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How cross-language similarity and task demands affect cognate recognition

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ABSTRACT

This study examines how the cross-linguistic similarity of translation equivalents affects bilingual word recognition. Performing one of three tasks, Dutch–English bilinguals processed cognates with varying degrees of form overlap between their English and Dutch counterparts (e.g., *lamp–lamp* vs. *flood-vloed* vs. *song-lied*). In lexical decision, reaction times decreased going from translation equivalents without any cross-linguistic orthographic overlap to very similar but non-identical cognates. Identical cognates showed a large discontinuous processing advantage and were subject to facilitation from phonological similarity. In language decision, the effect of orthographic similarity reversed: a cognate inhibition effect arose, the size of which increased with orthographic similarity. Here identical cognates were markedly slower than other cognates. In progressive demasking, no orthographic similarity effect was found for non-identical cognates, but a semantic similarity effect arose. In addition, there was a facilitation effect for identical cognates of low English frequency. The task-dependent result patterns are interpreted in terms of four accounts of cognate representation and provide evidence in favor of a localist connectionist account.

Introduction

Consider the following text (after Peter Verstegen): *Drink gin in restaurant, whiskey in hotel, champagne in bed. Later effect: Oh God, migraine. Tablet in warm water!* The remarkable property of this story is that both Dutch and English monolinguals can understand it perfectly, because it is composed entirely of words with the same form and meaning in the two languages. Translation equivalents that are identical or similar in their orthography across languages are usually referred to as 'cognates'. The cross-linguistic form overlap of cognates has been used by researchers to explore whether words from different languages are co-activated during the reading, listening, and speaking of bilinguals. If responses to such 'special' items differ from those to language-specific control items, this can be seen as evidence that both readings of the cognates have become active and affect each other.

The cognate facilitation effect

In many reaction time (RT) studies, involving a variety of experimental paradigms, cognates were responded to faster than control words that exist in only one language. This *cognate facilitation effect* has since long been established by studies on bilingual word recognition in the visual modality (e.g., Caramazza & Brones, 1979; Cristoffanini, Kirsner, & Milech, 1986; De Groot & Nas, 1991; Dijkstra, Grainger, & van Heuven, 1999; Dijkstra, van Jaarsveld, & ten Brinke, 1998; Dufour & Kroll, 1995; Kroll & Stewart, 1994; Lavaur & Font, 1998; Lemhöfer et al., 2008; Sánchez-Casas, Davis, & García-Albea, 1992; Schwartz, Kroll, & Diaz, 2007; Voga & Grainger, 2007). However, the effect has also been observed in the auditory modality (Marian & Spivey, 2003) and in word production

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(Costa, Caramazza, & Sebastian-Galles, 2000; Costa, Santesteban, & Cano, 2005; Kroll & Stewart, 1994). The observed cognate facilitation effect is usually larger in the second language (L2) than in the first language (L1) (Kroll, Dijkstra, Janssen, & Schriefers, 1999), but it can appear even in pure L1 contexts (Van Hell & Dijkstra, 2002). The cognate effect has also been observed in bilinguals using different scripts (Gollan, Forster, & Frost, 1997; Kim & Davis, 2003). Stronger facilitation effects can arise if the cognates in question exist in three languages rather than in two (Lemhöfer, Dijkstra, & Michel, 2004). Recent evidence indicates that cognate effects can be modulated by sentence context (Duyck, Van Assche, Drieghe, & Hartsuiker, 2007; Schwartz & Kroll, 2006; Van Hell & De Groot, 2008). Brain activity during cognate processing is also under study using electrophysiological and neuroimaging methods (e.g., De Bleser et al., 2003; Dijkstra, van Hell, & Brenders, in preparation). Again, these studies indicate that cognates are processed differently from controls.

The cognate facilitation effect has often been taken as evidence for a bilingual lexicon that stores words of two or more languages in an integrated fashion and/or for a lexical access procedure that activates word candidates in several languages in parallel. The effect has also been considered as evidence against the hypothesis that the orthographic and semantic representations of form-identical and similar cognates across languages are accessed in a language-selective way (Gerard & Scarborough, 1989; Smith, 1997). As such, cognates have been very useful as tools to investigate the language (non)specificity of lexical access in bilinguals (see Friel & Kennison, 2001).

Nevertheless, the precise representation of cognates remains a hotly debated topic (cf. Costa et al., 2005). Over the years, several theoretical accounts have been proposed. In the present study, we seeked to test and further develop these accounts by manipulating the cross-linguistic similarity of the cognate readings, and by comparing cognate processing in three different tasks. In our first experiment, we applied an English lexical decision task to examine the effects of cross-linguistic orthographic variation in cognates on processing; in our second and third experiment, we used largely the same stimulus materials in two different tasks, namely language decision and progressive demasking. In the remainder of this introduction, we will first discuss four theoretical accounts for cognate representation and processing, and then consider their predictions with respect to non-identical cognates (e.g., *tomato* in English, the translation equivalent of *tomaat* in Dutch). The task dependence of cognate effects and the related predictions of the four accounts will be considered before presenting Experiment 2.

Four positions on cognate representation and processing

Identical cognates are often assumed to have largely shared orthographic and semantic representations across languages. However, with respect to the representation of non-identical but similar cognates, at least four theoretical positions can be discerned (see Fig. 1 for a simplified graphical description, ignoring phonological and sublexical aspects).

One position is to assume that, as a consequence of their cross-linguistic form and meaning overlap, non-identical cognates have developed a single 'special' morphological representation that is not present for non-cognate translations (panel a in Fig. 1). For instance, the English word *tomato* and the Dutch word *tomaat* may share a morphological representation, which underlies the cognate facilitation effect observed in the studies mentioned above. This is a position taken by Kirsner et al. (Cristoffanini et al., 1986; Kirsner, Lalor, & Hird, 1993; Lalor & Kirsner, 2000) and Sánchez-Casas et al. (Sánchez-Casas, Davis, & García-Albea, 1992; Sánchez-Casas & García-Albea, 2005). These researchers have especially attempted to demonstrate that a shared morphological representation for cognates exists, but they have not specified this representation in detail (see Voga & Grainger, 2007, Fig. 1, for a proposal). It seems reasonable to assume that the shared morphological representation will be stronger for higher-frequency cognates than for lower frequency cognates. Therefore, the cognate facilitation effect should be larger for higher-frequency cognates. Furthermore, in order to establish a 'special' cross-linguistic morphological representation between two translation equivalents, these should probably share a minimal degree of cross-linguistic similarity. After all, the shared morphological representation is proposed only for (form-similar) cognates, not for just any translation equivalent.

A second theoretical position holds that translation equivalents, both non-identical cognates and non-cognates, are characterized by shared semantic representations and linked word form representations (panel b in Fig. 1). For instance, the Dutch–English cognate pair *tomaat–tomato* might have a common meaning representation and two linked lexically-orthographic representations (De Groot & Nas, 1991). In the theoretical framework of the Revised Hierarchical Model (Kroll & Stewart, 1994, pp. 162–166), the link would be associative in nature and therefore its strength would depend on the word frequency of the items involved. An analogous associative link would exist for non-cognate translation pairs (such as *man-hombre*). The cognate facilitation effect in this view would be found especially for L2 and would be a consequence of a faster retrieval of the L2 word meaning via the form-similar L1 word form. For example, in Dutch–English bilinguals, the English (L2) word form *tomato* would quickly activate the overlapping Dutch (L1) word form *tomaat* and then its meaning. This process would take place more quickly than for translation equivalents that do not share form overlap, such as English *bike* and Dutch *fiets*. In line with this argumentation, Kroll and Stewart (1994, p. 166) reported that 'words that are cognates in Dutch and English ... (were) translated more rapidly than non-cognates' and that 'naming latencies in L2 were long when an L1 cognate had a different pronunciation, and they were fast when an L2 cognate had the same pronunciation.' The same argumentation might apply to cognates processed in other tasks.

A third theoretical position is that of subsymbolic, distributed connectionist models (panel c in Fig. 1). According to this position, (bilingual) word recognition can be seen as following a path towards the target word in a multidimensional space set up with orthographic, phonological and

