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Number of Meanings and Concreteness:

Consequences of Ambiguity Within and Across Languages

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Abstract

We examined the effects of concreteness and ambiguity on language processing. In Experiment 1, English-Spanish bilinguals translated words with a single translation. Contrary to past findings, we observed no concrete-word advantage in translation latency. In Experiment 2, English-Spanish bilinguals translated words with one and more than one translation. Words with multiple translations were translated more slowly and showed the typical concrete-word advantage. Words with one translation showed a reversal of the typical concrete-word advantage in latency. Further, concrete words were uninfluenced by ambiguity. In Experiment 3, we explored whether the interaction between concreteness and ambiguity was a general property of the language processing system. Supporting this idea, in a monolingual lexical decision task, we found an interaction between concreteness and number of meanings analogous to the interaction in translation. We discuss the common mechanism that may lead to this interaction in both within and cross-language processing.

Key words: bilingualism, translation, concreteness, ambiguity, semantic representation, language production

Number of Meanings and Concreteness:

Consequences of Ambiguity Within and Across Languages

To translate words from one language to another, a bilingual must typically retrieve the meanings associated with those words (e.g., De Groot, 1992; Kroll & Stewart, 1994). Under some circumstances, translations will refer to similar meanings. However, languages often differ in how they label even common objects (e.g., Malt & Sloman, 2003; Malt, Sloman, & Gennari, 2003). And, for many abstract concepts, there are multiple interpretations that map onto different words in each language (Tokowicz, Kroll, De Groot, & Van Hell, 2002). Because much past research has compared performance on the picture naming and translation tasks to reveal the architecture of the bilingual production system (e.g., Potter, So, Von Eckhardt, & Feldman, 1984), many studies have used only concrete nouns that refer to objects with high name agreement within and across languages. It is therefore not surprising that these studies suggest that the bilingual's two languages access shared semantic representations.

Determining whether the same word meanings are retrieved in the bilingual's two languages is complicated by the fact that bilinguals are rarely equally proficient or dominant in both languages. It has been proposed that bilinguals become more aware of the language-specific distinctions in meaning with increased proficiency (De Groot, 1993, p. 41). Further, Zhang (1995) showed that ESL learners had different semantic structures from those of native English speakers for degree adverbs and frequency terms. Increased proficiency in English led to closer approximation of native-like semantic structures. Thus, the semantics of the two languages apparently become more distinct with increased proficiency in the L2.

Several studies using variants of the semantic or translation priming paradigm have shown that the first language (L1) is more likely to prime the second language (L2) than the reverse (e.g., Gollan, Forster, & Frost, 1997; Jiang, 1999; Keatley, Spinks, & De Gelder, 1994), which potentially reflects greater knowledge and more rapid access for L1 than for L2. However, other recent studies have suggested that L1 and L2 differ not only quantitatively but also qualitatively in terms of the type of information that is accessed and the type of representation that is formed for the L2. For example, Finkbeiner, Forster, Nicol, and Nakamura (2004) hypothesized that translation priming is typically not observed from L2 to L1 because L2 words only share a small subset of the senses of their L1 translation equivalents. Silverberg and Samuel (2004) further demonstrated that the age of acquisition of the L2 appears to constrain sensitivity to cross-language semantic priming, with only early and proficient bilinguals producing reliable L2 to L1 priming (L1 to L2 priming was not tested). Similarly, Kotz and Elston-Güttler (2004) showed that proficiency in the L2 determines the type of semantic relations to which bilinguals are sensitive, with greater constraints for semantic category relations than for associations.

Another notable exception to the conclusion that bilinguals access the same meanings for words in each of their languages comes from experiments on translation that have examined the effects of word concreteness. In an extensive series of studies, De Groot and her colleagues (e.g., De Groot, 1992; De Groot, Dannenburg, & Van Hell, 1994; De Groot & Poot, 1997; Van Hell & De Groot, 1998a, 1998b) have shown that bilinguals are slower to translate abstract than concrete words. To account for the concreteness effect in translation, De Groot (1992) proposed the Distributed Feature Model (see also the Distributed Representation Model, Van Hell & De Groot, 1998a). According to the model, word meanings are represented as sets of distributed features in memory. Concrete words are more likely than abstract words to share semantic features across languages because concrete concepts are more likely to be similar across languages and cultures. Thus, the explanation given for concreteness effects is that translation is mediated by meaning activation and because the semantic features for concrete words have considerable overlap across languages, they are translated more quickly and more accurately than abstract words.

Concreteness effects are widespread in tasks reflecting lexical access and memory within a single language alone (e.g., Kroll & Merves, 1986; Paivio, 1971; Schwanenflugel & Shoben, 1983; but see Samson & Pillon, 2004). Whereas early models attributed the advantage of concrete words to the greater imageability of concrete word meanings (e.g., Paivio, 1971), later accounts focused on the idea that concrete and abstract words differ in the nature of their meaning representations (e.g., Schwanenflugel & Shoben, 1983). According to context availability theory (e.g., Kieras, 1978; Schwanenflugel, Harnishfeger, & Stowe, 1988; Schwanenflugel & Shoben, 1983), it is easier to generate a context for concrete than for abstract words. Furthermore, concrete words generally appear in fewer contexts than abstract words (Schwanenflugel & Shoben, 1983). Assuming a language processing system with a set amount of available activation, the more concepts to which a word is associated, the weaker the association between the word and any one concept will be (e.g., the "fan effect"; Anderson, 1974, 1983). Concrete words are thus hypothesized to be strongly connected to few nodes in memory whereas abstract words are weakly connected to many nodes in memory. Schwanenflugel and Shoben provided support for the context availability theory by demonstrating that the advantage for concrete relative to abstract words was eliminated when the words were presented in sentence context. Furthermore, concrete and abstract words that were matched for rated context availability were processed similarly in an out-of-context lexical decision task (Schwanenflugel et al., 1988). Concrete words thus appear to have the ability to stand alone whereas abstract words are more dependent on context for their interpretation.

If the conceptual representations of concrete words are more easily and rapidly accessed than those for abstract words, even within a single language, then a unitary semantic system with differentiated concepts may be sufficient to account for cross-language concreteness effects. That is, it may not be necessary to assume differential overlap among translation equivalents, because any factor that slows conceptual access in general will also slow bilingual translation to the extent that conceptual access is a component of the task. According to this view, bilingual performance reflects the particular cross-language manifestation of general distinctions among concepts.

Critically, concepts tend to vary along multiple dimensions, each of which may contribute to how easily the concept is understood, produced, or translated from one language to another. Concepts may be concrete or abstract, animate or inanimate, and lexically or semantically ambiguous or unambiguous. To the extent that these dimensions are unlikely to be independent of one another, effects of one variable may reflect the contributions of another (e.g., Gernsbacher, 1984; Reilly, Ramey, & Milsark, 2004). With respect to concreteness, Schönpflug (1997) was the first to report that concrete words have fewer translations across languages than abstract words. This distinction may be a consequence of differences in conceptual representation for concrete and abstract words, of differences in the correlated features of concrete and abstract words, or a property of the particular cross-language instantiation of different types of concepts (e.g., De Groot, 1992).

To answer the question that was originally posed, whether bilinguals access the same concepts in their two languages, we need to begin to disentangle the contribution of the factors that are related to various conceptual distinctions. The purpose of the present study was to provide a first step toward this goal by examining the relation between word concreteness and ambiguity in terms of number of translations. We used a translation production task because this task has been used extensively in past research to examine the architecture of bilingual memory. Because concrete words tend to have fewer translations than abstract words, we began by examining the concrete-word advantage in translation for words that have only a single or dominant translation (Experiment 1). We showed that the large concreteness effect on translation latency reported in past studies (e.g., De Groot, 1992; De Groot et al., 1994) is eliminated when words have only a single translation equivalent. We then obtained number of translations norms on a large set of words that had been used in past studies and used these norms to manipulate number of translations and concreteness in a translation production task (Experiment 2). We found that the concreteness effect emerged when the words to be translated had more than one translation equivalent, and that concrete words were less influenced by ambiguity than abstract words. In a final experiment we explored whether the results in bilingual translation were due to a general property of conceptual representation or to unique aspects of conceptual access during cross-language processing. To do so, we obtained number of meanings norms for the words used in Experiment 2 and had native English speakers perform lexical decisions on these words. The monolingual results paralleled those for the bilinguals in Experiment 2 in that abstract words were more influenced by ambiguity than concrete words, suggesting that the observed interaction reflects a general property of the language processing system.

Experiment 1: Translating Concrete and Abstract Words with a Single Translation Equivalent

In Experiment 1 we examined translation performance for concrete and abstract words that have only one or a clearly dominant translation equivalent across languages. By holding the number of translations to a minimum, we were able to examine how concreteness affects translation of unambiguous words. We also manipulated the direction of translation to increase generalizability of our results and because some models of bilingual memory organization (e.g., the Revised Hierarchical Model, Kroll & Stewart, 1994) posit that semantic effects such as concreteness will have a greater impact on translation from L1 to L2 than the reverse, as was reported by De Groot et al. (1994).

Several models of language processing, both for within and cross-language tasks, make predictions for translation performance. The first are the general models of concreteness effects cited above that predict that words should be processed more quickly and accurately than abstract words. The Distributed Feature Model (DFM; De Groot, 1992) makes the same prediction based on the greater semantic overlap of concrete word meanings. Neither class of models assumes any asymmetry in the connections between the two languages, but rather assumes that words in both languages have direct access to meanings. Consequently, the DFM predicts that concreteness will influence translation from L1 to L2 and from L2 to L1 to a similar degree.

However, translation from L1 to L2 is often performed more slowly and less accurately than translation from L2 to L1 (the "translation asymmetry"; e.g., Kroll & Stewart, 1994; Sánchez-Casas, Davis, & García-Albea, 1992). In general, this pattern of results is more likely to be obtained with individuals who are more dominant and proficient in the L1 than the L2 (e.g., Kroll, Michael, Tokowicz, & Dufour, 2002). According to the Revised Hierarchical Model (RHM; Kroll & Stewart, 1994), the theoretical explanation for the differences between the two directions of translation is that translation from L1 to L2 necessarily involves the activation of meaning because word meanings are rapidly activated by L1 words (e.g., Kroll & Stewart, 1994; Sholl, Sankaranarayanan, & Kroll, 1995). In contrast, translation from L2 to L1 can sometimes be performed via word-to-word connections and without meaning activation, and therefore is performed more quickly and accurately than translation from L1 to L2.[1] The RHM does not distinguish between the general and language-specific models of concreteness but makes the overall prediction that these effects should be larger for translation from L1 to L2 than the reverse; in previous research concreteness effects have been found in both directions of translation but were larger in L1 to L2 translation (e.g., De Groot et al., 1994). We return to this issue in the general discussion.

The impact of number of translations has not been examined extensively in past research. However, to the extent that translation engages the same mechanisms as other production tasks, we expect that the need to select one word for output in Experiment 2 will lead to active competition between alternatives, the outcome of which will be slowed response time and reduced accuracy (e.g., Jacobs & Grainger, 1992; McClelland & Rumelhart, 1981, 1985).

It is not straightforward to select a sample of words with only a single or dominant translation equivalent. For example, De Groot and colleagues were aware of the importance of controlling for number of translations and attempted to do so in their experiments by only including words with one translation (De Groot et al., 1994, p. 606). However, in a subsequent collaboration with the authors of that study, we collected norms on the number of translations of their stimuli (Tokowicz et al., 2002). The normative data suggest that the stimulus selection procedures were not entirely successful in eliminating words with multiple translations; 38% of the concrete words and 57 % of the abstract words had more than one translation in one or both directions of translation. Although it is unclear what proportion of stimuli will have multiple translations in a *random* sampling of words, we estimate that it will be higher than 40 % because this is the percentage obtained when a deliberate attempt was made to choose words with only one translation.

Method

Task Instructions

Participants in this experiment were tested in both the United States and Mexico; to properly compare the participants in the two testing environments, it was important that the language of instruction match the primary language of the testing environment. Therefore, both verbal and written instructions for all tasks were given in English to participants tested in the

United States and in Spanish to participants tested in Mexico, regardless of their native language. Also, a Spanish language history questionnaire was administered to participants tested in Mexico.

Participants

Participants were 17 English-Spanish and 12 Spanish-English bilinguals who were students at The Pennsylvania State University, 22 English-Spanish bilinguals who were students at the Cemanahuac Educational Community, Cuernavaca, Morelos, Mexico, and 10 Spanish-English bilinguals living in Mexico. The participants were paid or given psychology course credit for their participation. No individual participated in more than one of the present experiments.

