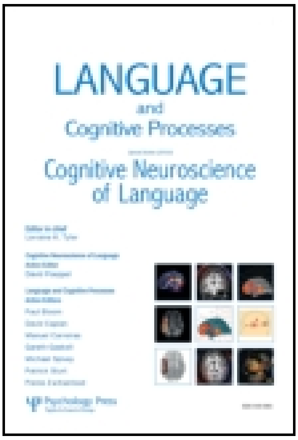

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Morphological Family Size effects in L1 and L2 processing: An electrophysiological study

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Morphological Family Size effects in L1 and L2 processing: An electrophysiological study

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The present study examined Morphological Family Size effects in first and second language processing. Items with a high or low Dutch (L1) Family Size were contrasted in four experiments involving Dutch–English bilinguals. In two experiments, reaction times (RTs) were collected in English (L2) and Dutch (L1) lexical decision tasks; in two other experiments, an L1 and L2 go/no-go lexical decision task were performed while Event-Related Potentials (ERPs) were recorded. Two questions were addressed. First, is the ERP signal sensitive to the morphological productivity of words? Second, does nontarget language activation in L2 processing spread beyond the item itself, to the morphological family of the activated nontarget word? The two behavioural experiments both showed a facilitatory effect of Dutch Family Size, indicating that the morphological family in the L1 is activated regardless of language context. In the two ERP experiments, Family Size effects were found to modulate the N400 component. Less negative waveforms were observed for words with a high L1 Family Size compared to words with a low L1 Family Size in the N400 time window, in both the L1 and L2 task. In addition, these Family Size effects persisted in later time windows. The data are discussed in light of the Morphological Family Resonance Model (MFRM) model of morphological processing and the BIA + model.

Keywords: Morphological Family Size; Bilingualism; ERPs; N400.

Words are productive entities. They can occur in many complex words. For instance, the word *time* occurs in derivations and compounds such as *timeless*, *timetable,* and *tea time*. The number of morphologically related complex words that can be derived from a target word is referred to as a word's Morphological Family Size. It is assumed that upon reading a word, many of its morphological family members become activated, because these family members are linked to the activated semantic representation of the target word (Schreuder & Baayen, 1997). Thus, when processing a word, its semantic representation is activated, and activation is then spread to other

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items that are linked to this semantic representation. This implies that, upon presentation of a word like *time*, over a hundred family members will be activated, leading to a large amount of global lexical activation.

Grainger and Jacobs (1996) have argued that, in lexical decision, global lexical activation in the lexicon caused by active nontarget word candidates can feed the positive response to a target word, resulting in a shorter response latency for this target. In line with this idea, increased lexical activation due to the activation of a large number of morphological family members has been shown to speed up target word processing. Monolingual studies in a variety of languages have observed that words with larger morphological families are processed faster and more accurately than words with a smaller number of morphological derivatives (Baayen, Lieber, & Schreuder, 1997; Bertram, Baayen, & Schreuder, 2000; De Jong, 2002; De Jong, Feldman, Schreuder, Pastizzo, & Baayen, 2002; De Jong, Schreuder, & Baayen, 2000; Juhasz & Berkowitz, 2011; Kuperman, Bertram, & Baayen, 2008; Kuperman, Schreuder, Bertram, & Baayen, 2009; Lüdeling & De Jong, 2002; Moscoso del Prado Martín, Bertram, Häikiö, Schreuder, & Baayen, 2004; Moscoso del Prado Martín et al., 2005).

In the present study, we want to deepen our knowledge of the effects of Morphological Family Size in several ways. Our first aim is to extend the finding of a Family Size effect in L1 processing from behavioural to electrophysiological data. Our second aim is to demonstrate cross-language Family Size effects in L2 processing in both behavioural and electrophysiological data. We will set the stage for a discussion of our experiments by considering a theoretical account and several empirical studies of Morphological Family Size effects in monolinguals and bilinguals.

To account for Family Size effects, De Jong, Schreuder, and Baayen (2003) have proposed the Morphological Family Resonance Model (MFRM). The model explains the facilitatory effect of Family Size in terms of resonance between lemmas and the semantic (and syntactic) representations to which these lemmas are linked (see Figure 1). When a semantic representation of a target word is linked to many lemmas (its morphological family members), these activated lemmas will spread back a large amount of activation. Over time, this will increase both the activation of the target's semantic representation and the target lemma. In other words, resonance within the morphological family will speed up the activation rate of the target lemma, thus speeding up word processing.

Research indicates that the effect of Family Size on target word processing is semantically driven. Schreuder and Baayen (1997) and Bertram et al. (2000) showed that the correlation between response latencies and Family Size decreased when family members were included in the Family Size count that were morphologically but not semantically related (for instance *honeymoon* is a semantically unrelated family member of *honey*). Furthermore, the Family Size effect has been observed for past participles that do not share the vowel with their stem (e.g., *zwem-gezw**o**mmen* "swim-swum" vs. ***roei**-ger**oei**d* "row-rowed"; De Jong et al., 2000). These studies showed that activation of semantic information underlies the activation of a word's family members and, consequently, that the Family Size effect is not a form effect only. These findings concerning the semantic character of the Family Size effect suggest that Family Size effects play a role at stages of word processing after word identification has taken place.

However, in a magneto-encephalographic (MEG) study, Pylkkänen, Feintuch, Hopkins, and Marantz (2004) observed that Family Size modulated the MEG response component M350, speeding up M350 latencies. The M350 component is considered to be an early subcomponent of the N400, an EEG component that is sensitive both lexical and postlexical stimulus factors (see Pylkkänen & Marantz,

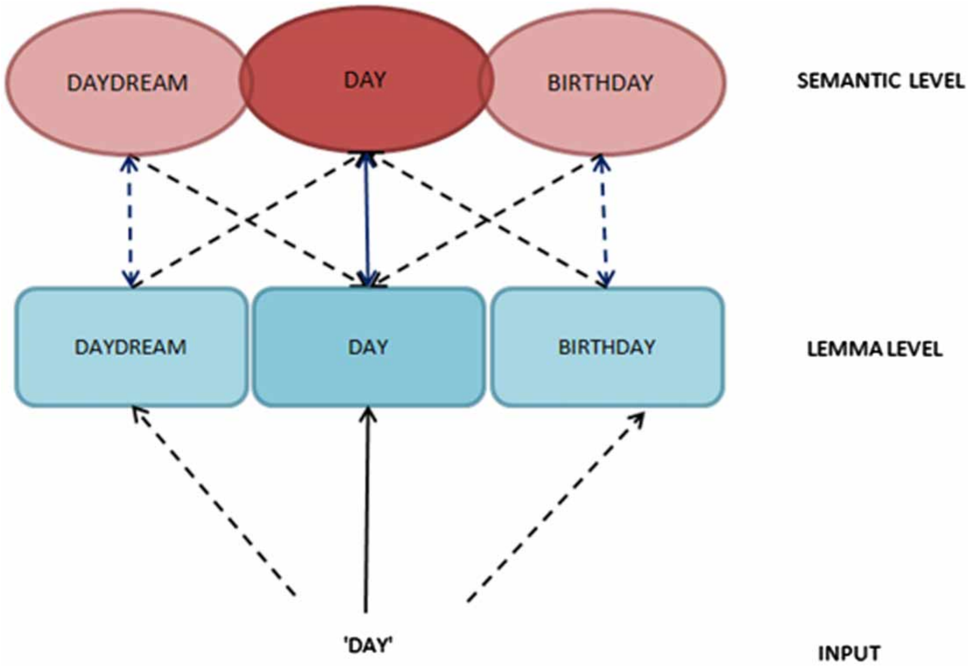

Figure 1. Schematic representation of the activation of morphological family members and the resonance between representations at the lemma and semantic levels.