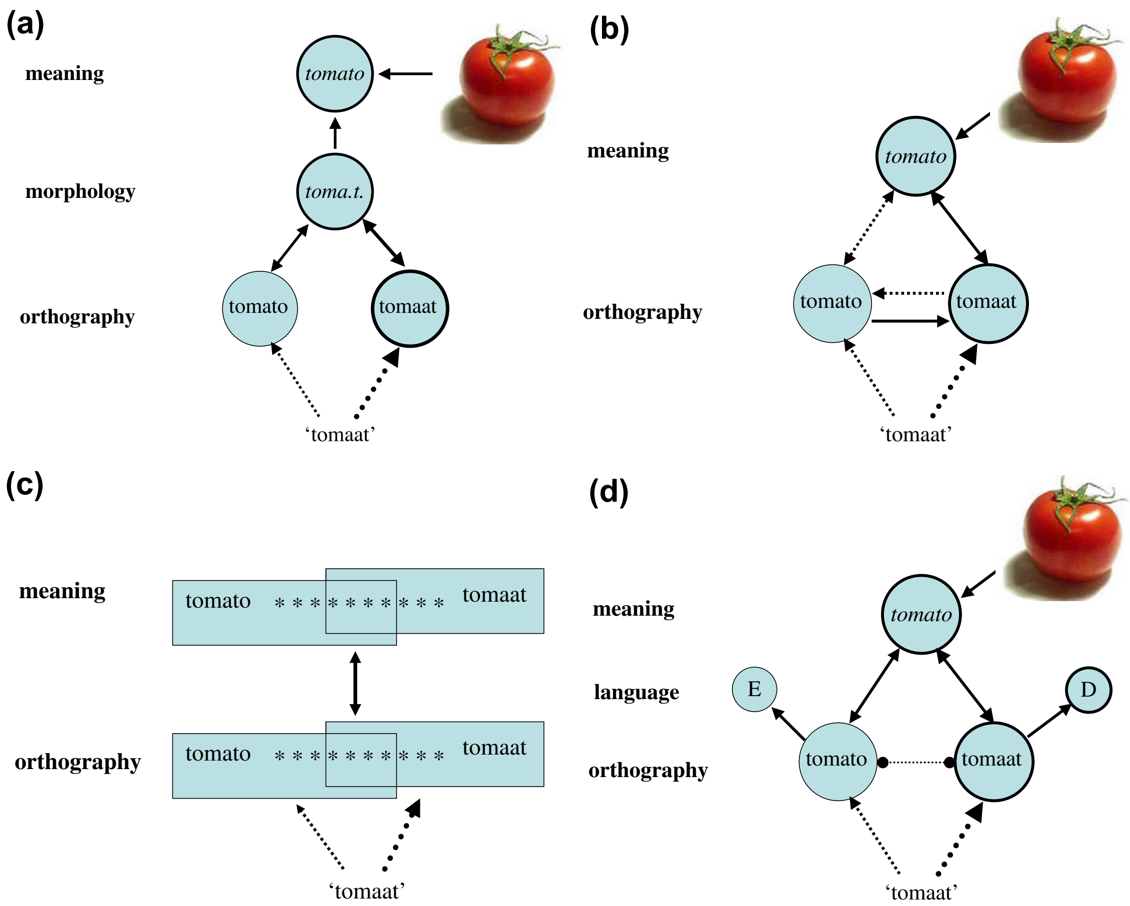

Fig. 1. (a–d) Graphical illustration of four theoretical positions on cognate representation. Input is the Dutch word *tomaat*, meaning 'tomato' in English. Dutch is assumed to be L1 and English is L2. Panel a: shared morphological representation; panel b: associatively linked orthographic representations; panel c: distributed connectionist representations; and panel d: localist connectionist representations. To facilitate the comparison of the four models, the models are simplified. Shared sublexical representations (in terms of graphemes or phonemes) are not indicated. In addition, linked lexical and sublexical phonological representations have been omitted.

semantic features as axis dimensions (see, e.g., de Groot, 1992; French & Jacquet, 2004; Thomas, 1997; Thomas & Van Heuven, 2005). Because they share so many orthographic and semantic features, the two members of a cognate pair are functioning as attractors that are closely positioned together in this multidimensional space. Said differently, their cross-linguistic similarity makes them stronger attractors than non-cognates, which affects their speed of retrieval. The degree of cross-linguistic similarity a cognate possesses is therefore an important determiner of its identification time. Frequency of cognate usage is such a determiner as well, because it will strengthen the attractors' force.

A fourth theoretical position assumes a symbolic, localist connectionist framework. As in the distributed connectionist approach, cognate translation equivalents are only 'special' relative to non-cognate translations in that they share more orthographic, semantic, and/or phonological features across languages (Dijkstra et al., 1999; Voga & Grainger, 2007; panel d in Fig. 1). According to this account, the cognate facilitation effect in reading might in fact be an orthographic–semantic priming effect: overlapping orthographic and semantic representations of both languages become active upon the presentation of one of the readings of the cognate, leading to a facilitated recognition of cognates relative to non-cognates. In this view, the cognate facilitation effect depends on both cross-linguistic similarity (e.g., number of shared letters in comparable word positions) and word frequency. Both a larger similarity of the two readings of a cognate and a higher frequency result in a more strongly activated shared semantic representation. Note that this view also predicts a cognate facilitation effect for cognates that partly share their phonological representations (not indicated in Fig. 1, panel d). The various model predictions are summarized in Table 1.

The cognate facilitation effect and cross-linguistic similarity

In many studies, the cognate facilitation effect is measured by comparing RTs for cognates and matched language-specific control words. Dijkstra et al. (1999) let Dutch–English bilinguals perform an English lexical decision task or an English progressive demasking task, in

Table 1
The predictions of four theoretical positions on cognate representation for three experimental tasks and the empirical data from this study.

Theoretical approach	Lexical decision (Exp. 1)	Language decision (Exp. 2)	Progressive demasking (Exp. 3)
a. Shared morphological representation	Facilitation depending on word frequency	Facilitation (without a task account) or Inhibition (assuming a task account)	Facilitation depending on word frequency
b. Linked O representations	Facilitation depending on word frequency	Facilitation depending on word frequency (without a task account)	Facilitation depending on word frequency
c. Distributed connectionist	Facilitation depending on O similarity and word frequency	Inhibition depending on O similarity and word frequency (assuming a task account)	Inhibition depending on O similarity and word frequency
d. Localist connectionist	Facilitation depending on O similarity and word frequency	Inhibition depending on O similarity	O similarity effect is canceled out Frequency effect
Empirical findings	Facilitation depending on O similarity and word frequency	Inhibition depending on O similarity	Null-effect for O similarity Frequency effect Semantic overlap effect

O stands for Orthographic. To facilitate model comparisons, sublexical and phonological aspects have been left out. Predictions might change depending on added (task) assumptions.

which they systematically varied the cross-linguistic semantic, orthographic, and phonological similarity of the target items (English 3–5 letter words) with their (not presented) Dutch translation equivalents. The results of both tasks were very similar. Semantic and orthographic overlap exerted a facilitatory effect on the RTs, whereas phonological overlap had an inhibitory effect. For instance, the bilingual participants were found to respond faster to cognates like *type*, which has the same meaning and spelling (but not pronunciation) in Dutch and English than to interlingual homographs like *stage*, which is only spelled the same (but in Dutch is pronounced differently and means 'internship'); both types of items were faster than control words that were completely different across languages. No such cross-linguistic effects were found in an English lexical decision task performed by American English monolinguals, indicating that these findings could not be ascribed to artifacts in the stimulus materials.

Note that this study made a discrete distinction between cognates with maximal cross-linguistic overlap and language-specific controls. However, orthographic identity or maximal phonological overlap are apparently not required for the cognate facilitation effect to arise. Font (2001), in collaboration with Lavaur, examined the processing of 'neighbor cognates' in French and Spanish in different tasks. Neighbor cognates are non-identical cognates that differ in just one letter between languages. In a lexical decision study with French–Spanish bilinguals, Font found that such non-identical cognates were still facilitated relative to language-specific controls, but significantly less than identical cognates. Furthermore, the amount of facilitation depended on the position of the deviating letter in the word. Neighbor cognates with the different letter at the end of the word (e.g., French *texte* – Spanish *texto*) were facilitated more than neighbor cognates with the different letter inside (e.g., French *usuel* – Spanish *usual*). In fact, facilitatory effects for the latter type of cognate disappeared and effects tended towards inhibition when such cognates were of low-frequency in both languages. Similar patterns of results were found in L1 and L2 processing.

These findings beg the question of how the cognate facilitation effect depends on cross-linguistic similarity. If form-identity is not required, how much form overlap between the two readings of a cognate will still induce a facilitation effect? Does the cognate facilitation effect decrease linearly or non-linearly with decreasing form overlap, e.g., going from *tennis* (Dutch: *tennis*) to *coffee* (Dutch: *koffie*) to *rain* (Dutch: *regen*) and *bike* (Dutch: *fiets*)?

The four viewpoints with respect to cognate representation discussed above appear to provide different answers to these questions. If cognates are represented by an all-or-none morphological representation (position 1), cross-linguistic similarity might not be such an important characteristic of cognates (as long as some minimal degree of orthographic and semantic overlap is present, the shared morphological representation would be established); in contrast, the word frequency of the cognates in either or both languages might be a determining factor of the cognate facilitation effect. If cognate representations are linked associatively (position 2), a similar prediction might be made. Because *all* translation equivalents are linked, also those of non-similar translation equivalents, the cross-linguistic similarity of items might be less important than their word frequency in determining the cognate effect. In any case, effects of orthographic similarity in cognates are not specified by this position (see Talamas, Kroll, & Dufour, 1999, for other form similarity effects).

In contrast, the other two theoretical positions discussed above predict that both cross-linguistic similarity and word frequency should be important determinants of cognate recognition time. Interestingly, somewhat different predictions are formulated with respect to this issue by distributed connectionist models such as proposed by Thomas (see Thomas & Van Heuven, 2005), French and Jacquet (2004) and Li and Farkas (2002), relative to localist connectionist models such as BIA (Van Heuven, Dijkstra, & Grainger, 1998; Voga & Grainger, 2007) and BIA+ (Dijkstra & Van Heuven, 2002a).

Distributed models (position 3) hold that the two readings for identical and nearly-identical cognates share most of the connections. The English and Dutch representations of these cognates therefore lie closely together in multidimensional space. Responses to such cognates should be faster than for control words, because, being in the same region, the attractors of the two representations of a cognate exert a joint force. Responses to decreasingly similar cognates should become slower and slower because the joint force decreases. There does not appear to be an obvious reason why the reduction in attractor strength would not be linear, although distributed models are known for their non-linear dynamics and actual simulations with a distributed model could prove this statement wrong. In any case, a sharp rise in RTs would not be expected when one compares form-identical to slightly non-identical cognates.

