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Semantic and translation priming from a first language to a second and back: Making sense of the findings

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The present study investigated cross-language priming effects with unique noncognate translation pairs. Unbalanced Dutch (first language [L1])–English (second language [L2]) bilinguals performed a lexical decision task in a masked priming paradigm. The results of two experiments showed significant translation priming from L1 to L2 (*meisje*–GIRL) and from L2 to L1 (*girl*–MEISJE), using two different stimulus onset asynchronies (SOAs) (250 and 100 msec). Although translation priming from L1 to L2 was significantly stronger than priming from L2 to L1, the latter was significant as well. Two further experiments with the same word targets showed significant cross-language semantic priming in both directions (*jongen* [*boy*]–GIRL; *boy*–MEISJE [GIRL]) and for both SOAs. These data suggest that L1 and L2 are represented by means of a similar lexico-semantic architecture in which L2 words are also able to rapidly activate semantic information, although to a lesser extent than L1 words are able to. This is consistent with models assuming quantitative rather than qualitative differences between L1 and L2 representations.

In the last decade, bilingual word processing has received increasing attention. A basic feature of being bilingual is that one often has multiple lexical representations (one in each language) for a particular meaning (e.g., *dog* and *hond* are the English and Dutch words, respectively, for the same animal). If these lexical representations are connected to either the same or overlapping semantic representations (or directly to each other), one might expect interactions between a bilingual's languages during word recognition. Indeed, there is a plethora of evidence for influences of a bilingual's first language (L1) on the processing of a second language (L2) (see below; for instance, Duyck, 2005; Keatley, Spinks, & de Gelder, 1994; Kim & Davis, 2003; Schoonbaert, Hartsuiker, & Pickering, 2007; Weber & Cutler, 2004). Depending on the organization of bilingual memory, a nondominant language may also influence the dominant language. The present article asks whether such influences from L2 on L1 processing exist, and if so, whether they are equally strong as the influences from L1 on L2.

A number of studies have observed effects from L2 on native language processing. For example, van Hell and Dijkstra (2002) showed that L1 (Dutch) targets having an L2 (English) and L3 (French) near-cognate translation equivalent (e.g., *banaan–banana–banane*) yielded faster lexical decision responses than did control words. However, despite the fact that these cross-language influences apparently seem to exist in both directions, it is a recurrent finding that L1 typically has more impact on L2 processing than vice versa. This well-known asymmetry has been reported in a number of studies using a wide range of paradigms (e.g., Duyck, 2005; Gollan, Forster, & Frost, 1997; Grainger & Frenck-Mestre, 1998; Marian & Spivey, 2003; Schoonbaert et al., 2007; Weber & Cutler, 2004). For instance, it has been claimed that in a lexical decision task with translation primes, there are clear effects from L1 to L2, but no—or unreliable—effects from L2 to L1 (Gollan et al., 1997; Jiang, 1999; Jiang & Forster, 2001).

A possible theoretical explanation is that words in L2 are represented and accessed in a qualitatively different way than are words in L1. For instance, in Jiang and Forster's (2001) episodic model, only L1 words are represented in semantic memory. L2 words, in contrast, are represented

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only as a trace (together with their L1 translation) in episodic memory. A second example of such a theory is offered by Kroll and Stewart's (1994) revised hierarchical model (RHM). They stated that both L1 and L2 words are represented in semantic memory, but that they differ with respect to the way in which the lexical representations are mapped onto underlying semantics. A very strict interpretation of this model implies that L2 words (unlike L1 words) are not mapped directly onto semantics, but that they primarily access meaning through their L1 translation equivalent (for a different view, see, e.g., Duyck & Brysbaert, 2004, 2008). Hence, in such a model, L2 representations are qualitatively different from L1 representations. This "qualitative" hypothesis is in line with the lack of consistent translation priming effects from L2 to L1 (assuming that the locus of such priming is semantic; see the General Discussion section).

However, an alternative hypothesis would be that the representational differences between L1 and L2—and the way in which these are activated—are not qualitative but quantitative. That is, an L2 word might activate only some of the semantic features that are activated by its L1 translation (see, e.g., the distributed representation model [DRM] proposed by van Hell & de Groot, 1998a) and cause weaker activation in these features (e.g., the model of Duyck & Brysbaert, 2004). Or, the activation in L2 representations may develop more slowly than it would in L1 representations (e.g., the temporal delay hypothesis proposed by Dijkstra & Van Heuven, 2002). This "quantitative" hypothesis could explain why L2 to L1 priming may be weaker than L1 to L2 priming without a priori excluding reliable priming effects from L2 to L1.

The present study was designed to test under which conditions two types of cross-language priming (namely, translation priming and cross-language semantic priming) occur in the lexical decision task. Doing this allows us to differentiate between models proposing qualitatively versus quantitatively different L1 and L2 representations. To this end, we investigated how the effect of L2 knowledge on L1 processing compared with the reverse effect. Before we go into more details about the present study, we will discuss the current state of affairs with respect to this issue.

The "General" Bilingual Asymmetry

Many studies have reported differential effects from L1 onto L2 and vice versa, across different modalities. When auditorily instructed to look at the picture of a *desk*, Dutch–English bilinguals in Weber and Cutler's (2004) eyetracking study were significantly distracted by a picture of a *lid*, because their L1 lexical representation of the distractor item (*deksel* [*lid*]) has the same initial phonemes as does the auditorily presented L2 word, *desk*. However, when the participants heard the L1 word *deksel*, the picture of a *desk* did not significantly distract participants' fixations of the target picture *lid*. This result shows how the native language interferes with auditory word recognition in L2 (English) but not vice versa, providing evidence for asymmetric cross-language interactions in bilingual auditory word recognition.

Like in the van Hell and Dijkstra (2002) study, Weber and Cutler (2004) investigated the influence of the other language without overt input in that language, and thus without directing participants' attention to that language. There is additional support for the bilingual asymmetry from studies explicitly bringing participants into a bilingual context. One of these studies is that of Schoonbaert et al. (2007), which showed that there is an asymmetric translation-equivalence boost for syntactic priming across languages. Dutch–English bilinguals (from the same bilingual population tested in the present study) tended to reuse the dative structure that they had previously heard in Dutch (e.g., *De kok toont een hoed aan de bokser* [*The cook shows a hat to the boxer*]; prepositional dative) to describe a dative target picture in English (*The monk gives a book to the waitress*; prepositional dative), instead of using the alternative dative structure (*The cook shows the boxer the hat*; double object dative). More importantly, this L1 to L2 syntactic priming effect was boosted when the L2 translation of the L1 prime verb (e.g., *toont* [*show*]) was to be used in the description of the dative target picture (e.g., *The monk shows a book to the waitress*). Although the study also observed syntactic priming from L2 to L1, this effect was not boosted by using translation-equivalent verbs. This finding was again interpreted as a demonstration of the bilingual asymmetry.

Other studies overtly confronting bilinguals with both of their languages include unmasked priming studies (Altarriba, 1992; Chen & Ng, 1989; Frenck & Pynte, 1987; Jin, 1990; Keatley et al., 1994; Schwanenflugel & Rey, 1986). Several of these have shown larger priming effects from L1 to L2 rather than from L2 to L1. In the next section, we will further discuss the masked variant of the priming paradigm as an interesting way to test for cross-language effects.

Masked Cross-Language Priming Asymmetries in Lexical Decision

A widely adopted approach to investigate spreading activation across languages from nontarget language representations without bilingual participants' awareness involves the masked priming paradigm (Forster & Davis, 1984). The present study adopted this popular paradigm to further investigate whether and to what extent the activation of lexical and semantic representations in L1 influences L2 processing, and vice versa. Translation priming occurs when the processing of a target is facilitated by a tachistoscopically presented translation prime (e.g., Dutch–English, *meisje*–GIRL) relative to an unrelated prime–target pair (e.g., *koffie* [*coffee*]–GIRL). We will briefly discuss the existing bilingual studies using this priming paradigm with a lexical decision task (Basnight-Brown & Altarriba, 2007; Duyck, 2005; Finkbeiner, Forster, Nicol, & Nakamura, 2004; Gollan et al., 1997; Grainger & Frenck-Mestre, 1998; Jiang, 1999; Jiang & Forster, 2001; Kim & Davis, 2003; Voga & Grainger, 2007), since this is the task we focused on in the present article. In general, L1 translation primes systematically speed up lexical decision times to L2 targets (Basnight-Brown & Altarriba, 2007; Gollan et al., 1997; Jiang, 1999; Jiang & Forster, 2001; Kim & Davis, 2003; Voga & Grainger, 2007; Williams, 1994). In contrast, evidence for L2 to L1 translation priming (e.g., *girl*–MEISJE) is less unequivocal. This suggests that translation priming is asymmetrical in the lexical decision task. We summarize the published data from masked translation priming studies (using the lexical decision task and noncognate stimuli) in Table 1. We did not include unmasked priming studies because these may induce strategic factors that influence nontarget language activation (Neely, Keefe, & Ross, 1989), and because our focus was on the processing of automatic cross-language activation spreading. The 13 studies (26 experiments) that meet these criteria are organized in Table 1 as a function of the type of script of the bilinguals' languages (different vs. comparable), of the specific languages used, and of the type of stimuli used (when available).[1]

Gollan et al. (1997) tested both English–Hebrew and Hebrew–English bilinguals and reported significant translation priming from L1 to L2, but failed to observe translation priming from L2 to L1. These results were basically replicated by Jiang (1999), who tested Chinese–English bilinguals. The L2–L1 priming effect was absent in all but one experiment, in which a 13-msec effect was obtained with highly frequent stimuli (see Table 1). In a similar study using comparable bilinguals, Jiang and Forster (2001) failed to obtain significant priming effects from L2 to L1, whereas priming from L1 to L2 was significant. The existence of a translation priming asymmetry in the lexical decision task is further supported by the studies of de Groot and Nas (1991), Kim and Davis (2003), Voga and Grainger (2007), and Finkbeiner et al. (2004), which showed the existence of L1–L2 priming in Dutch–English bilinguals, Korean–English bilinguals, and Greek–English bilinguals, and the absence of L2–L1 priming in Japanese–English bilinguals, respectively. However, although Grainger and Frenck-Mestre (1998) were unable to find L2 to L1 translation priming at very short stimulus onset asynchronies (SOAs) (below 50 msec) while testing French–English bilinguals, they did find a "healthy trend" (Grainger & Frenck-Mestre, 1998, p. 615) for L2 to L1 priming with a more commonly used (longer) SOA (57 msec). Another study by Basnight-Brown and Altarriba (2007) tested Spanish–English bilinguals in both the L1–L2 and the L2–L1 conditions. Both priming effects proved to be significant. There was no interaction between priming and direction, providing evidence against the translation priming asymmetry.