2003). The M350 has been found to be sensitive to factors affecting stages of lexical processing prior to word selection/identification, such as lexical frequency. The authors argue that their finding that Family Size modulates this MEG component, therefore, does not appear to be consistent with the assumption that Family Size affects processing postlexically (cf. Schreuder & Baayen, 1997).

Recently, studies on bilingual word processing have shown that the Morphological Family Size of words of both languages of a bilingual influence word processing when reading in only one of those two languages. Dijkstra, Moscoso del Prado Martín, Schulpen, Schreuder, and Baayen (2005) investigated Family Size effects on the processing of Dutch–English interlingual homographs in both English and Dutch lexical decision tasks. In both tasks, facilitatory effects were observed for the Family Size of the target language, while the Family Size effect of the nontarget language was inhibitory.

More recently, Mulder, Dijkstra, Schreuder, and Baayen (2012) investigated Family Size effects in cognate processing. More specifically, they addressed the questions of whether the cross-language Family Size effect might be task-dependent and sensitive to the degree of orthographic overlap in cognates. They observed target and nontarget language Family Size effects on cognate processing in both Dutch–English language decision and English lexical decision. In language decision, the bilingual participant must press one button as quickly as possible if a presented word belongs to one language and another button if it belongs to the other language. Because cognates overlap in their orthographic form, both of their readings will be activated, resulting in response competition when the language of the cognate must be determined. Reading cognates did indeed result in slower responses than reading noncognates. More importantly, cognates with a higher Family Size in English or in Dutch were processed slower than cognates with a lower Family Size in these languages, suggesting that the morphological families of each of the two languages became activated and contributed to the cross-linguistic response competition. The effects became larger when the Dutch and English Family Size were summed in one combined Family Size measure. Moreover, the inhibitory effect of combined Family Size was larger for identical cognates than for nonidentical cognates, most likely because these items induce maximal response competition.

When a similar reasoning is applied to lexical decision, a larger morphological family of the nontarget language should result in faster response times (because of a larger global activation or more resonance in the lexicon). Mulder et al. observed significant facilitatory effects of the Family Size of the nontarget language (Dutch) on the processing of cognates. Moreover, in lexical decision, the cross-language Family Size effect was not sensitive to the degree of form overlap between English and Dutch cognate readings. Importantly, cross-language Family Size effects were observed when the Family Size of the target language was controlled for. When the Family Size of both languages was varied, only the effect of target language Family Size remained. Because both effects worked in the same direction (resulting in facilitation), in the regression analysis the effect of English Family Size probably took away part of the effect of Dutch Family Size. The authors, therefore, argued that nontarget language Family Size effects are more likely to be found in a paradigm in which the Family Size of the target language is kept constant. In the present study, in which we will look at cross-language Family Size effects in English lexical decision, this design is adopted. In sum, previous studies suggest that the morphological family of the nontarget language is activated during cognate processing. The studies thus indicate that word representations in our lexicon, both within and across the languages we know, are highly interconnected in terms of their morphological relationships.

As indicated above, a major aim of this study is to examine cross-language Morphological Family Size effects in L2 processing. We will measure both RTs and Event-Related Potentials (ERPs). To our knowledge, Family Size effects have not been measured before by means of ERPs. Such electrophysiological measures might be more sensitive to possible effects of Family Size (and other word characteristics like cognate status, see Midgley, Holcomb, and Grainger, 2011) than behavioural measures, because they provide a direct, online measure of brain activity. Moreover, ERP measures will allow us to track the resonance of activation between target and family members as it develops over time. Assuming that the Family Size effect is at least partially a semantic effect, we expect it to influence ERP components that are sensitive to semantic aspects of word processing.

One ERP component that is sensitive to semantic aspects of word processing is the N400 (e.g., Kutas & Hillyard, 1980). The N400 is a negative-going component peaking around 400 ms after stimulus onset and is characterised by a large distribution over posterior electrode sites (Kutas & Van Petten, 1994). The amplitude of the N400 is assumed to reflect how easily a word can be semantically integrated into the current context, whether the context is a single word, a sentence, or a discourse (Kutas & Federmeier, 2000, p. 464; also see Van Berkum, Hagoort, & Brown, 1999).

In line with this view, monolingual and bilingual studies involving semantic priming have observed less negative amplitudes in the N400 time window for words that were preceded by a semantically related prime relative to a semantically unrelated prime (Kerkhofs, Dijkstra, Chwilla, & De Bruijn, 2006; Kutas & Hillyard, 1989). In addition, bilingual ERP studies involving cognates have found less negative-going N400 waves for cognates relative to noncognates (Midgley et al., 2011; Yudes, Macizo, & Bajo, 2010). These findings may reflect the easier processing of targets given more semantic information (from the prime or the co-activated cognate representation, see Dijkstra, Miwa, Brummelhuis, Sappelli, & Baayen, 2010).

Interestingly, in an ERP study on orthographic neighbourhood size effects, Holcomb, Grainger, and O'Rourke (2002) observed that words with many orthographic neighbours (i.e., words that differ from a given target word in one letter, such as *cat* and *car*; see Coltheart, Davelaar, Jonasson, & Besner, 1977) elicited a larger (i.e., more negative-going) N400 compared to words with few orthographic neighbours. Holcomb et al. argued that this N400 effect of orthographic neighbourhood size reflected overall semantic activation. In line with these findings, Müller, Duñabeitia, and Carreiras (2010) observed the same pattern for words with a large orthographic neighbourhood size. Even more interestingly, they observed the same pattern for words with a large number of semantic associates (e.g., the word *giraffe* could activate associates such as *zoo* or *animal*). Thus, activation of more semantic representations due to the activation of orthographically or semantically related items resulted in larger N400 amplitudes. Note that in the case of both orthographic neighbours and semantic associates, semantic representations are activated that are not convergent with that of the target word.

If we now consider the effects of differences in Morphological Family Size on the ERP signal, two possibilities arise. In addition to activating their own semantic representations, words with a high Family Size activate the semantic representations of a large number of morphologically related family members. This should result in more semantic activation compared to words with a low Morphological Family Size. In analogy to ERP evidence of the above mentioned studies on orthographic and associative neighbourhood density, more negative N400 amplitudes are expected to arise for words with a high Family Size compared to words with a low Family Size due to this increased semantic activation.

On the other hand, given the large semantic overlap between the target word and the activated morphological family members, the direction of the N400 effect of Family Size could differ. Morphological family members contain the target (e.g., *household* contains *house*), and consequently, strengthen the activation of the target word by means of co-activation. In analogy to ERP studies involving cognates (which also have converging semantics), *less* negative N400 amplitudes are expected to arise for words with a high Family Size compared to words with a low Family Size.

In this sense, investigating Morphological Family Size effects is particularly interesting due to the different nature of the semantic overlap between target word and family members compared to orthographic neighbours and semantic associates. The direction of the N400 effect of Family Size could reveal a potential sensitivity of this component to semantic aspects of single word processing (orthography mapping on diverging or converging semantic representations).

