., 2011) for several possible reasons. First, it is possible that language proficiency differences underlie these diverging results. Specifically, the effect in the present study seems to be driven by the lower-proficiency SE bilinguals. Note that these participants may be less proficient than the sample tested in Degani et al. (2011), especially if we consider that in the present study the influence of Spanish on English was tested in an English-speaking environment, whereas in Degani et al. (2011) the influence of Hebrew on English was examined in a Hebrew-speaking environment. In addition, the present study focused on intraword senses, such that in one condition the meanings shared a label in English only (split-condition), whereas in the other condition the two meanings shared two labels. The present results suggest that the effect of a shared-label may not be additive, such that the difference between one shared label and no shared label may not be the same as the difference between one shared label and two shared labels. Indeed, it seems that the former difference may initially entail an exaggerated shared-translation effect (facilitation), whereas the latter difference may initially entail exaggerated caution (inhibition).

To conclude, the present experiment demonstrates an influence of translation status on intraword sense relatedness of bilingual speakers. Joint-translation senses, which correspond to a single translation in Spanish, were less likely to be judged as related by SE bilinguals than were split-translation senses, which map to separate Spanish translations.

This influence of a bilingual's other language demonstrate the interconnectivity between multiple languages of bilingual speakers. Performance in an all-English task was influenced by participants' knowledge of another language (Spanish), such that the form-to-meaning mapping in L1 impacted semantic relatedness of intraword senses in L2. Such findings are consistent with models assuming an integrated bilingual lexicon (e.g., the BIA model: Dijkstra & van Heuven, 1998; the BIA+ model: Dijkstra & van Heuven, 2002), or in which words from both L1 and L2 can access and thus influence meaning representation (e.g., the distributed representation model: van Hell & De Groot, 1998; the revised hierarchical model: Kroll & Stewart, 1994). Moreover, because intraword sense relatedness influences how ambiguous words are processed (e.g., Rodd et al., 2012; Rodd et al., 2002), the present findings highlight an important difference between bilinguals and monolinguals. In particular, when the two senses of an ambiguous word are captured by two separate translations in a bilingual's L1 (i.e., a split-translation item), bilinguals are likely to process the ambiguous word as one with more related senses (i.e., more as a polyseme than as a homonym), and as such bilinguals are likely to differ from monolinguals in how they respond to and interpret such ambiguity. In the present experiment, we observed only an effect of L1 on L2 representation that was stronger for less-proficient bilinguals. Whether immersion in an L2 is indeed a prerequisite for bidirectional influences to emerge in semantic relatedness of intraword senses awaits future research.

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Appendix A

Table 7 Expression pairs with semantic similarity ratings (Rel)

Condition	Expression Pair	Rel
split	red rose–rose above	1.15
split	express train–train dogs	1.20
split	private plane–flat plane	1.20
split	soccer ball–formal ball	1.20
split	head count–Count Dracula	1.20
split	bed rest–all the rest	1.25
split	properly spell–magical spell	1.30
split	excessively mean–mathematical mean	1.30
split	white lie–lie down	1.35
split	bright light–light weight	1.35
split	suitcase–criminal case	1.40
split	iron clothes–iron supplement	1.40
split	pop rock–volcanic rock	1.40
split	wrist watch–watch television	1.45
split	match stick–stick around	1.50
split	half pound–pound loudly	1.55
split	left arm–fire arm	1.60
split	stand up–night stand	1.65
split	birthday party–democratic party	1.70
split	tsunami wave–wave good-bye	1.80
split	stop sign–sign here	1.85
split	hang up–hang out	1.90
split	oscillating fan–biggest fan	1.95
split	fly a plane–house fly	2.00
split	freezing cold–common cold	2.00
split	don't like–exactly like	2.10
split	trust me–trust fund	2.10
split	best-selling novel–completely novel	2.10
split	economic power–electric power	2.35
split	quick finish–glossy finish	2.40
split	grocery store–store grain	2.46
split	child's play–play music	2.50
split	cruise ship–ship across	2.50
split	dinner date–expiration date	2.60
split	kick the ball–kick the habit	2.65
split	fall down–fall leaves	2.75
split	car race–human race	2.90
split	don't approach–new approach	3.00
split	winter term–long- term	3.20
split	phone call–call out	3.25
split	stained glass–empty glass	3.35
split	pay rent–rent a movie	3.80
split	drink quickly–cold drink	3.80
split	burn quickly–third-degree burn	4.15
joint	infinitely patient–cancer patient	1.25
joint	house plant–power plant	1.50
joint	rhythmic movement–civil-rights movement	1.60
joint	mental state–southern state	1.65
joint	dinner reservation–Indian reservation	1.70
joint	master key–key problem	1.75
joint	dry skin–dry wine	1.95
joint	earned interest–extracurricular interest	2.00
joint	pharmaceutical company–pleasant company	2.10
joint	function properly–social function	2.33
joint	first act–act carefully	2.45
joint	theoretical model–fashion model	2.45
joint	shining star–movie star	2.75
joint	clotted blood–royal blood	2.90
joint	large object–direct object	3.07
joint	true nature–mother nature	3.10
joint	TV guide–tour guide	3.12
joint	military resistance–electric resistance	3.15
joint	impulsive reaction–chemical reaction	3.20
joint	military operation–mathematical operation	3.25
joint	good condition–first condition	3.35
joint	inherited fortune–good fortune	3.40
joint	reason why–use reason	3.50
joint	olive oil–motor oil	3.70
joint	embarrassing position–fetal position	3.85
joint	juicy orange–bright orange	3.95
joint	essay title–formal title	4.00
joint	storm cloud–mysterious cloud	4.05
joint	charitable contribution–scholarly contribution	4.05
joint	pancake breakfast–lonely breakfast	4.20
joint	artificial intelligence–military intelligence	4.20
joint	cough medicine–veterinary medicine	4.29
joint	hot lunch–ladies lunch	4.40
joint	dollar bill–weak dollar	4.45
joint	beautiful design–architectural design	4.50
joint	bad dream–childhood dream	4.50
joint	beating heart–broken heart	4.52
joint	big class–boring class	4.54