Localist models (position 4) leave open the possibility that there is a single symbolic representation for identical cognates, but two representations for non-identical cognates. If these localist models are right, a slight change in similarity from identical to nearly-identical cognates should have a catastrophic (i.e., either discontinuous or markedly non-linear) effect on cognate recognition speed. This is because the introduction of even a small mismatch implies that, instead of one representation (for form-identical cognates), participants activate two representations that inhibit each other via *lateral inhibition*. Lateral inhibition is a competitive mechanism between representations of the same level in localist connectionist models; its effects become stronger if there is more similarity between the representations concerned. This lateral inhibition would cause a sharp increase in RTs in *nearly*-identical cognates relative to *fully* identical cognates. If the similarity of cognate stimuli to their translations decreases further, the additional effect would not be as large as before, because the number of activated representations remains the same. As an example, consider the English–Dutch cognate pairs *lamp–lamp*, *train–trein*, and *tower–toren*. Other things being equal, the models predict a large RT-difference between the cognate *lamp*, having a perfect form overlap with its in the translation equivalent other language, and *train*, with just a small form difference. However, the difference between *train* and *tower*, having a larger form difference across languages, should be much smaller.

In the present study, we tested the four models against each other in two ways. We first tested the models' predictions with respect to the sensitivity of the cognate effect to cross-linguistic similarity in a lexical decision study. A continuum of cognates was selected that varied in their cross-linguistic similarity between complete form-identity and complete lack of orthographic overlap. Next, we considered how the models handled variations in task demands by examining cognate processing in two other tasks, language decision and progressive demasking. Before presenting the three experiments, we report a rating study set up for optimal stimulus selection.

Rating study

The rating study was designed to construct a list of words on a continuum ranging from completely identical cognates, via (semantically equivalent) translation equivalents that moderately resemble each other with respect to orthography and phonology, to words that have a completely different form in two languages. The stimulus materials in the three experiments were selected on the basis of this study.

Method

Participants

Twenty-four subjects (mean age 23.4 years, *SD* 2.0, 21 women, 3 men) took part in this experiment. They were all 3rd and 4th year students of Radboud University Nijmegen. They all had Dutch as their native language and had experience with the English language for at least 8 years (mean 11.75). In their study, they used English almost on a daily basis for reading literature and surfing the Internet. They were paid for participating or received course credit.

Stimulus materials

To obtain a list of test word pairs with a variable degree of cross-linguistic orthographic and phonological overlap (from identity to no overlap whatsoever), we had participants rate a large number of English–Dutch word pairs that were translations of each other (e.g., *bike* – *fiets*). The translation pairs to be evaluated were drawn from the Celex database (Baayen, Piepenbrock, & Van Rijn, 1993). The total number of translation pairs in the database used was roughly 25,000. Next, only translation pairs were selected for which the English member consisted of 4–6 letters and its Dutch counterpart of less than seven letters, and for which the two counterparts had some orthographic or phonological overlap. This selection resulted in a list of 1500 candidates.

Next, a measure of cross-linguistic orthographic similarity was computed for all remaining word pairs. The number of letters in corresponding positions of all these word pairs were counted, as well as the number of letters for which the position in the word had shifted one letter to the right or left. One point was given to every same-position letter and a half point to every moved-position letter. The total number of points for each word pair was then divided by the mean number of letters in the word pair. This resulted in an orthographic similarity score.

All 1500 words were then arranged from high to low orthographic similarity according to this score. Word pairs of which the English member had more than one high-frequency Dutch translation and was not a content word, were deleted from this list. From the remaining list, 180 word pairs were selected, ranging from high similarity score to low similarity score. Next, another group of 180 control words was selected, all of which had a similarity score below 2 and were approximately matched in terms of word length and word frequency. By selecting these two groups of items varying in similarity ratings, it was ensured that cognate-like items did not dominate the ultimate list of 360 items.

However, the orthographic similarity measure suffered from some problems. For example, a word pair, differing in length, in which only the final letters of both words match, would receive a relatively low similarity score, though the words in the pair could actually be quite similar. An example are the Dutch–English translation equivalents *fase* and *phase*. Furthermore, the measure did not take into account the cross-linguistic overlap in semantics and phonology. A recomputation of the orthographic similarity score for all items using Van Orden's (1987) similarity measure or the Longest Common Subsequence Ratio (LCSR; Melamed, 1999) would not solve these problems. We therefore resorted to collecting orthographic, phonological, and semantic overlap ratings from bilingual participants belonging to the same population for which we intended to conduct on-line experiments later. The selected 360 test items were distributed across three base lists of 120 Dutch–English translation pairs each. Of each base list, 24 pseudo-randomly mixed versions were made, one for each participant.

Procedure

Participants were seated in a normally lit room at a distance of 60 cm of a computer screen. They rated three lists of Dutch–English item pairs for cross-linguistic similarity by choosing a similarity rating on a seven point rating scale. One list had to be rated for orthographic (O) similarity, one for semantic (S) similarity, and one for phonological (P) similarity. The order of S, O, and P ratings was counter-balanced across participants. Because every participant only rated one of the three lists for S, and the other lists for O and P, every word was rated for S by only one third of the participants (by eight participants). The same was true for O and P. Each item appearing on the computer screen was followed by seven little circles that could be activated by a mouse click. Participants were instructed to click the leftmost circle if they thought there was no similarity at all between the words in a pair, and the rightmost circle if they thought there was perfect similarity between the words in a pair. They were also asked to immediately write down a word if it was not familiar to them. Finally, the participants completed a checklist that measured their experience with the English language.

Results

First, the mean ratings for S, O, and P were computed for each word pair, using all data (see Appendix A). Next, to decide if the O rating was a reliable measure, the correlation was determined between the O rating and the O measure as computed by the formula described earlier. This correlation turned out to be quite high (0.96). The correlation between the O and the P ratings was of similar strength (0.94). Fourteen items that were marked as unfamiliar by more than one participant or had a mean S-rating that was lower than 6, were removed from the data. Due to their relatively small cross-linguistic semantic overlap, such items do not conform to the standard definition of cognates. For the remaining 346 items, there was no significant correlation between their O- or P-rating scores and their English frequency, as indicated by correlations of 0 and -0.04, respectively.

Discussion

The item set that was ultimately selected has a number of properties. The highly significant correlation of the ratings for cross-linguistic orthographic overlap and the O-measures indicates that the two measures reflect more or less the same dimension. The O- and P-ratings are about equally distributed over the whole judgment scale, suggesting that participants were able to rate the stimuli in a sensitive way. The O- and P-ratings also show a similar rating pattern, as reflected in the high correlation ($r = .94$, $p < .001$) between them. Furthermore, the English frequency of the words was not correlated with their O- and P-ratings. This suggests participants were not influenced by the English frequency of the items while they were judging the orthographic or phonological similarities of the item pairs. In the three experiments to be described, selections of the items obtained in the rating task were used as stimulus materials. Note that following this approach, it was not *a priori* necessary to decide if a particular item was to be considered as a cognate or a non-cognate, thus avoiding artifacts in allocating particular items to one group or the other.

Experiment 1: English lexical decision

In Experiment 1, we conducted a lexical decision task involving English words that were translation equivalents varying on a cross-linguistic similarity (cognate to non-cognate) dimension. Assuming that an item will be recognized more easily when it has a translation equivalent that overlaps orthographically to a larger extent, we predict a negative linear relationship between orthographic overlap and RT for non-identical cognates. In other words, RTs should become monotonously faster if the cross-linguistic orthographic overlap of the two members of a translation pair increases. Depending on the bilingual word recognition model used for the predictions, RTs should gradually become shorter when similarity increases (distributed connectionist models) or gradually become shorter with similarity but show a steep decline going from non-identical to identical cognates (localist connectionist models).

Method

Participants

Twenty-three subjects (mean age 23, *SD* 3.1; 20 women, 3 men) took part in this experiment. They were drawn from the same population as in the rating study. They all had experience with the English language for at least 8 years (mean 11.3).

Stimulus materials

A selection was made out of the 360 stimuli used in the rating experiment. First, all words that were either unknown to some participants or were rated lower than 6 on the rating scale for semantic (S) similarity were taken out of the stimulus list. Next, a total number of 194 stimuli was selected, consisting of 97 words with similarity scores above 2, and 97 words with similarity scores below 2 that were matched with respect to English word frequency as indicated by non-significant *t*-tests (for a list of the stimuli used in Experiment 1, see Appendix A). This ensured that the proportion of form-similar translation equivalents in the experiment remained limited. Note that only the English member of the word pair was presented to the participants. Next, 194 non-words were derived from English words that were not used in the experiment to equate the proportion of required yes and no responses on the task (see Appendix B). Finally, six dummy items were added that preceded the test items during trial breaks. To present every participant with a different order of items, 23 pseudo-randomized list versions were made, with no more than four cognates, matched controls, or non-words in a row.

Procedure

All experiments were run on a Macintosh computer using software developed by the Technical Group of the Donders Centre for Cognition. Participants were seated in a normally lit room at a distance of 60 cm of a computer screen. They were instructed in English to push the right button of a button box when a presented letter string was an existing English word and the left button when it was not. Stimuli were presented in black 18-point lowercase Courier letters on a white background.

At the beginning of the experiment, participants pushed a button to start a practice block of 18 items including cognates, non-cognates, and non-words. Subsequently, the experimental items were presented in four blocks. A new trial started 1500 ms after the participant responded to an item, or 1500 ms after the maximum response time of 2 s was exceeded.

Results

First, we discarded the data from two participants who performed the task with an error rate of more than 15%. Eleven words (*tenant*, *oath*, *cork*, *rifle*, *napkin*, *choir*, *alley*, *saddle*, *throne*, *tire*, and *treaty*) elicited more than 30% errors and were removed. We also removed data points with RTs less than 300 ms from the data set. This left us with 3747 data points. Inspection of the distribution of the response latencies revealed marked non-normality. A comparison of a log transform and an inverse transform showed that the inverse transform was most successful in attenuating this non-normality. We therefore opted for an inverse transform, RT = −1000/RT, scaled by 1000, to avoid very small values for the dependent variable, and multiplied by −1 to ensure the transformed RTs and the original RTs are positively correlated instead of negatively correlated.