A similar asymmetry might be observed in another variant of cross-language priming—namely, cross-language semantic priming. Semantic priming is a well-documented effect in the monolingual domain (see, e.g., Bleasdale, 1987; Ferrand & New, 2003; Neely et al., 1989; Perea & Rosa, 2002a, 2002b; for reviews, see Hutchison, 2003; Lucas, 2000; Neely, 1991). In this paradigm, responses to target words such as GIRL are typically faster after presentation of a semantically related word such as *boy* than after an unrelated word such as *day*. When testing Dutch–English bilinguals, the cross-language version of this paradigm uses prime–target pairs such as *jongen* [*boy*]–GIRL (from L1 to L2) and *boy*–MEISJE [GIRL] (from L2 to L1). Using a lexical decision task, cross-language semantic priming has been found by Chen and Ng (1989), de Groot and Nas (1991), Jin (1990), Keatley et al. (1994), and Schwanenflugel and Rey (1986). However, all of these studies used unmasked priming techniques. As in translation priming, cross-language semantic priming effects are often larger from L1 to L2 than from L2 to L1 (see, e.g., Jin, 1990). Table 1 lists four studies that looked at cross-language semantic priming in a masked priming paradigm. The first study, by de Groot and Nas, failed to find cross-language semantic priming effects from L1 to L2 while testing Dutch–English bilinguals. A more recent study showed that L2 targets (e.g., CHURCH) are primed by L1 pseudohomophones (e.g., *pous*) of semantically related words (e.g., *paus* [*pope*]) in Dutch–English bilinguals (Duyck, 2005). This effect was not replicated with L1 targets (e.g., BEEN [LEG]) and L2 pseudohomophone primes (e.g., *knea* [*knee*]), revealing an asymmetry in cross-language semantic priming. The third study again failed to find a significant cross-language semantic priming effect in either priming direction, using prime–target pairs such as *dia* [*day*]–NIGHT in Spanish–English bilinguals (Basnight-Brown & Altarriba, 2007). In contrast, Perea, Duñabeitia, and Carreiras (2008) found an equivalent cross-language semantic priming effect for both directions in balanced Basque–Spanish and Spanish–Basque bilinguals.

Taken together, most cross-language translation priming studies provide evidence for a priming asymmetry, with stronger priming from L1 to L2 than the reverse. What is less clear is whether the asymmetry is a qualitative one (priming exists from L1 to L2, but not from L2 to L1) or a quantitative one (priming is stronger from L1 to L2 than from L2 to L1). In addition, although there are some indications for a similar asymmetry in cross-language semantic priming, the present evidence on the basis of masked priming does not allow us to draw any firm conclusions about this issue.

In the four experiments presented below, we compared translation and cross-language semantic priming for the same target words. This approach rules out stimulus differences as a confound of priming asymmetries observed across priming studies. The first two experiments were designed to test for masked translation priming. In Experiment 1, our aim was twofold: to replicate the L1 to L2 translation priming effect, and to show that this effect generalizes to a population of unbalanced Dutch–English bilinguals. In Experiment 2, we then tested the more debated L2 to L1 translation priming effect, using exactly the same stimuli as in Experiment 1 (reversing translation primes and targets) in the same bilingual population. The last two experiments (Experiments 3 and 4) were designed to test for masked cross-language semantic priming from L1 to L2 and vice versa, using semantically related primes for the same targets used in Experiments 1 and 2. A comparison between the two sets of experiments allowed us to test whether translation priming and cross-language semantic priming are both asymmetric to the same extent.

We manipulated two additional variables in the experiments. One word variable that might have an influence on the pattern of priming effects (see Table 1) is concreteness (see, e.g., van Hell & de Groot, 1998a). This variable was included in the present study for exploratory purposes. As

Table 1
Priming Effects on Lexical Decision Response Times (in Milliseconds) for Published Masked Cross-Language Priming Studies Using Noncognate Stimuli

Script	Bilinguals	Stimuli (Concreteness/Freq.)	N	n	Authors	Prime	Blank	Mask	SOA	L1 to L2	L2 to L1
					Translation Priming						
Different	Hebrew (L1)–English (L2)	–	40	16	Gollan, Forster, & Frost (1997, Exps. 1 and 3)	50	–	–	50	36*	9
	English (L1)–Hebrew (L2)	–	30	16	Gollan, Forster, & Frost (1997, Exps. 2 and 4)	50	–	–	50	52*	−4
	Chinese (L1)–English (L2)	abstract (high freq.)	52	16	Jiang (1999, Exp. 1)	50	–	–	50	45*	13*
		abstract	18/24	16	Jiang & Forster (2001, Exps. 3 and 4)	50	–	–	50	41*	4
		abstract	26	16	Jiang & Forster (2001, Exp. 1)	50	50	150	250	–	8
		concrete (low freq.)	44	16	Jiang (1999, Exp. 2)	50	–	–	50	68*	3
		concrete (high freq.)	16	16	Jiang (1999, Exp. 3)	50	50	–	100	–	4
		concrete (high freq.)	18	16	Jiang (1999, Exps. 4 and 5)	50	50	150	250	–	7/−2
	Korean (L1)–English (L2)	concrete	25	12	Kim & Davis (2003, Exp. 1)	50	–	–	50	40*	–
	Japanese (L1)–English (L2)	–	18	26	Finkbeiner, Forster, Nicol, & Nakamura (2004, Exp. 2)	50	–	150	200	–	−4
	Greek (L1)–English (L2)	–	30	10	Voga & Grainger (2007, Exp. 2)	50	–	–	50	23*	–
Comparable	German (L1–English (L2)	–	9	9	Williams (1994, Exp. 2b)	40	10	–	50	21*	
	Italian (L1)–English (L2)	–	6	9						45*	–
	French (L1)–English (L2)	–	3	9						45*	–
	French (L1)–English (L2)	concrete	12	60	Grainger & Frenck-Mestre (1998, Exp.1)	0	–	14	14	–	−4
						14	–	14	28	–	−3
						29	–	14	43	–	2
						43	–	14	57	–	10[a]
	Spanish (L1)–English (L2)	–	26	16	Basnight-Brown & Altarriba (2007, Exp. 2)	100	–	–	100	33*	24*
	Dutch (L1)–English (L2)	–	17/19	15	de Groot & Nas (1991, Exps. 3 and 4)	40	20	–	60	35*/40*/22*	–
	Dutch (L1)–French (L2)	–	24	11	Duyck & Warlop (2009)	56	–	56	112	48*	26*
					Cross-Lingual Semantic Priming						
Comparable	Dutch (L1)–English (L2)	–	17/19	15	de Groot & Nas (1991, Exps. 3 and 4)	40	20	–	60	13/4/−3	–
		–	20	17	Duyck (2005, Exps. 3 and 4)	57	–	57	114	33*	20
	Spanish (L1)–English (L2)	–	26	16	Basnight-Brown & Altarriba (2007, Exp. 2)	100	–	–	100	−8	6
	Basque (L1)–Spanish (L2)	concrete	20/16	20	Perea, Duñabeitia, & Carreiras (2008, Exps. 1 and 2)	47	–	–	47	11*/19*	15*
	Spanish (L1)–Basque (L2)	concrete	16	20	Perea, Duñabeitia, & Carreiras (2008, Exp. 3)	47	–	–	47	–	17*

Note—All priming effects were computed relative to an unrelated baseline condition. N, number of participants per experiment; n, number of observations per condition per participant. [a]F_1, $p < .10$; F_2, $p < .05$. *$p < .05$.

Table 2
Examples of the Four Different Kinds of Experimental Trials, As Used in the Experiments

		Concrete			Abstract		
		Prime Relation			Prime Relation		
Experiments	Direction	Translation	Semantic	Target	Translation	Semantic	Target
1 and 3	L1–L2	*meisje*	*jongen*	GIRL	*smaak*	*geur*	TASTE
2 and 4	L2–L1	*girl*	*boy*	MEISJE	*taste*	*smell*	SMAAK

will become clear, there was no significant interaction with priming, but merely a trend toward stronger cross-language priming for concrete versus abstract items (see below).

Additionally, the SOA was manipulated between subjects. Table 1 shows the use of a wide range of SOAs in previous studies. For this reason, we thought that it was interesting to compare two previously used SOAs in one design—namely, a 250-msec and a 100-msec SOA. The 250-msec SOA is on the edge of capturing automatic processes and is still relatively long in comparison with those in most studies reported (see Table 1). An SOA of 100 msec gives participants very little opportunity to develop strategies (Neely et al., 1989; Perea & Rosa, 2002a, 2002b). It is also more comparable to the short SOAs used in most recent masked priming studies (see Basnight-Brown & Altarriba, 2007; Duyck, 2005; Duyck & Warlop, 2009; see also recommendations by Altarriba & Basnight-Brown, 2007). Including both SOAs (250 vs. 100 msec) can give us an idea of the time course of cross-language priming and ultimately adds to the issue of qualitative versus quantitative differences in priming.

