Behavior Research Methods
2007, 39 (1), 1-18

Methodological considerations in performing semantic- and translation-priming experiments across languages

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Research in the field of bilingualism has had as its principal aim to describe the structure and function of memory for bilingual speakers. A primary technique that has been used to examine bilingual memory is an examination of cross-language word priming (semantic and translation), using the lexical decision and pronunciation tasks. Although studies have, on occasion, revealed greater degrees of word priming from a dominant to a subordinate language, in comparison with the reverse, a careful review of the methodology that has been used reveals a number of issues that render conclusions such as this quite problematic. Parameters of concern include language proficiency, cognate status, masking, control conditions, word frequency and length, stimulus onset asynchrony, relatedness proportion, and nonword ratio. These factors are discussed, as well as recommendations for conducting future empirical research in this area of investigation.

Bilingualism is much more common in the world than monolingualism, or the working knowledge of a single language (Bhatia & Ritchie, 2004; Edwards, 2004; Tabouret-Keller, 2004). The idea that individuals can at once speak or process information in a single language domain yet switch to a second mode of thought based in an alternate language has fascinated researchers in such fields as psychology, linguistics, sociology, anthropology, neuroscience, and the like. In fact, little is known about exactly how the mind develops the capability to accurately store and process multiple languages in memory and to effectively operate as a monolingual in one of those languages. In addition, the terminology used to describe bilinguals has been confusing at times, since the term *bilingual* has the ability to include many different people, depending on the definition that is used. Although the scope of the following article is not to debate and define bilingual terminology, it must be stated that the term *bilingual* is used here to describe those who show "both regular use and communicative competence" in their two languages (Francis, 1999, p. 194).

Well over 40 years of research have been devoted to the area of bilingual memory and bilingual language processing in the cognitive domain. Most of this research has focused on questions of the nature of the bilingual lexicons and whether or not features such as those that represent conceptual relations or those that are lexically based are shared or are stored separately for a bilingual's two languages (see, e.g., Kolers, 1978, 1979; McCormack, 1976, 1977). These explorations have led to the development of various models of word representation for bilingual speakers that have specified the routes by which they retrieve various linguistic aspects of words from memory. In more recent theoretical perspectives, it has been argued that both a separate and a shared view of representation are correct but that they reflect processing for different types of bilinguals (i.e., early vs. late; see, e.g., Kroll & Stewart, 1994). In newer formulations, processing issues have been examined apart from structural ones, and the focus has been more on connectionist theories and distributed models of representation in which the emphasis is more exclusively on the degree of featural overlap between words in different languages (see, e.g., Dufour & Kroll, 1995). The latter models have been based on findings that indicate differential processing of different word types across languages and individual differences in memory representation for linguistic knowledge (see, e.g., Altarriba, 2003).

One of the main tools that researchers in this area have used to uncover the mental representation of more than one language in memory is the semantic-priming technique. This technique is hailed as one that provides the clearest evidence regarding the automatic processing of language, as compared with other techniques that engender the use of strategic processing (more will be said about this issue later in this review of methodology). In fact, this paradigm has become one of the most important tools used to determine whether or not a bilingual's languages are somehow *interconnected* and the levels at which this interconnectivity occurs.

The purpose of the present article is to examine the methodology and claims made in the published research investigating cross-language semantic priming and to

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outline various recommendations in methodology that researchers might follow when planning studies that involve this technique. Various other paradigms of related interest, such as negative priming (Fox, 1996), studies involving pictures as stimuli (Chen & Ng, 1989, Experiment 2), studies in which cognate status has been manipulated (Cristoffanini, Kirsner, & Milech, 1986), and those in which semantic categorization has been examined (Sánchez-Casas, Davis, & García-Albea, 1992) will not be discussed, since the present review will have as its primary focus the literature that bears on the question of whether or not positive semantic priming occurs for cross-language words. The present review will focus only on work examining the use of the lexical decision task and the pronunciation task—the two major types of tools employed in this area of research. The literature is sizable; however, the present comprehensive review is timely in the development of this area of investigation and in the analysis of this body of work. The present review of methodology is an attempt to examine cross-language priming in a more focused and in-depth manner, where factors such as language proficiency, word frequency, word length, type of control, cognate use, relatedness proportion (RP), nonword ratio (NWR), stimulus onset asynchrony (SOA) length, and magnitude of priming effects are all examined and compared across experiments.

The present article will begin with a brief discussion of semantic priming in monolinguals. However, the bulk of the article will focus on the semantic-priming paradigm and how it has been used in the bilingual domain. This quantitative and qualitative discussion ends with a summary of some of the problems, or "pitfalls," in the methodologies used in many of the semantic and translation cross-language priming studies and with recommendations for future research.

Semantic Memory and Priming in Monolinguals

The organization of words and concepts in monolingual memory has been previously explored mainly by examining priming effects in lexical decisions (Meyer & Schvaneveldt, 1971; Meyer, Schvaneveldt, & Ruddy, 1975; Neely, 1977). This type of experimental paradigm, often used in cognitive psychology research, involves presenting participants with one or two letter strings on a computer screen. The participants are then instructed to decide as quickly and as accurately as possible whether or not the letter string composes a real word. This is often done by pressing one key if the letter string is a real word and a second key if a nonword is presented. The response times to each target item are then recorded for the participants. A priming paradigm involving a naming trial requires the participants to pronounce the target word aloud so that the response time can also be recorded and examined.

The concept behind semantic priming is that as a word is presented, automatic access to its meaning results in activation of both that concept and other concepts that are related to it. One of the most common effects that has been found to occur in lexical decision tasks is the semantic-priming effect. This effect occurs when prime and target words are semantically related, thereby producing faster response times than they would if they were unrelated. For example, the word *dog* semantically primes the word *cat* better than it does the word *box*, per se. In monolingual studies, semantic priming has proven to be a robust effect, found under several different experimental manipulations (for reviews, see McNamara & Holbrook, 2003; Neely, 1991).

The spreading activation theory (Collins & Loftus, 1975; Collins & Quillian, 1969), which proposes that concepts are represented as nodes in a semantic network, is useful in predicting semantic-priming effects. According to this model, nodes representing respective concepts are connected via associative pathways, which suggests that semantically related concepts form stronger links or may be stored closer together than those concepts that are unrelated (Neely, 1991). When one node is activated, activation spreads along the network to other concept nodes that are located nearby. With regards to the semantic-priming effect, the activation of a semantically presented prime word leads to shorter response times to the target word, since the distance traveled is much less than it will be if an unrelated prime word is presented.

As was mentioned earlier, spreading activation theory rests on the assumption that words are *automatically* activated. This implies that the process must be fast acting and capacity free, occurs without intention, is involuntary, and can occur without conscious awareness (see Neely & Kahan, 2001, for a more in-depth discussion on certain aspects of automaticity). However, it must be pointed out that even though automatic spreading activation is useful in explaining how words are represented internally, two other mechanisms have been proposed (Neely, 1991; Neely, Keefe, & Ross, 1989). The three-process theory of semantic priming is important in that it introduces the possibility that participants employ strategies when responding to target words. The first additional mechanism suggests that participants use an expectancy strategy in which a list of words related to the prime is mentally constructed prior to the presentation of the target. Therefore, if the target word presented is semantically related, it may already be in the expectancy set, which will cause the response to be faster than it would have been under normal circumstances. Two of the main methodological issues thought to be responsible for utilization of this strategy are SOA and RP.

Relatedness proportion. The RP refers to the proportion of related prime–target trials out of all the prime–word-target trials. It has been found that semantic priming increases in magnitude as the RP increases (de Groot, 1984). It has been suggested that as RP increases, participants will be more inclined to create expectancy sets because doing so will improve their performance, since most of the word pairs are related. However, if the RP is kept low, utilizing this strategy may prove to be less beneficial and may actually hinder one's performance (see Neely, 1991, for a more exhaustive review). Therefore, in order to obtain a fair estimate of priming effects, one will want to keep this proportion as low as possible when designing an experiment.