Stimuli

The stimuli were 160 English words and their Spanish translations. Approximately half of the stimuli were concrete; approximately one third were cognates. Cognates were included in this experiment to maintain representativeness of the stimuli and to match the stimulus characteristics of the De Groot et al. (1994) experiment, however, they served as filler items and therefore were not analyzed. The words were selected on the basis that they had only one or a clearly dominant translation in English and Spanish.

Context availability and concreteness ratings were obtained on the English words to be used in Experiment 1. The instructions used for the context availability and concreteness ratings were adapted from Schwanenflugel et al. (1988) and Spreen and Schulz (1966), respectively. Ratings for the target items were obtained from 25 native English speakers who were undergraduates at The Pennsylvania State University (12 completed imagery ratings; 13 completed concreteness ratings). The concrete and abstract words matched with respect to word length in English and Spanish and word frequency in English, but differed in terms of concreteness and context availability ratings (see Table 1 for stimulus properties and Appendix A for the stimuli and ratings). (Table 1 about here)

Procedure

Participants were presented with words to translate aloud, one at a time, at the center of a computer screen. Their responses were tape recorded for later coding of accuracy. Participants were instructed to respond as quickly and accurately as possible, and to indicate when they did not know the translation of the presented word by saying "no". Prior to the presentation of each target word, a fixation cross was presented until the participant initiated the beginning of the trial by pressing a key on the computer keyboard. The words were presented for 2000 ms[2] or until the participant made a verbal response. Reaction time (RT) was recorded by the computer program in milliseconds (ms) from the onset of stimulus presentation to the onset of articulation. Participants were given practice trials before beginning the critical trials.

At the end of the translation task, participants completed a language history questionnaire (Tokowicz, Michael, & Kroll, 2004) in which each participant rated his or her proficiency in first and second language reading, writing, conversation, and speech comprehension on a scale from one to ten, and indicated the age at which L2 learning began and the types of L2 exposure.

The presentation of stimuli was blocked according to direction of translation so that the participants were presented with words in only one language during a given block of trials. The presentation order of the directions of translation was counterbalanced across participants. The order of presentation of the words in each block was randomized for each participant. Two lists of materials were constructed such that the words that one group of participants translated in one direction were translated in the opposite direction by another group of participants; the two lists were matched on word length and frequency and had the same number of concrete and abstract words.

Results and Discussion

Data trimming. Data from 13 English-Spanish and 5 Spanish-English bilinguals who were not able to accurately translate at least 50 % of the time in both directions of translation were removed from the analyses. In addition, data from one English-Spanish and one Spanish-English bilingual were excluded because they failed to complete the task. Analyses were thus conducted on data from 41 participants. Reaction times that were 2.5 SDs above or below a given participant's mean response for that direction of translation were excluded from the analyses and treated as missing values (in the analysis by participants). In addition, data from trials on which the voice key failed were removed from the analyses. These procedures resulted in the exclusion of 1 % of the data. Reaction time analyses were conducted on data from correct trials only. In the analysis by items, words that did not have a reaction time because their mean accuracy was zero percent were replaced by the mean RT for all items in that direction of translation; this resulted in replacing missing cells with the mean 3 % of the time.

Language history questionnaire data. The language history questionnaire data for the final group of 41 participants are shown in Table 2. (Table 2 about here) Data from participants who rated themselves as higher in their L2 were recoded such that their L2 was considered their dominant language (hereafter referred to as L1). In addition, data from participants who rated themselves as equal in L1 and L2, but were living in an L2 environment were recoded as L2 dominant. Using these criteria, the data from four participants were recoded; three participants were switched from Spanish native to English dominant and one was switched from English native to Spanish dominant.

Reaction time and accuracy data. The data are shown in Table 3. (Table 3 about here) As in past research, translation from L1 to L2 was performed more slowly, F_1 (1, 40) = 11.61, MSE = 11829.43, $p < .01$; F_2 (1, 104) = 35.79, MSE = 7699.43, $p < .01$, and less accurately F_1 (1, 40)

= 22.91, $MSE = 76.17$, $p < .01$; F_2 (1, 104) = 21.90, $MSE = .01$, $p < .01$, than translation from L2 to L1. These findings are consistent with the predictions of the RHM.

Contrary to past research, concreteness did not influence translation latency (Fs < 1). This result is not consistent with past research or with the predictions of the DFM or general models of concreteness. Furthermore, the interaction between direction of translation and concreteness was not significant in either latency analysis, F_1 (1, 40) = 1.64, $MSE = 2064.96$, $p > .10$; F_2 (1, 104) = 2.18, $MSE = 4905.49$, $p > .10$. However, this interaction was significant in the accuracy analysis, F_1 (1, 40) = 7.82, $MSE = 83.33$, $p < .01$; F_2 (1, 104) = 6.17, $MSE = .01$, $p < .05$, such that direction of translation influenced translation of abstract more than concrete words. The interaction appears to reflect the reduced likelihood that bilinguals knew the translations for the abstract noncognates. The type of errors made by participants in this experiment supports this conclusion—participants were significantly more likely to omit responses (indicating that they did not know the correct response) for abstract than for concrete words (7.9 vs. 5.7 %), t (40) = 2.67, $p = .01$. This statistically-significant difference also holds if the timeout responses (i.e., when participants didn't make any response) are included as omitted responses (14.9 vs. 10.3 %), t (40) = 3.91, $p < .01$. Finally, the interaction between concreteness and direction of translation on accuracy qualifies a main effect of concreteness, which demonstrates that concrete words were translated more accurately than abstract words, F_1 (1, 40) = 104.12, $MSE = 81.13$, $p < .01$; F_2 (1, 104) = 8.10, $MSE = .14$, $p < .01$.

In sum, the results of this experiment are consistent with past research and the predictions of the RHM in that L1 to L2 translation took longer to perform than L2 to L1 translation (e.g., Kroll & Stewart, 1994; Sánchez-Casas et al., 1992). However, contrary to both general and language-specific models, concreteness did not influence translation latency. The explanation for concreteness effects offered by the DFM predicts longer reaction times *in addition to* lower accuracy for abstract words; that model proposes that there is greater semantic overlap for concrete than abstract words and that greater semantic overlap leads to faster and more accurate translation. The results suggest that the participants have not learned as many abstract as concrete words in the L2, but, for the words they know, they retrieved the translations equally quickly.

As with all reports of null effects, one potential concern is that a lack of statistical power is responsible for the pattern of results we obtained. To verify that this was not the case, we conducted a power analysis. The results demonstrated that we had sufficient power to detect a concreteness effect in RTs in Experiment 1.[3] Furthermore, an experiment similar to Experiment 1 was reported by Tokowicz (1997); like the results of Experiment 1, no effect of concreteness on translation latency was found, lending further support to the claim that concrete and abstract words with one translation are translated with similar speed.

On the basis of the findings in Experiment 1, we tentatively conclude that past reports of concreteness effects in translation are the result of comparing abstract words with more than one translation to concrete words with one translation. Because we would expect concreteness effects regardless of number of translations, a possible implication of our findings is that the meaning retrieval involved in translation is not the same as that involved in tasks in which concreteness effects have typically been shown (e.g., lexical decision). In Experiment 2, we will directly examine the impact of number of translations on translation performance by investigating the translation of concrete and abstract words with and without multiple translations.

Experiment 2: Translating Concrete and Abstract Words with Multiple Translation Equivalents

We obtained number of translations norms so that we could manipulate and examine the influence of both concreteness and number of translations in a translation task. The goals of Experiment 2 were to (1) determine the impact of number of translations on translation performance, and (2) determine whether past reports of a concreteness effect in translation may be the result of comparing concrete words with one translation to abstract words with multiple translations. To our knowledge, there is only one unpublished paper that has addressed the impact of number of translations on translation production (Schönpflug, 1997).

Because the words used in Experiment 1 were intentionally selected to have only one translation, examination of the different responses given to those words did not yield a sufficiently large number of words with multiple translations. Furthermore, because past research suggests that subjective measures are better predictors of performance than objective measures (e.g., Gernsbacher, 1984), and because multiple translation equivalents are only relevant when they are known by the bilinguals being tested, we chose not to obtain an objective measure of number of translation equivalents using a Spanish-English dictionary. Instead, we adopted the methodology employed by Schönpflug (1997; see also Tokowicz et al., 2002). See Appendix B for more information about the norming and coding procedures.

We were able to identify several sources of multiple translations, including words that have multiple meanings and near-synonyms. Although it would be interesting to investigate whether these different sources of ambiguity affect how these words are processed, our stimulus set was not sufficiently large to allow us to directly manipulate this factor. However, subsequent research suggests that in fact these types of ambiguity do not have different consequences for performance on this particular task (Tokowicz, Prior, & Kroll, 2006). Therefore, we will discuss the results without taking type of ambiguity into account, but will explore the importance of examining the types of multiple translations in the general discussion.

We hypothesized that past reports of a concreteness effect in translation may have been due to comparing concrete words with one translation to abstract words with multiple translations. If this is correct, we expect to find a concreteness effect in Experiment 2 when we compare the translation of concrete words with one translation to abstract words with multiple translations. Furthermore, we predict that ambiguous words (those with multiple translations) will be translated more slowly and less accurately than unambiguous words (those with one translation) because of the increased active competition associated with having to select one word out of several that are available for output (e.g., Duffy, Morris, & Rayner, 1988).

To summarize, if the absence of a concreteness effect in Experiment 1 was due to the presence of a single unambiguous translation equivalent for both abstract and concrete words, then when the number of translations is manipulated in Experiment 2, the concreteness effect should re-emerge but only when concrete words are compared to abstract words with more than one translation.

Method

Participants

The participants were 19 English-Spanish bilinguals and five Spanish-English bilinguals who were students at The Pennsylvania State University or the University of Pittsburgh. They were paid or given extra credit toward a psychology course for their participation.

Stimuli

The stimuli were 236 English words and their translations in Spanish. These words were selected on the basis of the number of translations data collected on a large corpus of words (see Appendix B), and were classified as having either one translation in each direction of translation (i.e., unambiguous) or as having more than one translation in at least one of the two directions (i.e., ambiguous).[4] Of the 236 items, 152 noncognates were used as critical items that were included in the statistical analyses; there were 38 words in each concreteness by number of translations condition (abstract with one translation, abstract with more than one translation, concrete with one translation, and concrete with more than one translation). Because cognates are less likely than noncognates to have multiple translations (see also Tokowicz et al., 2002), it was not possible to have the same number of cognates as noncognates with multiple translations and the cognates were therefore included as fillers to maintain a representative sample of cross-language items.[5] Fifty-two cognates and an additional 32 noncognates were included as filler items. Of these fillers, most had only one translation to reduce the likelihood that the participants would discover the purpose of the experiment.

Context availability and concreteness ratings in English were obtained on the materials in Experiment 2. The instructions were the same as those used in Experiment 1. Ratings for the target items were obtained from 40 native English speakers who were undergraduates at The Pennsylvania State University; 17 of them completed context availability ratings and 23 of them completed concreteness ratings. The concrete and abstract words matched with respect to word length in English and Spanish and word frequency in English, but differed in terms of concreteness and context availability ratings (see Table 4 for stimulus properties and Appendix C for stimuli and ratings).[6] (Table 4 about here)

Procedure

The procedure was the same as that of Experiment 1, with the exception that the words remained on the screen until the participant made a response.

Results and Discussion

Data Trimming

The data from two participants were excluded due to equipment failures. The statistical analyses were conducted on data from 22 participants. Because some words had more than one correct translation, the responses given by the participants varied. Only the expected translation was accepted to maintain the match across conditions with respect to word length word frequency.

Reaction times that were 2.5 SDs above or below a given participant's mean response for that direction of translation, translation latencies that were longer than 3000 ms, and data from trials on which the voice key failed were excluded from the analyses and treated as missing values in the analysis by participants. These procedures resulted in the exclusion of 6% of the data. Reaction time analyses were performed on data from correct trials only. In the analysis by items, missing cells were replaced by the mean RT for all items in that direction of translation; this resulted in replacing data 13.16 % of the time.

Language History Questionnaire Data

The language history questionnaire data for the 22 participants are shown in Table 2. (Table 2 about here) The same criteria used as in Experiment 1 revealed that English was the dominant language of all participants.