EXPERIMENT 1
Translation Priming From L1 to L2

Method

Participants. Sixty Dutch–English bilinguals from Ghent University participated in the experiment and received course credit in exchange. The mean age was 20.81 years ($SD = 2.13$). Participants were all native speakers of Dutch and primarily used their mother tongue in daily life. All of them were regularly exposed to English through media, such as textbooks, television, movies, music, and so on. They had received formal English education at school (starting around the age of 12). They all reported having normal or corrected-to-normal vision and they participated only in Experiment 1 of the present study.

Stimuli and Design. One hundred Dutch–English translation pairs were selected. A group of 20 Dutch–English bilinguals (from the same population as the participants in the experiments) was asked to give a spontaneous English translation for the Dutch items (L1–L2 translation), whereas a similar group of bilinguals was asked to translate the English items into Dutch (L2–L1 translation). The 52 word pairs that were translated identically by 80% of the participants, in both directions, served as unique (one-to-one) translation pairs in the following priming experiments. This is important, because a recent study by Tokowicz and Kroll (2007, Experiment 3) reported an interaction between concreteness and the number of word meanings in lexical decision: Only one-meaning words showed the traditional concreteness effect (i.e., a processing advantage for concrete words relative to abstract words). The 52 English words with unique translation equivalents in Dutch were selected as critical targets in a masked priming lexical decision experiment. The English word targets could be preceded by their Dutch translation, or by an unrelated Dutch word (see Table 2 and Appendix A). In this and all subsequent experiments, the translation pairs consisted of 26 abstract words (mean imageability rating of 3.43 [$SD = 0.71$] on a 7-point Likert scale from low to high imageable) and 26 concrete words (mean imageability rating of 6.53 [$SD = 0.26$]), following Dutch imageability norms gathered by Van Loon-Vervoorn (1985). The imageability ratings for the two groups of words differed significantly on a two-tailed *t* test ($p < .001$).

Fifty-two Dutch words, matched closely and item by item to the translation primes, were selected as unrelated primes for the English word targets. The Dutch translation primes and their respective controls were matched on length, number of syllables, frequency, and number of orthographic neighbors (all $ps > .25$, two-tailed *t* tests; see Table 3 for an overview). The measure used for this last variable was Coltheart's *N*, defined as the number of words differing by a single letter from the stimulus, preserving letter positions (e.g., *worse* and *house* are both orthographic neighbors of *horse*; Coltheart, Davelaar, Jonasson, & Besner, 1977). Neighborhood size and frequency measures for both Dutch and English were calculated using the WordGen stimulus generation program (Duyck, Desmet, Verbeke, & Brysbaert, 2004), based on the CELEX lexical database of Baayen, Piepenbrock, and van Rijn (1993). The mean printed frequency for all English word targets was 2.01 $\log_{10}$ per million, and ranged from 0.85 to 3.04. To avoid confounded priming effects of orthographical overlap, translation and control primes had the same number of shared letters with the target, in the same positions. Also, cognate or interlingual homograph prime–target pairs were excluded from our stimulus lists (as was suggested by Altarriba & Basnight-Brown, 2007). This constitutes a conservative test of non-target language activation during language processing.

The experiment involved a 2 (prime type: translation vs. unrelated) $\times$ 2 (concreteness: abstract vs. concrete) $\times$ 2 (SOA: 250 vs. 100 msec) design, with the first two variables as repeated measures, and with SOA as a between-subjects, but within-items, variable. Additionally, 52 nonwords were created that followed the English graphotactic constraints, serving as English filler targets for the lexical decision task. These nonword targets were matched with the English word targets on number of letters, number of syllables, bigram frequency, and number of orthographic neighbors (all $ps > .60$, two-tailed *t* tests), in order to ensure their wordlikeness and pronounceability. All nonwords were preceded by unrelated Dutch words. Prime–target pairing was counterbalanced using a Latin-square design, thus creating two presentation lists. Each participant was assigned to one list and consequently saw each target only once, either with the translation prime or its control. The relatedness proportion within each list was .5 (in accordance with recent suggestions made by Altarriba & Basnight-Brown, 2007, to avoid participants' creating expectancy sets).

Procedure. In the 250-msec SOA condition, each trial consisted of a sequence of four visual events. First, a row of 10 hash marks (##########), serving as a forward mask and as a fixation mark, was presented for 500 msec. Second, the prime was displayed on the screen for 50 msec (three refresh cycles on a 60-Hz monitor), immediately followed by a blank interval of 50 msec. Third, a backward mask (##########) was presented for 150 msec. Fourth, the target was presented for 500 msec, or until the participant's response. This was identical to the procedure that Jiang (1999, Experiments 4 and 5) and Jiang and Forster (2001, Experiment 1) used (see Table 1). In the 100-msec SOA condition, the 50-msec blank interval was dropped and the backward mask was presented

Table 3
Matched Variables and Summary of Stimuli Used in All Experiments

Prime	Freq	Length	Syll	BGFREQ	NB	R	Target	Freq	Length	Syll	BGFREQ	NB
L1							L2					
Experiment 1												
Translation	1.92	6.04	1.75	46,246.75	4.21	–	Concrete	1.85	5.69	1.69	10,551.19	2.92
Unrelated	1.84	6.06	1.85	53,485.13	4.31	–	Abstract	1.99	5.46	1.65	9,845.35	3.38
Experiment 3												
Semantic	1.62	5.58	1.65	50,766.98	3.67	0.29	Word	2.01	5.58	1.67	10,198.27	3.15
Unrelated	1.60	5.60	1.67	56,395.25	3.52	–	Nonword	–	5.62	1.67	9,897.96	2.92
L2							L1					
Experiment 2												
Translation	2.01	6.15	1.83	10,198.27	3.15	–	Concrete	1.85	6.04	1.85	47,325.31	4.23
Unrelated	1.99	6.13	1.85	11,184.04	3.15	–	Abstract	1.99	6.12	1.73	45,168.19	4.19
Experiment 4												
Semantic	1.82	5.35	1.52	9,454.73	4.85	0.29	Word	1.92	6.08	1.79	46,246.75	4.21
Unrelated	1.73	5.35	1.54	9,738.96	4.63	–	Nonword	–	5.81	1.77	44,680.50	4.56

Note—Freq, mean printed frequency in Loglnl—that is, the logarithm of frequency per million words; Syll, mean number of syllables; BGFREQ, mean bigram frequency; NB, mean number of orthographic neighbors (neighborhood size—e.g., Coltheart et al., 1977); R (relatedness), mean association strength between translation primes/targets and semantically related primes.

for 50 msec only (instead of 150 msec), thus creating an SOA of 100 msec.

Stimulus presentation and response registration were controlled by Experimental Runtime System software version 3.28 (BeriSoft Cooperation, 2006). All stimuli were presented centered on a standard 15-in. VGA color monitor in standard DOS font as yellow characters on a black background. Primes appeared in lowercase (font size 12), whereas targets were presented in uppercase (font size 14) to minimize visual feature overlap between primes and targets. For the masks, the same font size as that for the primes was used. In the 100-msec SOA condition, the hash marks of the backward mask were presented in a different font and size (Arial Black and 20, respectively) than the hash marks of the forward mask and the prime (standard DOS and 12, respectively). This was done to prevent the possibility of a so-called pop-out effect of the prime (see also Finkbeiner et al., 2004).[2] The order of the trials was randomized for each participant. Participants were asked to fixate the center of the screen and to decide as quickly and accurately as possible whether the target stimulus was an English word or not. The two possible response buttons were the right key (for a "yes" response) and the left key (for a "no" response) of a millisecond-accurate response box, which was connected to the printer port of a PC. The assignment of responses was reversed for half of the participants. None of the participants were informed about the presence of the primes. Instructions were given in Dutch (L1) by the experimenter (before the experiment) and were visually presented (on the screen). At the end, participants were asked to complete a short questionnaire about their L1 and L2 language proficiency (using a 7-point Likert scale), on the basis of which their relative L2 reading proficiency was calculated (by means of the equation [L2 score/L1 score] ∗ 7) (see Table 4).

Results

Only the correct responses of the word trials (94%) were analyzed. All participants had error rates below 25%. Because one abstract and one concrete target word were misjudged by more than 25% of all participants, they were discarded. Outlier data (response times [RTs] less than 200 msec and 2 *SD*s below or above the participant's mean word RT) were removed from the analyses, excluding less than 1% of all data. ANOVAs were carried out with participants (F_1) and items (F_2) as random variables, and with the mean RTs and the percentage of errors as the dependent variables. The factor stimulus list was included as a between-subjects variable (Pollatsek & Well, 1995). This analysis procedure was used in all experiments reported in the present article.