Stimulus onset asynchrony. A second factor that is capable of influencing whether an expectancy strategy is

employed by participants is SOA length. This is described as the time interval between the presentation of the prime and the onset of the target or, more simply, how much time one has to think about the prime before the target appears on the screen. A long SOA can raise problems in that the extended time given makes it easier for participants to generate an expectancy set of related words. Initial research appeared to indicate that SOA lengths less than or equal to 300 msec were capable of inhibiting any expectancy strategies. However, more recent work conducted by Hutchison, Neely, and Johnson (2001) has suggested that strategic priming still operates at a relatively short SOA of 300 msec. Their data indicated that when the SOA length was decreased to 167 msec, priming from a nonrepeated prime was no longer affected by RP. This implies that if semantic-priming facilitation is going to measure pure automatic priming effects in the absence of an operating expectancy mechanism, SOA length may need to be even shorter than was previously thought.

Nonword ratio. The second strategic process that may be utilized by participants in priming experiments is a semantic-matching strategy. This postlexical checking mechanism occurs after the target has been presented and participants check to see whether the prime and the target words are related, a process that may help them in making a final lexical decision. The RP and NWR of experimental word stimuli are most influential in determining whether or not this strategy is employed (Neely et al., 1989). The NWR is basically the proportion of nonwords out of all nonword and unrelated word pairs. When the NWR is below .5, participants may be biased to give a word response when a nonword has been presented. Meanwhile, if the NWR is above .5, a nonword response may be signaled, due to the large number of nonwords that have been encountered in the experiment. McNamara and Holbrook (2003) have pointed out that since equal numbers of word and nonword targets are usually used by researchers, the unrelated word pairs are usually fewer in number than the word-prime–nonword-target trials. This pattern in previous studies has led to NWRs that often exceed the recommended .5 value. However, it has also been suggested that semantic matching is due not to these factors and to the automatic spread of activation but, rather, to a composite cue that forms when the prime and the target combine at retrieval (Ratcliff & McKoon, 1988).

Word length and word frequency. Additional methodological issues that do not deal primarily with strategic processes must also be taken into consideration when priming experiments of this nature are designed. Frequency (Balota & Chumbley, 1984, 1985; Chumbley & Balota, 1984; Monsell, Doyle, & Haggard, 1989) and length of word primes and targets have been shown to affect the speed of word processing, recognition, and pronunciation. Balota and Chumbley (1990) have suggested that "the frequency with which one sees a word, retrieves a concept associated with a word, and retrieves information associated with a pronunciation of a word should have an influence on each of these components of word processing" (p. 236). Initial research conducted by Balota and Chumbley (1984) indicated that word frequency appeared to be more influential in lexical decision tasks, when compared with category verification and pronunciation tasks. Further work producing similar results led the authors to conclude that word frequency must influence a decision phase that occurs after lexical access (Chumbley & Balota, 1984). In addition, Raveh (2002) has shown that prime frequency is an important factor in determining the size of priming effects. In this study, prime words that were characterized as having either high- or low-frequency inflection points revealed larger priming magnitudes for high-frequency inflections than for low.

In conclusion, research conducted over the past 30 years has consistently shown that the semantic-priming paradigm is an extremely useful experimental technique that allows cognitive psychologists to examine how words and concepts are represented in memory. However, as the present section has revealed, there are several methodological factors that must be controlled when an experiment is designed, especially if one wants to explore the automatic processes behind language representation. In the following section, studies in which the semantic-priming paradigm has been used to explore how two languages are organized in memory will be discussed. Unfortunately, several of these experiments appear to contain some flaws in their methodology, which may explain why there has been a large amount of variation in the results that have been reported. However, those cross-language priming studies in which an attempt was made to control certain factors are able to shed some light on the way in which two languages are organized in memory.

Semantic Priming Across Languages

In the past couple of decades, the semantic-priming paradigm has been expanded to include between-language stimuli, in order to gain insight into the way in which a bilingual's two languages are stored in memory. As was mentioned previously, there has been a long-standing debate over whether a bilingual person exhibits shared or separate language stores. If bilinguals do share a common conceptual store for their two languages, the automatic spreading activation model, as was discussed in the previous section, would predict that presentation of a prime word would activate semantically related words in a second language (L2). For example, a related word pair in this type of experiment could be composed of the prime word *cat*, followed by the target word *perro*, the Spanish translation of *dog*. However, cross-language priming stimuli can be designed so that the prime is in the first (or dominant) language (L1) and the target is in the (weaker) L2 or vice versa. This allows researchers to examine different priming effects for each direction—L1–L2 and L2–L1.

Although this experimental technique has the potential to tap into the mental representation of both languages, the results from nearly one dozen priming studies have indicated a wide range of findings. Robust priming has been observed in both directions for some cross-language priming experiments (Chen & Ng, 1989; Frenck & Pynte, 1987; Keatley & de Gelder, 1992, Experiment 1; Kirsner, Smith, Lockhart, King, & Jain, 1984; Meyer & Ruddy, 1974; Schwanenflugel & Rey, 1986; Tzelgov & Eben-Ezra,

1992), whereas other research has yielded nonsignificant priming results (Frenck & Pynte, 1987; Grainger & Beauvillain, 1988; Keatley & de Gelder, 1992, Experiments 2 and 3; Keatley, Spinks, & de Gelder, 1994). In addition, confusion arises within this body of research, in that in a couple of studies, only priming in the L1–L2 direction has been examined (Larsen, Fritsch, & Grava, 1994; Williams, 1994), which leads to an incomplete picture regarding representation and processing direction (see Appendix A for a study-by-study analysis of methodological issues in cross-language semantic priming experiments).

Language proficiency. As was seen in the previous section, there are many methodological issues that are capable of influencing priming effects. It is also possible that differences in the groups of participants used in many of these studies are to blame for the varied priming results. For example, some have suggested that more proficient bilinguals would exhibit greater priming effects than do those who are less proficient in their second language. However, results from a study conducted by Frenck and Pynte (1987) revealed nonsignificant priming effects for those whom they classified as "skilled bilinguals" and rather larger, significant priming effects for those determined to be "less-skilled" (see Appendix A). In addition, some have turned the importance away from proficiency and have suggested that age of acquisition is a stronger determinant of how much priming is observed. This brings up the question regarding the language history and proficiency of those who have participated in cross-language semantic-priming studies. Some participants have been described as learning both languages simultaneously or at a very young age (Grainger & Beauvillain, 1988; Keatley & de Gelder, 1992; Keatley et al., 1994; Larsen et al., 1994; Schwanenflugel & Rey, 1986; Tzelgov & Eben-Ezra, 1992), whereas others appear to have acquired their L2 around adolescence (Chen & Ng, 1989; Kirsner et al., 1984, Experiment 5). Lastly, there were those participants who appeared to be proficient in both languages but who had acquired their L2 during or near adulthood (Frenck & Pynte, 1987; Meyer & Ruddy, 1974; Williams, 1994). In addition to differences in age of acquisition, it is also quite probable that differences in proficiency existed. Even though many of the participants were described as being fluent in both languages, the language questionnaires that were frequently used may have led some people to overestimate their proficiency level, whereas others felt that their skills were worse than they really were. One advantageous aspect of Schwanenflugel and Rey's (1986) experiment was that in addition to self-ratings, participants had to obtain scores on Spanish and English reading comprehension tests that did not differ by more than 19%. Methods such as these may allow bilinguals to be screened more carefully.