Reaction Time and Accuracy Data

The reaction time and accuracy data for the critical items are shown in Table 5. (Table 5 about here) One question of interest in this experiment was whether multiple translations influences translation latency or accuracy. Indeed, words with only one translation were translated more quickly, F_1 (1, 21) = 10.23, MSE = 36734.38, $p < .01$; F_2 (1, 148) = 16.59, MSE = 59303.19, $p < .01$, and more accurately, F_1 (1, 21) = 267.98, MSE = 84.81, $p < .01$; F_2 (1, 148) = 24.96, MSE = 1420.81, $p < .01$, than words with more than one translation.

As in Experiment 1, translation from L1 to L2 was performed more slowly than translation from L2 to L1, F_1 (1, 21) = 8.83, MSE = 92780.53, $p < .01$; F_2 (1, 148) = 9.03, MSE = 46279.56, $p < .01$. In addition, L1 to L2 translation was performed less accurately than L2 to L1 translation, F_1 (1, 21) = 7.15, MSE = 220.20, $p < .05$; F_2 (1, 148) = 10.84, MSE = 291.61, $p < .01$. These findings are consistent with the predictions of the RHM.

Overall, concreteness did not significantly influence translation latencies, F_1 (1, 21) = 2.18, MSE = 14909.18, $p > .15$; F_2 (1, 148) < 1, MSE = 59303.19, $p > .80$. However, there was a significant interaction between concreteness and number of translations for translation latency, F_1 (1, 21) = 27.05, MSE = 13017.32, $p < .01$; F_2 (1, 148) = 5.33, MSE = 59303.19, $p < .05$. Because the main effect of number of translations was significant, we performed Bonferroni-corrected *t*-tests to determine whether this effect differed for concrete and abstract words. These tests showed that number of translations did not influence the translation latencies of concrete words, t_1 (21) = .24, corrected $p > .10$; t_2 (74) = 1.19, corrected $p > .10$, but abstract words with one translation were translated more quickly than abstract words with multiple translations, t_1 (21) = 4.68, corrected $p < .01$; t_2 (74) = 4.03, corrected $p < .01$. Although concreteness did not influence translation latencies overall, one could also ask whether there was a concrete-word advantage for words with one versus more than one translation. These two additional comparisons did not change the significance of the other two contrasts. The additional comparisons showed that abstract words with more than one translation were translated more slowly than concrete words with more than one translation, although this difference was significant only in the analysis by participants, t_1 (21) = 3.00, corrected $p < .05$; t_2 (74) = 1.44, corrected $p > .10$. In addition, concrete words with only one translation tended to be translated more *slowly* than abstract words with only one translation, which is a reversal of the typical concreteness effect; however this reversal was reliable only in the analysis by participants, t_1 (21) = 3.09, corrected $p < .05$; t_2 (74) = 1.41, corrected $p > .10$. No other factors influenced translation latencies. We address this reversal of the typical concreteness effect in the general discussion. Note that the results for words with more than one translation are similar to those observed in past studies in which concreteness effects have been investigated.

As in the RT analyses, concreteness significantly interacted with number of translations in the accuracy analysis by participants, F_1 (1, 21) = 5.43, *MSE* = 66.82, $p < .05$; F_2 (1, 148) < 1, *MSE* = 1420.81, $p > .50$. To explore this interaction, we conducted follow-up *t*-tests using a Bonferroni correction to examine whether the concreteness effect was similar for words with one and more than one translation. These tests showed that words with one translation were translated more accurately than words with more than one translation for both abstract and concrete words, respectively, t_1 (21) = 11.89, corrected $p < .01$; t_2 (74) = 3.69, corrected $p < .01$; t_1 (21) = 13.27, corrected $p < .01$; t_2 (74) = 3.42, corrected $p < .01$. Further, for words with one translation, concrete words were translated more accurately than abstract words in the analysis by participants, t_1 (21) = 5.90, corrected $p < .01$; t_2 (74) = 2.06, corrected $p > .05$. Also, for words with more than one translation, concrete words were translated more accurately than abstract words, t_1 (21) = 9.71, corrected $p < .01$; t_2 (74) = 3.23, corrected $p < .01$. This interaction qualifies a main effect of concreteness on accuracy, F_1 (1, 21) = 94.50, *MSE* = 110.86, $p < .01$; F_2 (1, 148) = 10.97, *MSE* = 1420.81, $p < .01$. Like the results of Experiment 1, these results suggest that participants have a more limited vocabulary for abstract than for concrete words. The DFM predicts lower accuracy for abstract than for concrete words because the degree of semantic similarity between translations is hypothesized to be lower. The pattern of accuracy data in the two experiments we have reported suggest that accuracy may be determined by multiple factors. We observed a difference between concrete and abstract words in terms of accuracy in the absence of a similar difference in terms of RT in Experiment 1 and in the presence of a concreteness by number of translations interaction in Experiment 2. The accuracy of translation performance therefore seems likely to reflect both vocabulary knowledge as well as retrieval difficulty.

In summary, these results suggest that a new variable, number of translations, affects translation latency and accuracy; the presence of multiple translations slows translation latency and reduces translation accuracy. Thus, translation ambiguity leads to active competition, which affects selection when only a single word must be chosen for production. We further demonstrated that ambiguity influences concrete and abstract words differently; concrete words are relatively unaffected by ambiguity whereas ambiguous abstract words are translated more slowly than unambiguous abstract words.

We also demonstrated that the typical concreteness effect does not emerge for words with only a single translation, but does emerge and is sizeable for words with multiple translations. Thus, it should be noted that concreteness does not influence translation latencies in a simple manner. Rather, concreteness and ambiguity interact, and the typical pattern of concreteness effects is observed only for words with multiple translations. We have also demonstrated that, above and beyond the aforementioned findings, direction of translation reliably influences translation latency and accuracy.

In past studies, the finding of a concreteness effect in translation has been taken as evidence for semantic processing in a bilingual production task and as support for a model in which meanings across translation equivalents were hypothesized to overlap to varying degrees (De Groot, 1992; De Groot, 1993; De Groot et al., 1994; De Groot & Poot, 1997; Van Hell & De Groot, 1998a). The findings of the present study suggest that these past reports may have been the result of comparing translation performance for abstract words with multiple translations to concrete words with one or more than one translations. However, we propose that the basic idea that translation equivalents overlap to varying degrees is likely to be correct, but that additional factors must be taken into account when considering the degree to which translations will share meaning (see Tokowicz et al., 2002; Tokowicz et al., 2006).

Comparison of Experiments 1 and 2

The results from Experiment 2 for words with one translation are similar to those from Experiment 1 in that the standard concreteness effect was not observed, however, there was no reversal of the concreteness effect in Experiment 1. Furthermore, the overall reaction times are slower in Experiment 2 than in Experiment 1. Because the word frequencies of the stimuli in the two experiments are similar, we speculate that this difference is due to the inclusion of ambiguous words in Experiment 2. Including words with multiple translations may slow RT to all words because of the list context. Alternatively, because the norm may be to have a set of words that are mixed in terms of number of translations, it is more likely that the RTs were *speeded* in Experiment 1 by virtue of the unambiguous nature of the stimuli.

Number of Translation Equivalents and Within-Language Ambiguity

When are there multiple translation equivalents across languages? When a word has a number of different meanings in one language, it is likely to have multiple translations in another language. Thus, the number of translation equivalents across languages is related to the ambiguity of lexical concepts within a language. Additionally, some words may have multiple translations because they have near-synonyms (e.g., couch and sofa).

Because number of translations across languages is partly related to number of meanings within a language (one measure of within-language ambiguity), we sought to determine whether the interaction between number of translations and concreteness was due to a general property of language processing or a specific property of cross-language processing. To this end, we had native English speakers perform lexical decisions to English words that varied in their number of meanings and concreteness. Note that a similar comparison using words with near-synonym names is less straightforward due to the smaller availability of such stimuli.

Experiment 3: Concreteness and Number of Meanings in Within-Language Lexical Decision

Concreteness and number of meanings (NOM) have been shown to influence lexical decision latencies in the past (e.g., James, 1975; Rubenstein, Garfield, & Millikan, 1970), however, to our knowledge, the two factors have not been examined simultaneously. One possible exception is a study reported by Rubenstein et al., in which an interaction between concreteness and NOM was found. However, in that study words were classified as abstract if they had abstract *and* concrete meanings, and no words with only multiple abstract meanings were included. Therefore, it is unclear how these results relate to performance on ambiguous words with only abstract meanings.

If the interaction we observed in translation is the result of a general characteristic of the language processing system, then we would expect a similar interaction between concreteness and ambiguity to be obtained in a within-language task. However, if the results were due to a specific manifestation of concreteness and ambiguity for cross-language processing, then we would not expect to find the same pattern of results, but rather main effects of NOM and concreteness. Currently, there are theories of lexical access that make predictions about concreteness and/or ambiguity, but none have considered the potential interaction between these factors (but see Rodd, Gaskell, & Marslen-Wilson's, 2002, research on ambiguity and meaning relatedness).

Within-Language Ambiguity Effects

Although the effects of NOM have been somewhat inconsistent, in most cases, words with more than one meaning typically have a speed advantage over words with one meaning in lexical decision (e.g., Hino & Lupker, 1996; Jastrzembski, 1981; Jastrzembski & Stanners, 1975; Millis & Button, 1989; Rubenstein et al., 1970; Rubenstein, Lewis, & Rubenstein, 1971; cf. e.g., Forster & Bednall, 1976; Gernsbacher, 1984, who found no speed advantage for the two-meaning words). Note that the selection requirements associated with different tasks are responsible for ambiguous words being responded to more slowly than unambiguous words in production tasks such as translation, but more quickly than unambiguous words in lexical decision studies. Because translation production requires one alternative to be selected for output, the resulting *active* competition slows the translation process (e.g., Jacobs & Grainger, 1992; McClelland & Rumelhart, 1981, 1985). In contrast, lexical decision is a comprehension task and the activation of a lexical entry or meaning is sufficient to make a lexical decision (e.g., Forster & Chambers, 1973). Therefore, the super-threshold activation of any node will suffice, which results in *passive* competition among the nodes.

More recent research suggests that the typical finding of a processing advantage for words with multiple meanings holds only for words with multiple related senses, but a processing disadvantage is found for words with multiple distinct (unrelated) meanings (Rodd et al., 2002). The pattern of results presented by Rodd et al. suggests that multiple semantic interpretations of words become active during the lexical decision task, and that it is the competition among the semantic alternatives that slows processing and results in a disadvantage in lexical decision for words with unrelated meanings. It is possible that concrete and abstract words differ in the likelihood that their meanings are related, such that concrete words have related meanings whereas abstract words have unrelated meanings; to our knowledge, this possibility has not yet been tested, and it is outside the scope of the present experiment.

Because of the differences between the translation and lexical decision tasks, we expected that opposite effects of ambiguity would be observed on these two tasks. Indeed, Piercey and Joordens (2000) showed that the typical lexical decision advantage for ambiguous words becomes a disadvantage when the specific meaning must be understood, as in a reading task.

Within-Language Concreteness Effects

Concreteness has also been shown to influence lexical access in within-language tasks. In the lexical decision task in particular, concrete words are generally responded to more quickly than abstract words (e.g., James, 1975; Kroll & Merves, 1986; Schwanenflugel et al., 1988; Schwanenflugel & Shoben, 1983). Although both ambiguity and concreteness have been shown to influence lexical access, these two variables have not been studied simultaneously. However, Jastrzembski (1981) identified a correlation between concreteness and number of meanings in a study by Ellis and Shepherd (1974), and suggested that a possible explanation for the discrepant results in the NOM literature is that concreteness has not been taken into account in the majority of these studies. Furthermore, it is possible that in some past studies, abstract and concrete words have been differentially distributed across the categories of words with few versus many meanings, and that NOM effects were sometimes eliminated by concreteness effects (e.g., if concrete words with few meanings were compared to abstract words with many meanings).

To test the generalizability of the interaction between concreteness and ambiguity, we examined how these factors influence processing in a lexical decision task. In Experiment 2, concreteness influenced the translation of multiple-translation words in the typical manner, but this was not the case for single-translation words. If the interaction between ambiguity and concreteness is not specific to cross-language processing, we would expect to find an analogous interaction between concreteness and ambiguity in a within-language task. In particular, we would predict that ambiguity in terms of number of meanings would influence the processing of abstract words to a greater extent than concrete words.

Method

Participants

One hundred and twelve right-handed native speakers of English participated in this experiment; they did not participate in any of the related norming tasks. They received extra credit in a Psychology course for their participation.