An ANOVA was performed with prime type (translation vs. unrelated) and concreteness (abstract vs. concrete) as repeated measures factors. The SOA (250 vs. 100 msec) was treated as a between-subjects variable in the participants analysis, and as a within-items variable in the item analysis. English targets preceded by their Dutch translation (557 msec) were recognized faster than were those preceded by an unrelated Dutch word (616 msec). This 60-msec priming effect was significant [$F_1(1,56) = 194.40$, $p < .001$, and $F_2(1,46) = 146.30$, $p < .001$]. The main effect of SOA was significant, but only in the by-items analyses [$F_1(1,56) = 2.40$, $p < .13$, and $F_2(1,46) = 115.80$, $p <$

Table 4
Relative L2 Proficiency Based on Self-Ratings of Reading Ability in L1 and L2 [(L2 score/L1 score) ∗ 7]

	Relative L2 Proficiency			
	250-msec SOA		100-msec SOA	
Experiment	*M*	*SD*	*M*	*SD*
Experiment 1 (L1 to L2 translation priming)	5.9	1.4	6.0	0.9
Experiment 2 (L2 to L1 translation priming)	6.4	1.0	6.0	0.8
Experiment 3 (L1 to L2 cross-language semantic priming)	6.1	1.0	5.7	0.9
Experiment 4 (L2 to L1 cross-language semantic priming)	6.2	1.3	6.2	1.0

Note—Self-ratings based on 7-point Likert scale ratings (1 = *very poor*, 7 = *excellent*).

Table 5
Mean Response Times (RTs, in Milliseconds), Mean Error Rates, and Priming Effects in the Participants Analysis of Experiment 1

			Concreteness			
	Overall		Abstract		Concrete	
L1 to L2	RT	% Error	RT	% Error	RT	% Error
250-msec SOA						
Translation	561	6	564	7	557	4
Unrelated	661	8	657	9	664	6
Priming	+100***		+93***		+107***	
100-msec SOA						
Translation	553	5	560	6	545	4
Unrelated	572	9	570	9	573	8
Priming	+19***		+10~		+28***	

~$p < .1$. ***$p < .001$.

.001]. The interaction between prime type and SOA was significant [$F_1(1,56) = 71.70$, $p < .001$, and $F_2(1,46) = 83.80$, $p < .001$]. The priming effect in the 250-msec SOA condition (100 msec) was stronger than in the 100-msec SOA condition (19 msec). The main effect of concreteness was not significant (both Fs < 1), but its interaction with prime type tended toward significance [$F_1(1,56) = 3.90$, $p < .06$, and $F_2(1,46) = 2.90$, $p < .10$].

Further analyses examined the effects separately for each SOA condition. The mean RTs per SOA are presented in Table 5 as a function of prime type and concreteness.

250-msec SOA. The 100-msec priming effect was significant [$F_1(1,56) = 187.84$, $p < .001$, and $F_2(1,46) = 133.02$, $p < .001$] and did not interact with concreteness (both Fs < 1). Planned comparisons showed that the priming effects for both abstract and concrete targets, respectively, were significant [$F_1(1,56) = 62.68$, $p < .001$, and $F_2(1,46) = 57.51$, $p < .001$; $F_1(1,56) = 85.85$, $p < .001$, and $F_2(1,46) = 76.16$, $p < .001$].

100-msec SOA. The 19-msec priming effect was significant [$F_1(1,56) = 22.61$, $p < .001$, and $F_2(1,46) = 34.70$, $p < .001$] and did not interact with concreteness (both Fs < 1), although planned comparisons showed that the priming effect for abstract targets (see Table 5) did not reach significance in the participants analysis [$F_1(1,56) = 3.83$, $p < .06$, and $F_2(1,46) = 4.62$, $p < .05$ (for abstract targets); $F_1(1,56) = 15.74$, $p < .001$, and $F_2(1,46) = 38.20$, $p < .001$ (for concrete targets)].

A second ANOVA revealed that the effect of prime type on the percentage of errors to the words did not reach significance [$F_1(1,56) = 2.37$, $p < .14$, and $F_2(1,46) = 1.59$, $p < .22$], although the concreteness effect did [$F_1(1,56) = 14.27$, $p < .001$, and $F_2(1,46) = 4.73$, $p < .05$]. The overall percentage of errors was higher for abstract words than for concrete words (8% vs. 6%). The interaction between prime type and concreteness also tended toward significance [$F_1(1,56) = 3.92$, $p < .06$, and $F_2(1,46) = 3.06$, $p < .10$].

Discussion

Experiment 1 showed a significant translation priming effect from L1 to L2 for both the 250-msec and the 100-msec SOA conditions, with the latter effect being weaker. In other words, the priming effect decreased with decreasing SOA, but was still significant at the 100-msec SOA. These findings are consistent with earlier studies showing that L1–L2 translation priming is a robust finding in bilingual word recognition, even at very short SOAs (see, e.g., Gollan et al., 1997; Jiang, 1999; Jiang & Forster, 2001; Kim & Davis, 2003). In Experiment 2, we tested whether translation priming from L2 to L1 could be obtained using the same stimuli. The L2 targets from Experiment 1 were now L2 primes, whereas the L1 primes from Experiment 1 were now L1 targets (see Table 2).

EXPERIMENT 2
Translation Priming From L2 to L1

Method

Participants. Sixty new Dutch–English bilinguals from Ghent University took part in this experiment for course credit. The mean age was 20.22 years ($SD = 2.33$). They belonged to the same population as, and had a similar L2 history to, the participants in Experiment 1.

Stimuli. The 52 English word targets of Experiment 1 and their respective Dutch translation primes were used again, but now as English (L2) translation primes and corresponding Dutch (L1) word targets, respectively (see Table 2 and Appendix B). The average $\log_{10}$ of the printed frequency (per million) for these targets was 1.92 (range from 0.60 to 3.14). The 52 Dutch nonword targets satisfied the criteria mentioned in Experiment 1 (all ps $> .60$, two-tailed t tests). English unrelated primes and Dutch nonwords (following Dutch grapheme–phoneme conversion rules) were selected, also following the same criteria described in Experiment 1 (all ps $> .25$; see Table 3).

Design and Procedure. The design and procedure of the present experiment were identical to those of Experiment 1. Only the languages of primes and targets were reversed.

Results

Less than 1% of all correct word trials (97%) were outliers and they were therefore excluded from all analyses. Because of a malfunctioning response box, the data of 1 participant could not be analyzed and were discarded from the analyses. We also excluded the translation of the excluded abstract and concrete target mentioned in Experiment 1.

An ANOVA was performed with prime type (translation vs. unrelated) and concreteness (abstract vs. concrete) as repeated measures factors. The SOA (250 vs. 100 msec) was treated as a between-subjects variable in the participants analysis, and as a within-items variable in the item analysis. Dutch targets preceded by their English translation (510 msec) were recognized faster than were those preceded by an unrelated English word (530 msec). This 20-msec priming effect was significant [$F_1(1,55) = 22.01$, $p < .001$, and $F_2(1,46) = 16.00$, $p < .001$], and so was the main effect of SOA [$F_1(1,55) = 4.83$, $p < .05$, and $F_2(1,46) = 149.30$, $p < .001$]. The interaction between prime type and SOA did not reach significance [$F_1(1,55) = 2.85$, $p < .10$, and $F_2(1,46) = 1.40$, $p < .24$], although numerically the priming effect was stronger for the 250-msec SOA condition (28 msec) than for the 100-msec SOA condition (12 msec). The concreteness factor did not lead to significant main or interaction effects (all ps $> .10$).

Table 6
Mean Response Times (RTs, in Milliseconds), Mean Error Rates, and Priming Effects in the Participants Analysis of Experiment 2

			Concreteness			
	Overall		Abstract		Concrete	
L2 to L1	RT	% Error	RT	% Error	RT	% Error
250-msec SOA						
Translation	527	2	528	2	525	1
Unrelated	554	5	554	5	554	4
Priming	+28***		+26**		+29**	
100-msec SOA						
Translation	495	4	495	4	494	3
Unrelated	506	6	502	6	510	5
Priming	+12**		+7		+16*	

*$p < .05$. **$p < .01$. ***$p < .001$.

We will now further examine the pattern of effects for each SOA condition. Mean RTs per SOA are presented in Table 6 as a function of prime type and concreteness.

250-msec SOA. The 28-msec priming effect was significant [$F_1(1,55) = 14.89, p < .001$, and $F_2(1,46) = 7.92, p < .01$]. This effect did not interact with concreteness (both Fs < 1). Planned comparisons showed, however, that the 26-msec priming effect for abstract targets reached significance in the participants analysis only [$F_1(1,55) = 7.33, p < .01$, and $F_2(1,46) = 2.53, p < .12$ (for abstract targets); $F_1(1,55) = 8.22, p < .01$, and $F_2(1,46) = 5.71, p < .05$ (for concrete targets)].

100-msec SOA. This 12-msec priming effect was significant [$F_1(1,55) = 7.12, p < .01$, and $F_2(1,46) = 14.11, p < .001$]. It did not interact with concreteness (both Fs < 1), although planned comparisons showed that the 16-msec priming effect for concrete targets reached significance [$F_1(1,55) = 6.71, p < .05$, and $F_2(1,46) = 14.11, p < .001$], whereas the 7-msec priming effect for abstract targets did not [$F_1(1,55) = 1.48, p < .23$, and $F_2(1,46) = 2.42, p < .13$].

A second ANOVA revealed that the effect of prime type on the percentage of errors to the words was significant [$F_1(1,55) = 8.22, p < .01$, and $F_2(1,46) = 12.93, p < .001$]. Participants recognized Dutch targets preceded by an unrelated English word less accurately than they did those preceded by their English translation (5% vs. 3%). The concreteness and SOA factors did not lead to significant main or interaction effects (all ps $> .10$).