Although certain modifications may be useful, the proficiency of bilingual participants has been the subject of a long-standing debate and remains a difficult problem when such studies are conducted. Francis (1999) has discussed the wide range of terminology that has been used to define bilinguals and has concluded that an intermediate definition proposed by Grosjean (1992, cited in Francis, 1999) may be the most beneficial: "Bilingualism is the regular use of two (or more) languages, and bilinguals are those people who need and use two (or more) languages in their everyday lives" (p. 51). It has also been suggested that since it is often difficult to find bilinguals who are equally balanced, researchers should present adequate information regarding their bilingual participants. Grosjean (1998) has suggested that some experimenters may be most concerned with reading ability, others with language use and speaking skills, whereas some feel that language stability (whether the bilingual is still acquiring their L2 or not) should be emphasized. Therefore, since the information often obtained and the way in which bilinguals are assessed may be vastly different, it is possible that "we have very different bilinguals in the studies published" (Grosjean, 1998, p. 9). This may very well be one of the factors contributing to the diverse range of priming effects reported in semantic-priming studies. As a way of coping with this challenge, it has been suggested that researchers include information not only on biographical data, but also on language history as well. Therefore, it will be useful to know the age at which each language has been learned, as well as the way in which it was learned (type of educational system, etc.). In addition to proficiency ratings in the four skill areas (reading, writing, speaking, and listening), language stability and when and where each language has been used most may also be information that is advantageous to researchers (Grosjean, 1998). Although these recommendations may seem superfluous and difficult to carry out, the benefits of such diligence will give bilingual research more consistency. Finally, researchers are encouraged to use an online measure of proficiency or dominance as an assessment tool when examining language background. Picture-naming or translation tasks may be useful in this regard.

Cognate status. Additional methodological concerns in much of the semantic-priming literature have to do with the word stimuli that have been chosen. One of the areas in which variation has been found to occur deals with the use of cognates, or words that are similar in spelling, pronunciation, and meaning across languages (e.g., *music* and *musica*). Since these words are so similar in both languages, it is important that they be excluded from word stimuli if automatic and pure priming effects are being investigated. Fortunately, most researchers have explicitly stated that no cognates have been used in their studies (Frenck & Pynte, 1987; Keatley et al., 1994; Kirsner et al., 1984; Larsen et al., 1994; Schwanenflugel & Rey, 1986; Williams, 1994), but others have not mentioned whether they were included or not (Grainger & Beauvillain, 1988; Keatley & de Gelder, 1992; Meyer & Ruddy, 1974).

Masking effects. Another methodological difference observed in some of the studies is the visibility of the prime word. Although most researchers have chosen to use unmasked priming paradigms, a couple of studies included a masked design (de Groot & Nas, 1991, Experiment 3, for associative word pairs; Williams, 1994, Experiment 1a). Since masking often results in decreased visibility of the prime word, the implementation of this type of design may be beneficial, in that it may minimize

the use of strategic processes by participants. The priming effects measured across these cross-language priming studies may also differ because they were determined using different types of word stimuli as a control. Simply stated, some researchers have measured priming effects by comparing related word pairs with unrelated word pairs (Chen & Ng, 1989; Grainger & Beauvillain, 1988; Keatley & de Gelder, 1992; Keatley et al., 1994; Kirsner et al., 1984; Larsen et al., 1994; Meyer & Ruddy, 1974; Tzelgov & Eben-Ezra, 1992; Williams, 1994), whereas others have chosen neutral targets as the control (Keatley et al., 1994, Experiment 1; Schwanenflugel & Rey, 1986). Meanwhile, Frenck and Pynte (1987) examined response times to related prime–target pairs and how they compared with the same target words when they were not preceded by a prime.

Word frequency and word length across languages. As was discussed in the section on monolingual priming, frequency and length of words can be influential in altering priming effects if these variables are not controlled for when the experiment is designed. In many of the semantic-priming studies under review, an attempt has been made to keep these factors constant; however, this has not been the case for every study. Some authors have specifically stated that words used in both languages had fairly equivalent mean letter lengths (Frenck & Pynte, 1987; Grainger & Beauvillain, 1988; Keatley & de Gelder, 1992; Keatley et al., 1994; Kirsner et al., 1984; Meyer & Ruddy, 1974). Chen and Ng (1989) mentioned that they controlled for word length in English, but due to the fact that Chinese characters were used, it was impossible to equate and compare both languages on length. Others have stated that "they attempted to control for word length, but were only partially successful" (Schwanenflugel & Rey, 1986, p. 608), whereas for a couple of studies, there was no mention of whether these variables were monitored or not (Larsen et al., 1994; Tzelgov & Eben-Ezra, 1992).

Experimental design differences. An analysis of some of the methodological factors that are responsible for allowing participants to utilize strategic processes reveals some of the most diverse differences in experimental design. For example, the SOA length implemented by many of the researchers ranged anywhere from 0 msec to 4.5 sec. Meyer and Ruddy (1974) and Kirsner et al. (1984) chose to use a double lexical decision task, where both the prime and the target were presented simultaneously, resulting in an SOA of 0 msec. In a majority of the experiments, the tendency has been to use an SOA ranging from 200 to 300 msec (Chen & Ng, 1989; Grainger & Beauvillain, 1988; Keatley & de Gelder, 1992; Keatley et al., 1994; Larsen et al., 1994; Schwanenflugel & Rey, 1986). However, there still have been a significant number of studies that have contained longer SOAs ranging from 500 msec on up (Frenck & Pynte, 1987; Grainger & Beauvillain, 1988; Keatley et al., 1994; Tzelgov & Eben-Ezra, 1992; Williams, 1994). SOAs of this length may raise problems, in that they allow participants to utilize expectancy strategies. A long SOA may allow participants to translate the prime into the alternate language, which can indicate that automatic processing of both languages is not being accurately measured. However, it must be mentioned that several authors have included a long and a short SOA, in order to see whether there were differences in the size of the priming effect (Grainger & Beauvillain, 1994, Experiment 1; Keatley et al., 1994; Tzelgov & Eben-Ezra, 1992). Adding to the confusion is the fact that Grainger and Beauvillain reported significant priming only in the L2–L1 direction at the long SOA (750 msec), whereas data from Keatley et al. indicated nonsignificant priming effects for both directions at both the short and the long SOAs (250 and 2,000 msec, respectively). Meanwhile, Tzelgov and Eben-Ezra revealed robust priming effects that were collapsed across SOA length for both directions.

Relatedness proportion and nonword ratio in bilingual priming. An analysis of additional methodological factors, including RP and NWR, has also revealed a large range of values. The suggested NWR of .50 was used by Schwanenflugel and Rey (1986); however, in other studies, NWR has been just slightly above this recommended value (Keatley & de Gelder, 1992; Keatley et al., 1994; Kirsner et al., 1984). A few studies have not appeared to be as successful, with NWRs ranging from .67 to .75 (Chen & Ng, 1989; Frenck & Pynte, 1987; Kirsner et al., 1984, Experiment 5; Meyer & Ruddy, 1974; Tzelgov & Eben-Ezra, 1992; Williams, 1994). It should also be noted that the study conducted by Larsen et al. (1994) did not include any nonwords, since a pronunciation task was chosen for the experiment.

An analysis of RP has also shown values that were very high, indicating that strategic processes may have been employed by participants. Grainger and Beauvillain (1988), Keatley and de Gelder (1992), and Keatley et al. (1994) all made extensive efforts to maintain low RPs of .167, .25, and .25, respectively. However, there were also those studies in which a high RP of .67 was used (Chen & Ng, 1989; Frenck & Pynte, 1987).

One last issue of concern that may affect the interpretation of reported priming effects is the mean response times for the related cross-language word pairs. Response times approaching and/or reaching 1,000 msec (Chen & Ng, 1989; Kirsner et al., 1984; Meyer & Ruddy, 1974) may indicate that the participants were translating the primes. This may have been one of the factors that was partially responsible for the robust priming effects reported by Chen and Ng.

Summary. In conclusion, the semantic-priming experiments that have been conducted are useful in that they attempt to explain the way in which a variety of languages (romance languages, languages using different alphabets and characters, etc.) may be represented in memory. However, it is apparent that there are many methodological issues of concern that need to be taken into consideration when this type of experiment is designed. Furthermore, many of the factors that have been discussed may help shed some light on why current priming studies have revealed such a wide range of inconsistent results. In the section that follows, cross-language translation priming studies will be examined. Although these studies tend to be more recent, they are also plagued by some of the same methodological issues of concern.