Stimuli

The critical stimuli used in this experiment were 400 words that differed in their concreteness and number of meanings (see the section on number-of-meanings norms below). Participants were randomly assigned to one of five versions. In addition, an equal number of orthographically-permissible nonwords were matched to the target words in terms of length (number of letters). With several exceptions to accommodate small length differences across lists, the same nonwords were used in all versions of the task.

Concreteness and context availability ratings were obtained from six and ten native English speaking students at The Pennsylvania State University, respectively. They received extra credit in a psychology course for their participation. The instructions used for the concreteness and context availability ratings were adapted from Spreen and Schulz (1966) and Schwanenflugel et al. (1988), respectively.

The number-of-meanings norms were obtained from fifty native speakers of English who were students at The Pennsylvania State University. They received extra credit in a psychology course for their participation. The words were divided into five lists, each list was assigned an approximately equal number of abstract and concrete words. The words were printed in random order in booklets and participants wrote all *distinct* meanings they thought of for each word in one of the five lists. Their responses were coded for accuracy using the American Heritage Electronic Dictionary (1992).

Number-of-meanings norms were gathered using the average meaning metric (e.g., Millis & Button, 1989). The number of noun, verb, adjective, and adverb meanings listed for each word by each participant was calculated. The sum number of meanings across syntactic categories given by each participant was calculated. Then, the average of these sums across participants was calculated. This measure gives an estimate of the total number of meanings reported across participants and will henceforth be referred to as “number of meanings”. This method of obtaining number-of-meanings norms differs from the method we used to obtain number-of-translations norms in Experiment 2 because the number-of-meanings norms required that the participants list separately what they considered to be distinct meanings of a word. Although it is straightforward to determine different responses when single-word translations are given, it would be difficult to associate the same meaning given by different participants if each participant listed only the first meaning that came to mind.

Lexical Decision Procedure

A practice block was given prior to the critical block. Participants were presented with one stimulus at a time, at the center of the computer screen. Each stimulus was preceded by a fixation point that remained on the screen for 500 ms. There was an ISI of 100 ms, after which the stimulus appeared and remained on the screen until the participant responded. Participants were instructed to respond to each item by pressing one button to indicate that the stimulus was a real word in English and another button to indicate that it was not. Reaction time in ms was recorded by the computer program from the onset of stimulus presentation to the response. The ITI was 250 ms. The PsyScope computer program was used to present the stimuli in a random order and to record RT and accuracy (Cohen, MacWhinney, Flatt, & Provost, 1993).

Results and Discussion

Data Trimming

Data from two participants were lost due to equipment failures. Data from 35 participants who did not respond accurately at least 90% of the time for both real and nonwords were excluded from the analyses.[7] The final analyses included data from 75 participants (15 for each of the five stimulus lists). Reaction times that were faster than 300 ms or slower than 3000 ms were excluded from the analyses, resulting in the exclusion of 0.10 % of the data. In addition, RTs that were 2.5 *SD*s above or below the participant's mean RT were excluded from the analyses and were treated as missing values. These criteria were applied to the words and nonwords separately and resulted in the removal of 2.7 and 2.9 % of the data for the words and nonwords, respectively. The data from one word, "organdy", were removed because the word was never responded to accurately.

Reaction Time and Accuracy Data

Word status effects. The average nonword and real word data across participants and items were compared using *t*-tests to evaluate word status effects on RT and accuracy. As in past research, nonwords were responded to more slowly than real words (678 vs. 589 ms), t_1 (74) = 11, $p < .01$; t_2 (1031) = 20.07, $p < .01$ (e.g., Kroll & Merves, 1986; Rubenstein et al., 1970; Schwanenflugel et al., 1988). Nonwords were also responded to less accurately than real words (93.7 versus 94.6 %), t_1 (74) = 3, $p < .01$; t_2 (1032) = 1.65, $p < .05$.

Real word trials. To determine whether concreteness and/or number of meanings influenced processing of words, a hierarchical linear regression analysis was used to analyze the data from correct trials on real words only (e.g., Tompkins, Baumgaertner, Lehman, & Fassbinder, 2000). This procedure allowed us to co-vary the effects of factors that were not of interest to examine the effects of concreteness and NOM. In this analysis, the stimulus length and logarithmic transform of word frequency served as covariates. Concreteness and context availability ratings, that have more consistently predicted lexical decision latencies than ambiguity in the past, were entered on the second step of the analysis. Numbers of meanings were entered on the third step. Finally, the interactions between concreteness and number of meanings and between context availability and number of meanings were entered on the fourth step. We used concreteness and context availability ratings jointly to predict performance;

because these ratings are so highly correlated, it could not be determined which measure was a better predictor of performance. In subsequent discussion of this analysis, "concreteness" refers to this combined measure. The dependent variable was the mean RT. The change in the proportion of variance (ΔR^2) accounted for by each step in the analysis as well as the associated semi-partial correlation coefficients (*sr*s) were evaluated (see Table 6). (Table 6 about here) The RTs reported below reflect estimates derived from the regression equations.

The results of the hierarchical regression analysis showed that the length and frequency of the stimulus were significant predictors of RT, as expected, $R^2 = .29$, $F(2, 396) = 80.38$, $p < .01$. The overall effect of concreteness was also significant, such that words higher in concreteness were responded to more quickly than words lower in concreteness (574 vs. 613 ms), $\Delta R^2 = .12$, $F(2, 394) = 38.04$, $p < .01$. In addition, number of meanings significantly affected lexical decision latencies, such that words were responded to more quickly the more meanings they had (601 vs. 562 ms for words with one and two meanings, respectively), $\Delta R^2 = .01$, $F(1, 393) = 9.38$, $p < .01$. Finally, the interaction between concreteness and number of meanings was significant, $\Delta R^2 = .01$, $F(2, 391) = 3.50$, $p < .05$. Exploration of this interaction (see Figure 1) (Figure 1 about here) shows that the results resembled those observed in Experiment 2—the effects of ambiguity were present only for words low in concreteness. Also like the results of Experiment 2, there was a reversal of the concrete-word advantage, but it was for multiple meaning words rather than single translation words. Also, as predicted, the ambiguity effect overall was reversed from a disadvantage in Experiment 2 to an advantage in Experiment 3 in the context of the different task demands. The results confirm the hypothesis that the interaction between ambiguity and concreteness reflects a general property of language processing and not a unique aspect of cross-language processing.

Because of a distributional violation regarding the assumption of homoscedasticity and a limited range of variance that could not be corrected using arc-sine transformations, a regression analysis was not used to evaluate the predictors of accuracy. On average, the words were responded to with 95.1 % (*SD* = 8.2) accuracy; the range was from 33 to 100 %.

Similar to the interaction between concreteness and number of translations we observed in Experiment 2, we found an interaction between concreteness and number of meanings in Experiment 3, such that the effects of ambiguity were present only for abstract words and the typical concreteness effect was found only for one-meaning words. Taken together, these results suggest that the interaction between concreteness and ambiguity reflects a general property of language processing. Furthermore, these results suggest that to the extent that concreteness and ambiguity are correlated in natural language, random selection of stimuli may lead to correlations in stimulus sets. These correlations may then complicate the interpretation of results for studies in which only one of the two factors is considered.

The main effects of ambiguity and concreteness we observed are consistent with the models of these effects that have been described in the literature. Based on the present results, we suggest that existing models may be adapted so that they can account for the interaction between concreteness and number of meanings. We believe that the relatedness of multiple meanings of concrete and abstract words is a promising avenue for future research.

General Discussion

In three experiments, we examined the effects of concreteness and ambiguity on language processing. There were several notable findings. First, ambiguity generally slowed translation production (Experiment 2), but speeded lexical decision (Experiment 3). Second, when ambiguous and unambiguous words were mixed in the same experiment, concrete words were unaffected by ambiguity (Experiments 2 and 3). Third, under these mixed conditions, abstract words were processed more *quickly* than concrete words when words were relatively unambiguous and a single alternative could be selected quickly, but more slowly than concrete words when words were highly ambiguous and selection among a set of competing alternatives was required (Experiments 2 and 3). The similar pattern of findings for cross-language translation and within-language lexical decision suggests that a specific model of concreteness is not needed to explain how concreteness affects bilingual language processing. Rather, the findings observed during bilingual translation are likely to be a manifestation of general properties of conceptual representation.

The first finding, that ambiguity can produce either facilitation or interference in processing, is consistent with models that predict different consequences of ambiguity as a result of the task demands; the need to choose one option for output will lead to active competition (e.g., Jacobs & Grainger, 1992; McClelland & Rumelhart, 1981, 1985), but when activation of any option will suffice (e.g., in lexical decision), passive competition will result and processing will be speeded (e.g., Rubenstein et al., 1970).

To our knowledge, the second and third findings, that abstract words are differentially sensitive to ambiguity and can be processed more rapidly than concrete words under some circumstances, are not predicted by any existing models of within- or cross-language processing. In particular, the reversal of the typical concrete-word advantage for the faster conditions of Experiments 2 and 3 in the presence of the typical concreteness effect for the slower conditions, was not predicted. Of note, however, is that this reversal does not indicate a cost to processing concrete words under unambiguous conditions. Rather, the effect is driven almost entirely by the marked effect of ambiguity for processing abstract words. Note that the reversal of the concreteness effect was found in the fastest conditions of the present experiments—in the two-meaning condition of Experiment 3 and the single-translation condition of Experiment 2.

Furthermore, the reversal was larger in the fastest of these conditions—when translation was performed from L2 to L1.

During the translation of an unambiguous word, there is minimal competition for selection because consistent cross-language mappings will have been acquired. This situation reduces the need for full specification of meaning because the task is only to choose the single translation, not to use it in context. Similarly, during lexical decision of a multiple-meaning word, a response requires only general activation of meaning to provide evidence that the word has a meaning. This task difference interacts with the activation of meaning features of concrete and abstract words because the features of concrete words tend to be more correlated than those of abstract words (McRae, De Sa, & Seidenberg, 1997; McRae & Boisvert, 1998; and see Schwanenflugel et al., 1988). Assuming that all features of concrete words become activated simultaneously, full meaning specification will occur regardless of whether full specification is required for the task. As a result, performance on concrete words will not differ as a function of the level of ambiguity. However, for tasks that can be accomplished on the basis of gist alone, abstract words will have an advantage over concrete words, resulting in the reversal of the concreteness effect that we observed both within and across languages.

Recent neuropsychological findings also provide support for the idea that concrete and abstract word meanings are represented and accessed differently. Crutch, Ridha, and Warrington (2006; see also Crutch & Warrington, 2005) examined concrete and abstract word processing in a patient with semantic refractory access dysphasia, which is an impairment characterized by inconsistent responding, sensitivity to the semantic relatedness of stimuli, and insensitivity to word frequency (see Gotts & Plaut, 2002, for a model of this phenomenon). Individuals with this impairment have difficulty processing words that are presented in semantic groupings or that are repeated across short intervals. To examine how concrete and abstract words are represented, Crutch et al. used a spoken word-written word matching task in which the stimuli were concrete and abstract words presented in different types of groupings. The patient demonstrated impaired processing on concrete but not abstract words that were displayed in semantically-similar groupings (categorical for the concrete words and synonymous for the abstract words). By contrast, this patient showed impaired processing of abstract but not concrete words that were displayed in associatively-related groupings.

Crutch et al. (2006) concluded that concrete and abstract word representations differ in that highly concrete words are represented mostly categorically whereas highly abstract words are represented mostly associatively. What is critical for present purposes is that concrete and abstract words, by virtue of their relatively different representations, are likely to be differentially affected by ambiguity, with concrete words more likely to activate features that tend to be correlated (in categories).

A remaining issue is why we did not observe a reversal of the concreteness effect in Experiment 1, in which all words had a single translation. As mentioned earlier, the reaction times were also much faster in Experiment 1 than in the single-translation condition of Experiment 2 despite similar stimulus characteristics. This pattern suggests that there may be a strategic component of processing that is affected by the difference between abstract and concrete concepts. A related finding in the within-language concreteness literature was reported by Kroll and Merves (1986) who demonstrated that concreteness effects were eliminated when abstract and concrete words were presented in blocks and the abstract block was processed first; by contrast, a standard concreteness effect was observed when the concrete block was processed first, and when the same words were presented in a single block of trials. The fact that processing of a single concept type in a block of trials can affect comparisons to other concept types highlights the importance of using a varied stimulus set (e.g., De Groot, 1992; Tokowicz et al., 2006).