Combined analysis for Experiments 1 and 2. To test for a translation priming asymmetry, we analyzed the data from Experiments 1 and 2 in one design. A t test indicated that the participants' relative L2 proficiency (see Table 4) in both translation priming experiments (from L1 to L2 and vice versa) was comparable ($p > .25$) and thus ensured comparable groups of participants. Hence, a four-way ANOVA was run with direction (L1–L2 vs. L2–L1) as an additional between-subjects factor in the participants analysis and as a within-items factor in the item analysis. We again treated the mean RT on correct trials as the dependent variable. As was expected, the overall translation priming effect was significant (40 msec) [$F_1(1,111) = 187.90, p < .001$, and $F_2(1,46) = 130.40, p < .001$]. The main effect of direction was also significant [$F_1(1,111) = 10.20, p < .01$, and $F_2(1,46) = 234.00, p < .001$]; responses to L2 targets (586 msec) were generally slower than to L1 targets (520 msec). Additionally, the main effect of SOA was significant [$F_1(1,111) = 6.40, p < .05$, and $F_2(1,46) = 253.00, p < .001$], as was its interaction with prime type [$F_1(1,111) = 47.60, p < .001$, and $F_2(1,46) = 38.60, p < .001$], and the three-way interaction with prime type and direction of translation [$F_1(1,111) = 29.70, p < .001$, and $F_2(1,46) = 59.80, p < .001$]. In the 250-msec SOA condition, the priming effect interacted significantly with direction of translation [$F_1(1,111) = 64.71, p < .001$, and $F_2(1,46) = 63.24, p < .001$]. The effect of L1 primes on their L2 translations (100 msec; see Table 5) was larger than the effect of L2 primes on their L1 translations (28 msec; see Table 6). In the 100-msec SOA condition, the priming effect interacted significantly with the direction of translation, but only in the participants analysis [$F_1(1,111) = 4.16, p < .05$, and $F_2(1,46) = 3.39, p < .08$]. The effect of L1 primes on their L2 translations (19 msec) was slightly larger than the effect of L2 primes on their L1 translations (12 msec). Except for a weak prime type × concreteness interaction [$F_1(1,111) = 4.40, p < .05$, and $F_2(1,46) = 3.80, p < .06$] (again showing a trend for stronger priming with concrete vs. abstract targets), there were no other significant effects (all ps $> .10$).

Discussion

Experiment 2 showed an overall significant translation priming effect of 20 msec from L2 to L1, for both the 250-msec and the 100-msec SOA conditions (28 and 12 msec, respectively). Numerically, this overall priming effect was 40 msec smaller than the overall priming effect observed in the L1–L2 condition (Experiment 1). The combined analysis of Experiments 1 and 2 confirmed that this difference in priming was significant. Further analyses indicated that the difference in priming was also significant for the 250-msec SOA condition (100 vs. 28 msec), but not quite for the 100-msec SOA condition (19 vs. 12 msec). In general, the expected translation priming asymmetry in the lexical decision task was observed. Important to note, however, is that the L2–L1 translation priming effect was significant. So, the difference in priming was a quantitative one, rather than a qualitative one.

EXPERIMENT 3
Cross-Language Semantic Priming From L1 to L2

To gain further insight into the language asymmetry in the masked cross-language priming paradigm, we ran two more experiments using cross-language semantic priming. As is shown in Table 1, the evidence for a language asymmetry is much less clear for this particular paradigm. Basnight-Brown and Altarriba (2007) found no priming in either direction, whereas Perea et al. (2008) found priming effects of a very similar magnitude in each direction.

In a similar cross-language semantic priming paradigm, Duyck (2005) observed asymmetric priming (from L1 to L2, but not vice versa) with pseudohomophones of semantically related words in the prime position. Thus, it remains to be seen whether the cross-language semantic priming effect can be replicated, and if so, whether the effects are asymmetrical or not.

In Experiment 3, we examined cross-language semantic priming from L1 to L2, using the same target words as in Experiment 1. The primes were semantic associates of the targets, as was the case in the previously reported cross-language semantic priming studies reported in Table 1. As before, half of the stimuli were abstract words, whereas the other half were concrete words (see Table 2).

Method

Participants. Sixty-two new Dutch–English bilinguals from Ghent University took part in the experiment for course credit. The mean age was 19.80 years (*SD* = 1.91). They were selected from the same population as, and had a similar L2 history to, did the participants in Experiments 1 and 2.

Stimuli and Design. All target stimuli were identical to those in Experiment 1. Fifty-two Dutch words were selected as semantically related primes, replacing the translation primes of Experiment 1 (see Table 2 and Appendix A). These related primes were selected from the University of South Florida Free Association Norms (Nelson, McEvoy, & Schreiber, 1998). The mean forward cue-to-target strength of English target words and their respective semantically related primes (translated to Dutch) was 0.27 for abstract words and 0.31 for concrete words ($p > .55$, two-tailed t test). Primes for semantically related concrete words were also concrete, whereas primes for semantically related abstract words were also abstract. In addition, 52 Dutch words were selected as unrelated primes, again closely matched item by item to the semantically related primes, following the same criteria as in Experiments 1 and 2 (all $ps > .25$, two-tailed t tests; see Table 3). Two matched presentation lists were constructed (counterbalanced over participants). This resulted in a 2 (prime type: semantically related vs. unrelated) × 2 (concreteness: abstract vs. concrete) × 2 (SOA: 250 vs. 100 msec) design, with the first two variables as repeated measures, and with SOA as a between-subjects, but within-items, variable.

Procedure. The same procedure as in Experiments 1 and 2 was used for stimulus presentation and data collection.

Results

Less than 1% of all correct word trials (95%) were outliers, and they were therefore excluded from analyses. One participant responded incorrectly to more than 25% of the word trials, and was discarded from the analyses. Additionally, one abstract and one concrete target word were misjudged by more than 25% of all participants, and one concrete target word seemed to have an unforeseen semantic relationship with its unrelated prime. These items were also discarded from the analyses (see Appendix A).

An ANOVA was performed with prime type (semantically related vs. unrelated) and concreteness (abstract vs. concrete) as repeated measures factors. The SOA (250 vs. 100 msec) was again treated as a between-subjects variable in the participants analysis, and as a within-items variable in the item analysis. English targets preceded by a semantically related Dutch word (584 msec) were recognized faster than were those preceded by an unrelated Dutch word (597 msec). This 13-msec priming effect was significant [$F_1(1,57) = 10.25$, $p < .01$, and $F_2(1,45) = 7.48$, $p < .01$]. The main effect of SOA was significant in the item analysis [$F_1(1,57) = 3.14$, $p < .09$, and $F_2(1,45) = 44.13$, $p < .001$], whereas the interaction between prime type and SOA reached significance only in the participants analysis [$F_1(1,57) = 8.03$, $p < .01$, and $F_2(1,45) = 2.56$, $p < .12$]. However, numerically the priming effect was stronger for the 250-msec SOA condition (23 msec) than for the 100-msec SOA condition (4 msec). The concreteness factor did not lead to significant main or interaction effects (all $ps > .10$).

We will now further examine the pattern of effects per SOA condition. The mean RTs per SOA are presented in Table 7 as a function of prime type and concreteness.

250-msec SOA. The 23-msec priming effect was significant [$F_1(1,57) = 13.21$, $p < .001$, and $F_2(1,45) = 5.17$, $p < .05$]. This effect did not interact with concreteness (both $Fs < 1$). Planned comparisons showed that the 19-msec priming effect for abstract targets did not reach significance [$F_1(1,57) = 3.65$, $p < .07$, and $F_2(1,45) = 1.54$, $p < .23$], whereas the 26-msec priming effect for concrete items did in the participants analysis [$F_1(1,57) = 8.27$, $p < .01$, and $F_2(1,45) = 3.87$, $p < .06$].

100-msec SOA. The 4-msec priming effect was not significant [$F_1 < 1$, and $F_2(1,45) = 1.19$, $p < .29$]. This effect did not interact significantly with concreteness (both $Fs < 1$), although numerically concrete targets

Table 7
Mean Response Times (RTs, in Milliseconds), Mean Error Rates, and Priming Effects in the Participants Analysis of Experiment 3

			Concreteness			
	Overall		Abstract		Concrete	
L1 to L2	RT	% Error	RT	% Error	RT	% Error
250-msec SOA						
Cross-language semantic	597	4	603	4	591	6
Unrelated	620	6	622	7	617	6
Priming	$+23^{***}$		$+19^{\sim}$		$+26^{**}$	
100-msec SOA						
Cross-language semantic	570	5	572	4	568	4
Unrelated	574	7	572	5	575	6
Priming	+4		0		+7	

$^{\sim}p < .1$. $^{**}p < .01$. $^{***}p < .001$.

(7 msec) showed larger priming than did the abstract targets (0 msec).

ANOVAs on the percentage of errors to words yielded no significant effects.

Discussion

We found a significant cross-language semantic priming effect from L1 to L2 when using a 250-msec SOA, but not when using a 100-msec SOA. On the one hand, finding an effect in the 250-msec SOA condition is consistent with the data observed in recent semantic priming studies by Duyck (2005; employing a 114-msec SOA). On the other hand, not finding a significant semantic priming effect from L1 to L2 in the 100-msec SOA condition is in line with the findings of Basnight-Brown and Altarriba (2007; employing a 100-msec SOA). Note, however, that Perea et al. (2008) found significant cross-language semantic priming effects with an SOA as short as 47 msec in balanced bilinguals. This finding shows that L1 to L2 semantic priming is possible to obtain, provided that the SOA is long enough or that participants are proficient enough. Before further discussing these observations, we will first present the data of Experiment 4.

EXPERIMENT 4
Cross-Language Semantic Priming From L2 to L1

In Experiment 4, we used L2 primes and L1 targets. In order to preserve the same association strength from prime to target as in Experiment 3, we translated the L1 prime (to L2) and the L2 target (to L1) from Experiment 3 instead of swapping them. Examples for abstract and concrete conditions are shown in Table 2.