Before considering L1 Morphological Family Size effects in L2 processing, we first investigate L1 Family Size effects in L1 processing in two experiments. Dutch words with high and low Dutch Family Size are tested behaviourally in a Dutch lexical decision task (Experiment 1) and in an ERP study incorporating the same materials in a Dutch go/no-go lexical decision task (Experiment 2). The goal of this ERP study is to investigate whether the ERP signal is sensitive to differences in Family Size between words.

Next, we focus on L1 Family Size effects in L2 processing in two subsequent experiments. Our intention is to show that activation of the nontarget language in L2 processing is not restricted to the nontarget language lemma itself, but is passed on to nontarget language family members of the target word. Cross-language Family Size effects are investigated by manipulating the Dutch (L1) Family Size of Dutch–English cognates while controlling for English (L2) Family Size and word frequency. Again, the materials are tested both behaviourally in an English lexical decision task (Experiment 3) and electro-physiologically in an English go/no-go task while ERPs are recorded (Experiment 4).

MORPHOLOGICAL FAMILY SIZE EFFECTS IN L1 PROCESSING

Experiment 1: Behavioural data

Method

Participants. Twenty-six right-handed native speakers of Dutch with good knowledge of English (mean age = 21.7 years, *SD* = 2.66) were paid or received course credits to take part in this experiment.

Stimuli. The experimental stimuli were 80 Dutch words, extracted from the CELEX lexical database (Baayen, Piepenbrock, & Gulikers, 1995). Only word items with a lemma frequency of at least one per million in the CELEX database and a length from four to six characters were selected. All items were mono-morphemic noncognate words. For each item, the Dutch Morphological Family Size values were calculated and logarithmically transformed. Half of the items had a high Dutch Morphological Family Size (above 30, mean 37.7) and the other half had a low Dutch Family Size (below 10, mean 5.6). The difference between the mean numbers of Dutch family members in both sets was statistically significant. This contrast in Family Size was based on the contrast used in Experiments 3 and 4 that distinguished cognates with high and low Family Size, to allow for a comparison between Family Size effects in L1 and L2 processing. Moreover, this contrast in Family Size is comparable (i.e., differing in less than one log unit) to the contrast used by Schreuder and Baayen (1997) and De Jong et al. (2000). Both sets of words were matched on Dutch lemma frequency and on the number of Dutch orthographic neighbours. Table 1 presents the characteristics of the experimental items.

Finally, 80 pseudo-words were included that resembled Dutch words with respect to their orthography and phonology. They were created by replacing one or more letters of existing Dutch words. The pseudo-words were matched to the experimental stimuli on length. The presentation order of the items was randomised for each participant individually and had the restriction that no more than three words or nonwords could follow each other directly.

Procedure. Participants performed a Dutch lexical decision task. In this task, participants have to decide whether or not the word they are presented with is an existing Dutch word or not by pressing a button corresponding to the answer ‘yes’ or ‘no’.

TABLE 1
Item characteristics of the experimental items used in the L1 lexical decision data (Experiment 1 and 2)

	Length	*Log Dutch frequency*	*Log Dutch neighbours*	*Log Dutch Family Size*
High Family Size	*4.8*	3.35	1.84	3.63
Low Family Size	*4.65*	3.31	1.87	1.73

The visual stimuli were presented in white capital letters (24 points) in font Courier New in the middle of the screen on a dark grey background. Participants were seated at a table at a 60 cm distance from the computer screen. The maximum height and width of the stimuli were such that no saccades were necessary to be able to read the stimuli.

Each trial began with the onset of a fixation cross which remained on the screen for 500 ms and was followed by 300 ms of blank screen. A target word then appeared on the screen for 1500 ms. The next trial began after 700 ms of blank screen with the fixation cross. The experiment started with an instruction screen in Dutch followed by a short practice session to assure good performance during the experiment. The items were presented in two blocks of each 80 stimuli (requiring approximately four minutes) with one pause in between. The length of the pause was determined by the participant.

Results

Data cleaning was first carried out based on the error rate for participants and word items. All participants had an error rate of 15% or less on the word items (mean accuracy 96%, range 88–100%). Therefore, no participant data were removed. The mean accuracy for the word items was 96% (range 50–100%). One item from the low Family Size condition that elicited errors in more than 15% of the trials (*grap*) was removed from the data set. Furthermore, two items from the high Family Size condition (*fonds*, *rente*) that elicited slow mean RTs (more than 2 SD above item mean) were removed from the data set. RTs from incorrect responses or null responses were removed from the remaining data set (3.25% of the remaining data points). Finally, outlier RTs that were 2.5 SD above or below the subject and item mean (4.07%) were removed. This resulted in a data set with 1858 data points.

A repeated measures analysis of variance (ANOVA) was conducted on the RT and accuracy data with Family Size (high vs. low) as a within-subject factor. In the RT data, a main effect of Family Size was observed in the by-participant analysis [$F1(1, 25) = 6.87$, $MSE = 141.79$, $p < .05$; $F2\ (1, 75) = 2.07$, $MSE = 953.84$, $p = .15$], revealing slower RTs for words with smaller morphological families compared to words with a high Family Size. The accuracy data also revealed a main effect of Family Size in the by-participant analysis [$F1(1, 25) = 5.505$, $MSE = 0.001$, $p < .05$; $F2\ (1, 75) = 2.34$, $MSE = 0.002$, $p = .10$], showing higher accuracy scores for words with a high Family Size. Mean response latencies and accuracy scores are presented in Table 2.

Discussion

The RT data of Experiment 1 are consistent with earlier behavioural findings on Morphological Family Size effects in monolingual word processing: Words with larger morphological families were responded to faster and more accurately than words with

TABLE 2
Mean response latencies and accuracy scores and their standard deviations between parentheses for words with high and low Family Size in the L1 lexical decision data (Experiment 1)

	RT (SD)	*Accuracy* (SD)
High Family Size	505 (54.36)	0.98 (0.04)
Low Family Size	514 (50.45)	0.96 (0.04)

smaller morphological families. The Family Size effect was significant in the by-participant analyses and showed a trend in the by-item analyses. Although we used a contrast in Family Size that was comparable to the contrast used by Schreuder and Baayen (1997), the effect is smaller than the effect reported by Schreuder and Baayen. This can be explained by the considerably faster mean RTs to word items in the present study (505 ms for words with high Family Size, and 514 ms for words with low Family Size) relative to those in Schreuder and Baayen's study (553 and 594 ms for words with high and low Family Size, respectively). The effect in our data is more comparable to that observed by De Jong et al. (2000), whose response latencies corresponded in size to the latencies reported in our experiment (502 and 521 ms, respectively), and who reported a 19 ms advantage for nouns with high Family Size compared to nouns with a low Family Size.

This suggests that the size of the Family Size effect is a function of response speed, and becomes larger when RTs get longer, just like semantic effects in semantic priming studies tend to be larger for slow responses (Flores d'Arcais, Schreuder, & Glazenborg, 1985).[1] Alternatively, the magnitude of the effect might also depend on the frequency of the items.