Although concrete and abstract words appear to differ in the form of their conceptual representation, they are also likely to differ in how they can be ambiguous. Words can have several types of multiple translations—near-synonym translations (e.g., sofa and couch for *sofá*), colloquial translations (e.g., *sombrilla* for umbrella instead of *paraguas*), and multiple meaning translations (e.g., *vidrio* and *vaso* for glass). Because of inherent differences between concrete and abstract words, one may expect the type of ambiguity to differ for these word types (note that multiple meaning translations by definition will be of lower semantic relatedness than multiple near-synonym or colloquial use translations). Although we cannot rule out this possibility completely, there are several reasons that ambiguity differences between concrete and abstract words are unlikely to be responsible for our findings. First, our subsequent research demonstrates that multiple meaning and near-synonym translations do not have different consequences for performance on the translation production task, although this could be due to a relative insensitivity of this task to determine the level at which ambiguity has a role (Tokowicz et al., 2006). Second, the interaction between concreteness and ambiguity holds even when the different types of ambiguity are under investigation (Experiments 2 and 3). Thus, our findings are more likely to be due to ambiguity affecting the speed of processing than to the particular source of ambiguity.

The presence of multiple translations across languages has implications for how second language learners acquire meanings in their new language, and for whether they acquire all of the meanings that are available to native speakers of that language. For example, translations are often taught as direct one-to-one mappings, which does not encourage additional nuances of meaning to be learned. Furthermore, the availability of multiple translations relates to the issue of linguistic relativity in that “thinking for speaking” (e.g., Malt & Sloman, 2004; Slobin, 1996) may be different for bilinguals when labels vary across their languages (see Kan & Thompson-Schill, 2005, for the consequences of translation differences for meaning activation). When translations do not map closely across languages, thought may be different in L1 and L2. The process of re-mapping semantics to align better with the second language is thought to require extensive practice and exposure to the second language (e.g., Zhang, 1995). Therefore, subtle differences in meaning and comprehension may remain throughout L2 learning.

An interesting implication of our results is that the presence of translations that do not map easily across languages may be likely to encourage code-switching or borrowing; bilinguals may prefer to use a word that encompasses the precise meaning they wish to convey, regardless of the language of that word. In this way, speakers may opt to maintain the semantic integrity of the message by changing languages.

Conclusions

The present results suggest that concreteness and ambiguity influence both within and cross-language processing similarly, and are consistent with a growing body of evidence that suggests that factors that make it difficult to select a single alternative tend to exaggerate concreteness effects (e.g., small morphological families, Feldman, Pastizzo, & Basnight-Brown, 2006; having higher frequency orthographic neighbors, Samson & Pillon, 2004). Thus, a single, general model may suffice to parsimoniously explain their influence. Furthermore, our results may help to explain why prior studies on translation performance and on the effects of number of meanings on lexical retrieval have produced conflicting findings. As such, the present results provide a promising new direction for identifying the factors that influence meaning retrieval in both the native and second languages.

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Appendix A

Context Availability, Imagery, and Concreteness Ratings for Stimuli of Experiment 1

Concrete Noncognate Stimuli

English Stimulus	Spanish Stimulus	Context Availability	Imagery	Concreteness
army	ejército	6.36	3.42	2.77
beer	cerveza	6.82	5.75	6.77
blanket	manta	6.55	6.17	7.00
body	cuerpo	6.55	5.75	5.92
bone	hueso	5.82	5.58	6.85
brick	ladrillo	6.45	5.92	7.00
bullet	bala	6.18	6.00	6.46
butter	mantequilla	6.73	6.17	7.00
cat	gato	6.82	5.75	6.92
chairs	sillas	5.82	4.58	4.31
corn	maíz	6.64	5.5	5.62
corner	esquina	6.18	4.58	5.77
cotton	algodón	6.36	5.67	6.23
cow	vaca	6.64	6.25	7.00
door	puerta	5.55	3.17	3.31
fire	fuego	6.73	6.25	6.77
fist	puño	6.55	6.17	7.00
furniture	muebles	6.64	6.83	6.69
gift	regalo	5.09	4.25	3.23
gold	oro	5.18	3.75	2.62

English Stimulus	Spanish Stimulus	Context Availability	Imagery	Concreteness
grandmother	abuela	6.91	6.00	6.69
hat	sombrero	6.45	6.08	6.92
head	cabeza	6.45	5.67	6.62
honey	miel	4.82	2.33	2.85
horses	caballos	6.91	6.17	6.77
house	casa	6.64	5.83	6.77
kitchen	cocina	6.27	5.92	5.62
leg	pierna	6.45	6.25	6.92
library	biblioteca	6.64	5.75	6.46
mail	correo	5.09	3.50	3.00
meat	carne	6.82	4.83	6.54
mirror	espejo	6.45	5.67	6.69
movie	película	6.45	5.17	6.23
needle	aguja	6.27	6.17	6.77
newspaper	periódico	6.45	5.92	6.92
pencil	lápiz	6.64	5.67	6.92
rice	arroz	6.09	5.42	6.77
scissors	tijeras	6.55	5.75	6.92
sheep	oveja	6.45	5.67	6.15
shirt	camisa	6.73	6.17	6.77
shoe	zapato	7.00	6.17	6.92
snow	nieve	6.82	5.42	4.85
soap	jabón	6.27	6.17	7.00

English Stimulus	Spanish Stimulus	Context Availability	Imagery	Concreteness
song	canción	6.45	4.33	4.92
sugar	azúcar	6.82	5.17	6.46
sweat	sudor	6.55	6.33	6.92
table	mesa	6.09	4.58	6.23
throat	garganta	6.64	5.33	6.46
truck	camión	6.73	5.92	6.85
umbrella	paraguas	5.36	4.08	3.15
village	aldea	6.45	5.17	5.92
water	agua	6.82	6.42	6.77
woman	mujer	5.91	4.92	3.85
		Concrete Cognate Stimuli		
ambulance	ambulancia	6.00	6.25	6.77
boot	bota	6.91	5.75	6.69
captain	capitán	6.27	3.83	5.54
circle	círculo	5.73	5.00	2.15
elephant	elefante	6.36	4.58	5.77
fruit	fruta	6.82	6.33	6.92
garden	jardín	6.64	5.92	6.77
guitar	guitarra	6.55	5.25	7.00
hospital	hospital	6.64	5.75	6.77
machine	máquina	6.27	6.08	6.92
map	mapa	6.55	5.92	7.00
market	mercado	5.55	3.08	2.54

English Stimulus	Spanish Stimulus	Context Availability	Imagery	Concreteness
material	material	6.09	4.50	6.62
music	música	6.91	6.33	6.69
office	oficina	7.00	6.67	5.69
park	parque	6.55	6.17	7.00
pearl	perla	6.45	6.25	6.62
person	persona	6.18	6.92	6.62
pirate	pirata	6.18	6.00	6.54
rose	rosa	5.55	6.00	6.31
station	estación	6.09	4.00	5.69
student	estudiante	6.73	5.00	6.46
tea	té	6.09	3.00	3.85
tiger	tigre	6.18	6.42	6.85
tobacco	tabaco	5.45	4.33	3.92
triangle	triángulo	6.55	6.08	6.00
violin	violín	6.55	6.5	7.00
	Abstract Noncognate Stimuli			
advantage	ventaja	4.73	2.33	2.31
age	edad	6.55	4.58	3.31
arrival	llegada	5.73	5.83	6.23
beauty	belleza	6.18	5.5	2.77
belief	creencia	5.00	3.17	2.38
century	siglo	6.09	3.08	4.38
danger	peligro	5.45	4.50	3.38

English Stimulus	Spanish Stimulus	Context Availability	Imagery	Concreteness
death	muerte	6.45	5.5	6.54
deceit	engaño	3.91	2.58	2.15
dream	sueño	6.18	4.83	5.54
ease	facilidad	5.09	2.33	2.15
effort	esfuerzo	5.55	3.08	2.69
fever	fiebre	6.09	4.50	4.77
health	salud	6.55	4.08	4.77
hell	infierno	5.64	4.08	2.15
hope	esperanza	5.55	3.25	2.31
hunger	hambre	6.18	5.17	4.38
inheritance	herencia	5.64	3.33	3.62
joke	chiste	5.82	3.33	3.38
lie	mentira	5.64	3.83	3.15
loan	préstamo	6.64	6.58	6.54
love	amor	6.64	4.50	3.23
loyalty	lealtad	4.73	4.00	2.46
luck	suerte	6.18	4.92	3.92
mind	mente	5.45	4.17	5.62
miracle	milagro	6.73	5.17	6.85
noise	ruido	6.82	6.25	6.85
nonsense	tonterías	4.45	3.00	2.31
oath	juramento	5.00	3.33	2.85
pain	dolor	6.36	4.00	2.62

English Stimulus	Spanish Stimulus	Context Availability	Imagery	Concreteness
peace	paz	5.55	4.25	3.38
pound	libra	4.91	4.08	2.38
pride	orgullo	6.09	5.25	6.46
rage	rabia	6.36	5.92	6.77
sadness	tristeza	5.45	5.17	3.08
shame	vergüenza	5.36	3.08	2.23
sin	pecado	5.73	4.08	2.69
size	tamaño	5.82	4.25	3.08
soul	alma	6.00	2.83	1.77
south	sur	5.36	4.17	2.54
stench	hedor	6.27	4.25	4.54
struggle	lucha	5.36	3.67	3.85
summer	verano	6.55	5.50	4.85
thought	pensamiento	4.82	3.58	2.92
threat	amenaza	5.91	3.75	2.69
truth	verdad	5.55	3.42	2.46
war	guerra	6.27	5.5	4.69
warmth	calor	6.45	4.00	3.31
weakness	debilidad	5.45	3.33	2.15
week	semana	5.55	3.42	3.85
word	palabra	6.45	5.75	6.92
yesterday	ayer	6.36	2.92	3.08
youth	juventud	5.91	4.42	3.92

English Stimulus	Spanish Stimulus	Context Availability	Imagery	Concreteness
		Abstract Cognate Stimuli		
ability	habilidad	5.55	2.75	2.38
action	acción	6.09	3.17	2.46
art	arte	6.27	5.67	4.62
attention	atención	5.00	2.75	2.00
chaos	caos	5.18	4.58	2.69
color	color	6.18	5.33	6.62
comedy	comedia	6.27	5.5	4.15
confession	confesión	5.82	3.83	3.00
crisis	crisis	5.09	2.92	2.38
cruelty	crueldad	5.55	3.25	2.85
culture	cultura	5.45	3.75	2.62
fame	fama	5.64	3.42	2.08
favor	favor	5.09	2.58	2.85
future	futuro	5.73	4.17	2.15
glory	gloria	5.00	3.42	2.38
honor	honor	5.73	3.00	2.54
hour	hora	6.64	4.17	3.77
idea	idea	5.45	4.25	2.69
influence	influencia	5.09	2.92	2.46
innocence	inocencia	5.45	3.58	2.38
method	método	6.18	5.92	6.85
panic	pánico	5.91	4.33	5.23

English Stimulus	Spanish Stimulus	Context Availability	Imagery	Concreteness
passion	pasión	6.55	5.83	6.31
promise	promesa	5.45	3.33	4.00
silence	silencio	5.00	3.00	3.62
talent	talento	6.45	4.83	6.69
victim	víctima	6.09	4.58	4.46

Appendix B

Number of Translations Norming Procedure

Participants

The participants in the number-of-translations task were eight English-Spanish and eight Spanish-English bilinguals who were students at The Pennsylvania State University. They were paid or given psychology course credit for their participation. The language history questionnaire data for these participants are given in Table 2. The same criteria were used as in Experiment 1 to determine each participant's dominant language. Using these criteria, two participants were switched from Spanish native to English dominant.

Materials

The stimuli were the 500 words that had been used in several translation experiments (the present Experiment 1; Kroll & Rogg, 1994; Miller & Kroll, 2002). Several words were not included because they were the plural form of another item. The words were divided into two lists; the two lists were matched such that they did not differ with respect to word length in English or Spanish or English word frequency. Each participant translated words from only one of the two lists; assignment of list to direction of translation was counterbalanced across participants so that the words that a given participant translated from English to Spanish were translated by another participant from Spanish to English. The words were listed in random order in the booklets.

Procedure

Task

Participants first completed a brief version of the language history questionnaire used in Experiments 1 and 2. Each participant translated words into only one language; half of the participants of each native language translated words from English to Spanish, and the other half translated words from Spanish to English. The participants then completed the translation booklet by writing only one translation for each word listed. They were instructed to write the first translation that came to mind, and to not go back in the list or change their responses. If they did not know the translation of a given word, they were to skip that item and move on to the next one.