Translation Priming Across Languages

In addition to the cross-language semantic-priming studies, there are also nearly one dozen translation-priming studies that have been conducted in the past decade. In accordance with the previous studies noted earlier, translation-priming studies involve the presentation of a prime in one language and a target in a different language. However, instead of semantically related word pairs, words and their respective translations compose the word pairs in this paradigm. For example, a typical trial would present the prime word *cat* followed by the target word *gato* (the Spanish translation of *cat*). However, in the same vein as many of the semantic-priming studies, the methodological issues of concern that were previously discussed are also prevalent in this body of literature. Below, various parameters that may influence the outcome of translation-priming studies and suggestions for avoiding various methodological "pitfalls" in this area of research will be given.

Language proficiency. Once again, the proficiency of bilinguals participating in these studies often has not been fully explained at times. Some participants have been described as acquiring their L2 before adolescence (Altarriba, 1992; Gollan, Forster, & Frost, 1997; Jin, 1990; Keatley et al., 1994), whereas others began to learn the L2 either during or after adolescence (Chen & Ng, 1989; Grainger & Frenck-Mestre, 1998; Jiang, 1999; Jiang & Forster, 2001; Williams, 1994). However, the lack of information given regarding participants' language history and background is evident in a statement from one study, which described all the participants as being "reasonably good" at comprehending English (de Groot & Nas, 1991). Again, the use of performance measures as a screening device may aid in the ability to describe proficiency and dominance for bilingual participants.

Selection of word stimuli and masking. Although an analysis of the word stimuli used in these experiments reveals many of the same problems as those already observed in the priming literature, one advantage of the translation-priming studies is that they are more recent and, therefore, attempts have been made to regulate many potentially problematic factors (see Appendix B for a review of cross-language translation-priming experiments). For example, all of these studies have used one common control—unrelated prime–target word pairs—when priming effects were calculated. In addition, all the studies have reported that cognates were not included in word stimuli, except for those studies in which the purpose was to examine differences between cognates and noncognates (de Groot & Nas, 1991; Gollan et al., 1997). Another experimental manipulation that is more prevalent in this body of literature is the use of masked priming techniques. Whereas only two semantic-priming studies have included a masked procedure (de Groot & Nas, 1991, Experiment 3; Williams, 1994, Experiment 1a), the use of a mask in translation priming has been used by more authors (de Groot & Nas, 1991; Gollan et al., 1997; Grainger & Frenck-Mestre, 1998; Jiang, 1999; Jiang & Forster, 2001; Williams, 1994). In most studies, the forward masked priming procedure (or a variation of this procedure) first introduced by Forster and Davis (1984) has been used. In this paradigm, each trial begins with a fixation and is followed by the mask, which usually appears as a row of number signs (######) and remains on the screen for 450 or 500 msec. The prime word then appears for 50 msec (100 msec in some of the bilingual studies) and is then replaced by the target word.

Word frequency and word length. An examination of the average length and frequency of word stimuli used in translation priming reveals that in some of the studies, an attempt has been made to control for these variables (Altarriba, 1992; Gollan et al., 1997; Grainger & Frenck-Mestre, 1998; Jiang, 1999; Jiang & Forster, 2001; Keatley & de Gelder, 1992; Keatley et al., 1994; Williams, 1994). However, several other studies have not mentioned whether length and frequency were monitored (de Groot & Nas, 1991; Jin, 1990), whereas one study discussed only the control of word length (Chen & Ng, 1989). Clearly, for reasons noted earlier, both of these variables should be controlled, if possible, when one works with cross-language stimuli.

Stimulus onset asynchrony. With regard to some of the factors that are capable of allowing strategic processes to develop, a comparison of the SOA length used in the translation-priming studies indicates that SOA length has been kept very short. Multiple studies have used an SOA of 50 msec (Gollan et al., 1997; Jiang, 2001; Williams, 1994), whereas de Groot and Nas (1991) and Grainger and Frenck-Mestre (1998) chose SOA lengths of 60 and 56 msec, respectively. The only SOA of extreme length, 1,000 msec, is observed in Altarriba's (1992) study; however, a short SOA of 200 msec was also included in this study so that a comparison between SOA lengths could be made. As was expected, the data produced by the varying SOA lengths did indicate larger priming effects at the longer SOA.

Relatedness proportion and nonword ratio. An analysis of NWR and RP in the translation-priming literature shows a wide range of ratios that often deviate from ideal values. Four studies revealed NWRs that hovered around the suggested .50 value (Gollan et al., 1997; Keatley & de Gelder, 1992; Keatley et al., 1994; Williams, 1994), whereas all the other studies appeared to have NWRs that were either lower or higher than .50. The calculated RPs for most of these studies showed relatively high values, ranging from .50 to .67 (Chen & Ng, 1989; de Groot & Nas, 1991; Gollan et al., 1997; Grainger & Frenck-Mestre, 1998; Jiang, 1999; Jiang & Forster, 2001; Jin, 1990; Williams, 1994). However, the studies conducted by Altarriba (1992), Keatley and de Gelder (1992), and Keatley et al. (1994) were successful in maintaining low RPs of .33, .25, and .25, respectively.

Summary. Therefore, it is evident that since many of these methodological issues of concern show such diverse values, it is not surprising that robust translation-priming effects in the L1–L2 and L2–L1 direction have been observed in some studies (Chen & Ng, 1989; Jin, 1990; Keatley & de Gelder, 1992; Jiang, 1999, Experiment 1; Keatley et al., 1994), but not in others (Gollan et al., 1997; Jiang & Forster, 2001, Experiment 2). In addition, in some studies,

only priming for noncognates in the L1–L2 direction has been examined (de Groot & Nas, 1991; Williams, 1994), whereas others have been concerned only with priming in the L2–L1 direction (Grainger & Frenck-Mestre, 1998; Jiang & Forster, 2001). However, the fact that L2–L1 priming yielded nonsignificant priming effects for several studies (Altarriba, 1992, at an SOA length of 200 msec; Gollan et al., 1997, Experiments 2 and 4; Grainger & Frenck-Mestre, 1998; Jiang, 1999, Experiment 2; Jiang & Forster, 2001) has led some to specifically examine the processing behind asymmetrical priming effects in a very creative and interesting way (see Finkbeiner, Forster, Nicol, & Nakamura, 2004; Jiang & Forster, 2001).

In conclusion, one can see that many of the translation-priming studies appear to have some of the same methodological issues of concern that were observed in the cross-language semantic-priming studies. Once many of the methodological issues that have been previously discussed are monitored and controlled, future translation-priming studies should be capable of providing more insight into the way in which a bilingual represents his or her two languages.

Conclusions

In an attempt to interpret some of the overall observations that can be made regarding Appendices A and B, some trends appear to emerge. First, it might be the case that the asymmetry that appears to be stronger for translation priming, in comparison with semantic priming, may be due to the use of shorter SOAs and more tightly constrained presentation rates and RPs than in the semantic-priming literature. For example, the work of Williams (1994, Experiment 2b) indicated significant priming (33 msec) in the L1–L2 direction, under well-constrained conditions (e.g., 50-msec SOA, etc.). In this article, a variety of language combinations also were examined, and it was concluded that priming was similar across various language groupings. However, priming in the L2–L1 direction was not investigated. Second, as one might expect from the monolingual literature, an increase in SOA also appears to be correlated with an increase in the magnitude of semantic priming. For example, Grainger and Beauvillain's (1988) data for a short SOA (150 msec) indicated no evidence of cross-language priming for English–French bilinguals. In contrast, the data provided by Williams (1994, Experiment 1a), using an SOA of 728 msec, indicated a positive 34-msec effect in the L1–L2 direction. Thus, although systematic increases in SOA and RP and increased visibility of prime words all served to produce more priming of both kinds (semantic and translation), it also appears that those effects were moderated, at least in part, by more strategic and less automatic processing.