Method

Participants. Sixty new Dutch–English bilingual volunteers participated in this experiment. The mean age was 21.49 years (*SD* = 2.57). They were drawn from the same population as, and had a similar L2 history to, the participants in Experiments 1–3.

Stimuli. The 52 L1 word targets were the Dutch translations of the English primes in Experiment 3. The L2 semantically related primes were the English translations of the Dutch targets in Experiment 3 (see Table 2 and Appendix B). This approach ensured that the same concepts were used across both cross-language semantic priming experiments. English unrelated primes and Dutch nonwords were selected and controlled as in the previous experiments.

Design and Procedure. The design and procedure were identical to those of Experiment 3.

Results

Less than 1% of all correct word trials (96%) were outliers, and they were therefore excluded. One participant responded incorrectly to more than 25% of the word trials and was discarded from the analyses. We also excluded the translation of the excluded abstract and concrete targets in Experiment 3 (see Appendix B).

An ANOVA was performed with prime type (semantically related vs. unrelated) and concreteness (abstract vs. concrete) as repeated measures factors. The SOA (250 vs. 100 msec) was treated as a between-subjects variable in the participants analysis, and as a within-items variable in the item analysis. Dutch targets preceded by a semantically related word in English (535 msec) were recognized faster than were those preceded by an unrelated English word (545 msec). This 10-msec priming effect was significant [$F_1(1,55) = 9.33$, $p < .01$, and $F_2(1,45) = 6.20$, $p < .05$]. The main effect of SOA was also significant [$F_1(1,55) = 9.00$, $p < .01$, and $F_2(1,45) = 157.80$, $p < .001$], but did not significantly interact with prime type (both *F*s < 1). However, numerically the priming effect was stronger in the 250-msec SOA condition (12 msec) than in the 100-msec SOA condition (8 msec). The main effect of concreteness was significant, but only in the participants analysis [$F_1(1,55) = 5.57$, $p < .05$, and $F_2(1,45) = 2.00$, $p < .17$]. All other effects were not significant (all *p*s > .10).

We will now further examine the pattern of effects per SOA condition. Mean RTs per SOA are presented in Table 8 by prime type and concreteness.

250-msec SOA. The 12-msec priming effect was significant [$F_1(1,55) = 4.71$, $p < .05$, and $F_2(1,45) = 4.16$, $p < .05$]. This effect did not interact with concreteness (both *F*s < 1). Planned comparisons showed that the 7-msec priming effect for abstract targets did not reach significance (both *F*s < 1), whereas the 17-msec priming effect for concrete targets did [$F_1(1,55) = 5.62$, $p < .05$, and $F_2(1,45) = 5.03$, $p < .05$].

Table 8
Mean Response Times (RTs, in Milliseconds), Mean Error Rates, and Priming Effects in the Participants Analysis of Experiment 4

	Overall		Concreteness: Abstract		Concreteness: Concrete	
L2 to L1	RT	% Error	RT	% Error	RT	% Error
250-msec SOA						
Cross-language semantic	563	5	560	5	566	5
Unrelated	575	3	567	6	583	5
Priming	+12*		+7		+17*	
100-msec SOA						
Cross-language semantic	507	5	506	5	508	5
Unrelated	515	6	508	3	521	3
Priming	+8*		+2		+13*	

*$p < .05$.

100-msec SOA. This 8-msec priming effect was significant [$F_1(1,55) = 5.10$, $p < .05$, and $F_2(1,45) = 4.09$, $p < .05$]. This effect did not interact with concreteness (both Fs < 1), although planned comparisons showed that the priming effect for abstract targets (2 msec) was not significant (both Fs < 1), whereas the numerically larger priming effect for concrete targets (13 msec) was [$F_1(1,55) = 5.51$, $p < .05$, and $F_2(1,45) = 5.86$, $p < .05$].

ANOVAs on the percentage of errors to words did not yield any significant effects.

Combined analysis for Experiments 3 and 4. To test for differences between cross-language semantic priming in both directions, we analyzed the data from Experiments 3 and 4 in one design. A *t* test again indicated that participants' relative L2 proficiency (see Table 4) in both cross-language semantic priming experiments (from L1 to L2 and vice versa) was comparable ($p > .63$), and thus ensured comparable groups of participants. Therefore, a four-way ANOVA was run with direction (L1–L2 vs. L2–L1) as an additional between-subjects factor in the participants analysis and as a within-items factor in the item analysis, and the mean RT on correct trials was run as the dependent variable. The overall cross-language semantic priming effect (12 msec) was significant [$F_1(1,112) = 19.40$, $p < .001$, and $F_2(1,45) = 12.10$, $p < .001$]. As in translation priming (Experiments 1 and 2), responses to L2 targets (590 msec) were slower than they were to L1 targets (540 msec) [$F_1(1,112) = 11.97$, $p < .001$, and $F_2(1,45) = 84.70$, $p < .001$]. Additionally, the main effect of SOA was significant [$F_1(1,112) = 11.23$, $p < .001$, and $F_2(1,45) = 239.70$, $p < .001$]. Although numerically, the semantically related priming effect of L1 primes on L2 targets (13 msec) was somewhat larger than the effect of L2 primes on L1 targets (10 msec), this interaction was not significant (both Fs < 1). Likewise, the three-way interaction between SOA, prime type, and direction did not reach significance [$F_1(1,112) = 3.09$, $p < .09$, and $F_2(1,45) = 1.0$, $p < .33$], which was confirmed by planning comparisons showing no prime type × direction interaction in both the 250- and 100-msec SOA conditions (all ps $> .10$). Except for a weak concreteness × direction of translation interaction [$F_1(1,112) = 4.15$, $p < .05$, and $F_2(1,45) = 1.90$, $p < .18$] (showing a trend for faster processing of abstract targets relative to concrete targets in the L2–L1 direction only), there were no other significant effects (all ps $> .10$).

Discussion

Experiment 4 showed a significant L2 to L1 cross-language semantic priming effect, regardless of the SOA condition. The combined analysis for Experiments 3 and 4 further showed that the overall cross-language priming effect did not interact with the direction of priming (from L1 to L2, or vice versa). Cross-language semantic priming did not seem to be asymmetric in any of the SOA conditions. These findings are in line with those of Perea et al. (2008), who reported symmetric priming effects for balanced bilinguals.

GENERAL DISCUSSION

The present study tested translation priming and cross-language semantic priming from L1 to L2 and vice versa in unbalanced Dutch–English bilinguals. We used a lexical decision task with noncognate prime–target pairs. In Experiment 1, we replicated the translation priming effect from L1 to L2 with Dutch–English bilinguals (e.g., *meisje*–GIRL). The results of Experiment 2 showed a reliable translation priming effect from L2 to L1 (e.g., *girl*–MEISJE), in contrast with a number of previous studies that failed to find such effects (Table 1). Experiment 3 and Experiment 4 added to the very small amount of literature on cross-language semantic priming. These experiments showed that such priming can be observed both from L1 to L2 (e.g., *jongen* [*boy*]–GIRL; Experiment 3), and from L2 to L1 (e.g., *boy*–MEISJE [GIRL]; Experiment 4). Although there was a consistent trend for larger priming effects with concrete words than with abstract words, none of the cross-language priming effects interacted significantly with concreteness. We tested a 250-msec SOA condition, as well as a shorter 100-msec SOA condition. The longer SOA boosted the priming effects but did not change the

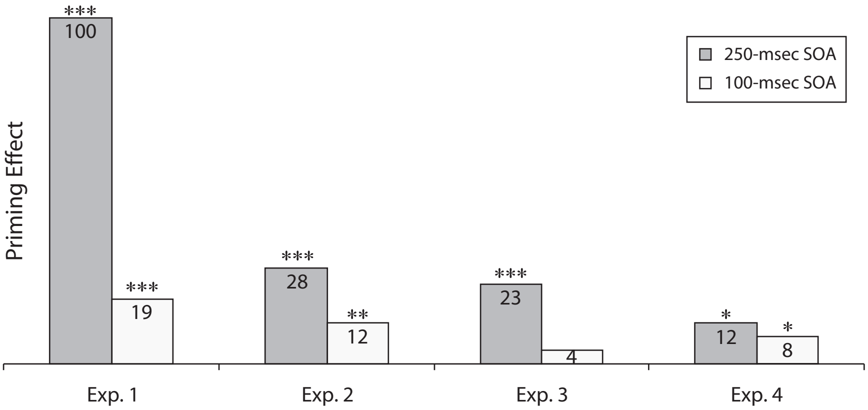

Figure 1. Priming effects (in milliseconds) for both SOA conditions in all four experiments. Significant effects (planned comparisons) are marked with an asterisk: *$p < .05$. **$p < .01$. ***$p < .001$.

Table 9
Priming Effects on Lexical Decision Response Times (in Milliseconds) for the Present Masked Cross-Language Priming Study Using Noncognate Stimuli

	Script	Bilinguals	Stimuli (Concreteness/Freq.)	*N*	*n*	Authors	Prime	Blank	Mask	SOA	L1 to L2	L2 to L1
Translation priming	Comparable	Dutch (L1)–English (L2)	abstract vs. concrete	20	26[a]	Schoonbaert et al.	50	50	150	250	100*	28*
				40		(Exps. 1 and 2)	50	–	50	100	19*	12*
Cross-lingual semantic priming	Comparable	Dutch (L1)–English (L2)	abstract vs. concrete	20	26[a]	Schoonbaert et al.	50	50	150	250	23*	12*
				40		(Exps. 3 and 4)	50	–	50	100	4	8*

Note—All priming effects were computed relative to an unrelated baseline condition. *N*, number of participants per experiment; *n*, number of observations per condition per participant. [a]Collapsed across concreteness levels (to increase comparability with the other studies). $^*p < .05$.

overall pattern of effects (only the L1 to L2 semantic priming effect did not reach significance in the 100-msec SOA condition; see Figure 1).[3] Overall, we found clear masked priming effects in both the 250-msec and the 100-msec SOA conditions.