Coding

There are several ways in which number of translations can be calculated. We used the "first translation" method that was used by Schönpflug (1997; see also Tokowicz et al., 2002). A similar method has been adopted in the polysemy literature to calculate number of meanings (e.g., Rubenstein et al., 1970). The "first translation" method also best matches the requirements of the translation production task on which we were attempting to predict performance. An alternative method, that may seem the most straightforward method initially, would be to have each participant write all translations they know for a given word. However, the most important advantage of the "first translation" approach is that if participants were asked to list multiple translations, they may have engaged in retrieval strategies that were quite distinct from those normally used (and those typically involved in the translation task), such as generating associations or other words simply to satisfy the criterion of listing multiple words. In addition, it is complicated to determine how to calculate the number of translations on the basis of such a measure, because there are several options (the largest number of translations any individual gave, the total number of translations that were given by all participants, the total number of translations given overall, etc.).

Number of Translations Data

The translations given for each word were coded as one of the following: *expected* (when the expected translation was given), *omit* (when the participant skipped that item), *near-synonym* (when the participant listed a word that had essentially the same meaning as the expected translation, e.g., translating "alegría" into "happiness" rather than "joy"), *other meaning* (when the participant translated another meaning of the word, e.g., translating "floor" to mean level of a building or "piso", rather than ground or "suelo"), *verb meaning* (when the participant translated the verb, rather than the intended noun meaning of the word, e.g., translating "spell" into its verb meaning "deletrear", rather than its noun meaning "encanto"), *colloquial use* (when the participant listed a colloquial usage of a word, e.g., translating "umbrella" into "sombrilla", that translates to "parasol", rather than using the literal Spanish translation of umbrella, "paraguas"), or *error* (when the participant gave a translation that did not fall into one of the above categories and was not listed in an English-Spanish dictionary; The Collins Spanish Dictionary, 1990).

Appendix C

Context Availability and Concreteness Ratings for Critical Stimuli of Experiment 2

Concrete Stimuli with One Translation

English Stimulus	Spanish Stimulus	Context Availability	Concreteness
avocado	aguacate	4.35	6.70
bird	pájaro	6.53	6.57
bone	hueso	6.24	6.64
book	libro	6.41	6.57
butter	mantequilla	6.71	6.83
carrot	zanahoria	6.47	6.83
daughter	hija	6.29	6.36
eye	ojo	6.59	6.65
finger	dedo	6.41	6.64
fire	fuego	6.41	6.52
furniture	muebles	6.24	6.30
grandmother	abuela	6.59	6.48
hat	sombrero	6.47	6.39
head	cabeza	6.29	6.52
highway	carretera	6.59	6.22
keys	llaves	6.59	6.35
leg	pierna	6.24	6.48
library	biblioteca	6.47	6.35
mail	correo	6.35	5.87

English Stimulus	Spanish Stimulus	Context Availability	Concreteness
men	hombres	6.47	6.00
mountain	montaña	6.12	6.26
mustache	bigote	6.12	6.44
pumpkins	calabazas	6.41	6.83
rain	lluvia	6.65	6.48
room	cuarto	6.18	6.09
scissors	tijeras	6.18	6.35
shoe	zapato	6.88	6.57
shoulder	hombro	6.18	6.22
sidewalk	acera	6.18	6.09
snow	nieve	6.88	6.44
soap	jabón	6.53	6.48
sun	sol	6.65	6.13
supper	cena	6.06	5.48
throat	garganta	6.12	6.26
tray	bandeja	5.77	6.52
tree	árbol	6.59	6.74
wall	pared	5.71	6.44
winter	invierno	6.77	5.52

Concrete Stimuli with More than One Translation

English Stimulus	Spanish Stimulus	Context Availability	Concreteness
airplane	avión	6.06	6.61
boys	chicos	6.47	6.26
candle	vela	6.24	6.17
car	coche	6.77	6.70
chair	silla	6.12	6.48
children	niños	6.38	6.35
clothes	ropa	6.47	6.13
coat	abrigo	6.59	6.39
coins	monedas	6.12	6.26
corn	maíz	6.29	6.74
cup	taza	6.24	6.61
feather	pluma	6.24	6.48
floor	suelo	6.18	6.39
forest	bosque	5.88	6.09
gift	regalo	6.24	6.04
grass	hierba	6.53	6.44
hair	pelo	6.82	6.44
jungle	selva	5.71	5.82
lady	señora	6.47	6.35
lock	cerradura	5.59	5.65
meat	carne	6.06	6.35

English Stimulus	Spanish Stimulus	Context Availability	Concreteness
missile	proyectil	5.35	5.74
mother	madre	6.77	6.39
newspaper	periódico	6.65	6.61
pepper	pimienta	6.06	6.44
picnic	merienda	6.18	5.26
rug	alfombra	6.12	6.48
shop	tienda	6.29	5.83
smoke	humo	6.12	5.52
square	cuadrado	5.59	5.26
stone	piedra	5.88	6.57
string	cuerda	5.71	6.00
town	pueblo	6.12	5.13
truck	camión	6.65	6.48
twins	gemelos	6.00	6.26
umbrella	paraguas	6.41	6.61
vegetable	legumbre	6.06	6.17
watch	reloj	6.35	5.00
	Abstract Stimuli with One Translation		
advantage	ventaja	4.24	2.44
age	edad	6.06	3.78
arrival	llegada	5.12	2.96
blind	ciego	5.12	3.91
boil	hierva	5.88	4.83

English Stimulus	Spanish Stimulus	Context Availability	Concreteness
dream	sueño	5.41	2.83
fever	fiebre	5.77	4.74
flaw	defecto	4.71	2.87
greed	codicia	4.94	2.26
hope	esperanza	4.71	2.32
hunger	hambre	5.82	4.04
jeopardy	riesgo	4.41	2.24
joy	alegria	5.65	2.59
kindness	bondad	5.12	2.44
lie	mentira	5.24	2.39
light	luz	6.06	5.78
loan	préstamo	5.18	3.70
loyalty	lealtad	4.82	2.36
luck	suerte	4.65	1.91
luxury	lujo	4.71	3.09
mind	mente	5.24	2.48
miracle	milagro	4.41	2.22
mischief	travesura	4.94	2.96
night	noche	6.53	5.09
noise	ruido	6.41	4.74
peace	paz	5.35	2.91
sadness	tristeza	5.77	2.78
soul	alma	4.18	1.87

English Stimulus	Spanish Stimulus	Context Availability	Concreteness
south	sur	5.77	3.39
support	apoyo	4.35	2.13
thought	pensamiento	5.00	2.57
voice	voz	5.65	5.27
war	guerra	5.82	4.35
weakness	debilidad	4.82	2.86
week	semana	5.71	3.78
welfare	bienestar	4.06	3.13
word	palabra	5.35	4.74
yesterday	ayer	6.06	4.13
	Abstract Stimuli with More than One Translation		
advice	consejo	4.88	2.70
anger	enojo	6.12	2.39
attempt	intento	4.47	2.61
blame	culpa	4.53	2.39
blessing	bendición	5.41	2.13
break	fractura	5.47	3.86
buy	compra	6.06	3.17
carry	lleva	5.41	4.13
cooks	cocina	5.24	4.91
discover	descubre	4.56	2.48
dry	secar	5.71	4.65
fact	hecho	4.82	3.22

English Stimulus	Spanish Stimulus	Context Availability	Concreteness
freedom	libertad	4.71	2.17
game	juego	6.06	4.55
gathering	reunion	5.41	3.61
ghost	fantasma	5.56	3.61
happy	alegre	5.71	2.78
heaven	cielo	5.29	2.87
inheritance	herencia	5.35	3.48
inside	adentro	4.77	4.30
joke	chiste	5.77	3.78
leave	sale	5.94	2.74
madness	locura	4.53	2.39
mercy	piedad	3.69	2.30
mistakes	errores	5.71	3.22
pain	dolor	5.47	3.65
repair	arreglo	5.06	3.87
run	corro	6.00	5.17
shame	vergüenza	4.35	2.26
sin	pecado	5.41	2.17
size	tamaño	5.71	3.61
spell	encanto	5.00	3.22
story	cuento	6.24	5.00
strength	fuerza	5.29	3.09
struggle	lucha	5.24	2.30

English Stimulus	Spanish Stimulus	Context Availability	Concreteness
task	tarea	4.47	3.30
view	vista	5.00	3.52
youth	juventud	4.94	2.91

Appendix D

Number of Meanings and Concreteness/Context Availability Ratings for Stimuli of Experiment 3

English Stimulus	Number of Meanings	Concreteness	Context Availability
ability	1.10	2.17	5.00
abuse	2.12	2.33	5.40
action	1.11	2.17	5.10
address	2.20	4.00	6.40
adult	2.10	5.50	6.50
advantage	1.10	2.33	4.80
advice	1.00	2.17	5.90
age	2.00	3.33	5.80
agility	1.00	2.67	4.10
airplane	1.00	6.67	6.70
allegory	1.00	2.33	2.00
altar	1.00	4.83	4.90
ambulance	1.00	6.83	6.90
anger	2.00	3.67	6.40
anguish	1.00	1.50	3.00
animal	1.00	6.17	6.70
answer	1.80	2.33	4.90
anxiety	1.00	2.50	5.10
apple	1.00	7.00	7.00
aptitude	1.00	2.83	3.70
army	1.10	6.00	6.70

English Stimulus	Number of Meanings	Concreteness	Context Availability
arrival	1.11	2.67	5.40
arrow	1.50	6.83	6.70
atrocity	1.14	1.83	3.40
attacks	1.00	3.00	5.80
attempt	2.00	2.17	4.90
attention	1.22	2.50	5.10
attitude	1.40	2.50	5.00
audience	1.00	5.67	5.60
avocado	1.00	7.00	5.60
baby	2.30	7.00	6.90
bath	2.22	6.00	6.70
beauty	1.10	3.33	5.50
bed	1.10	7.00	6.80
beer	1.00	6.17	7.00
belief	1.10	1.67	4.20
bird	1.00	6.67	6.60
blame	2.11	2.50	5.40
blanket	2.00	6.83	6.00
blessing	2.44	1.83	6.20
body	1.00	6.33	6.20
bone	1.00	6.83	6.40
book	2.00	6.83	6.80
boot	2.14	6.83	6.30

English Stimulus	Number of Meanings	Concreteness	Context Availability
boredom	1.00	2.83	5.00
bottle	2.00	6.67	6.40
box	2.50	6.17	6.50
boys	1.00	6.00	6.50
break	2.11	4.00	5.30
brick	2.00	6.67	6.70
buffalo	1.00	6.83	6.30
bullet	1.20	6.67	6.70
bungalow	1.00	5.67	3.70
butter	2.00	6.33	6.90
button	2.20	6.67	6.20
calendar	1.22	6.67	6.50
candle	1.00	6.67	6.70
capacity	1.30	2.00	4.80
capitol	2.00	3.83	5.90
captain	2.70	6.17	6.20
car	1.10	6.50	6.90
carrot	1.00	6.67	6.70
cart	2.10	6.33	5.20
case	2.00	6.00	5.90
cat	1.00	6.83	7.00
cause	2.12	2.00	3.60
century	1.00	2.83	5.40

English Stimulus	Number of Meanings	Concreteness	Context Availability
chaos	1.00	3.00	4.00
cigar	1.00	6.83	6.00
circle	2.00	5.83	6.20
clothes	2.00	6.00	6.60
coat	2.10	6.67	6.80
coffee	1.10	6.50	6.40
color	3.00	4.50	6.00
comb	2.20	7.00	6.30
comedy	1.22	3.33	5.80
compulsion	1.00	2.17	4.00
computer	1.00	6.83	6.40
concept	1.00	1.67	3.70
condition	2.20	2.33	4.50
confession	1.20	2.17	5.30
corn	1.00	6.83	6.60
corner	1.40	6.33	6.00
cotton	1.30	6.67	6.80
cow	2.10	7.00	6.70
creation	1.30	2.33	5.20
crisis	1.10	3.50	5.80
cruelty	1.00	2.83	5.00
culture	1.30	3.00	6.50
cup	1.50	7.00	6.60