We analyzed the response latencies with a linear mixed effects model with subject and word as crossed random effects (see, e.g., Bates, Maechler, & Dai, 2007; Baayen, 2008; Baayen, Davidson, & Bates, 2008, and references cited there). We first fitted a model to the data, including all 3735 data points. Next, we removed potentially harmful outliers (defined as data points with standardized residuals exceeding 2.5 standard deviation units) from the data set (less than 3% of the data). We then fitted a new model with the same predictors to this trimmed data set. It is for this trimmed model that we report the parameters and their associated statistics.

We first fitted a simple main effects model to the data set, with as predictors the Orthographic Rating, the Phonological Rating, and log transformed Frequency (the word's lemma frequency as available in the CELEX lexical database), and random intercepts for subjects and for words. We explored the predictivity of the 2 (highly correlated) ratings. Although both emerged with significant negative slopes when considered in isolation, a model including both selected the Orthographic Rating as significant, rejecting the Phonological Rating ($t = -0.6$). Clearly, the Orthographic Rating is the superior predictor.

However, a reviewer suggested to us that for words sharing exactly the same form in English and Dutch, an effect of phonological similarity might be observed. In order to test this possibility, we introduced a factor *Same* specifying whether the English and Dutch written forms are identical. The factor had the levels Identical Cognates and Other Words, for identical cognates and other items (non-identical cognates and non-cognates), respectively. Furthermore, we orthogonalized the 2 ratings by regressing the Phonological Ratings on the Orthographic Ratings, and replacing the original Phonological Ratings by the residuals of this linear model. The residualized Phonological Ratings were positively correlated with the original ratings ($r = .34$, $p < .0001$) and can be interpreted as a measure of phonological similarity uncontaminated by orthographic similarity. In order to allow for a phonological effect specific to words with the same orthographic form, we introduced an interaction of Same by residualized Phonological Rating into the model specification.

Table 2 summarizes the coefficients of the fixed effects of the resulting model, as well as their 95% Highest Posterior Density (HPD) intervals and *p*-values based on 10,000 Markov Chain Monte Carlo samples of the posterior samples of the parameters. The standard deviation for the by-item random intercepts was 0.11, that for the by-subject random intercepts was 0.24, and that of the residual error was 0.28. Fig. 2 visualizes the partial effects of orthographic similarity rating (panel a) and (log) English frequency (panel b). As expected, panel (a) shows that the effect of orthographic similarity for non-identical cognates was facilitatory and linear in nature, and also illustrates the discontinuity in the effect of orthographic similarity for identical cognates with average phonological similarity. The effect of Frequency was also facilitatory, as can be seen in panel (b) of Fig. 2.

Interestingly, phonological similarity revealed an additional effect, but only for identical cognates (sharing exactly the same spelling). As shown in panel (c) of Fig. 2, phonological facilitation was absent for non-identical cognates, and increased to a 100 ms effect for identical cognates with a very high phonological similarity (i.e., for the item type called 'SOP cognate' by Dijkstra et al., 1999). The same effects are mirrored in the analysis of the accuracy measure (see Table 3), with higher accuracy replacing shorter RTs.[1]

[1] Very similar results are obtained when the Orthographic Rating is dichotomized into high (>2) and low ($\leqslant$2), although in general dichotomization is not advisable (see, e.g., Cohen, 1983; MacCallum, Zhang, Preacher, & Rucker, 2002).

Table 2
Coefficients of Orthographic Rating, English frequency, Phonological Rating, Same written form (reference level: other words) and the interaction of (orthogonalized) Phonological Rating by Same, in the regression model for the response latencies in Experiment 1 (lexical decision), together with the lower and upper bounds of the corresponding Highest Posterior Density credible intervals, and *p*-values based on 10,000 Markov Chain Monte Carlo samples of the posterior distributions of the parameters.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC
(Intercept)	−1.524	−1.5206	−1.6309	−1.4069	0.0001
PrevRT	0.0752	0.0779	0.0513	0.1033	0.0001
O Rating	−0.0103	−0.0103	−0.0206	−0.0001	0.0492
Log English Frequency	−0.0533	−0.0532	−0.0694	−0.0373	0.0001
Same (identical cognates)	−0.1297	−0.1300	−0.2051	−0.0509	0.0008
P-Rating residual	0.0024	0.0025	−0.0229	0.0281	0.8432
Same (identical cognates) by P-Rating residual	−0.1032	−0.1036	−0.1906	−0.0143	0.0210

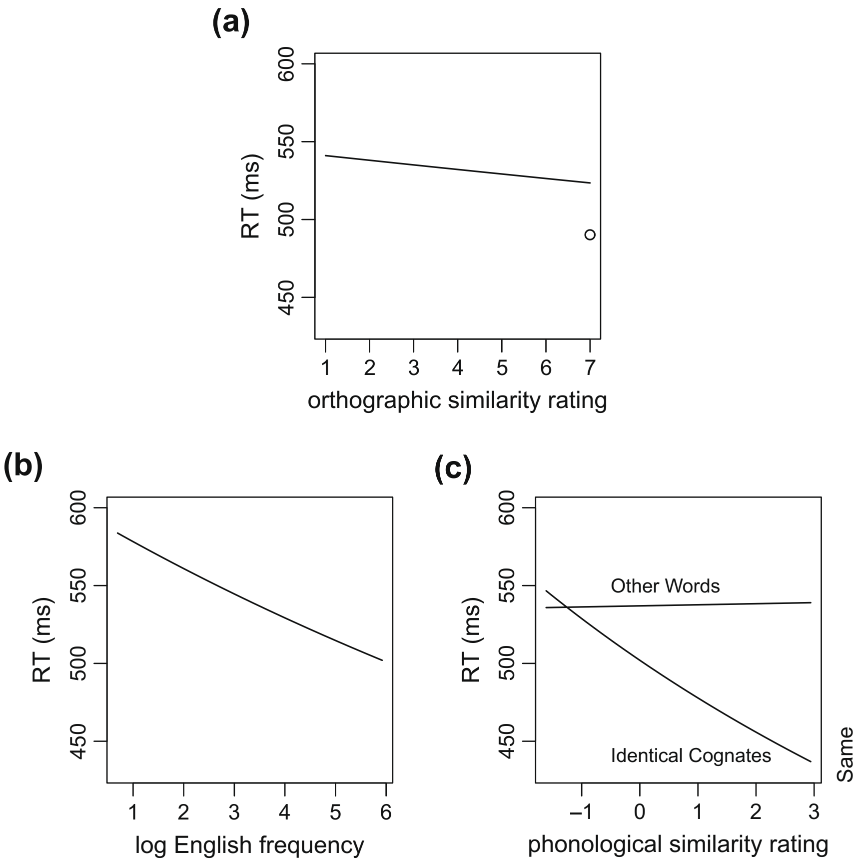

Fig. 2. Experiment 1 (English lexical decision). Effects of orthographic similarity (panel a), English word frequency (panel b), and (residualized) phonological similarity in interaction with the identity factor *Same* (panel c), for lexical decision latencies. Panel (a) illustrates the discontinuity for identical cognates for words with mean (residualized) phonological similarity rating. For RT and accuracy data, see Table 2 and Table 3, respectively.

Table 3
Coefficients (on logit scale) of the logistic regression model for the accuracy data of Experiment 1 (lexical decision). Higher coefficients indicate greater probabilities for correct responses.

	Estimate	Std. error	*z* Value	*p* Value
(Intercept)	0.1042	0.4509	0.231	0.8173
O Rating	0.2091	0.0756	2.764	0.0057
Log English Frequency	0.8500	0.1184	7.179	<0.0001
Same (identical cognates)	2.6796	1.7532	1.528	0.1264
P Rating	−0.2388	0.1960	−1.218	0.2230
Same (identical cognates) by P Rating	2.9342	1.6498	1.779	0.0753

Discussion

The responses in English lexical decision became faster when the cross-linguistic orthographic similarity of the English target words with their Dutch translation equivalent increased. The effect was largest when items were orthographically identical across languages, i.e., for identical cognates. A cognate facilitation effect was also found when items were not completely identical across languages, indicating that only a partial similarity is sufficient for the cognate facilitation effect to arise. For identical cognates, and only for identical cognates, a large facilitatory effect of phonological similarity was present. This finding is in line with the finding of Schwartz et al. (2007, p. 120) that cognates with high orthographic similarity across languages were named faster when they had a highly similar phonological code than when they were more distinct.

The observed effects for non-identical cognates and non-cognates were dependent on both cross-linguistic orthographic similarity and English word frequency. According to one interpretation of the shared morphological representation hypothesis, similarity should not play an important role as soon as it is above a threshold; the results are not favorable to this view. For the position that cognates have associatively linked form representations and (largely) shared semantics, the same conclusion holds: cognate effects depended on word frequency, but also varied gradually with orthographic overlap, which was not necessarily expected.

Connectionist models correctly predicted the dependence of cognate effects on both word form frequency and cross-linguistic similarity. Interestingly, for words with average residualized Phonological Rating (0), response latencies were some 50 ms shorter, suggesting that there is indeed a catastrophic degradation in performance when going from full identity to close similarity. This finding can be seen as evidence supporting localist connectionist accounts of the cognate facilitation effect. When cross-linguistic orthographic similarity changed from complete identity to near-complete identity, a sharp increase in RTs was observed (relative to RT changes as a result of further decreases in cross-linguistic orthographic similarity (see Fig. 2, panel a). This increase is predicted by localist connectionist models as a consequence of the presence of lateral inhibition between different representations and its absence for one, identical, representation. It remains to be shown that this discontinuity can also be accounted for by distributed connectionist models.