Table 7 (continued)

Condition	Expression Pair	Rel
joint	state park–amusement park	4.55
joint	main road–icy road	4.80
joint	teen magazine–glossy magazine	4.90
joint	history article–popular article	5.00
joint	best-selling book–leather-bound book	5.05
joint	phone message–urgent message	5.10
joint	light dinner–formal dinner	5.10
joint	planet earth–fertile earth	5.10
joint	brute force–military force	5.15
joint	daily newspaper–shredded newspaper	5.25
joint	cotton dress–cotton thread	5.30
joint	major difference–difference between	5.33
filler	rock band–rubber band	1.05
filler	organ donor–pipe organ	1.10
filler	lean meat–lean towards	1.10
filler	diamond ring–loud ring	1.15
filler	plaster cast–news cast	1.20
filler	savings bank–riverbank	1.30
filler	breached contract–contract the flu	1.30
filler	grizzly bear–bear down	1.31
filler	spring rain–coiled spring	1.35
filler	good pick–ice pick	1.35
filler	ironing board–school board	1.35
filler	degrees Fahrenheit–college degrees	1.40
filler	night club–wooden club	1.40
filler	investment capital–capital letter	1.45
filler	hair comb–rooster's comb	1.45
filler	cookie jar–jar suddenly	1.45
filler	Sunday drive–internal drive	1.50
filler	wood bat–vampire bat	1.50
filler	cardboard box–kick box	1.55
filler	right angle–reporter's angle	1.60
filler	bird's wing–east wing	1.60
filler	large square–square root	1.60
filler	movie admission–false admission	1.65
filler	wooden block–mental block	1.65
filler	love letter–letter grade	1.70
filler	kitchen cabinet–presidential cabinet	1.75
filler	solid ground–finely ground	1.75
filler	American Revolution–axial revolution	1.79
filler	barely try–try in court	1.79
filler	mini skirt–skirt around	1.80
filler	contact lens–human contact	1.80
filler	power drill–practice drill	1.85
filler	hall pass–barely pass	1.90
filler	sex appeal–legal appeal	1.90
filler	laser beam–wood beam	1.90
filler	red lip–protective lip	2.00
filler	secret passage–literary passage	2.05

Table 7 (continued)