English Stimulus	Number of Meanings	Concreteness	Context Availability
custom	2.11	3.00	4.60
danger	1.00	2.50	5.50
data	1.00	3.83	5.70
daughter	1.00	5.50	6.90
death	1.00	2.33	6.10
deceit	2.00	2.00	3.50
decision	1.20	1.80	5.30
demand	2.00	2.33	5.00
demon	1.20	5.33	6.10
desk	1.00	6.67	6.50
detail	2.00	2.83	5.10
devil	2.10	4.50	6.30
devotion	1.33	2.33	4.70
difference	1.30	2.83	6.00
difficult	1.30	2.33	4.80
director	1.10	6.17	5.80
disorder	1.40	3.17	4.30
district	1.00	4.33	5.00
doctor	1.30	6.33	6.60
dollar	1.00	6.33	6.70
door	1.00	6.83	6.60
dream	2.57	3.67	6.10
earnestness	1.00	2.00	3.60

English Stimulus	Number of Meanings	Concreteness	Context Availability
ease	2.10	1.83	4.10
economy	1.11	3.67	4.90
effort	1.22	2.67	5.60
elbow	2.00	6.60	6.60
elephant	1.00	6.83	6.40
elm	1.00	6.17	5.20
enemy	1.00	2.83	5.70
equity	1.12	3.17	4.20
example	1.00	2.83	5.70
expression	1.20	3.67	5.90
fact	1.00	3.33	5.60
factory	1.00	6.33	6.50
faith	1.30	2.17	4.40
fame	1.00	2.00	5.60
family	1.10	5.50	6.70
fantasy	2.00	1.83	5.40
farmer	1.00	6.67	6.50
fate	1.10	1.67	4.80
favor	1.00	3.50	5.30
feather	1.10	6.50	6.80
feud	2.00	3.17	4.90
fever	1.10	3.00	6.10
finger	2.60	7.00	6.90

English Stimulus	Number of Meanings	Concreteness	Context Availability
fire	2.25	6.67	6.30
fist	1.00	6.83	5.90
flame	1.00	6.33	6.30
flaw	2.00	3.67	5.00
flower	1.00	6.67	6.80
fly	2.90	5.83	5.89
folly	1.25	3.60	4.00
foot	1.50	7.00	6.90
forest	1.00	5.67	6.80
freedom	1.00	1.67	5.60
fruit	1.00	6.67	6.90
fun	2.00	3.17	6.30
furniture	1.00	6.00	6.50
future	2.00	2.17	5.70
game	1.80	5.50	6.20
garden	2.00	6.50	6.60
gathering	1.50	3.83	5.10
ghost	1.10	4.83	6.10
gift	1.30	5.83	6.60
glory	2.37	2.00	4.70
gold	1.40	6.00	6.60
governor	1.12	6.00	6.00
grandmother	1.00	6.67	6.70

English Stimulus	Number of Meanings	Concreteness	Context Availability
grapes	1.00	7.00	6.20
grass	1.33	6.83	6.70
greed	1.00	2.00	5.20
grief	1.11	2.67	4.50
guitar	1.00	6.83	6.50
hat	1.00	6.67	6.80
hatred	1.00	3.17	5.40
head	1.44	6.67	6.80
health	1.00	2.83	6.50
heart	1.50	5.67	6.20
honey	1.57	6.50	6.60
honor	2.17	2.67	5.20
hope	2.14	2.17	5.90
hospital	1.00	7.00	7.00
hotel	1.00	6.67	6.70
hour	1.00	3.50	6.30
house	1.00	6.67	6.80
hunger	1.33	4.00	5.80
idea	1.30	1.83	5.30
illusion	1.20	2.50	4.40
impression	1.60	2.83	5.40
indians	1.33	6.50	5.80
influence	2.14	2.33	4.50

English Stimulus	Number of Meanings	Concreteness	Context Availability
inheritance	1.00	3.17	4.70
innocence	1.22	1.50	5.50
insect	1.00	6.33	6.60
insight	2.00	3.67	6.10
insult	2.00	2.33	5.30
irony	1.20	2.00	3.80
jeopardy	1.10	2.17	5.70
joke	1.40	3.00	5.60
joy	1.20	3.00	5.60
juice	1.00	6.33	6.60
jungle	1.00	6.50	6.60
justice	1.00	3.33	5.90
kindness	1.11	2.67	5.70
kitchen	1.00	6.17	6.80
lab	1.30	6.17	6.10
lady	1.11	6.83	6.40
lawyer	1.00	6.50	6.50
leg	1.89	6.50	6.60
lemon	1.00	7.00	6.20
library	1.00	6.33	6.60
lie	2.25	1.67	5.90
light	1.50	5.17	6.10
loan	2.00	3.50	5.70

English Stimulus	Number of Meanings	Concreteness	Context Availability
lock	2.00	6.67	5.10
love	2.00	1.83	6.30
loyalty	1.00	2.17	4.50
luck	3.00	1.83	4.80
luxury	2.22	3.00	5.30
machine	1.00	6.17	5.80
mail	2.10	6.17	6.40
malice	1.00	2.67	2.80
manner	1.30	3.00	5.10
map	2.00	6.67	6.60
mark	1.40	5.17	4.70
market	2.30	6.17	5.70
material	1.40	4.83	4.20
meaning	1.40	2.33	4.00
meat	3.00	6.67	6.70
mechanic	2.00	6.33	5.70
memory	1.40	2.00	4.90
men	1.00	5.83	7.00
mercy	1.12	1.83	5.00
method	1.40	2.50	3.70
middle	2.00	2.83	4.60
mind	2.10	2.17	5.80
minute	2.20	3.67	5.90

English Stimulus	Number of Meanings	Concreteness	Context Availability
miracle	1.00	2.17	4.20
mirror	2.00	6.33	6.60
mischief	1.00	2.33	5.20
misery	1.20	2.83	5.30
missile	1.00	6.67	6.10
mistakes	2.00	2.00	4.70
mittens	1.00	6.83	6.50
moment	1.10	3.50	6.00
moral	2.00	2.50	5.90
mother	2.25	6.17	7.00
mountain	1.00	6.50	6.90
mouse	1.00	6.67	6.60
movie	1.00	6.00	6.70
music	1.00	5.83	6.10
needle	1.22	6.83	6.20
newspaper	1.00	6.83	6.90
night	1.10	5.00	6.60
noise	1.00	5.17	5.90
nonsense	1.00	1.83	4.30
norm	1.00	2.33	4.40
nucleus	1.20	4.33	5.20
nurse	2.00	6.33	6.50
oath	1.10	2.50	5.00

English Stimulus	Number of Meanings	Concreteness	Context Availability
office	1.00	6.17	6.40
officer	1.50	6.67	6.00
opera	1.00	5.83	6.40
operator	1.00	6.17	4.90
opinion	1.00	2.50	5.60
organdy	0.20	3.25	1.00
pain	1.30	2.33	5.80
pamphlet	1.00	6.17	5.30
panic	3.00	2.33	6.00
paper	1.20	6.83	6.50
park	2.30	6.17	6.30
passion	1.50	2.83	5.60
peace	1.40	1.83	6.10
pearl	2.10	6.83	6.50
pencil	1.00	6.67	6.80
pepper	2.30	6.83	6.60
photo	1.00	6.50	6.80
phrases	1.10	2.67	3.90
pianist	1.00	6.00	6.00
picnic	1.00	6.00	6.80
pinnacle	1.00	4.83	3.10
pirate	2.00	6.67	6.30
plane	1.20	6.67	6.70

English Stimulus	Number of Meanings	Concreteness	Context Availability
plate	1.40	6.83	6.30
points	2.22	3.50	4.30
policeman	1.00	6.17	6.70
pound	2.10	4.67	5.80
power	1.50	2.83	5.70
preference	1.00	1.83	4.70
prestige	1.00	3.33	4.10
price	1.20	3.83	6.60
pride	2.00	2.17	5.20
princess	1.00	6.17	6.50
promise	2.00	2.83	4.70
pumpkins	1.10	7.00	6.40
rage	2.00	2.00	5.60
reaction	3.44	2.00	4.90
reason	2.10	2.00	5.10
recipe	1.00	5.83	6.80
remnant	1.00	3.17	2.30
resistance	1.10	2.17	4.60
respect	2.68	2.33	5.70
rhythm	1.30	2.83	4.30
rice	1.00	6.83	6.50
river	1.00	6.33	6.40
rose	2.00	6.00	6.60

English Stimulus	Number of Meanings	Concreteness	Context Availability
rug	1.10	6.50	6.70
sadness	1.20	2.67	5.80
safety	1.10	2.67	5.80
sailor	1.00	6.67	6.30
satire	1.10	3.17	3.20
school	1.20	6.33	6.90
scissors	1.00	7.00	5.50
sea	1.10	6.50	6.10
seconds	1.40	3.50	5.80
sections	2.30	3.83	6.00
shame	2.11	2.17	4.60
sheep	1.10	7.00	6.50
shirt	1.00	6.17	6.80
shoulder	1.22	6.83	6.70
silence	2.10	2.33	5.50
sin	2.00	1.17	5.00
situation	1.00	2.17	5.00
size	2.00	4.00	6.80
skirt	2.10	6.67	6.90
snow	2.00	6.50	6.80
soap	2.00	6.83	6.60
song	1.00	5.50	6.50
soul	1.33	2.80	5.80

English Stimulus	Number of Meanings	Concreteness	Context Availability
soup	1.00	6.50	6.70
south	2.38	3.17	6.70
space	3.00	4.67	5.90
spell	3.44	2.83	5.30
spider	1.00	6.50	7.00
spirit	1.70	3.17	5.40
spoon	1.10	6.83	6.50
square	3.00	6.00	6.60
station	1.50	6.33	6.10
stench	1.00	4.00	5.20
stone	1.00	7.00	6.60
street	1.00	6.00	6.70
strength	1.50	2.67	5.90
string	1.33	6.17	6.20
struggle	1.11	3.50	5.10
student	1.00	6.50	6.80
stuff	2.00	3.83	4.80
sugar	2.00	6.67	6.40
summer	1.00	5.50	6.60
support	1.60	3.00	5.30
sweat	2.10	6.00	6.60
table	2.20	6.33	6.70
talent	1.10	3.33	6.10

English Stimulus	Number of Meanings	Concreteness	Context Availability
task	1.00	3.17	5.70
tea	1.12	6.33	5.70
telephone	2.00	6.83	6.90
tendency	1.10	1.67	3.50
terrain	2.00	4.50	5.90
theme	3.11	1.83	4.50
theory	1.33	3.00	5.00
thing	1.12	3.50	4.20
thought	1.00	1.67	5.60
thread	2.00	6.17	6.10
threat	1.00	2.50	5.10
throat	1.00	6.33	6.70
thumb	2.00	6.50	6.50
tiger	1.00	7.00	6.80
tobacco	1.00	6.67	6.50
tomato	1.00	6.83	6.40
tooth	1.10	6.83	6.20
town	1.00	5.50	5.60
tragedy	1.50	2.83	5.78
train	2.10	6.17	6.70
tranquility	1.00	1.83	4.90
tree	1.00	6.83	6.90
triangle	1.00	6.33	5.80

English Stimulus	Number of Meanings	Concreteness	Context Availability
truck	2.00	6.83	6.40
truth	1.00	1.50	5.30
tuba	1.00	7.00	6.40
turkey	1.20	6.83	6.80
twins	1.10	5.33	6.10
umbrella	1.00	7.00	6.90
vanity	1.20	1.83	4.40
victim	1.00	3.67	5.20
victory	1.00	3.50	5.90
village	1.00	6.17	6.70
violence	1.00	2.83	6.00
violin	1.00	7.00	6.20
virtue	1.12	1.83	3.30
virus	1.20	4.67	5.70
voice	2.00	4.00	5.60
volcano	1.00	6.33	6.00
war	2.00	3.83	6.00
warmth	1.60	2.60	6.10
water	1.00	6.83	7.00
weakness	1.40	2.00	4.80
week	1.33	3.50	6.00
welfare	1.20	1.50	5.20
whale	1.00	7.00	6.50

English Stimulus	Number of Meanings	Concreteness	Context Availability
wheat	1.00	7.00	6.20
wheel	2.00	6.83	6.50
winter	1.00	6.17	6.40
woman	3.00	6.00	6.80
word	2.00	5.00	6.00
work	2.43	3.83	6.20
wrinkle	2.11	5.50	5.50
year	1.00	4.00	5.60
yesterday	4.00	3.33	5.70
youth	1.50	3.83	5.10
zebra	1.10	7.00	6.80

Notes

1. In some cases, however, the translation asymmetry has not been obtained, (e.g., De Groot & Poot, 1997; La Heij, Hooglander, Kerling, & Van der Velden, 1996) or the influence of meaning factors such as concreteness has been found during both L2 to L1 and L1 to L2 translation (e.g., De Groot et al., 1994). Thus, there remains a debate in the literature regarding the component processes of the two directions of translation, and of the architecture of the bilingual memory system.