Remarkably, the response to identical cognates also appeared to reflect an effect of phonological identity. In a localist connectionist model, the sudden emergence of this phonological similarity effect in identical cognates could be considered as a consequence of the same mechanism that operated for orthographic similarity, namely lateral inhibition. For matching lexical-phonological representations, lateral inhibition would be absent; in contrast, for very similar phonological representations in the two languages, it would be very strong. Note that distributed connectionist models might expect a phonological similarity effect that would be more gradually dependent on phonological similarity. We will consider the issue of cognate representation in more detail in the General Discussion.

The cognate facilitation effect and task demands

Just like interlingual homograph effects (Dijkstra, 2005; Dijkstra, Timmermans, & Schriefers, 2000; Dijkstra et al., 1998), cognate effects might be task-dependent. Indeed, cognate *inhibition* effects might arise in tasks where two cognate representations need to be distinguished. One such task is the language decision task, which was used by Font (2001) in addition to lexical decision and progressive demasking to examine the processing of 'neighbor cognates' in French and Spanish (see Introduction). Whereas neighbor cognates led to facilitation in lexical decision, they showed inhibition effects in both languages of the French–Spanish bilinguals in language decision. The effects were larger for non-identical cognates with a different letter in internal relative to initial position of the item.

In the present study, we tested the hypothesis of task-dependent cognate effects by means of three tasks. As we saw, in Experiment 1 we used lexical decision, which is a task where the response can benefit from the shared or linked cognate representation. In our next Experiment 2, we used language decision, in which response competition occurs precisely *because* the cognate representation is assumed to be shared or linked. In our Dutch–English language decision task, participants pressed one button if a presented word was Dutch and another button if it was English. In Experiment 3, we used a third task, progressive demasking (see Dufau, Stevens, & Grainger, 2008, for a detailed task description and experimentation software). In this task, letter strings (usually words) are presented, alternated by a mask consisting of a checkerboard pattern. Progressively, the presentation duration of the letter string is prolonged and that of the mask is shortened. Participants press a button as soon as they recognize the word. Subsequently, they type in the word they have recognized. The response time in this task is standardly measured from the onset of the first mask. Note that in progressive demasking (in contrast to lexical decision and language decision), a response can only be given when there is a unique identification of the target word.

The four theoretical positions with respect to cognate representation discussed in the Introduction predict the following outcomes. Suppose cognates share a morphological representation across languages (position 1), possibly with a higher subjective (personal) frequency due to bilingual usage than a matched language-specific control word, and that they can therefore be activated more quickly (cf. Gollan et al., 1997; Gollan, Montoya, Cera, & Sandoval, 2008). This simple theoretical account would predict relatively stable cognate effects across various tasks, because always one and the same shared morphological representation is involved (see Voga & Grainger, 2007, p. 939, for a similar argumentation with respect to masked cognate priming across scripts). Alternatively, a task account could be formulated holding that, as a consequence of the shared representation, inhibition effects arise when the two cognate members must be distinguished for responding, e.g., as in language decision. These inhibition effects should then depend on word frequency rather than on cross-linguistic similarity. Note that this account does not seem to predict the occurrence of null-effects. In progressive demasking, for instance, the shared morphological representation should lead to facilitation, just as in lexical decision. This finding would be in line with the reported high correlations between progressive demasking and lexical decision (Dijkstra & Van Heuven, 1998; Dijkstra et al., 1999).

A similar argumentation can be proposed for the theoretical account that assumes associatively linked form representations for cognates (position 2). If cognates have strongly linked word form representations, frequency-dependent facilitation effects might be predicted for both language decision and progressive demasking, because each form representation of the cognate would benefit from the link (as in word naming). If a task account is added, one might predict inhibition effects for cognates in language decision on the basis of a co-activation of associated representations (e.g., *tomato* and *tomaat*). However, this task account would also lead one to expect inhibition effects for cognates in lexical decision and naming tasks. Instead, such tasks have shown cognate facilitation and not inhibition (e.g., Dijkstra et al., 1998; Schwartz & Kroll, 2006). It therefore appears that this account has some difficulty in explaining Font's (2001) findings of inhibition in language decision.

Because they assume differentiated representations, the connectionist positions (positions 3 and 4) can easily account for cognate inhibition effects by assuming that representations are used differently in different tasks. According to a distributed connectionist approach (position 3), the two representations of a cognate are lying closely together in multidimensional space. This should make them easier (faster) to locate than language-specific control words in lexical decision, but harder to distinguish in both language decision and progressive demasking.

Finally, according to a localist connectionist approach (position 4), the co-activation of two orthographic representations by non-identical cognates should lead to response facilitation in lexical decision, but to response competition in language decision. The underlying lexical activation patterns in the bilingual's lexicon would be the same in both tasks, but the response in language decision would be based on the use of competing language membership nodes, rather than on lexical-orthographic or semantic activation.

In progressive demasking, the situation is more complex. On the one hand, lexical competition between non-identical cognate readings slows the identification of the input letter string. This inhibition effect becomes stronger if the two readings of a cognate are more orthographically similar or of higher frequency. On the other hand, the two readings of a cognate map onto a partially shared semantic representation, feeding back to orthography and leading to a faster response. This facilitation effect becomes stronger with more orthographic overlap or a higher frequency of the cognate. As a result, the combination of lexical inhibition and mediated semantic facilitation in progressive demasking may reduce or even wash out the effects of orthographic similarity on cognate processing. Instead, the RTs to cognates varying in cross-linguistic orthographic similarity are best predicted here by word frequency and *semantic* overlap.

At this moment, the available evidence with respect to this last issue is undecisive. Font (2001) let French–Spanish bilinguals perform a progressive demasking task including cognates and obtained ambiguous results: small inhibition effects arose for non-identical cognates that were only significant in the participant analysis. Lemhöfer et al. (2008) performed a large scale progressive demasking study with 1025 words. Among these were also identical cognates. A small but significant cognate facilitation effect was found.

In the next two experiments, we will test the four accounts in a language decision (Experiment 2) and a progressive demasking task (Experiment 3).

Experiment 2: Dutch–English language decision

Method

Participants

Twenty-four subjects (mean age 22.4 years, *SD* 2.9; 17 women, 7 men) took part in Experiment 2. The participants were from the same population as before. They all had Dutch as their native language and had experience with the English language for at least 6 years (mean 12.2 years).

Stimulus materials

A selection of 314 words was made from the same rated list of 360 words as in Experiment 1. We excluded ambiguous words that were not suited for language decision because they had multiple readings in both languages (e.g., the word form *bad* is ambiguous in the context of language decision, as it can be an English word or the Dutch word for 'bath').

Procedure

Each participant saw one of four subsets of 157 English and 157 Dutch words. Each pseudo-randomized subset was balanced with respect to their word frequency and cognate similarity. As in Experiment 1, the words were presented in black 18-point lowercase Courier letters on a white background. The experiment started with 14 practice trials followed by 314 trials separated into four blocks. The participants were asked to decide whether the presented word is a Dutch word or an English word as quickly and accurately as possible, by pressing the right or the left button of a button box. If the item was a possible word form in both languages (i.e., an identical cognate), they were told to respond to the reading that came to mind first. Response button allocation was counter-balanced across participants to minimize confounding effects of hand dominance. Each participant only saw either the Dutch or the English reading of a given translation pair and responded to an equal number of Dutch and English words.

Results

All participants responded with less than 15% error rate, and the data of no participants were excluded from the

Table 4
The regression model for Experiment 2 (language decision): coefficients, lower and upper boundary of the 95% Highest Posterior Density (HPD) credible interval, and the corresponding value, based on 10,000 Markov Chain Monte Carlo (MCMC) samp*p*-les from the posterior distributions of the parameters.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC
(Intercept)	−1.1987	−1.1993	−1.3262	−1.0793	0.0001
PrevRT	0.1933	0.1933	0.1704	0.2157	0.0001
O Rating	0.0066	0.0066	0.0006	0.0126	0.0308
Same (identical cognates)	−0.1803	−0.1805	−0.4248	0.0529	0.1424
Target language (English)	−0.3868	−0.3857	−0.5069	−0.2633	0.0001
Log Dutch Frequency	−0.0429	−0.0428	−0.0547	−0.0309	0.0001
Same (identical cognates) by Dutch frequency	0.0413	0.0413	0.0097	0.0730	0.0100
Target language (English) by Dutch frequency	0.0500	0.0499	0.0342	0.0657	0.0001

analysis. We excluded 11 words that elicited over 30% error rate (*mythe*, *boot*, *jury*, *hel*, *poet*, *baker*, *teder*, *cool*, *enorm*, *motor*, and *tender*). We further excluded data points with RTs shorter than 300 ms. This left us with 6791 data points.

As in Experiment 1, we applied an inverse transformation to RTs (−1000/RT) and analyzed the data by means of a linear mixed effects analysis with subjects and words as crossed random effects. Only data points with a correct response were analyzed in the RT analysis.

In the final regression model, we included orthographic similarity, Dutch lemma Frequency, Language Membership of the target item, and Previous Trial RT as predictors. Log English Frequency was not significant and dropped out of the model. Potentially harmful outliers with standardized residuals exceeding 2.5 standard deviations were excluded. The model is summarized and visualized in Table 4 and Fig. 3 respectively. All *p*-values were supported by Markov Chain Monte Carlo confidence intervals sampled from the posterior distribution of the predictors. As can be seen in panel (a) of Fig. 3, increasing cross-linguistic orthographic similarity significantly slowed down responses, and there was a disproportionally large RT increase going from nearly-identical to completely identical cognates.[2] As shown in panel (b) for reference level Dutch, faster RTs arose for non-identical cognates and non-cognates (but not for identical cognates) when Dutch word frequency increased. The panels (c) and (d) make a distinction between identical cognates and other items (non-identical cognates and non-cognates) with respect to the interaction between Dutch frequency and language membership. A comparison of these panels shows that the interaction between Dutch frequency and target language (English or Dutch) was reversed depending on whether the item was an identical cognate or not.