Condition	Expression Pair	Rel
filler	undeniable proof–proofread	2.05
filler	double-sided tape–video tape	2.05
filler	introductory course–collision course	2.08
filler	mastermind–mind your manners	2.10
filler	under cover–bed cover	2.10
filler	bread mold–plaster mold	2.15
filler	sharp point–point a finger	2.15
filler	shoot a turkey–photo shoot	2.20
filler	camp fire–gun fire	2.21
filler	suspension bridge–playing bridge	2.25
filler	true story–second story	2.25
filler	dash mark–high mark	2.25
filler	first impression–shoe impression	2.30
filler	winter coat–clear coat	2.30
filler	indoor tracks–deer tracks	2.30
filler	jury trial–clinical trial	2.35
filler	figure caption–body figure	2.41
filler	left foot–foot long	2.45
filler	television volume–volume measure	2.45
filler	large head–organization's head	2.50
filler	flea market–housing market	2.55
filler	informal atmosphere–polluted atmosphere	2.55
filler	honorable cause–might cause	2.60
filler	human body–administrative body	2.65
filler	whole grain–coarse grain	2.65
filler	charitable foundation–strong foundation	2.70
filler	waffle cone–traffic cone	2.75
filler	gossip column–support column	2.90
filler	control panel–advisory panel	2.90
filler	summer home–funeral home	2.95
filler	right hand–helping hand	3.05
filler	bow tie–tie tightly	3.15
filler	touching scene–panoramic scene	3.15
filler	combination lock–please lock	3.25
filler	compact disc–compact car	3.35
filler	police barrier–language barrier	3.39
filler	long dress–dress appropriately	3.50
filler	straight line–checkout line	3.55
filler	fair chance–chance of a lifetime	3.55
filler	primary aim–aim higher	3.60
filler	guest room–adequate room	3.70
filler	multiple-choice examination–thorough examination	3.80
filler	laundry pile–pile up	3.95
filler	open space–outer space	4.00
filler	slow answer–correct answer	4.00
filler	sensitive issue–previous issue	4.04
filler	feature film–35-mm film	4.06
filler	express concern–national concern	4.10

Table 7 (continued)

Condition	Expression Pair	Rel
filler	in the air–fresh air	4.10
filler	foreign country–wine country	4.15
filler	security guard–coast guard	4.71
filler	marinated lamb–baby lamb	4.95
filler	fried chicken–clucking chicken	5.23
filler	profitable business–legitimate business	5.70

"Rel" reflects mean semantic similarity ratings on a scale of 1–7, on which 1 indicates *completely different* and 7 indicates *exactly the same*, collected from a separate group of 20 monolingual English speakers. Filler expression pairs were deemed such on the basis of the translation overlap norms (see the text for details)

Appendix B: Principal-component analyses of the individual-difference measures

Several individual difference measures were used in the present study. For bilinguals, these include performance (accuracy and RT) on an English and a Spanish lexical-decision task; English and Spanish picture naming tasks; the operation-word span task; the Raven's progressive matrices task; and self-rated proficiency and use of English and Spanish (see Degani, 2011, for further details regarding these tasks). Scores on all measures were available for 46 of the 60 bilingual participants, 22 of whom were ES bilinguals, and the remaining 24 were SE bilinguals. Because these factors were strongly correlated (Bartlett's test of sphericity produced $p<.001$), a principal-component analysis was applied to the data in order to reduce collinearity in the predictors. Factors with eigenvalues over 1 were extracted, and a Varimax rotation was applied to increase the interpretability of the factors by increasing the likelihood that each original test would correlate highly with only one factor. This resulted in the extraction of four orthogonal factors that cumulatively captured 73.57 % of the variance in these predictors. The rotated component matrix is shown in Table 8.

Table 8 Rotated component matrix

	Spanish Proficiency	English Proficiency & Use	Spanish Use	Nonlinguistic Abilities
Overall variance explained by the factor	41.27 %	12.45 %	10.99 %	8.86 %
Spanish lexical decision RT	**–.52***	.16	**.58***	–.01
Spanish lexical decision accuracy	**.87***	–.24	.09	–.12
Spanish picture naming RT	**–.80***	.28	.16	–.11
Spanish picture naming accuracy	**.86***	–.29	.08	–.09
Rated Spanish proficiency	**.81***	–.25	–.32	–.07
Rated current Spanish use	.10	–.06	**–.81***	–.09
English lexical decision RT	.37	**–.51***	.47	–.23
English lexical decision accuracy	–.07	**.72***	.32	.20
English picture naming RT	.15	**–.80***	–.02	–.12
English picture naming accuracy	–.36	**.81***	.08	–.08
Rated English proficiency	–.38	**.84***	.01	.10
Rated current English use	–.23	**.65***	–.06	–.28
Operation–word span (PCU)	–.25	.00	–.10	**.83***
Raven's-number of correct responses	.23	.11	.46	**.68***

Tests were assigned to a factor when their correlations with it exceeded .50, and these are denoted in bold and with asterisks

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