The finding that words with a large number of family members are responded to faster than words with a smaller Family Size can be accounted for in two ways. First, the activation of many family members produces a large amount of global lexical activation that can facilitate a positive decision (cf. Grainger & Jacobs, 1996). This would imply that Family Size members are activated pre-lexically and influence word processing before word identification has been completed. Alternatively, the faster response could be due to the increased amount of semantic information that is available through the activation of family members. Facilitatory effects of Family Size could then be considered as a late lexical or postlexical effect arising via the mechanism of resonance (De Jong et al., 2003). Because lexical decision has a response component, these accounts cannot be disentangled.

In Experiment 2, the same materials were tested in an ERP study using a Dutch go/no-go lexical decision task. This task requires no response to words, which makes it possible to disentangle the two accounts. If the ERP signal is sensitive to the morphological productivity of words in the lexicon, Family Size effects are especially expected to arise within the N400 time window, since the N400 is associated with lexical-semantic integration. The effect should arise even when no response is required. Given that more semantic information becomes available with the activation of a large number of morphological family members, more negative amplitudes in the N400 time window could be expected for words with larger morphological families compared to words with smaller families (cf. Müller et al., 2010). However, if the ERP signal is sensitive to the semantic convergence between target word and activated family members, this could result in less negative N400 amplitudes for words with larger morphological families.

[1] A correlation analysis on the monolingual data did not reveal a significant relationship between the mean response latencies on the task as a whole and the difference in latencies between the high and low Family Size conditions. This is not surprising given that the differences between the Family Size conditions per participant are rather small. Interestingly, we did observe a significant correlation for our relatively slower L2 participants in Experiment 3 ($r = -.44$, $p = .03$, one-tailed), showing that the slower cognates are responded to, the larger the facilitating Family Size effect is. This supports the assumption that effect of Family Size varies as a function of response speed.

Experiment 2: ERP data

Method

Participants. Fifteen native speakers of Dutch with good knowledge of English participated in the ERP experiment (mean age = 24.7 years, $SD = 2.25$). All were right-handed and had normal or normal-to-corrected visual acuity and no history of neurological disorders.

Stimuli. The experimental stimuli were identical to those used in the lexical decision task.

Procedure. Participants performed a Dutch go/no-go lexical decision task. This task is similar to the lexical decision task of Experiment 1 in that participants have to decide whether or not the visually presented stimulus is an existing Dutch word or not. However, in this task, a button press was only required for Dutch pseudowords (randomly appearing in 50% of the trials). This procedure had several advantages. First, it reduced the risk of recording ERPs contaminated by motor artifacts due to button presses. Second, it allowed us to observe any Family Size effects that occur at later stages of word processing (from 600 ms onwards), which would presumably not have been possible if we had included a response component in the task.

The trial presentation procedure was identical to that of the lexical decision task. Presentation of all visual stimuli and digitising of the EEG was synchronised with the vertical retrace interval (60 Hz refresh rate) of the stimulus PCs video card to ensure precise time marking of the ERP data.

EEG recording. Participants were seated in a comfortable chair in a sound proof room and were fitted an elastic cap (ActiCap 32, Brain products GmbH) equipped with 32 tin electrodes. The electrodes were placed at locations from the standard International 10–20 system. Four electrodes were used to monitor for eye-related artifacts (blinks and vertical or horizontal eye-movement): one below, above, and next to the left eye, and one next to the right eye. All electrodes were referenced to an electrode placed over the left mastoid. A final electrode was placed over the right mastoid. The signal was re-referenced to the average to the left and right mastoids before analysis. The 32 channels of electrophysiological data were amplified using a Brain Amp amplifier system (Brain Products, GmbH) with cut-offs set at 0.016 and 100 Hz. The output of the amplifier was continuously digitised with a sampling rate of 1,000 Hz throughout the experiment.

ERP data analysis. The data of the channels were re-referenced to the right mastoid. A low cut-off filter of 0.53 Hz and high cut-off filter of 30 Hz was applied. Data points containing eye-blinks and button presses were removed from the data set (21.5% of the experimental trials). Data of two participants containing artifacts in more than 30% of the experimental trials were removed from the data set. All target items were base-lined to the average of activity in the 100 ms before target onset.

Mean amplitudes were calculated for Dutch target words with a high and a low Family Size in three latencies windows: 100–300 ms to capture early activity prior to the N400, 300–500 ms to capture the N400 itself, and 500–800 to capture later activity. Repeated measures analyses of variance (ANOVA) were conducted with Family Size (high vs. low), Site and Hemisphere (left vs. right) as within-subject factors. The Geisser and Greenhouse correction was applied to all repeated measures with more than one degree of freedom.

To analyse these factors, we adopted the approach from Holcomb and Grainger (2006), dividing the head up in one midline column and six lateral columns along the anteroposterior axis of the head (see Figure 2). The midline analysis included the factors Family Size and Site, containing five levels (Fcz, Fz, Pz, Cz, and Oz). The lateral analysis involved, besides Family Size, the anterior/posterior electrode Site factor with three (column 1: FC1/FC2 vs. C3/C4 vs. CP1/CP2), or four levels (column 2: F3/F4 vs. FC5/FC6 vs. CP5/CP6 vs. P3/P4; column 3: FP1/FP2 vs. T7/T8 vs. P7/P8 vs. O1/O2) and the factor Hemisphere. The electrodes at the midline and columns 1, 2, and 3 were identical to those used by Holcomb and Grainger, except for the two frontal electrodes F7 and F8 from column 3, which were used to detect eye artifacts.