The study of priming effects for semantically related word pairs and translation word pairs is important for various reasons. First, the methodology used is widely accepted as one that leads to the discovery of the representational structure of language in human memory. Second, the issue investigated in the field has to do with a circumstance that is common among a majority of people in the world—that of knowing and using more than one language to communicate. Third, work in this general area has led to the development of research tools that have been used to uncover general language-processing mechanisms that apply to monolingual populations as well (see, e.g., Altarriba, Kambe, Pollatsek, & Rayner, 2001; Altarriba, Kroll, Sholl, & Rayner, 1996; Altarriba & Soltano, 1996), since cross-language stimuli may assist in the examination of basic levels of language representation (e.g., semantics) while others are held constant (e.g., lexicality). Fourth, the priming methodology is widely held to be one that can be used to investigate the *automaticity* of language processing—an approach that is most informative when models of language representation and processing are derived. Finally, investigations of this nature are pragmatic and relatively easy to implement, indicating that the refinement of this type of method and careful analysis of the methodological issues contained in this area of research are extremely important to the promotion of this type of work across cultures.

Recommendations for Future Research

As researchers continue to use semantic- and translation-priming paradigms to describe the representational structure of multiple languages in memory, the following methodological recommendations should be followed.

1. *Test explicitly for language proficiency in the language skill being manipulated in the protocol*. There is a need to include more information on the language history of bilingual participants and, perhaps, to conduct studies in which variables are manipulated within participants. The difficulty with generalizing across the reported studies lies in the variability of the participants and of their mode of language acquisition and the varying age of acquisition across the participants. Furthermore, the use of actual tests of language proficiency that are aligned with the variables under investigation (e.g., reading tests for visual reading studies, etc.), along with comprehensive language history surveys, should be adopted. These measures should also be developed so as to allow for the identification of which language is dominant for a given speaker. Once more comprehensive proficiency data have been collected on participants, it is possible that certain language background factors can be entered as a covariate, so that one can examine how the results covary with dominance.

2. *Match stimuli across paradigms within the same experiment*. If both lexical decision tasks and pronunciation tasks are being used, the same stimuli should also be used. Varying the items used across paradigms within a given series of experiments also adds variability in terms of items. This issue leads to the suggestion that item analyses should also be a common feature of these types of investigations.

3. *Eliminate cognates and homographic noncognates if they are not the focus of the research question*. Researchers should strive to eliminate the use of cognates or homographic noncognates when conducting semantic- and translation-priming research across languages, unless these are the very items that are under investigation. An examination of various word lists that have been used

across this literature indicates that these word types have been included among other noncognate items without reference to their possible confounding effects.

Conversely, the use of different item types in terms of word class (e.g., emotion words vs. concrete words vs. abstract words) is a potentially fruitful area of investigation, since this type of study would help to delimit certain models of bilingual processing. That is, given that hierarchical models (e.g., Kroll & Stewart, 1994) can shed light on the representation of words that share translation equivalents and that other distributed models (e.g., de Groot, 1993) describe representation for other word types as well, the use of different word classes in cross-language investigations can either support or fail to support a given model's predictions. Therefore, the use of different word types can help to discriminate between models and, perhaps, to develop new ones that are more comprehensive in nature.

Furthermore, when lexical decision tasks are used to examine bilingual memory representation, it is important that two types of nonwords be created. It would be advantageous to have one set of nonwords that is formed by changing one letter in words in the L1, which will result in nonwords that are pronounceable in the L1. However, nonwords that are phonologically possible in the L2 should also be included. This will result in the creation of nonwords that are not biased toward one language.

4. *Use a consistent baseline across experiments within a series*. Clearly, a variety of baselines have been used throughout this literature, ranging from neutral conditions to unrelated word conditions. This difference across experiments, sometimes within a single article, also makes it difficult to generalize priming effects across the general population. The use of a consistent baseline across a set of experiments is recommended. Truly neutral baselines are often difficult to achieve. One recommendation here is to counterbalance the items used so that items appear in both related and unrelated conditions across prime–target pairs. At the very least, the same items will be used in both of the primary conditions of interest.

5. *Word frequency and word length should be controlled across conditions within an experiment*. Researchers in this area of investigation are typically concerned with word frequency and word length and their impact on performance within priming experiments. If orthographies are similar across languages, the number of characters in words should be equated across experimental and control conditions. For other types of languages that are nonalphabetic, for example, controlling for syllable number or length, or perhaps bigram frequency, might be a possibility. Participants' response times can often be influenced by the inclusion of words that are either too long or too short, and if an item and its corresponding control differ dramatically in length, this variable could serve to moderate the magnitude of the priming effect. Word frequency—printed word frequency—is also an important factor. If stimuli are presented visually, a word frequency count for words in print should be consulted, regardless of the language under investigation. Many different corpora exist in different languages. However, caution should be exercised when consulting these norms as there may be dialectical differences that should be considered before a specific database is used (e.g., Spanish spoken in Spain vs. Spanish spoken in Puerto Rico). In addition, one may also want to take phonotactic factors into consideration, which can be used to examine the phonological configurations that are common in a specific language. Since this variable may influence word retrieval it may be important to know the extent to which two languages overlap in phonetic combinations and/or word onsets.

6. *The SOA should be kept short if automatic processing is under examination*. The length of the SOA, as described previously, could moderate the strength of the priming effect, as well as influencing the degree to which strategic processing occurs. Short SOAs, those under 200 msec, are less likely to produce relatedness checking or other postlexical processing strategies than are SOAs that are longer in duration.

7. *The nonword ratio should be controlled in order to minimize the use of strategic processing*. If participants can develop expectancies for the nature of an item, given a previous trial, these expectancies can contribute to an overall strategy for responding to words or nonwords. A nonword ratio of approximately .50 would help to minimize bias in either direction and would increase the uncertainty for subsequent trials in a given stimulus list.

8. *The relatedness proportion within a list should be kept low in order to minimize the use of an expectancy strategy by participants*. When the proportion of related word–word trials is high, as compared with the number of overall word–word trials, participants may develop a strategy for responding that might link positive "word" responses to related word pairs. In order to minimize the use of this particular type of expectancy strategy, it is suggested that this proportion be kept as low as possible, while still providing enough data per participant to lead to reasonable analyses.

9. *Use a masking procedure to minimize the use of predictive strategies by participants*. The use of masked priming experiments serves to greatly minimize the use of predictive strategies, since participants typically cannot consciously identify a particular word prime. However, various features of the word, such as its semantic or conceptual representation, influence performance on word-target trials. Thus, it is recommended that a given set of stimuli and participants be tested in both a masked and an unmasked condition within a single experiment with the proper counterbalancing of items.

10. *Choose a presentation format (single vs. double vs. sequential) that would minimize relatedness checking strategies across primes and targets*. As was noted in the present review, procedures have varied from double lexical decision trials, to single lexical decision trials, to the naming of targets following the silent reading of primes. Perhaps a method that should be considered more carefully within this area of research involves a sequential presentation of items requiring a response to each and every one (see, e.g., McNamara & Altarriba, 1988). This method discourages the coupling of primes and targets into pairs, thereby minimizing the overt linking of related primes and targets. It has been successfully used to inves-

tigate direct priming and mediated priming in studies of monolingual speakers.

11. *When cross-language effects are examined, include within-language conditions, as well as a comparison*. In some instances, within the studies reviewed here, researchers examined processing across language in a single direction (e.g., L1–L2 or L2–L1). These studies present only half of the picture, at best, and their design does not allow for the full specification of data that might address representational issues with regard to the development of bilingual memory models. Researchers should examine both processing directions, as well as possibly including within-language demonstrations (see de Groot & Nas, 1991; Gollan et al., 1997; and Jiang, 2001, as good examples). The latter recommendation would assure investigators that the items do indeed produce priming, if only within languages, as opposed to across languages.

12. *Strive to test a particular set of hypotheses across a specific set of languages, prior to working across varying languages within a single set of studies*. Clearly, part of the variability in results reported across the studies reviewed here lies with the use of many different languages. Although one would expect that the basic processes that produce priming effects would influence processing in the same way, regardless of language per se, this variability, coupled with the many issues addressed above, adds to the overall difficulty in generalizing basic findings. Although researchers capitalize on their resources in terms of the availability of language participants of a particular background, until a given language or set of languages has been examined across a variety of settings and paradigms, it will remain difficult to draw strong conclusions regarding the existence of semantic or translation priming across any languages at all.