The data of our experiments (summarized in Table 9), together with the overview of previous studies in Table 1, reveal some of the factors that affect masked cross-language priming. One conclusion that clearly stands out is that none of the factors involves a qualitative difference. It is not the case that cross-language priming is possible from L1 on L2, but not from L2 on L1. Similarly, it is not the case that cross-language priming is limited to translation primes and cannot be observed for semantic primes. In the same vein, it is not the case that priming is limited to words referring to concrete objects or to persons. Finally, it is not the case that priming is observed at long SOAs only. Rather, the pattern of results that emerges is one of quantitative differences: The priming effect is larger from L1 on L2 than from L2 on L1; it is larger for translation priming than for semantic priming; it is slightly (but not significantly) larger for concrete words than for abstract words; and it is larger for a long SOA than for a short SOA (in particular for translation priming).

Given these quantitative rather than qualitative differences, it seems unnecessary to assume a model with different mechanisms for different types/languages of targets and primes to understand cross-language priming. It is better to use a model that relies on a single mechanism for all types of stimuli. One such model is the DRM proposed by de Groot and colleagues (de Groot, 1992a, 1992b, 1993; de Groot, Dannenburg, & van Hell, 1994; de Groot & Hoeks, 1995; van Hell & de Groot, 1998a, 1998b). This model can account for our data set through a single, parsimonious mechanism of gradual spreading of activation. The DRM assumes that word translation times and priming effects depend on the number of semantic features shared by the L1 word and the L2 word. This idea was picked up by Duyck and Brysbaert (2004), who proposed a reformulation of the classical RHM to explain a consistent pattern of semantic effects in the translation of L1 and L2 number words (which have almost maximal semantic similarity across languages). A similar idea was also proposed in the sense model of Finkbeiner et al. (2004), in which they assumed that cross-language priming effects depend on the proportion of senses shared by the L1 and L2 word.

Our account in terms of the DRM builds on several additional assumptions that have been made in other studies or that can be defended. First, for unbalanced bilinguals, we assume that the semantic representation is richer for the dominant language than for the secondary language (for a similar view, see Tokowicz, Kroll, de Groot, & van Hell, 2002, p. 439; see also Duyck & Brysbaert, 2002, 2004). This means that, in general, more conceptual nodes will be activated by L1 words than by L2 words. A similar idea can again be found in the sense model, where it is assumed that the proportion of (shared) senses activated by an L1 prime is much higher than the proportion of senses activated by an L2 prime. This assumption was supported by evidence showing within-language semantic priming from many to few sense words, but not from few to many sense words (see Finkbeiner et al., 2004). Second, the semantic overlap is assumed to be larger for translations than for semantically related and associated words (see, e.g., de Groot & Nas, 1991). This means that more shared conceptual nodes will be activated by a translation prime than by a semantically related prime. Third, there is more overlap in the semantic representations of L1 and L2 translations for concrete words than for abstract words. This means that more shared conceptual nodes will be activated by concrete primes than by abstract primes (de Groot, 1992a, 1992b, 1993; de Groot et al., 1994; de Groot & Hoeks, 1995; van Hell & de Groot, 1998a, 1998b). This assumption is supported by the significant correlation that has been found between ratings of semantic similarity of translation pairs and the concreteness ratings of those words (Tokowicz et al., 2002).

Figure 2 shows how the DRM could explain the different findings by assuming that the magnitude of the priming effect depends on the proportion of the target's conceptual nodes that are activated by the prime. First, it easily explains why translation priming is typically stronger than semantic priming, since a translation prime shares more conceptual nodes with the target than with a

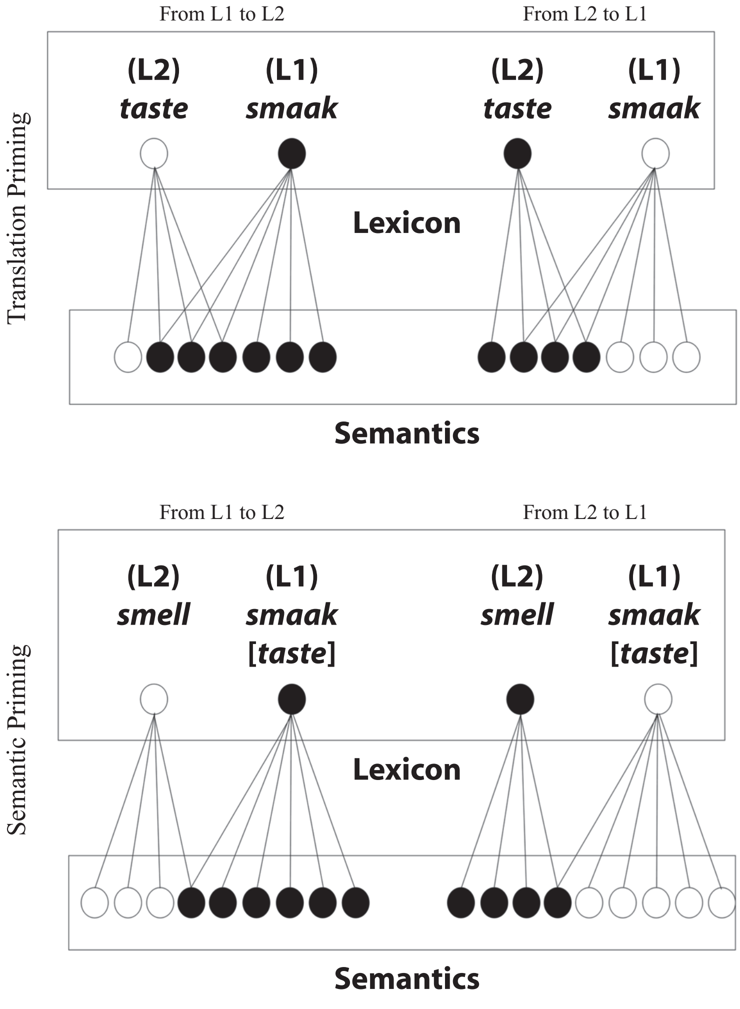

Figure 2. A refined version of the distributed representation model of bilingual conceptual memory first presented by Duyck and Brysbaert (2004). According to this model, the degree of cross-language priming depends on the percentage of semantic nodes connected to the target that are activated by the prime. In the upper-left panel, we see that three out of four nodes connected to the L2 word *taste* are activated by the L1 translation prime *smaak*. This will result in a good deal of priming. Priming will be less when an L1 target is preceded by its L2 translation (upper-right panel), since in this case, only three of the six nodes connected to the L1 target are activated by the L2 prime. The same principle can explain why semantic priming is less strong than translation priming (fewer shared nodes activated) and why the language asymmetry here is smaller (see the lower panel of the figure).

semantically related prime (compare the upper panel of Figure 2 with the lower panel).

Second, it also accounts for the finding that priming from L1 to L2 is stronger than priming from L2 to L1. As long as an L2 prime activates only a subset of the L1 target's conceptual nodes, the percentage of activated conceptual nodes will be lower than 100% (compare the right figure in each panel of Figure 2 with the left figure). An objection to this interpretation might be that the absolute number of shared activated conceptual nodes is the same from L1 to L2 as it is from L2 to L1 (e.g., five in the upper panel of Figure 2 and two in the lower panel). However, it is common practice in connectionist modeling to correct the connection weights for the number of connections, so that a node connected to 100 other nodes does not change the activation of all of those 100 to the same extent as does a node that is only connected to 10 others (Cohen & Grossberg, 1987). Similarly, a node that receives input from 20 nodes does not receive the same amount of activation from each node as does a node that receives input from only 2 nodes. Otherwise, the former node would always dominate the latter. More fundamentally, this normalization prohibits that a word or concept is activated by only a few of its features and thus attempts to minimize the amount of false positives.

Our data also showed a translation priming asymmetry (Experiments 1 and 2), as opposed to more symmetric results in cross-language semantic priming (Experiments 3 and 4). An additional joint analysis of the four experiments further confirmed this by a three-way interaction.[4] This finding can be accounted for by the model in Figure 2 if we assume that the difference in the number of shared features activated by L1 and L2 is bigger in the case of translation priming than in the case of semantic priming (compare the difference in activated shared features by an L1 translation prime vs. an L2 translation prime in the upper panel, in comparison with the difference in shared features activated by both the L1 and the L2 cross-language semantically related prime in the lower panel).

Finally, the degree of priming will also differ as a function of the percentage of conceptual nodes that are shared by the L1 and the L2 nodes. Priming will be stronger for two translations that share a lot of their features than for translations that share only a few of their nodes (i.e., because they have several meanings and senses that are not present in the other language; see also Finkbeiner et al., 2004). Assuming that the overlap is greater for concrete words than for abstract words, this predicts more cross-language priming for the former than for the latter. This assumption is more tentative, since our results suggest that the average difference between both types of words probably is not very large (and was not significant in our studies). The major selling point of the DRM in the present study is that it can explain the gradual, quantitative (and not qualitative) differences observed in the present cross-language priming experiments. The cross-language semantic priming experiment from L2 to L1 may have taken this quantitative difference near the limit, meaning that it provided the weakest, but still significant, overall priming effect. In other studies, using bilinguals with different proficiency levels, other stimuli, and other SOAs, this threshold for observing significant priming may be different—for example, resulting in a null effect for L2 to L1 translation priming.