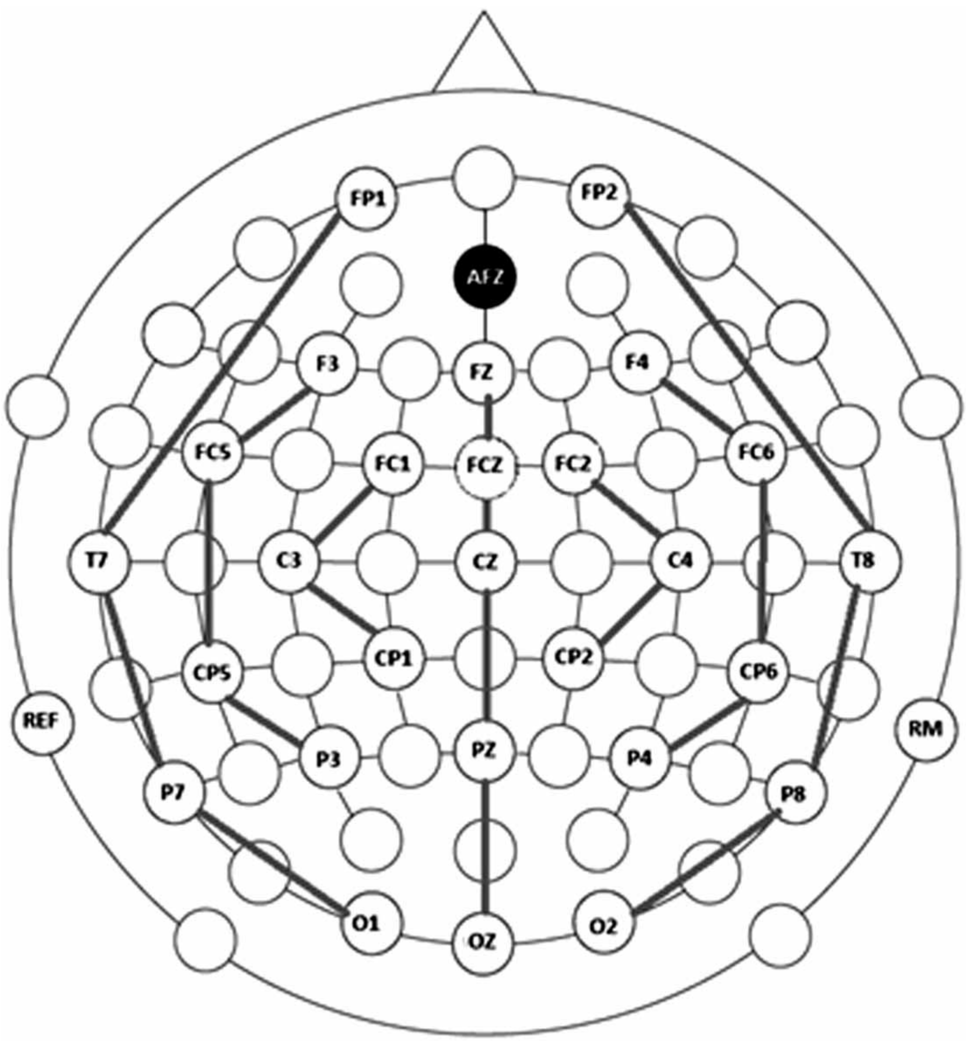

Figure 2. Electrode montage and four regions (midline, c1, c2, and c3) used for the analysis of the electrophysiological data.

Results

Error rate. Trials in which participants either pressed the response button when they were presented with a word, or did not press when they encountered a pseudoword were counted as errors. The mean percentages of errors on the overall task and on the target words in specific were 1.97% and 1.63%, respectively.

Event-related potentials. Grand-average waveforms at the midline sites for items with high and low Family Size, time-locked to the onset of the stimulus, are presented in Figure 3. Visual inspection of Figure 3 suggests a difference between the two conditions in both the 300–500 ms time windows and the 500–800 ms time windows: more negative-going waveforms for items with a low Family Size in the former windows and less positive-going waveform in the latter compared to items with a high Family Size. Moreover, there seems to be an early difference in the 100–300 ms time window. Figure 4 displays the topographic maps obtained by interpolation from 27 sites used for analyses in the 100–300 ms, 300–500 ms, and 500–800 ms time windows.

100–300 ms time window

The ANOVAs with Family Size and Site as within-subject factors on the midline column, and with the additional factor Hemisphere in the three lateral columns revealed no significant main effects of Family Size and no interaction with Site. A significant interaction between Family Size and Hemisphere was obtained in Column 2 [$F(1, 12) = 9.34$, $MSE = 5.38$, $p < .05$], showing higher positive amplitudes for words

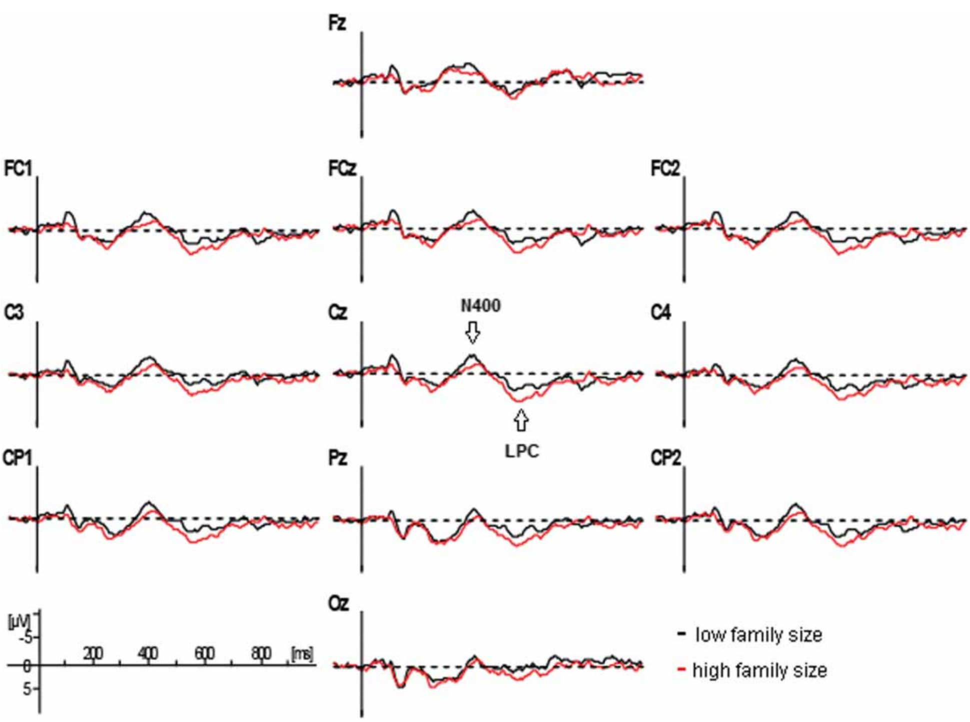

Figure 3. Grand average waveforms of Dutch words with a low Family Size compared to words with a high Family Size.

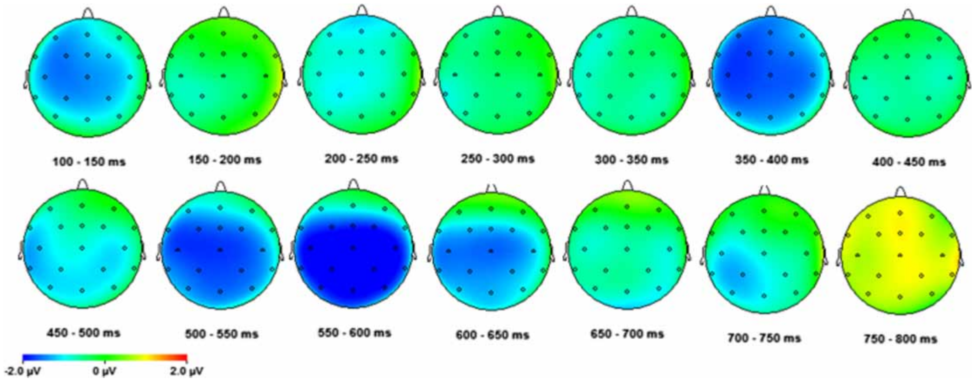

Figure 4. Voltage maps of the difference waves of Dutch words with low Family Size compared to Dutch words with high Family Size, for 50 ms time windows.

with a high Family Size compared to words with a low Family Size in the left hemisphere only. Follow-up *t*-tests show that the effect of Family Size is significant in the left hemisphere [$t(1, 51) = -2.87$, $MSE = 0.23$, $p < .01$], but not in the right hemisphere [$t < 1$].

Additional analyses on time windows of 50 ms (see Table 3) revealed no significant main effects of Family Size, and no interactions with Site. However, there was a significant interaction between Family Size and Hemisphere between 150 and 200 ms in the two most lateral columns: Column 2 and Column 3, and between 250 and 300 ms in Column 2. Moreover, this interaction effect was marginally significant between 200 and 250 ms in Column 2. Follow-up *t*-tests on these columns all show more positive-going waveforms for words with a high Family Size compared to words with a low Family Size in the left hemisphere only.