AUTHOR NOTE

Portions of this work were presented at the VIII Conference on Applied Linguistics (Spanish and Other Languages), Universidad de las Américas, Cholula, Puebla, Mexico, as well as at the XIII Conference of the European Society for Cognitive Psychology (ESCOP), Granada, Spain. We thank Roberto R. Heredia and an anonymous reviewer for their insightful comments on an earlier version of the manuscript. Correspondence related to this work can be sent to J. Altarriba, Department of Psychology, University at Albany, SUNY, Social Sciences 369, Albany, NY 12222 (e-mail: ja087@albany.edu).

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APPENDIX A
Summary of Semantic Priming Studies ($N = 11$)

Table A1
Languages

Authors	Languages Used	No. Participants	Language History/Proficiency	Lexical Decision Task (LDT) vs. Pronunciation	Single vs. Double LDT
Meyer & Ruddy (1974)	English–German	8	"Equally fluent in both languages according to the terminology of MacNamara (1967)." (p. 21) However, all lived in the U.S., so English was probably more dominant.	LDT	Double
Kirsner, Smith, Lockhart, King, & Jain (1984)					
Experiment 4	Hindi–English	12	All participants rated themselves as fluent or highly competent in both languages.	LDT	Double
Experiment 5	French–English	12	Participants had 10 years of experience in both languages and claimed to be fluent in each language.	LDT	Single
Schwanenflugel & Rey (1986)					
Experiment 1	Spanish–English	16	Spanish was the 1st language, but most learned English at a young age. Participants scored similarly on a reading test in both languages.	LDT	Single
Frenck & Pynte (1987)	English–French	24	All were native English speakers who learned French as adults. Half lived in France for a mean of 14 years, and the other half for a mean of 3 years.	LDT	Single
Grainger & Beauvillain (1988)					
Experiment 1	English–French	40	All had studied French for a minimum of 10 years and were living in France at the time.	LDT	Single
Experiment 2	English–French	32	Half were English dominant, and the other half were French dominant. Both languages were acquired during infancy.	LDT	Single
Chen & Ng (1989)					
Experiment 1	Chinese–English	24	Chinese was the first language, but all had studied English for more than 12 years.	LDT	Single
Keatley & de Gelder (1992)					
Experiment 1	French–Dutch	32	French was the first language, but Dutch was learned at a young age. All participants were studying to be professional translators.	LDT	Single
Experiment 2	French–Dutch	16	Same as above	LDT	Single
Experiment 3	Dutch–French	16	All participants learned to read in Dutch, but showed reading abilities that were within one *SD* from a native French reading speed.	LDT	Single
Tzelgov & Eben-Ezra (1992)					
Experiment 1	Hebrew–English	20	Hebrew was the first language for most, but 4 learned both languages simultaneously.	LDT	Single
Experiment 2	English–Hebrew	16	Native English speakers who had come to Israel 5–28 years earlier.	Pronunciation	Single
Keatley, Spinks, & de Gelder (1994)					
Experiment 1	Chinese–English	40	Chinese was the first language, but all had studied English since primary school.	LDT	Single
Experiment 2	Dutch–French	32	Dutch was the first language, but all began learning French by age 7.	LDT	Single
Williams (1994)					
Experiment 1a	English–French	44	Native English speakers who all had 7 years of formal education in French.	LDT	Single
Experiment 1b	English–French	20	Same as in Experiment 1a	LDT	Single
Larsen, Fritsch, & Grava (1994)	Latvian–English	47	Compound and coordinate bilinguals participated, but Latvian was the first language for all.	Pronunciation	Single

APPENDIX A (Continued)

Table A2
Characteristics

Authors	Masked/ Unmasked	Were Cognates Used?	Control	Word Frequency and Word Length
Meyer & Ruddy (1974)	Unmasked	Not mentioned	Unrelated	No, some German words had more letters than English words. English words averaged 5.4 letters, while German words averaged 6.3 letters.
Kirsner, Smith, Lockhart, King, & Jain (1984)				
Experiment 4	Unmasked	N/A*	Unrelated	Word pairs were chosen based on category membership defined by Battig and Montague (1969).
Experiment 5	Unmasked	No	Unrelated	Each word had 3–7 characters. Words had highly correlated frequency counts.
Schwanenflugel & Rey (1986)				
Experiment 1	Unmasked	No	Neutral	"They attempted to control for word length, but were only partially successful. No attempt was made to control for frequency." (p. 608)
Frenck & Pynte (1987)	Unmasked	No	No primes	All words were 3–9 letters long. Length and number of syllables were matched.
Grainger & Beauvillain (1988)				
Experiment 1	Unmasked	Not mentioned	Unrelated	Word frequency and word length were controlled.
Experiment 2	Unmasked	Not mentioned	Unrelated	Word frequency and word length were controlled.
Chen & Ng (1989)				
Experiment 1	Unmasked	N/A*	Unrelated	All words were concrete nouns, and English words were composed of 5 letters each.
Keatley & de Gelder (1992)				
Experiment 1	Unmasked	Not mentioned	Unrelated	Medium to high frequency. Word length was 5.27 for French words and 5.05 for Dutch words.
Experiment 2	Unmasked	Not mentioned	Unrelated	Same as above
Experiment 3	Unmasked	Not mentioned	Unrelated	Same as above
Tzelgov & Eben-Ezra (1992)				
Experiment 1	Unmasked	N/A*	Unrelated	Not mentioned
Experiment 2	Unmasked	N/A*	Unrelated	Not mentioned
Keatley, Spinks, & de Gelder (1994)				
Experiment 1	Unmasked	N/A*	Unrelated and neutral	Length was 3–8 letters with a mean of 4.2. Chinese characters had 2–16 strokes.
Experiment 2	Unmasked	No	Unrelated	Words were of medium to high frequency. Length was 5.27 for French words and 5.05 for Dutch words.
Williams (1994)				
Experiment 1a	Masked	No	Unrelated	Log frequency per million words was 1.51 for semantically related pairs and 1.79 for associated pairs. Word length was controlled.
Experiment 1b	Unmasked	No	Unrelated	Word length was controlled.
Larsen, Fritsch, & Grava (1994)	Unmasked	No	Unrelated	Not mentioned

*Nonapplicable in the cognate category, since languages that require the use of different orthographies cannot possibly have any cognates.

APPENDIX A (Continued)

Table A3
Results

Authors	SOA	Nonword Ratio	RP	Priming Effects		Mean RTs (Unrelated)		Mean RTs (Related)	
				L1–L2	L2–L1	L1–L2	L2–L1	L1–L2	L2–L1
Meyer & Ruddy (1974)	0 msec	.71	.50	+143*	+116*	1,280*	1,240*	1,137*	1,124*
Kirsner, Smith, Lockhart, King, & Jain (1984)									
Experiment 4	0 msec	.53	.50	+45	+255	1,031	1,151	986	896
Experiment 5	4.5 sec	.75	.40	+44	+48	650	624	606	576
Schwanenflugel & Rey (1986)									
Experiment 1	300 msec	.50	.50	+135 (high typicality)	+47 (high typicality)	802	743	667	696
Frenck & Pynte (1987)	500 msec	.75	.67	+63 (n.s.) (skilled bilinguals)	+51 (n.s.) (skilled bilinguals)	797	760	734	709
				+141 (less skilled)	+66 (less skilled)	834	685	693	619
Grainger & Beauvillain (1988)									
Experiment 1	150 msec	.54	.33	Not examined	SOA 150: −7 (n.s.)		592		599
	750 msec				SOA 750: +17		616		599
Experiment 2	150 msec	.44	.167	SOA 150: +7 (n.s.)	SOA 150: +12 (n.s.)	568	549	561	537
	750 msec			SOA 750: +18 (n.s.)	SOA 750: +26	576	552	558	526
Chen & Ng (1989)									
Experiment 1	300 msec	.67	.67	+125*	+60*	1,150*	975*	1,025*	915*
Keatley & de Gelder (1992)									
Experiment 1	200 msec	.80	.75	High RP: +20	High RP: +33	577	538	557	505
		.57	.25	Low RP: +37	Low RP: +21	585	533	548	512
Experiment 2	200 msec	.57	.25	+6 (n.s.)	−2 (n.s.)	526	508	520	510
Experiment 3	200 msec	.57	.25	+11 (n.s.)	+8 (n.s.)	540	454	529	446
Tzelgov & Eben-Ezra (1992)									
Experiment 1	240 msec	.67	.50	+100*	+12*	925*	675*	825*	663*
	840 msec								
Experiment 2	240 msec	.67	.50	+45*	+5*	755*	600*	710*	595*
	840 msec								
Keatley, Spinks, & de Gelder (1994)									
Experiment 1	250 msec	.57	.25	SOA 250: +38	SOA 250: −5 (n.s.)	636	592	598	597
	2,000 msec			SOA 2,000: +14 (n.s.)	SOA 2,000: −14 (n.s.)	612	610	598	624
Experiment 2	200 msec	.57	.25	+42	+11 (n.s.)	639	502	597	491
Williams (1994)									
Experiment 1a	728 msec	.67	.50	Semantic pairs: +34	Not examined	640		606	
				Associates: −9 (n.s.)		615		624	
Experiment 1b	720 msec	.67	.50	Associates: +36	Not examined	647		611	
Larsen, Fritsch, & Grava (1994)	250 msec	No nonwords	.50	−3.56 (n.s.)	Not examined	782.25		785.81	