A final element that may contribute to the differences between L1 and L2 priming concerns the speed with which L1 and L2 words can activate the conceptual features. Several authors assume that form and meaning activation may take more time in L2 than in L1 (e.g., the bilingual interactive activation model by Dijkstra & Van Heuven, 2002; Grainger & Frenck-Mestre, 1998). Tables 1 and 9 show that the cross-language priming effect from L1 to L2 increases with increasing SOA (as was also exemplified by the significant prime × SOA interaction in Experiments 1 and 3). The same seems to be true for the translation priming from L2 to L1 (although the prime × SOA interaction was not significant in Experiments 2 and 4). Interestingly, this delay may explain why L2 to L1 priming seems to be less strong when the scripts of the languages differ (see Table 1). An advantage of a shared script is that many of the early processes in word recognition (e.g., letter identification, phonological coding) can be shared between L2 and L1, so that L2 word recognition can profit from the already well-established and fast-operating L1 machinery (see Brysbaert & Van Wijnendaele, 2003, and MacWhinney, 1997, for evidence along these lines). In contrast, the processing of words in a different script relies on other processes that are not as well practiced as the processes of L1, so they take more time to complete.

Interestingly, the model depicted in Figure 2 suggests that all differences in translation priming and cross-language semantic priming can be explained on the basis of the semantically mediated route. This seems to go against the RHM (Kroll & Stewart, 1994), which postulates an important role for the direct word–word connections between L1 and L2. The reason we cannot use the word–word associations to explain the cross-language priming effects is that these associations result in wrong predictions. First, because the word–word associations are supposed to be stronger from L2 to L1 than from L1 to L2, one would have to predict stronger translation priming from L2 on L1 than the other way around. This is not in line with any of the evidence obtained (Tables 1 and 9). Second, because semantic priming cannot be based on direct connections between the words in the different lexicons (these are limited to translation equivalents), the RHM would be more comfortable with an absence of cross-language semantic priming than with the significant effect observed in Experiment 4 (see also Perea et al., 2008). Indeed, Kroll and Stewart (1994, p. 167) used the absence of cross-language semantic priming from L2 to L1 as evidence for the strong word–word connections from L2 to L1.

To conclude, the present experiments showed that translation priming and semantic cross-language priming can be generalized to a new population—namely, unbalanced Dutch–English bilinguals. We also showed that the much-debated priming effect from L2 to L1 does exist, but that it is weaker than the reverse effect, using exactly the same stimuli and type of bilinguals. This asymmetry was more clearly present for translation priming than for cross-language semantic priming. Finally, we believe that the overall data pattern indicates that the difference between the processing of L1 and L2, between translation and cross-language semantic associates, and maybe even between concrete and abstract words, is a quantitative difference rather than a qualitative one—at least if one accepts that translation and semantic priming are conceptually mediated and not based on direct lexical connections.

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NOTES

1. Note that we limited the present overview of cross-language priming to recognition studies (using a lexical decision task). We mentioned only priming studies using noncognate translation pairs, because the special status of cognate stimuli is beyond the scope of the present article.

2. We thank an anonymous reviewer for this suggestion.

3. Note that the interaction between SOA and prime type did not reach significance in the items analyses for cross-language semantic priming. Semantic priming was less boosted by the use of a longer SOA (250 vs. 100 msec). This finding is also supported by a semantic priming study by Perea and Rosa (2002a) that showed comparable masked priming effects for three SOA conditions (66, 116, and 166 msec).

4. An analysis across all four experiments revealed a significant three-way interaction between priming (related vs. unrelated), direction (L1–L2 vs. L2–L1), and relation (translation vs. semantically related) [$F_1(1,223) = 29.50$, $p < .001$; $F_2(1,45) = 18.6$, $p < .001$].

APPENDIX A
Word Targets and Corresponding Primes Used in Experiments 1 and 3

English (L2) Target	Dutch (L1) Translation	Dutch (L1) Control for Translation	Dutch (L1) Related	Dutch (L1) Control for Related
		Abstract		
AREA	gebied	helpen	streek	moreel
TRUTH	waarheid	zekerheid	leugen	keuken
FUTURE	toekomst	toestand	verleden	herhalen
HONOR	eer	bar	hulde	harem
FEELING	gevoel	geheel	stemming	bewering
MARRIAGE	huwelijk	zedelijk	scheiding	socioloog
AGE	leeftijd	bezoeker	jaren	laten
WEAKNESS	zwakte	vlakte	sterkte	spreker
SPACE	ruimte	eerste	komeet	ruiter
RUMOR[ab]	gerucht	kruisen	roddel	roepen
PEACE	vrede	feit	oorlog	minuut
SOUL	ziel	geel	geest	tekst
QUESTION	vraag	hoofd	antwoord	concreet
DISTANCE	afstand	verstand	mijl	film
STORY	verhaal	periode	sprookje	schroom
LANGUAGE	taal	hals	spaans	staand
LIFE	leven	lopen	dood	arts
DANGER	gevaar	gebaar	risico	crisis
CRIME	misdaad	kermis	getuige	functie
TASTE	smaak	blaas	geur	werk
LAW	wet	wip	regel	kerel
HABIT	gewoonte	behoefte	ritueel	titelen
CHOICE	keuze	derde	optie	notie
LOSS	verlies	telkens	winst	angst
ABUSE	misbruik	bestaand	gebruik	gebouwd
DOUBT	twijfel	terrein	schaamte	patiente
		Concrete		
COLOR	kleur	blaar	verf	grof
SUNSHINE	zonneschijn	clandestien	straal	stroom
CEILING[ab]	plafond	plagend	vloer	bloem
RAIN	regen	roman	paraplu	paradox
CURTAIN	gordijn	verstaan	douche	schuld
FATHER	vader	kamer	moeder	verder
FIRE	vuur	haar	draak	grond
BULLET	kogel	gevel	geweer	dekker
QUEEN	koningin	kapitein	koning	mening
EARTH	aarde	aardig	hemel	heling
MOUNTAIN	berg	kerk	heuvel	geheim
GIRL	meisje	koffie	jongen	voegen
RABBIT	konijn	muziek	wortel	gordel
ANIMAL	dier	hier	boerderij	spoorlijn
CHILD	kind	eind	ouder	baden
CASTLE	kasteel	voorstel	paleis	dansen
BODY[b]	lichaam	reactie	lijk	hals
HUMAN	mens	mond	wezen	groen
SNAKE	slang	staal	hagedis	dateren
CHAIR	stoel	geest	zitplaats	diagonaal
KEY	sleutel	ongeluk	slot	dank
BUILDING	gebouw	gebrek	kantoor	venster
BRACELET	armband	wasbak	halssnoer	samenstel
PLANE	vliegtuig	vloedgolf	vlucht	sluis
TRIANGLE	driehoek	vrijheid	vierkant	ledikant
BEACH	strand	middag	schelp	scherm

[a]Removed from Experiment 1. [b]Removed from Experiment 3.

APPENDIX B
Word Targets and Corresponding Primes Used in Experiments 2 and 4

Dutch (L1) Target	English (L2) Translation	English (L2) Control for Translation	English (L2) Related	English (L2) Control for Related
		Abstract		
GEBIED	area	fuel	region	regime
WAARHEID	truth	north	lie	pie
TOEKOMST	future	little	past	cast
EER	honor	labor	tribute	crackle
GEVOEL	feeling	reality	mood	whom
HUWELIJK	marriage	continue	divorce	dispose
LEEFTIJD	age	she	years	sense
ZWAKTE	weakness	awakening	strength	eyesight
RUIMTE	space	force	comet	comer
GERUCHT[a][b]	rumor	rural	gossip	glance
VREDE	peace	sense	war	far
ZIEL	soul	goal	spirit	poison
VRAAG	question	business	answer	appear
AFSTAND	distance	instance	mile	hope
VERHAAL	story	yours	fairytale	rationale
TAAL	language	landlord	spanish	measure
LEVEN	life	like	death	reach
GEVAAR	danger	badger	risk	rich
MISDAAD	crime	prime	witness	vicious
SMAAK	taste	basic	smell	smile
WET	law	how	rule	hide
GEWOONTE	habit	visit	ritual	attain
KEUZE	choice	anyone	option	hardly
VERLIES	loss	lass	profit	tragic
MISBRUIK	abuse	bushy	use	ask
TWIJFEL	doubt	short	shame	pause
		Concrete		
KLEUR	color	solar	paint	month
ZONNESCHIJN	sunshine	crushing	ray	hay
PLAFOND[a][b]	ceiling	decline	floor	clock
REGEN	rain	ruin	umbrella	wherever
GORDIJN	curtain	surgeon	shower	supper
VADER	father	matter	mother	number
VUUR	fire	work	dragon	tricky
KOGEL	bullet	valley	gun	gap
KONINGIN	queen	learn	king	sing
AARDE	earth	early	heaven	chapel
BERG	mountain	position	hill	hall
MEISJE	girl	high	boy	day
KONIJN	rabbit	credit	carrot	mellow
DIER	animal	origin	farm	burn
KIND	child	which	parent	amount
KASTEEL	castle	vastly	palace	malice
LICHAAM[b]	body	very	corpse	corner
MENS	human	woman	being	penny
SLANG	snake	snack	lizard	lethal
STOEL	chair	night	seat	sort
SLEUTEL	key	new	lock	loan
GEBOUW	building	bulletin	office	others
ARMBAND	bracelet	brandish	necklace	navigate
VLIEGTUIG	plane	close	flight	slight
DRIEHOEK	triangle	printing	square	nature
STRAND	beach	black	shell	soup

[a]Removed from Experiment 2. [b]Removed from Experiment 4.

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