Discussion

In language decision, cross-language orthographic similarity had inhibitory effects on RTs. Remarkably enough, the task demands imposed by language decision did not change the catastrophic effect of orthographic identity as compared to degrees of similarity. However, changing the task demands did change the directionality of the effects. As a comparison of Figs. 2 and 3 shows, the pattern of inhibitory orthographic similarity effects in language decision was opposite to the corresponding facilitatory orthographic similarity effects witnessed in lexical decision (Experiment 1).

An interesting issue is how these results came about, i.e., how the bilingual participants performed the Dutch–English language decision task. A first option is that coactivated orthographic representations of the Dutch and English readings of the cognates spread activation to Dutch and English language nodes. The participants then base their response on a read-out of the Dutch and English language nodes. The resulting response competition would lead to cognate inhibition effects depending on orthographic overlap. A second option is that the binary decision required for language decision was based on a Dutch-or-non-Dutch asymmetrical language selection mechanism (rather than an English selection mechanism).

Note that when the target word belonged to English but was not an identical cognate, Dutch frequency did play a prominent role, while English frequency was not predictive at all (panel d of Fig. 3). For identical cognates, the higher the Dutch frequency was, the slower the response to the English reading became. These two findings are in line with the proposed Dutch-or-non-Dutch language selection mechanism. Participants apparently scanned the visual input for divergences from Dutch orthographic patterns and rejected a word as a Dutch word on the basis of this scan, without accessing English phonological representations (there is no effect of phonological similarity) or English lexical representations (there is no English frequency effect). Note that the observed orthographic similarity effect indicates that participants could not ignore the co-activated English cognate readings during language selection. However, when the word activation process and the word selection strategy pertain to subsequent stages in processing, there is no logical contradiction here.

Going from nearly-identical to fully identical cognates in language decision, a discontinuous strong increase in cognate inhibition was observed, the mirror image of the discontinuity characterizing lexical decision (Fig. 3 panel a). However, unlike for lexical decision, this discontinuity was not modulated by phonological similarity in language decision. Nevertheless, the strong increase in RTs suggests

[2] As in Experiment 1, we confirmed that a model with orthographic similarity is superior to a model with the cognate (Orthographic Rating >2) vs. non-cognate (Orthographic Rating $\leqslant 2$) dichotomy in the language decision. The use of a gradient scale improves the AIC value from 4831 to 4747. A likelihood ratio test informally suggests that the difference in goodness of fit is significant ($\chi^2(1) = 52$, $p < 0.0001$).

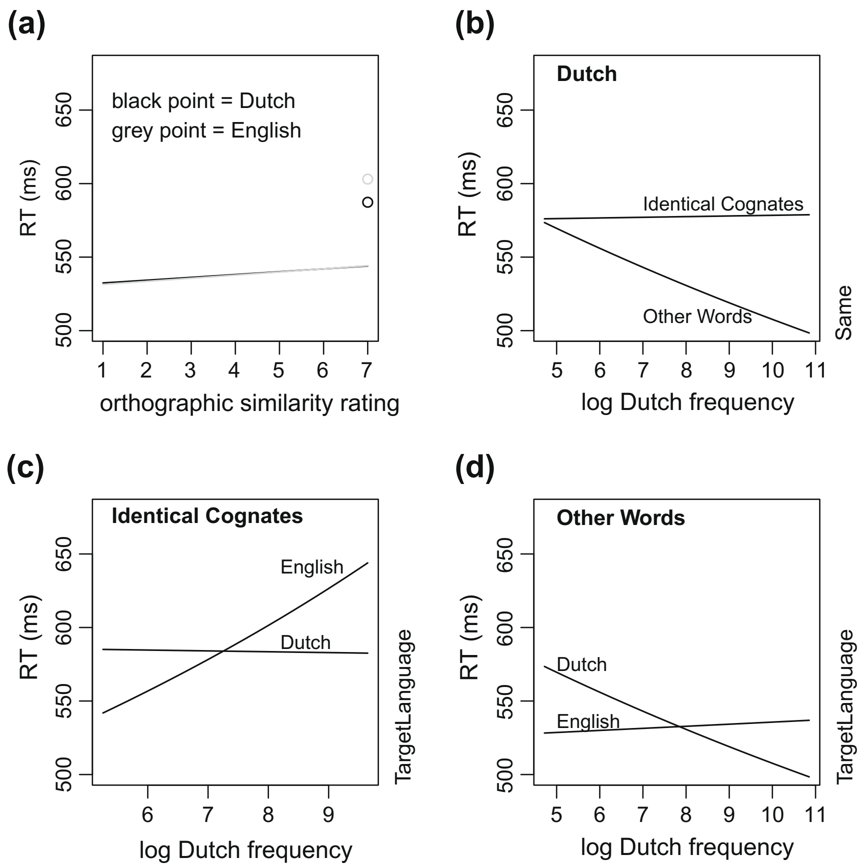

Fig. 3. Experiment 2 (Dutch–English language decision). Effects of orthographic similarity (panel a) and Dutch word frequency, modulated by the (non-)identity of the target word (panel b), for language decision latencies. Panel (c) splits up the data for identical cognates, and panel (d) for other words (non-identical cognates and non-cognates). Panel (a) illustrates the discontinuity for identical cognates.

that there is a fierce competition going on for identical cognates. This competition could be accounted for in different ways. First, the identical cognate may activate both the Dutch and English response, which would then compete (response competition, see Dijkstra, 2005). Second, if participants would use the Dutch-non-Dutch selection strategy, they might scan for orthographic deviance from Dutch (as support for the response 'English'). Thus, they would be in trouble when the word would be spelled identically in both target languages. The difference in frequency effects for identical and other cognates might be more in line with this latter view.

We now turn to Experiment 3, focussing on how the task demands of progressive demasking affect the processing of cognates.

Experiment 3: English progressive demasking

Method

Participants

Twenty-six subjects (mean age 23.3 years, *SD* 2.7; 22 women, 4 men) of the same population as before took part in this experiment. They had experience with the English language for at least 8 years (mean 12.3).

Stimulus materials

A new selection was made out of the 360 stimuli used in the rating experiment. First, 14 words were taken out of the stimulus list because they were either unknown to some participants or were rated lower than 6 on the rating scale for semantic similarity. Six further words were excluded because they could not be properly matched on English frequency with a control word. The total number of stimuli in the experiment was 320 (see Appendix C). One half of these had orthographic similarity ratings of two or higher; the other half, matched with respect to English word frequency, had ratings below 2. Only the English member of the word pair was presented to the participants.

Procedure

Participants were instructed in English to press a button as soon as they recognized a word that slowly appeared out of a checkerboard pattern, and subsequently type in the word on a special typing screen that appeared as soon as they pushed the button. Stimuli were presented in black 18-point lowercase Courier letters on a white background.

At the beginning of a trial, a masking stimulus (a checkerboard) was presented, alternating with a real English word. The exposure time of the mask decreased while the exposure time of the stimulus increased. At the start of the trial, the mask was exposed for 333 ms and the stimulus was exposed for 13.3 ms. Next, the mask was presented again, but now 13.3 ms shorter and the stimulus was exposed for 13.3 ms longer. This alternation of mask and target continued until the participant recognized the word. As soon a participant recognized the word, (s)he pressed a button and typed in the word they thought (s)he had seen. The RT was the time between the first presentation of the mask and the participant's button press. The next trial started as soon as the participant pressed the button again, making the experiment self-paced.

Each participant first went through a practice block of 12 items with cognates and non-cognates. Subsequently, the 320 experimental items were presented in four blocks, with a break after every 80 items. Trial order was different for every participant and determined by a pseudo-randomization procedure, with no more than four cognates or controls in a row.

Results

Participants made only few errors (3.3% of the data), where an error is defined as a different word being reported than was presented. For the regression analysis, we removed five outliers with RTs below 500 ms, excluded four words that induced more than 20% error rate (*rhythm*, *thigh*, *length*, and *mill*), and considered only correct responses, resulting in 7973 data points. We log transformed the response latencies, resulting in an approximately normal distribution of RTs. A linear mixed effects analysis with crossed random effects for subject and item was fit to the data, using a stepwise variable selection procedure. As for Experiment 1, we refitted the model after removal of overly influential outliers. The following variables did not reach significance as predictors (i.e., their regression weights were not significantly different from zero) and were therefore dropped from the model: Dutch frequency of the cognate, length of the English word, average rating of phonological overlap, and average rating of orthographic overlap. All *p*-values were supported by Markov Chain Monte Carlo confidence intervals sampled from the posterior distribution of the predictors, as can be seen in Table 5. Here, Trial denotes the trial number of a word in a subject's stimulus list. Trial emerged with a significant negative coefficient, indicating that as subjects progressed through the experiment they responded more quickly. This probably reflects an effect of familiarization with the task.

The key predictors in this regression model are English frequency and Semantic Similarity. Panel (a) of Fig. 4 shows that across all items we did not obtain any orthographic similarity effect in progressive demasking and that there was no discontinuity of RTs between identical and non-identical cognates. However, panel (b) indicates the effect of English frequency was reversed for identical cognates and other words. Note that there was a facilitatory effect for identical cognates relative to other items for cognates of a low English frequency.

Panels (c) and (d) of Fig. 4 visualize the interaction between English frequency and semantic similarity for identical cognates and other words. We note that the range of variation in semantic similarity ratings was (intentionally) small, between 6 and 7. The mode of the distribution of semantic similarity is at 7.