Note—SOA, stimulus onset asynchrony; RP, relatedness proportion; RT, response time; L1, first language; L2, second language. All priming effects are reported at the $p < .05$ level, unless otherwise noted. All RT values and priming effects are reported in milliseconds. *Priming effects and RTs were estimated from a graph; an effort was made to contact the authors in order to obtain the most accurate results.

APPENDIX A (Continued)

Table A4
Additional Notes

Authors	Notes
Meyer & Ruddy (1974)	Used concrete words only. Abstract words might have produced different results. "Results appear to favor integrated memory over segregated memories; however, it appears that different encoding and retrieval operations are used to access words in different languages." (p. 15)
Kirsner, Smith, Lockhart, King, & Jain (1984)	
Experiment 4	Experiment 4 was performed to see whether a language using different orthographies could produce facilitation. The design for this experiment was the same as that used by Meyer and Ruddy (1974).
Experiment 5	Experiment 5 examined how priming is affected by varying lags. The results showed that semantic priming could occur only when there was successive presentation of the primes and targets. Therefore, the data presented here are those from the shortest lag (0).
Schwanenflugel & Rey (1986)	
Experiment 1	Participants had to obtain a score (without a 19% or more difference) on Spanish and English reading comprehension tests. This was done in addition to self-ratings. Primes were category labels. These results were replicated using a short SOA (100 msec; Experiment 2).
Frenck & Pynte (1987)	Category primes were used because the authors felt that category names were a better indicator of semantic networks, since it is possible that associated words may not be associated across languages, due to cultural factors. Facilitation was observed across and within languages for both groups, although priming was significant only in less skilled bilinguals when data for the two groups were analyzed separately.
Grainger & Beauvillain (1988)	
Experiment 1	Experiment 1 revealed nonsignificant priming in the L2–L1 direction, the only direction tested. Therefore, Experiment 2 was designed to examine priming in both the L1–L2 and L2–L1 directions.
Experiment 2	Since the results from Experiment 2 show nonsignificant priming for both directions, the authors concluded that lexical representations of associated words in different languages are not directly linked in the bilingual lexicon. They believe that cross-language semantic priming observed by others must be due to the use of strategies by participants.
Chen & Ng (1989)	
Experiment 1	The results indicate a significant semantic priming effect. However, reaction times were rather long, indicating that participants may have translated the primes.
Keatley & de Gelder (1992)	
Experiment 1	Since priming effects were equal in both high and low proportion categories, the authors concluded that manipulating relatedness proportion did not affect priming. However, the authors also noted that since participants were given feedback on their response times after each trial, it is possible that their attention was diverted at times.
Experiment 2	The same word stimuli as those for the low-proportion condition in Experiment 1 were used in Experiment 2. However, participants were instructed to respond with a reaction time as close to 500 msec as possible.
Experiment 3	Once again, participants were instructed to respond with reaction times as close to 500 msec as possible.
Tzelgov & Eben-Ezra (1992)	
Experiment 1	The data revealed no difference in priming as a result of SOA. Therefore, the results are in contrast to Grainger and Beauvillain's (1989) results where cross-language priming occurred only at the long SOA.
Experiment 2	Participants pronounced words and nonwords in this experiment in order for the experimental stimuli and conditions to remain similar to those in Experiment 1.
Keatley, Spinks, & de Gelder (1994)	
Experiment 1	The results from Experiment 1 show an asymmetrical cross-language priming effect in both experiments. However, participants were provided with feedback after each trial, which may have affected the results. It is also important to note that effort was taken to keep the relatedness proportion low, consistent with that of Keatley and de Gelder (1992).
Experiment 2	The results from Experiment 2 indicated asymmetrical priming effects. However, significant priming was observed in the L1–L2 direction.
Williams (1994)	
Experiment 1a	In Experiment 1a, half the participants were given semantically related pairs, and half were presented with pairs that were associates. The results led the authors to conclude that when masking is present, cross-language priming can occur for word pairs that are highly semantically similar, but not for those that are associates.
Experiment 1b	Data from Experiment 1b indicated that cross-language priming can occur when primes are unmasked (replicating the results of de Groot, 1991).
Larsen, Fritsch, & Grava (1994)	It was hypothesized that priming would occur for compound bilinguals and not for coordinate bilinguals. However, the data revealed an inhibitory effect, but the authors did not present the results separately for each group so that a comparison could be made.

APPENDIX B
Summary of Translation Priming Studies ($N = 11$)

Table B1
Languages

Authors	Languages Used	No. Participants	Language History/Proficiency	Lexical Decision Task (LDT) vs. Pronunciation	Single vs. Double LDT
Chen & Ng (1989)					
Experiment 1	Chinese–English	24	Chinese was the first language learned, but all had studied English for more than 12 years.	LDT	Single
Jin (1990)					
Experiment 1	Korean–English	24	Korean was the first language learned, but English was learned before adolescence.	LDT	Single
de Groot & Nas (1991)					
Experiment 3	Dutch–English	68	Dutch was the first language learned, and all participants were described as being "reasonably good" at comprehending English.	LDT	Single
Altarriba (1992)	Spanish–English	64	Participants had spoken each language for 16–24 years. Spanish was the first language, but they were actually more proficient in English.	LDT	Single
Keatley & de Gelder (1992)					
Experiment 4	Dutch–French	16	Dutch was the first language learned.	LDT	Single
Williams (1994)					
Experiment 2b	German–English, Italian–English, French–English	18 (9 German; 6 Italian; 3 French)	English was the second language for all participants. They were all in intermediate or advanced English classes, but their proficiency was lower than those in Experiment 1.	LDT	Single
Keatley, Spinks, & de Gelder (1994)					
Experiment 3	Dutch–French	32	All were native Dutch speakers who had studied French from age 7.	LDT	Single
Gollan, Forster, & Frost (1997)					
Experiments 1 & 3	Hebrew–English	40	Hebrew was the first language, but all participants had been exposed to both languages from an early age. However, dominance was determined from within-language LDT data.	LDT	Single
Experiments 2 & 4	English–Hebrew	30	English was the first language, but all had been exposed to both languages from an early age.	LDT	Single
Grainger & Frenck-Mestre (1998)	English–French	12	All were native English speakers who had been in France for 10–25 years and were highly skilled in the second language.	LDT	Single
Jiang (1999)					
Experiment 1	Chinese–English	52	All were Chinese graduate students who had studied English for at least 8 years and who had been in the U.S. for 8 months to 7 years.	LDT	Single
Experiment 2	Chinese–English	44	The participants were Chinese graduate students who did not participate in Experiment 1, but whose level of proficiency was similar to participants in that experiment.	LDT	Single
Jiang & Forster (2001)					
Experiment 1	Chinese–English	26	Chinese graduate students who had at least 8 years of formal English and who had been living in the U.S. for 1–7 years.	LDT	Single