TABLE 3
Main effect of Family Size (MFS) and Interaction effect of MFS by Site as reported by their *F*-values on the within-subjects test on the midline and lateral columns in L1 processing (Experiment 2) in time windows of 50 ms

Column	*100–150*	*150–200*	*200–250*	*250–300*	*300–350*	*350–400*	*400–450*	*450–500*	*500–550*	*550–600*	*600–650*	*650–700*	*700–750*	*750–800*
MFS														
midline	2.6	<1	1.5	<1	1.2	**12.7**	<1	3.0	**7.3**	**9.4**	**5.6**	1.3	1.3	1.0
C1	3.0	<1	<1	<1	1.0	**10.3**	<1	4.3	**9.4**	**10.8**	**4.8**	1.3	1.7	<1
C2	1.3	<1	<1	<1	1.5	**15.3**	<1	**4.9**	**7.4**	**8.1**	2.7	<1	<1	1.9
C3	<1	<1	<1	<1	<1	4.4	<1	<1	3.5	3.4	1.6	<1	<1	1.4
MFS*Site														
midline	<1	<1	<1	<1	<1	<1	<1	<1	<1	2.1	1.7	1.9	<1	1.8
C1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2	<1	<1	<1	<1	<1	<1	<1	<1	<1	2.2	1.4	1.8	1.5	<1
C3	<1	<1	1.3	<1	<1	1.3	<1	1.3	1.4	<1	<1	1.1	<1	<1
MFS* Hemisphere														
C1	1.4	2.1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	4.6	<1
C2	2.4	**13.9**	3.5	**5.5**	2.6	2.4	<1	3.5	1.9	<1	1.4	<1	**5.9**	<1
C3	<1	**6.1**	2.1	2.2	1.0	<1	<1	<1	2.5	<1	<1	2.9	**5.5**	<1

Note: Underlined $p < .1$, bold $p < .05$, and bold underlined $p < .01$.

300–500 ms time window

The ANOVA on the midline column revealed a main effect of Family Size [$F(1, 12) = 5.58$, $MSE = 3.16$, $p < .05$]. The analyses on the lateral columns revealed a main effect of Family Size in Column 1[$F(1, 12) = 4.91$, $MSE = 7.56$, $p < .05$.], and Column 2 [$F(1, 12) = 5.91$, $MSE = 3.98$, $p < .05$] but not in the most lateral Column 3. The direction of the effect is similar in the four columns: Less negative waves for words with a high Family Size compared to words with a low Family Size. No significant interactions of Family Size with Site or Hemisphere were found.

Additional analyses on time windows of 50 ms (see Table 3) show that the main effect of Family Size was significant in the 350–400 ms time window for both the midline and Columns 1 and 2, and marginally significant for Column 3. Furthermore, a significant main effect of Family Size was observed in the time window of 450–500 ms in the lateral Column 2, and a marginal significant effect in Column 1. In this latter time window, a positivity arose that continued in the 500–800 time window. The main effect of Family Size was reflected in more positive amplitudes for words with a high Family Size compared to words with a low Family Size. Moreover, there was a marginally significant interaction between Family Size and Hemisphere in Column 2 for this time window, showing more positive amplitudes for words with a high Family Size compared to words with a low Family Size in the left hemisphere. Follow-up *t*-tests show that this Family Size effect was not present in right hemisphere.

500–800 ms time window

The ANOVA revealed a marginally significant effect of Family Size for the midline [$F(1, 12) = 4.54$, $MSE = 4.64$, $p = .05$] and for Column 1 [$F(1, 12) = 3.91$, $MSE = 8.99$, $p = .07$], showing more positive amplitudes for words with a high Family Size compared to words with a low Family Size. No interactions between Family Size and Site or Hemisphere were observed.

Further analyses on the main effect of Family Size and interactions with Site in time windows of 50 ms (see Table 3) revealed significant main effects of Family Size between 500 and 550 ms for both the midline column and Columns 1 and 2, and a marginally significant effect in Column 3. Furthermore, the main effect of Family Size was significant between 550 and 600 ms on the midline, and marginally significant in Column 3. After 600 ms, the main effect was reduced to a more central distribution with significant effects between 600 and 650 ms at the midline and Column 1. Finally, a significant interaction between Family Size and Hemisphere was observed between 700 and 750 ms in the most lateral columns and a marginally significant interaction was observed in Column 1, all showing higher positive amplitudes for words with high Family Size in the left hemisphere only. Follow-up *t*-tests revealed that words with a higher Family Size elicit more positive amplitudes in the left hemisphere only in Column 1, and less negative amplitudes in the left hemisphere only in Columns 2 and 3.

Discussion

In Experiment 2, the ERP signal in the N400 (300–500 ms) time window was characterised by a negativity, starting around 300 ms with a frontal negativity, and gaining a wider, centro-parietal distribution, peaking at 400 ms. A significant effect of Family Size in this window was observed. Analysis of separate windows of 50 ms shows that this effect was significant in the 350–400 ms time window. Although the duration of the effect was limited, the direction of the effect is as expected: more negative-going waveforms for words with a low Family Size compared to words with a high Family Size. This is in line with the hypothesis that words that activate a large number of morphological family members are easier to process because more converging semantic information is available, but not in line with the hypothesis that the effects depend only on the amount of semantic activation generated.

The 500–800 ms time windows revealed a positivity, already starting around 450 ms following the negativity in the 300–500 time window, and peaking between 500 and 600 ms. This could reflect a Late Positive Complex (LPC) following the N400 (see also Müller et al., 2010, who observed LPC effects when manipulating orthographic and associative neighbourhood size). The ERP data revealed significantly less positive waveforms for words with a low Family Size than for words with a high Family Size. The observed activation in the 500–800 time windows suggests that even after the lexical decision has been made (i.e., the decision not to press the button because the target is an existing Dutch word), family members remain activated, and resonance of activation persisted.

Interestingly, we also observed early effects of Family Size in the 100–300 ms time window as demonstrated by the interaction between Family Size and Hemisphere in the two most lateral columns. Words with a high Family Size were found to have higher positive amplitudes compared to words with a low Family Size in the left hemisphere. This suggests that Family Size may also affect early stages of word processing. It is, however, not clear to us whether these effects reflect the semantic activation of family members or are effects related to the processing of the word-form of the target word. We will come back to this issue in the General discussion section.

In Experiments 3 and 4, we examined cross-language L1 Family Size effects on cognate processing in an L2 context. Following the language nonselective access account of bilingual word processing, bilinguals co-activate words from the L1 when reading words from the L2 as long as there is enough formal overlap between the two words (for an overview, see Dijkstra & Van Heuven, 2002). Many studies report a facilitation effect of cognates compared to control words (e.g., De Groot & Nas, 1991; Dijkstra, Grainger, & Van Heuven, 1999; Dijkstra, Van Jaarsveld, & Ten Brinke, 1998; Dijkstra et al., 2010; Kroll & Stewart, 1994; Lemhöfer et al., 2008; Sanchez-Casas, Davis, & Garcia-Albea, 1992; Schwartz, Kroll, & Diaz, 2007; Voga & Grainger, 2007). The question is whether during reading in the L2, this co-activation is restricted to the L1 nontarget cognates themselves or whether activation spreads to words that are morphologically related to these L1 cognates.