From a comparison of the two panels, it follows that for the lower frequency words in our experiment, semantic similarity had a facilitatory effect. This effect was especially large for identical cognates. As word frequency increases, the effect of semantic similarity dies away.

An analysis of the accuracy data revealed a main effect for log frequency only: words with greater frequency were more likely to elicit a correct response (beta = 0.20 on the log odds scale, $Z = 2.8$, $p < .01$).

Discussion

In strong contrast with the RT-patterns of Experiments 1 and 2, those of progressive demasking were not dependent on orthographic similarity ratings, but on English word frequency, semantic similarity ratings, and on whether the item was an identical cognate or not. The observed absence of an orthographic similarity effect for non-identical cognates in bilingual progressive demasking is in line with the results by Font (2001) for neighbor cognates. Font found only a trend ($.05 < p < .10$) towards a facilitation effect for identical cognates and a non-significant inhibition effect for neighbor cognates in L2 (relative to non-cognates). At the same time, both Lemhöfer et al. (2008) and Dijkstra et al. (1999) observed significant facilitation effects for identical cognates in a progressive demasking task. In our study, there was no overall facilitation effect for identical cognates (with an Orthographic Rating of 7, mean RT = 1724 ms) relative to non-cognates (with an Orthographic Rating of 2 or less, mean RT = 1718 ms). However, a facilitation effect did arise for lower frequency identical cognates relative to other items (panel b of Fig. 4). This finding indicates that, as might be expected, identical English low-frequency cognates profit more from the coactivation of their Dutch counterparts than high-frequency cognates do.

The importance of precisely the factors English word frequency and semantic similarity would be expected if lexical competition and semantic overlap between the two readings of the cognate play a major role in this task situation (see introduction on task demands before Experiment 2). These findings cannot easily be reconciled with the view that cognates share a major (morphological) representation across languages, because that hypothesis leads us to expect a frequency-dependent RT effect for non-identical cognates (above a minimal similarity threshold) also in the progressive demasking task. However, no such effect (neither facilitatory or inhibitory) was observed (closer inspection did not even reveal such effects in individual participants). The same reasoning holds for the theoretical positions that the representations of the two cognate members are associatively linked or close attractors. These approaches might predict a facilitatory frequency effect, following the same theoretical reasoning as for the lexical decision task.

In contrast, the combined results can be understood in terms of a theoretical account proposing that non-identical

Table 5
Coefficients for the mixed-effects regression model for the response latencies in progressive demasking (Experiment 3): coefficients, lower and upper boundary of the 95% Highest Posterior Density (HPD) credible interval, and the corresponding *p*-value, based on 10,000 Markov Chain Monte Carlo (MCMC) samples from the posterior distribution of the parameters.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC
(Intercept)	8.2006	8.1939	7.4099	9.0245	0.0001
PrevRT	0.1162	0.1162	0.0968	0.1367	0.0001
Trial No.	−0.0004	−0.0004	−0.0004	−0.0003	0.0001
Semantic similarity	−0.2362	−0.2351	−0.3494	−0.1207	0.0001
Log English Frequency	−0.3241	−0.3224	−0.5344	−0.1101	0.0034
Same (other words)	0.1321	0.1319	0.0282	0.2316	0.0124
Semantic similarity by Log English Frequency	0.0481	0.0479	0.0162	0.0779	0.0024
Log English Frequency by Same (other words)	−0.0311	−0.0311	−0.0555	−0.0054	0.0172

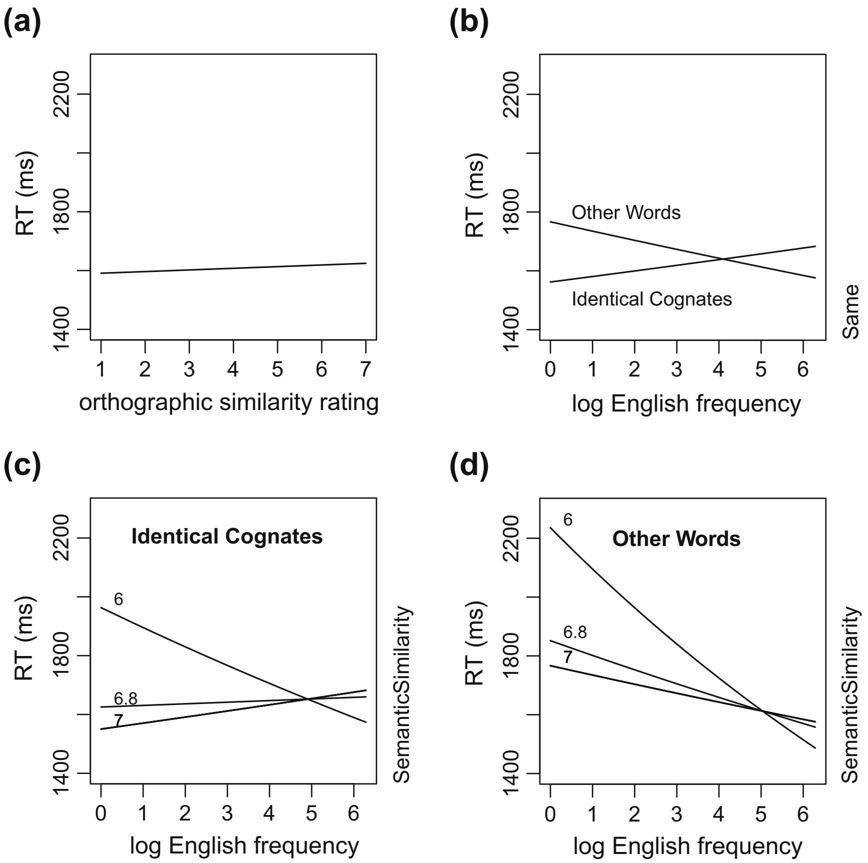

Fig. 4. Experiment 3 (progressive demasking). Non-significant effect of orthographic similarity (panel a), the interaction of English log frequency and the cognate identity *Same* (panel b), and the interaction of English log frequency and semantic similarity (panels c and d) for progressive demasking latencies. Panel (c) presents these data for identical cognates only, and panel (d) for other words (non-identical cognates and non-cognates) only.

cognates have two different but overlapping orthographic representations and a (partially) shared semantic representation. An increase in the orthographic similarity of the two readings of a cognate then leads to an increase both in lexical competition and in semantic co-activation. Because the response in progressive demasking can only be given if the English representation is exactly identified, English word frequency becomes a major determinant of RT. In addition, even small variations in semantic similarity between the two cognate readings apparently already affect the speed of identification of the English items – recall that the amount of variation in the semantic ratings was deliberately limited.

General discussion

In this paper, we investigated cognate processing using an off-line rating study and three on-line experiments. In the rating study, a high correlation was found between ratings of cross-linguistic overlap for Dutch–English translation equivalents in terms of orthography (O-rating) and phonology (P-rating). Thus, for this language combination, a word pair with a highly similar orthography generally also has a highly similar phonology and vice versa. Across the range of test items, similarity ratings were not correlated with English frequency. Selections of the stimulus materials of the rating study varying in cross-linguistic similarity were used in lexical decision (Experiment 1), language decision (Experiment 2), and progressive demasking (Experiment 3).

In English lexical decision, a facilitatory effect arose that was dependent on the degree of orthographic overlap and on the English word frequency of the cognates involved. A cognate facilitation effect was found even when orthographic overlap was incomplete (cf. Dijkstra et al., 1999; Font, 2001; Van Hell & Dijkstra, 2002). In fact, even relatively little overlap between words in two languages appeared to aid the recognition of these words. Word pairs like *guide–gids* and *rhythm–ritme* (with, respectively, ratings of 3.5 and 4.0; see Appendix A), which are not strictly orthographic neighbors in the definition by Coltheart, Davelaar, Jonasson, and Besner (1977), were apparently sufficiently similar to elicit orthographic facilitation.

Completely opposite results were obtained for Dutch–English language decision. Here, a cognate inhibition effect was found, the size of which depended on the orthographic similarity between the translation equivalents of the target item in question. Thus, cognate effects, like the effects for false friends (interlingual homographs and interlingual homophones) are task-dependent.

This conclusion was confirmed for the English progressive demasking task, in which no clear effect of orthographic similarity between translation equivalents was found. Instead, a significant facilitation effect was observed for low-frequency identical cognates (in contrast to Dijkstra et al., 1999; Lemhöfer et al., 2008). These results deviate somewhat from previous studies that reported cognate facilitation effects irrespective of word frequency. At the same time, our progressive demasking experiment was sensitive to a combination of the word frequency of the English target item and the semantic similarity between the translation equivalents.

In the following, we will first consider the cognate facilitation effects in English lexical decision in terms of the four theoretical positions discerned in the introduction, paying special attention to the localist and distributed connectionist models. Next, we will consider how the task-dependent effects found in all experiments can be accounted for.

The cognate facilitation effect and cross-linguistic similarity

When we formulated predictions for cognate processing according to four theoretical positions, at least two deficiencies became evident. First, there often was a lack of specification that made it hard to derive exact predictions. Second, it appeared that in several cases, a task-specific account was missing. These aspects make it difficult to unambiguously confirm or reject the models.

As an example, consider the theoretical position that cognates are characterized by shared morphological representations (position 1). We found mixed support for this view (see Table 1). For the purpose of testing, we have assumed that shared morphological representations are developed when bilinguals perceive that two word translations have a minimally similar orthographic core; in fact, the existence of such representations might lead to the prediction of a similarly sized cognate effect for identical and nearly-identical cognates, a pattern that was not found. However, we have not found this aspect discussed in the studies offering this viewpoint. Furthermore, based on this assumption, there should be no effect of orthographic similarity across a whole range of orthographical similarity of cognates. However, our data indicate that RTs for cognates become shorter if orthographic similarity increases.