APPENDIX B (Continued)

Table B2
Characteristics

Authors	Masked/ Unmasked	Were Cognates Used?	Control	Word Frequency and Word Length
Chen & Ng (1989)				
Experiment 1	Unmasked	N/A*	Unrelated	All words were concrete nouns, and English words were composed of five letters each.
Jin (1990)				
Experiment 1	Unmasked	N/A*	Unrelated	Not mentioned
de Groot & Nas (1991)				
Experiment 3	Both	Yes, since the purpose here was to examine both cognates and noncognates.	Unrelated	Not mentioned
Altarriba (1992)	Unmasked	No	Unrelated	Spanish primes and targets were slightly longer than in English. Frequency was controlled according to Kučera and Francis (1967).
Keatley & de Gelder (1992)				
Experiment 4	Unmasked	No	Unrelated	Words were 3–8 letters long. Frequency was medium high.
Williams (1994)				
Experiment 2b	Masked	No	Unrelated	Log frequency of English targets was 1.38.
Keatley, Spinks, & de Gelder (1994)				
Experiment 3	Unmasked	No	Unrelated	Words were of medium frequency and were 3–8 letters long.
Gollan, Forster, & Frost (1997)				
Experiments 1 & 3	Masked	Yes, but the purpose was to test priming differences in cognates and noncognates.	Unrelated	"All words were comparable in length and frequency. However, Hebrew words tended to be slightly shorter because vowels are omitted." (p. 1125)
Experiments 2 & 4	Masked	Same as above	Unrelated	Same as in Experiments 1 and 3
Grainger & Frenck-Mestre (1998)	Masked	No	Unrelated	All words were matched in length and frequency. Word length ranged from 3 to 10 letters.
Jiang (1999)				
Experiment 1	Masked	N/A*	Unrelated	Mean frequency for English words was 191 per million, and for Chinese words it was 157 per million.
Experiment 2	Masked	N/A*	Unrelated	Frequency was lower than in Experiment 1, with English words occurring at 39 per million and Chinese at 34 per million.
Jiang & Forster (2001)				
Experiment 1	Masked	N/A*	Unrelated	Materials used were similar to those in Jiang (1999). Mostly high-frequency nouns were used, all of which had translations composed of two-character bisyllabic Chinese words.

*Nonapplicable in the cognate category, since languages that require the use of different orthographies cannot possibly have any cognates.

APPENDIX B (Continued)

Table B3
Results

Authors	SOA	Nonword Ratio	RP	Priming Effects		Mean RTs (Unrelated)		Mean RTs (Related)	
				L1–L2	L2–L1	L1–L2	L2–L1	L1–L2	L2–L1
Chen & Ng (1989)									
Experiment 1	300 msec	.67	.67	+280*	+180*	1,150*	975*	870*	795*
Jin (1990)									
Experiment 1	150 msec	.54	.67	+150	+36	806	658	656	622
de Groot & Nas (1991)									
Experiment 3	240 msec (unmasked)	.75	.67	Unmasked: +113	Not examined for noncognates	628		515	
	60 msec (masked)			Masked: +35		588		553	
Altarriba (1992)	200 msec	.33	.33	SOA 200 msec: +70	SOA 200 msec: +17 (n.s.)	749	609	679	592
	1,000 msec			SOA 1,000 msec: +76	SOA 1,000 msec: +52	697	613	621	561
Keatley & de Gelder (1992)									
Experiment 4	200 msec	.57	.25	+42	+14	535	460	493	446
Williams (1994)									
Experiment 2b	50 msec	.67	.50	+33	Not examined	723		690	
Keatley, Spinks, & de Gelder (1994)									
Experiment 3	200 msec	.57	.25	+66	+34	642	511	576	477
Gollan, Forster, & Frost (1997)									
Experiments 1 & 3	50 msec	.67	.50	Noncognate: +36 (Experiment 1)	Noncognate: +9 (n.s.) (Experiment 3)	712	574	676	565
Experiments 2 & 4	50 msec	.67	.50	Noncognate: +52 (Experiment 2)	Noncognate: −4 (n.s.) (Experiment 4)	979	582	927	586
Grainger & Frenck-Mestre (1998)	27 msec				SOA 27 msec: −3 (n.s.)		554		557
	42 msec				SOA 42 msec: +2 (n.s.)		556		554
	56 msec				SOA 56 msec: +10		573		563
Jiang (1999)									
Experiment 1	50 msec	.67	.50	+45	+13	755	581	710	568
Experiment 2	50 msec	.67	.50	+68	+3 (n.s.)	814	635	746	632
Jiang & Forster (2001)									
Experiment 1	250 msec	.67	.50	Not examined	LDT: +8 (n.s.)		580		572
					Episodic: +29 (old)		733		704
					−6 (new) (n.s.)		728		734

Note—SOA, stimulus onset asynchrony; RP, relatedness proportion; RT, response time; L1, first language; L2, second language. All priming effects are reported at the $p < .05$ level, unless otherwise noted. All RT values and priming effects are reported in milliseconds. *Priming effects and RTs were estimated from a graph; an effort was made to contact the authors in order to obtain the most accurate results.

APPENDIX B (Continued)

Table B4
Additional Notes

Authors	Notes
Chen & Ng (1989)	
Experiment 1	Since RTs were relatively long, participants may have been translating the words and thereby using strategic processes.
Jin (1990)	
Experiment 1	Translation priming was significant. Associative priming was also found but only for concrete pairs.
de Groot & Nas (1991)	
Experiment 3	Experiments 1 and 2 examined cognates only. In addition, Experiment 3 included some associative pairs, but significant priming was found only in the unmasked condition.
Altarriba (1992)	Results are similar to those of Jin (1990). L1–L2 priming was larger than L2–L1 priming. The priming effect increased at the longer SOA, indicating that participants may have been translating the words.
Keatley & de Gelder (1992)	
Experiment 4	Participants were told to respond within a certain time in order to minimize any strategic processes.
Williams (1994)	
Experiment 2b	All targets were in English in this experiment, indicating that priming in only one direction was analyzed. Priming for French and Italian was +45 msec, and for German the effect was +21 msec. However, there were no significant differences when comparing different languages.
Keatley, Spinks, & de Gelder (1994)	
Experiment 3	Priming appeared to occur across languages in both directions. The authors concluded that as compared with the results of semantic priming in Experiments 1 and 2, it appears that translations have stronger L1–L2 links than associates do. In addition, the results demonstrated an asymmetrical priming effect across languages.
Gollan, Forster, & Frost (1997)	
Experiments 1 & 3	These experiments were designed to test whether the increase seen in priming of cognates is purely phonological or the result of orthography and phonology. Therefore, Hebrew was the chosen language because it allows orthographic overlap to be eliminated.
Experiments 2 & 4	Overall, the results indicated that no priming occurred for noncognates. The authors suggest that translation priming is observed only when the prime is in the L1.
Grainger & Frenck-Mestre (1998)	Participants performed a lexical decision task, as well as a semantic categorization task. However, the data presented here are only from the lexical decision task. All targets were in English, indicating that priming was only examined in the L2–L1 direction.
Jiang (1999)	
Experiment 1	Great effort was taken to ensure that the translation pairs were equivalent in meaning in both languages. Results from Experiment 1 demonstrated an asymmetrical effect of cross-language priming.
Experiment 2	Experiment 2 indicated that priming was absent in the L2–L1 direction.
Jiang & Forster (2001)	
Experiment 1	The asymmetry observed in L2–L1 priming led the authors to investigate whether the L2–L1 lexical connections are really part of the episodic system. In Experiment 1, participants performed an LDT in addition to an episodic task that required participants to study a list of 35 Chinese words prior to the priming test. All participants performed both tasks; however, they were given 2 weeks in between each test phase. These results indicate that L2–L1 priming occurs episodically, whereas L1–L2 priming is lexical.

(Manuscript received April 21, 2005;
revision accepted for publication August 31, 2005.)