2. The stimulus presentation duration was selected by adding 2.5 times the standard deviation to the mean L1 to L2 translation latency in two past experiments with participants from a similar population. This resulted in two latencies of approximately 2000 ms. The presentation time was therefore set to 2000 ms in the present experiment based on the assumption that this would be ample time for the participants to translate the stimuli, but not so long as to encourage participants to respond more slowly than they would otherwise.

3. The means and standard deviations are not provided in the De Groot (1992) or De Groot et al. (1994) papers. Therefore, we calculated power using the results from the present Experiment 2 for concrete and abstract words with more than one translation (a condition in which reliable concreteness effects were observed). We calculated the sample size that would be needed to detect a difference between these conditions using an alpha level of .05. The sample size in Experiment 1 yields a power of nearly .80 (our $n = 41$; n required for power of $.80 = 44$). Because past research suggests that abstract words are more likely to have multiple translations than concrete words (Schönpflug, 1997; Tokowicz et al., 2002), we also calculated power using the means for abstract words with more than one translation and concrete words with only one translation. Under these conditions, the statistical power of Experiment 1 exceeds .90.

4. Data on the number of translations can be analyzed in a number of different ways. For the purposes of the present experiment, words were classified as either ambiguous or unambiguous (i.e., having only one dominant translation or more than a single translation) using the most general criteria, averaging over the two translation directions. Although it may be the case that that ambiguity is direction-specific, the existence of multiple translations in the opposite direction may reflect some property of language that is important. For example, the word *glass* translates into Spanish as both *vidrio* and *vaso* depending on the meaning that is intended. If you are translating *glass*, you have two options. If you are instead translating *vaso*, it is possible that, by virtue of your knowledge of English, that *vidrio* may become activated. Indeed, our previous research (Tokowicz et al., 2002) demonstrates that words with multiple translations are considered less semantically-similar than words that have only a single translation. Therefore, ambiguity may be important regardless of the particular direction of translation being performed. However, we wished to address directly whether our classification system affected our analyses. To this end, we conducted a hierarchical regression analysis in which we predicted performance based on the number of translations in the particular direction of translation being performed. The pattern of results was identical to what was obtained using the analysis of variance with ambiguity coded generally. We report only the details of the analysis of variance because of the greater availability of post-hoc tests for probing higher-order interactions with analysis of variance.

5. One might well argue that cognates with more than a single translation are not true cognates because only one of the multiple alternatives is likely to share word form with its translation. In many cases, these words represent language change such that a foreign word is borrowed into the language and eventually becomes commonly used. For example, in Spanish, the word for computer is “ordenador”, but the word “computadora” is commonly used in some

Spanish-speaking countries and is therefore a cognate in its dominant usage. In the present experiment these materials were included for purposes of representativeness but do not provide a critical test of the central hypotheses.

6. Note that the range of concreteness ratings differs between Experiment 1 and 2. However, what is most critical for the test of the hypotheses is that the concrete words with one and more than one translation have a similar concreteness rating, that the abstract words with one and more than one translation have a similar concreteness rating, and that the concrete and abstract words differ in their concreteness ratings. Because only the *pattern* of findings is being compared across experiments, it is not necessary for the same range to be employed across experiments.

7. The data from these participants were excluded on the basis that they may not have paid sufficient attention to the task. This conclusion was drawn due to their relatively low accuracy on the nonwords (86 %). In addition, the overall printed word frequency of the real word stimuli was rather high (86 occurrences per million), and even the words low in frequency are fairly familiar (e.g., trauma, malice). For these reasons, the data from these participants were replaced by participants who were tested subsequently and who met the accuracy criteria.

Table 1

Properties of the Critical Stimuli Used in Experiment 1

Measure	Abstract Words	Concrete Words
English Length	5.5	5.2
Spanish Length	6.4	5.8
Context Availability Rating (English; n=11)	5.8	6.4
Concreteness Rating (English; n=13)	4.8	6.0
Word Frequency (English)	110.5	104.4

Note. Length was measured in number of letters. Context availability ratings were performed using a 7-point scale on which 1 indicated "very hard to think of a context" and 7 indicated "very easy to think of a context". Imagery ratings were performed using a 7-point scale on which 1 represented low imagery and 7 indicated high imagery. Concreteness ratings were performed using a 7-point scale on which 1 represented least concrete and 7 indicated most concrete. English word frequency was taken from Francis and Kucera (1982) and is measured in terms of number of occurrences per million. The concrete words were rated significantly higher than the abstract words on context availability, F (1, 156) = 43.91, MSE = .29, p < .01, imagery, F (1, 156) = 66.92, MSE = 1.02, p < .01, and concreteness, F (1, 156) = 93.67, MSE = 2.09, p < .01. All other Fs < 1.

Table 2

Language History Questionnaire Data by Experiment

	Experiment		
Measure	1	2	Number of Translations Norming (Appendix)
Age (years)	25.9	21.8	24.6
Age Began L2 (years)	13.7	10.4	13.6
Time Studied L2 (years)	9.0	11.0	9.1
L2 Immersion Experience (months)	43.4	39.4	33.1
L2 Reading Ability	7.9	8.2	7.4
L2 Writing Ability	7.6	7.7	7.0
L2 Conversation Ability	7.8	8.1	7.6
L2 Speech Comprehension Ability	8.1	8.8	8.2

Note. Reading, writing, conversational, and speech comprehension abilities were rated on a 10-point scale on which 1 indicated the lowest level of ability and 10 indicated the highest level of ability.

Table 3

Reaction Time (ms) and Accuracy (%) Data from Experiment 1

Reaction Time Data			
Direction of Translation	Abstract Words	Concrete Words	Concreteness Effect
L1 to L2	1150 (154)	1135 (132)	15 ms
L2 to L1	1083 (122)	1086 (118)	-3 ms
Accuracy Data			
Direction of Translation	Abstract Words	Concrete Words	Concreteness Effect
L1 to L2	48 (12)	67 (11)	-19 %
L2 to L1	59 (12)	69 (14)	-10 %

Note. Standard deviations are given in parentheses.

Table 4

Properties of the Critical Stimuli Used in Experiment 2

	Abstract Words		Concrete Words	
Measure	More Than One Translation	One Translation	More Than One Translation	One Translation
English Length	5.5	5.5	5.4	5.5
Spanish Length	6.2	6.0	6.0	6.2
Context Availability Rating (English; n=17)	5.2	5.2	6.2	6.3
Concreteness Rating (English; n=23)	3.3	3.3	6.2	6.4
Word Frequency (English)	110.4	111.2	85.3	112.9
Number of Translations-English to Spanish	1.9	1.0	1.7	1.0
Number of Translations-Spanish to English	1.6	1.0	1.6	1.0

Note. Length was measured in number of letters. Context availability ratings were performed using a 7-point scale on which 1 indicated "very hard to think of a context" and 7 indicated "very easy to think of a context". Concreteness ratings were performed using a 7-point scale on which 1 represented least concrete and 7 indicated most concrete. English word frequency was taken from Francis and Kucera (1982) and is measured in terms of number of occurrences per million. The concrete words were rated significantly higher than the abstract words on context availability, F (1, 148) = 153.55, MSE = .26, p < .01, and concreteness, F (1, 148) = 633.57, MSE = .54, p < .01. All other Fs < 1.

Table 5

Reaction Time (ms) and Accuracy (%) Data from Experiment 2

Reaction Time Data						
	Number of Translations					
Direction of Translation	More than One			One		
	Abstract Words	Concrete Words	Concreteness Effect	Abstract Words	Concrete Words	Concreteness Effect
L1 to L2	1519 (301)	1373 (239)	146 ms	1301 (223)	1353 (236)	-52 ms
L2 to L1	1327 (262)	1240 (227)	87 ms	1181 (222)	1254 (222)	-73 ms
Accuracy Data						
	Number of Translations					
Direction of Translation	More than One			One		
	Abstract Words	Concrete Words	Concreteness Effect	Abstract Words	Concrete Words	Concreteness Effect
L1 to L2	25 (13)	45 (14)	-20 %	52 (16)	67 (19)	-15 %
L2 to L1	34 (14)	51 (14)	-17 %	59 (14)	69 (16)	-10 %

Note. Standard deviations are shown in parentheses.

Table 6

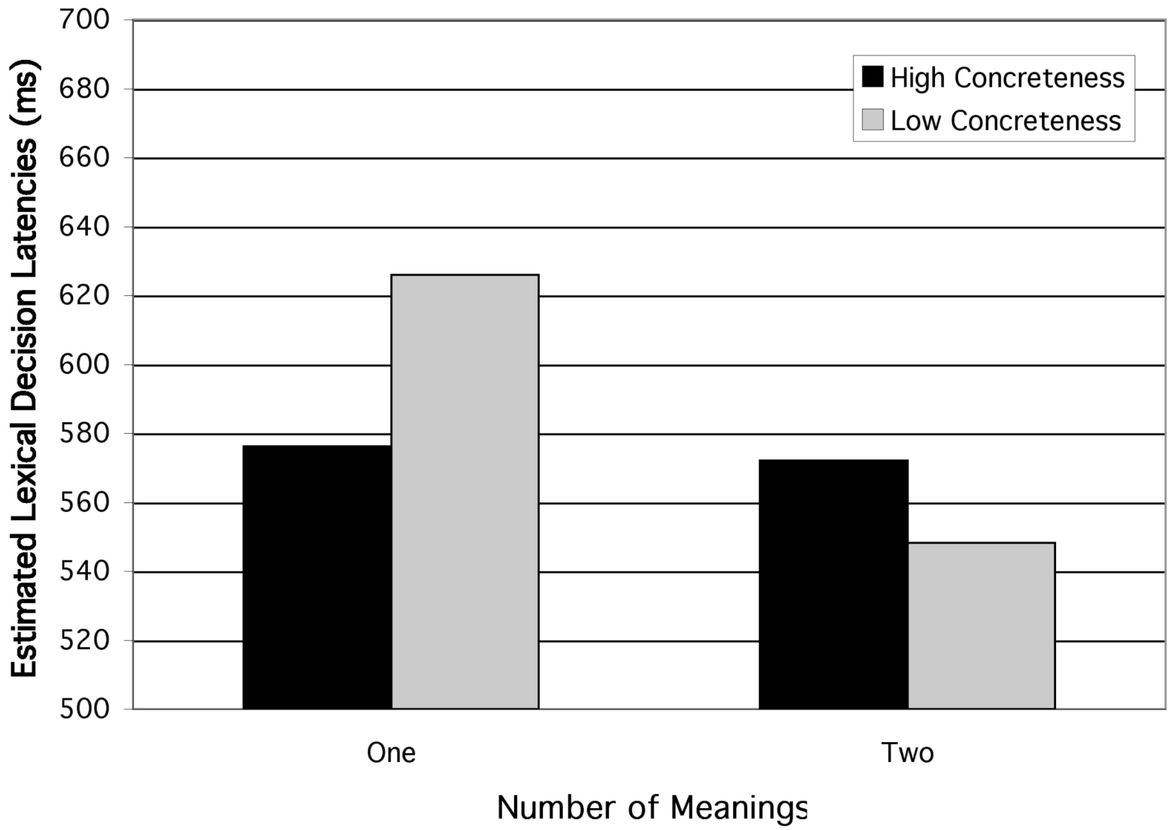
Summary of the Hierarchical Regression Analysis for Variables Predicting Reaction Time in the Lexical Decision Task in Experiment 3

	Model 1		Model 2		Model 3		Model 4	
Variable	β	*sr*	β	*sr*	β	*sr*	β	*sr*
Stimulus Length	.318**	.314	.239**	.227	.220**	.205	.224**	.208
Log Frequency	-.386**	-.381	-.293**	-.273	-.277**	-.256	-.267**	-.245
Context Availability Rating			-.482**	-.314	-.484**	-.315	-1.301**	-.138
Concreteness Rating			.207**	.138	.194**	.128	.414	.047
Number of Meanings					-.121**	-.118	-1.022**	-.113
Context Availability x Number of Meanings							1.293*	.090
Concreteness x Number of Meanings							-.247	-.027

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

Figure Caption

Figure 1. Estimated lexical decision latencies for words in Experiment 3 as a function of concreteness/context availability and number of meanings.



Estimated Lexical Decision Latencies (ms)
700
680
660
640
620
600
580
560
540
520
500
High Concreteness
Low Concreteness
One
Two
Number of Meanings