Further evidence against this theoretical position was collected by Voga and Grainger (2007), who tested Greek–French bilinguals performing a lexical decision task on French target words preceded by masked Greek prime words. It was argued that priming with cognate translations should induce a similar RT-pattern as cross-language morphological priming if the cognate effect was indeed based on a shared morphological representation. However, the patterns for the two conditions were quite different (Experiment 1). Cognate primes produced faster RTs than morphological primes at both a 50 ms and a 66 ms prime duration, while a significant morphological facilitation effect (relative to a control condition) appeared only at the 66 ms prime duration.

From a theoretical point of view, we would like to add that the assumption of shared morphological representations would seem to be more appropriate for cognates like *accomodation/accomodacion* than for *rhythm/ritme*. The items of the first pair consist of two identical stem morphemes followed by a similar suffix, whereas those of the second pair are monomorphemic and less similar in their orthographic form. It does not seem attractive to assume a shared morphological representation for target words that are monomorphemic within a language and have quite diverse orthographic and phonological representations across languages. For instance, the monomorphemic Dutch word *tomaat* is a non-identical cognate with its English counterpart *tomato*, but is written and pronounced differently and has a different plural form (*tomaten* vs. *tomatoes*).

A second theoretical position assumes that cognates have associatively linked orthographic representations and semantically shared representations. This position could be taken to predict frequency-dependent cognate facilitation effects in various tasks. If the additional assumption is made that multiple orthographically similar words become activated on the basis of the input, the effects of orthographic similarity across Dutch and English could also be accounted for (cf. Dijkstra & Van Heuven, 2002b, p. 222). However, more difficult to explain by this account are the cognate facilitation effects observed by Voga and Grainger (2007). In their Greek (L1) – French (L2) masked priming task, overlap-dependent facilitation effects arose for Greek–French cognate primes relative to unrelated control primes (Experiments 2 and 3). It is hard to see how L1–L2 word associations could be directly affected by (phonological) form overlap when the two languages involved are characterized by different scripts. In addition, a task account is badly needed to explain why lexical decision, language decision, and progressive demasking lead to different result patterns for associatively linked cognate representations.

For cognates in the lexical decision task, both localist and distributed connectionist models of bilingual word recognition (positions 3 and 4) predict increasingly large facilitation effects with increases in cross-linguistic similarity of translation equivalents. However, the proposed underlying mechanisms are quite different (see Fig. 1).

In distributed connectionist models (position 3), word attractors lying in the same area of a multidimensional space set up by stimulus dimensions will exert a joint 'pull' during the word recognition process. Co-activated cognate readings will therefore lead to faster RTs than language-specific control words; this is the cognate facilitation effect. Furthermore, because the joint attractor force is larger the closer the two representations are, cognates with more overlap have faster RTs; this is the more general orthographic similarity effect. Finally, a higher frequency of usage might strengthen the connections between representations and allow faster movement through multidimensional space. (Note that according to unpublished data we have, the English and Dutch word frequencies of cognate pairs are often quite highly correlated, from .40 to .70 upwards.)

In localist connectionist models (position 4), a processing consequence of an increase in cross-linguistic similarity of the cognate (e.g., *tomato*) is that its counterpart in the other language (e.g., *tomaat*) becomes more activated. Because both readings of the cognate converge at the semantic level, there is relatively more semantic activation in the lexicon than for non-cognates. The largest co-activation would be expected to arise for identical cognates. However, going from very similar to identical cognates, the facilitation effect on the RTs is not expected to increase linearly, but discontinuously, exactly as observed, because the accompanying lateral inhibition would drop to zero for identical cognates. This discontinuity effect might be expected to happen for both lexical-orthographic and lexical-phonological representations.

Summarizing the results for lexical decision, it appears these are more completely accounted for by connectionist models. The discontinuous dependence on orthographic similarity and the frequency effect were best predicted by localist connectionist models. The assumptions of a shared morphological representation or linked orthographic representations do not appear to be required to account for the present data set.

The cognate facilitation effect and task dependence

Although all tasks included nearly the same test stimulus materials, lexical decision led to different result patterns than language decision and progressive demasking. Theoretical approaches that offer no account of how result patterns change under the influence of task demands therefore have difficulty explaining our data. So far, task accounts are lacking for the positions assuming morphologically shared or lexically linked representations and for distributed connectionist models. Only the localist connectionist approach, as implemented in the BIA/BIA+ models, has proposed both a processing and a task account (Dijkstra & van Heuven, 2002a). We will now apply this account to the different result patterns of the three tasks in our study.

In terms of processing, an input letter string activates both readings of the cognate to an extent that depends on their frequency and their similarity to the input (see Fig. 1). Both activated representations then feed activation forward to a (partially) shared semantic representation, which, in the next step, feeds activation back to both orthographic representations. For instance, when the English word *tomato* is presented to a Dutch–English bilingual, it activates the orthographic representation of *tomato* to an extent that depends on its L2-frequency of usage. In addition, it activates the orthographic representations of all words in the two languages of the bilingual that overlap significantly with the input. One of these is the Dutch word *tomaat*. The activation of this item depends on the size of its partial overlap with the target and its L1-frequency. Next, because they are translation equivalents, both *tomato* and *tomaat* activate their associated meaning representation, which is shared by *tomato* and *tomaat*. This semantic representation then feeds back activation to the orthographic level, strengthening both *tomato* and *tomaat* (Pecher, 2001). This feedback account is also consistent with Voga and Grainger's (2007) findings of cognate facilitation effects across different scripts (Greek and Latin) in lexical decision involving masked cross-linguistic priming.

According to this account, the similarity-dependent cognate facilitation effect in lexical decision depends on (the combined effect of) two factors. First, as a consequence of orthographic and semantic overlap, more semantic activation will arise for cognates than for non-cognates. Second, the two cognate readings together may induce more global activation in the lexicon than other similar words (such as neighbors) do.

This processing and task account for lexical decision can be applied to language decision as well if we assume that the participants' response is instead based on the relative activation of the two language nodes. A larger orthographic overlap of cognate readings will not only lead to a larger co-activation of the non-target orthographic representation, but also of the non-target language node. This increases response competition in language decision and causes a larger cognate inhibition effect. As an alternative, an asymmetric (e.g., Dutch-non-Dutch) language selection strategy could be considered, in which the participants perform the language decision task with one language as target.

Importantly, the observed cross-linguistic similarity effects for cognates in language decision were also discontinuous in nature, with an abrupt increase in RT going from near-identical to identical cognates. In the present account, this directly follows from the fact that the underlying mechanism (but not the task requirements) is the same for both tasks: the competition between two lexical representations that are co-activated on the basis of the input. Indeed, the Pearson correlation between the responses to the same 92 English items in lexical decision and language decision was −.284 ($p < .006$), in spite of all the differences between the two tasks (in terms of participants, response hand allocation, presence of non-words or Dutch words, etcetera).

The discontinuity effect for identical cognates was found not only in lexical decision and language decision, but also in progressive demasking (Experiment 3). So far, few other studies have systematically varied word form similarity in cognates across a larger range. In recent eye-tracking work, Duyck and colleagues (Duyck et al., 2007) reported a linear effect of cognate similarity for cognates in sentence context; they did not note a discontinuity effect between identical and orthographically very similar cognates. However, a limited number of cognates was involved in their study and the RT-difference between identical and non-identical cognates was not the direct focus of their research.

The orthographic similarity effects for non-identical cognates observed in lexical decision and language decision were absent in progressive demasking. Note that lexical decision and progressive demasking differ in their task demands. In lexical decision, participants may use global activation in the lexicon to perform their task. In contrast, in progressive demasking, participants must precisely identify the right word for report and suppress any competing words activated by the input. One might therefore expect frequency-dependent inhibition effects for non-identical cognates here. In contrast, semantic overlap should facilitate the recognition of such cognates, because the non-target cognate reading would co-activate the shared semantic representation. As a consequence, a cognate similarity effect for non-identical cognates might be absent in progressive demasking because the lexical-orthographic competition effects and the semantic co-activation effects cancel each other. This argument is in line with the finding in Experiment 3 that English word frequency and semantic overlap are important determinants of the RT.

In sum, a localist connectionist model like BIA+ provides both a detailed processing account and a task account for cognate processing in which the results of the three experiments of this study can be interpreted quite well. Task accounts for other approaches to cognate processing, such as the distributed connectionist approach, are eagerly awaited for.

To conclude, our study has led to several conclusions about cognate processing and representation in bilinguals. First, facilitatory cognate effects were obtained in L2 lexical decision and inhibitory effects in L1–L2 language decision. Both types of effects increased linearly with an increasing degree of orthographic form overlap between the two readings of a non-identical cognate.

Second, in lexical decision and language decision, a discontinuous transition in RTs was observed between identical and nearly-identical cognates, which appears to be more in favor of a localist connectionist type of model than of a distributed model.

Third, to account for our findings, the assumptions of a 'special' morphological or linked lexical representation for cognates are not required. The findings of lexical decision and language decision can be explained by assuming that (1) form overlap between the two readings of the cognates leads to a frequency-dependent parallel activation of these readings, and (2) both form representations activate a (largely) shared semantic representation and separate language membership nodes. The findings of progressive demasking can be explained within the same orthographic–semantic network account when task-specific processing assumptions are added.

Finally, there is a strong effect of task demands on cognate processing. Lexical decision, language decision, and progressive demasking are all performed in their own way. Although more research is needed to find out the exact nature of the demands posed by various tasks, the present study shows that the different results they produce may be informative with respect to the underlying representation of cognates.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jml.2009.12.003.

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