As has been mentioned in the Introduction, in order to grasp L1 morphological Family Size effects on cognate processing in L2 lexical decision, the Family Size of the L2 needs to be controlled for. This was done in Experiment 3 in which English cognates with a high and a low Dutch Family Size were contrasted in an English lexical decision task while the English Family Size has been kept constant. If a high L1 Family Size facilitates cognate processing, then this should result in faster RTs for cognates with larger morphological families compared to cognates with a smaller number of family members.

L1 MORPHOLOGICAL FAMILY SIZE EFFECTS IN L2 PROCESSING

Experiment 3: Behavioural data

Method

Participants. Nineteen right-handed native speakers of Dutch (mean age = 20.0 years old, *SD* = 2.75) with good knowledge of English received money or course credits to participate in this experiment. Experience with and proficiency in the (L2) English was assessed by using a language background questionnaire and the X-Lex vocabulary task (Meara & Milton, 2003), respectively.

Stimuli. The stimulus set consists of 300 items, half of which are English words and half are pseudo-words. All word items were selected from the CELEX database (Baayen et al., 1995). Only mono-morphemic words with a lemma frequency of at least one per million in the CELEX database and a length between four and six characters were selected. For each item, the English Family Size values were calculated and logarithmically transformed.

The experimental word items were 60 English–Dutch cognates, i.e., translation equivalents that share their form in Dutch and English. The cognates could be either identical cognates (i.e., items that have complete orthographic overlap in two languages, such as HOTEL and NORM), or nonidentical cognates (e.g., THIEF and PLANET, in Dutch "dief" and "planeet", respectively). For the latter items, the overlap was not completely identical and differed on maximally two letter positions. The degree of orthographic overlap was calculated by the Levenshtein distance measure (Levenshtein, 1966; the minimal number of deletions, insertions, or substitutions that is required to transform the source string into the target string). For each cognate item, the Dutch Family Size was calculated and logarithmically transformed. Half of the cognate items had a high Dutch Family Size (above 30, mean 37.6) and the other half had a low Dutch Family Size (below 10, mean 3.6). The difference between the mean numbers of Dutch family members in both sets was statistically significant ($p < .01$). Finally, to be sure that any significant effects could only be explained by differences in Dutch Family Size (high vs. low) and not by English Family Size or English or Dutch frequency, we controlled for these variables by keeping them constant over the two sets of cognates. Moreover, we controlled for Levenshtein distance and English bigram frequency (all p's $> .05$).[2]

The experimental word items were matched with 60 noncognate English control items on English Family Size, English frequency, the number of English orthographic neighbours, and length in letters. Note that these items do not have a Dutch reading, and consequently no Dutch Family Size. The experiment also included 30 noncognate filler words to reduce awareness of the presence of cognate items. These items were matched on English frequency and length to the cognate items. Characteristics of experimental and control items are presented in Table 4. Finally, 150 pseudo-words were included that resembled English words with respect to their orthography and phonology. They were created by replacing one or more letters of existing English words. The pseudo-words were matched to the experimental stimuli on length. The presentation order of the items was randomised for each participant individually and had the restriction that no more than three words or nonwords could follow each other directly.

Procedure. Participants performed an English lexical decision task. In this task, they have to decide whether or not the word they are presented with is an existing

[2] Because cognates are productive in terms of the number of family members, they generally also have a higher number of orthographic neighbours compared to words that are morphologically less productive. Thus, it was not possible to match them on English or Dutch orthographic neighbourhood size (mean number of orthographic neighbours for the high Family Size and low Family Size conditions, respectively: English neighbours 6.07/2.83, Dutch neighbours 3.37/1.93). However, regression analysis on the RT data revealed no significant effect of either Dutch or English neighbourhood size measure, while there was an effect of Dutch Family Size.

TABLE 4
Item characteristics of the experimental items used in the L2 lexical decision data (Experiment 3 and 4)

	Length	*Log English frequency*	*Log English Family Size*	*English bigram*	*Levenshtein distance*	*Log Dutch frequency*	*Log Dutch Family Size*
Cognates with high Family Size	4.8	3.62	2.15	13.9	0.83	3.44	3.58
Cognates with low Family Size	4.65	3.56	1.78	14	0.7	2.95	1.06
Controls	4.97	3.61	1.74	11.7	–	–	–

English word or not by pressing a button corresponding to the answer yes or no. The procedure concerning the presentation of the stimuli is identical to that of Experiment 1. The items were presented in two blocks of each 150 stimuli (requiring approximately seven minutes) with one pause in between.

Results

Data cleaning was first carried out based on the error rate for participants and word items. All participants had an error rate of 15% or less on the word items (mean accuracy 94%, range 88–100%). Therefore, no participant data were removed. The mean accuracy for the word items was 94% (range 21–100%). Six items (one cognate from the low Family Size condition: *altar*, two cognates from the high Family Size condition: *bible, lung*, and 3 controls: *cereal*, *debt*, *parcel*) that elicited errors in more than 30% of the trials were removed from the data set. RTs from incorrect responses or null responses were removed from the remaining data set (4.1% of the remaining 2166 data points). Finally, outlier RTs that were 2.5 *SD* above or below the subject and item mean were removed (3.9% of the remaining 2077 data points). This resulted in a data set with 1994 data points.

Repeated measures analyses of variance (ANOVA) were conducted on the RT and accuracy data with Family Size (high vs. low) as a within-subject factor. A main effect of Family Size was observed in the RT data [$F1(1, 18) = 14.2$, $MSE = 354.86$, $p < .01$; $F2(1, 55) = 3.16$, $MSE = 1793.83$, $p = .08$], revealing slower RTs for cognate with smaller Dutch morphological families compared to words with a high Dutch Family Size. Furthermore, an ANOVA with Stimulus Category (cognate vs. controls) as a within-subject variable revealed a facilitation effect for cognates [$F1(1, 18) = 28.8$, $MSE = 149.25$, $p < .001$; $F2\ (1, 112) = 7.67$, $MSE = 2063.43$, $p < .01$].

The accuracy data showed no main effect of Family Size in the accuracy rates on cognates [$F1 < 1$; $F2 < 1$]. Furthermore, the ANOVA with Stimulus Category as a within-subject variable revealed that cognates had significantly higher accuracy scores than controls [$F1(1, 18) = 6.67$, $MSE = 0.001$, $p < .05$; $F2(1, 112) = 6.33$, $MSE = 0.004$, $p < .05$].

Mean response latencies and accuracy scores for cognates with high and low Family Size as well as mean response latencies for cognates and controls are displayed in Table 5.

TABLE 5
Mean response latencies and accuracy scores and their standard deviations between parentheses for cognates with high and low Family Size, and for cognates and controls in the L2 lexical decision data (Experiment 3)

	RT (SD)	*Accuracy* (SD)
Cognate high Family Size	561 (72.51)	0.97 (0.03)
Cognate low Family Size	583 (83.93)	0.97 (0.03)
Cognate	572 (77.51)	0.97 (0.03)
Control	593 (77.34)	0.94 (0.05)

Discussion

As predicted, the data of Experiment 3 revealed a processing advantage for cognates compared to noncognate control words, indicating that participants activated both the target language and nontarget language representations of cognate words.

We further predicted that, if nontarget language (L1) words are activated during L2 processing, the L1 family members should be activated as well and influence L2 word processing. Indeed, as for the L1 data of Experiment 1, L1 Family Size had a facilitatory effect on the lexical decision latencies. Cognate words with a higher number of morphological derivates in the L1 were processed faster than cognate words with a smaller number of L1 family members. Importantly, this result indicates that the Family Size of the L1 is activated during L2 word processing. This finding for cognates is in line with Dijkstra et al. (2005), who observed L1 Family Size effects for interlingual homographs in L2 lexical decision. Furthermore, the direction of the effect is in accordance with the findings of Mulder et al. (2012) that activation of cross-language family members facilitates cognate processing in an L2 lexical decision task when the target language Family Size is controlled for.

In Experiment 4, the same materials were tested by using ERPs. If Family Size modulates cognate processing in a way similar to what was observed in the behavioural task of Experiment 3, namely facilitating cognate processing, then this should translate into less negative waveforms in the N400 time window for cognates with a high Family Size compared to cognates with a low Family Size. This would be in line with the hypothesis that the activation of convergent semantics leads to less negative-going N400 waves for words with a high Family Size (as observed in Experiment 2).

EXPERIMENT 4: ERP DATA

Method

Participants

Nineteen native speakers of Dutch (mean age = 22.57 years old, $SD = 3.32$) were recruited and compensated for their time. All were right handed and had normal or corrected-to-normal visual acuity with no history of neurophysiological disorders. Participants were matched on English proficiency to the participants of Experiment 3 by means of the X-Lex vocabulary task (Meara & Milton, 2003), and a language background questionnaire.

Stimuli

The stimuli were identical to those of Experiment 3.

Procedure

The procedure was identical to that of Experiment 3, except that the participants performed an English go/no-go lexical decision task. In this task, participants had to read words presented in isolation and pressed a response button whenever they saw an English pseudo-word (randomly appearing in 50% of the trials).

EEG recording

The settings for the EEG recording were identical to that of Experiment 2.

ERP data analysis

Data were analysed following the same procedure as in Experiment 2. Data points containing eye-blinks and button presses were removed from the data set (23% of the experimental trials). Data of six participants containing artifacts in more than 30% of the experimental trials were removed from the data set. All target items were baselined to the average of activity in the 100 ms before target onset.

Mean amplitudes were calculated for English target words with a high and a low Dutch Family Size in the three latencies windows that are similar to the ones used in Experiment 2: 100–300 ms to capture early activity prior to the N400, 300–500 ms to capture the N400 itself, and 500–800 ms to capture later activity. Repeated measures analyses of variance (ANOVA) were conducted with Family Size (high vs. low), Site, and Hemisphere (left vs. right) as within-subject factors. Separate ANOVAs were conducted to examine Family Size effects at the midline, and three lateral columns used in Experiment 2. Finally, to determine whether there was a cognate effect, separate ANOVAs with the factor Stimulus Category (cognate vs. control) were conducted in the three time windows mentioned above.

Results

Error rate

The mean percentages of errors on the overall task and on the target words in specific were 7.5% and 3.85%, respectively.

Event-related potentials

Grand-average waveforms at the midline sites for items with high and low Family Size, time-locked to the onset of the stimulus, are presented in Figure 5. Visual inspection of Figure 5 suggests a difference between the two conditions in both the 100–300 ms and 300–500 ms time windows, and the 500–800 ms time window: more negative-going waveforms for items with a low Family Size in the former windows and more positive-going waveforms in the latter compared to items with a high Family Size. Figure 6 displays the topographic maps obtained by interpolation from 27 sites used for analyses in the three time windows.

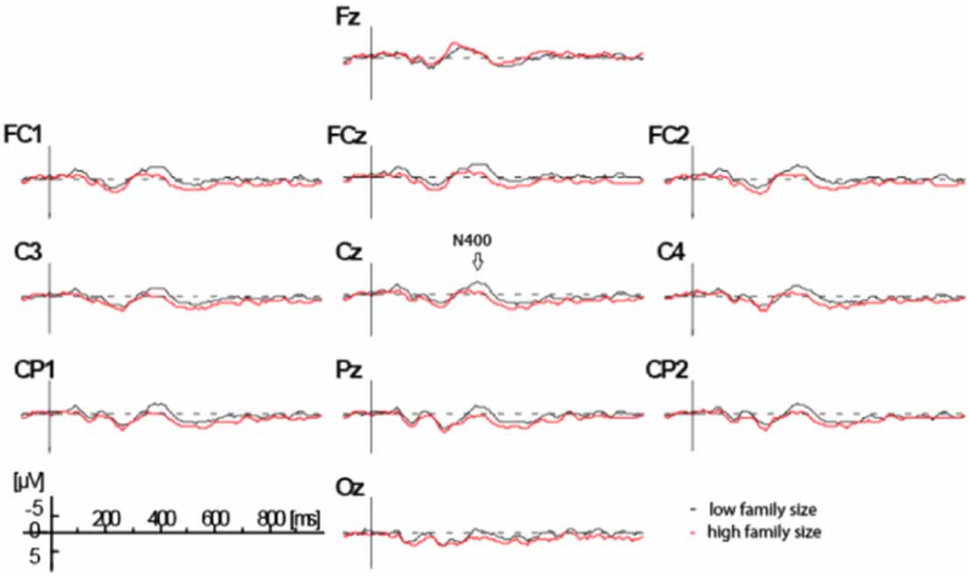

Figure 5. Grand average waveforms of English words with a low Dutch Family Size compared to English words with a high Dutch Family Size.

100–300 ms time window

The ANOVA with Family Size and Site as within-subject factors on the midline column showed no main effects of Family Size, nor was there an interaction between Family Size and Site. The ANOVA with Family Size, Site and Hemisphere on the lateral columns revealed a marginally significant effect of Family Size in Column 1 [$F(1, 12) = 3.99$, $MSE = 9.23$, $p = .07$], showing more positive amplitudes for words with a high Family Size compared to words with a low Family Size.

Additional analyses on time windows of 50 ms (see Table 6) show that the main effect of Family Size is only marginally significant between 100 and 150 ms in Column 1, and between 150 and 200 ms on the midline and in Column 1, with more positive amplitudes for words with a high Family Size compared to words with a low Family Size. However, there was a significant interaction between Family Size and Site between

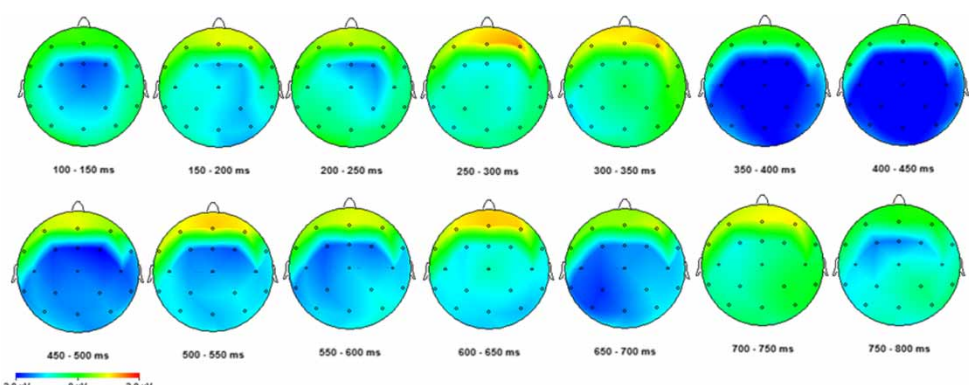

Figure 6. Voltage maps of the difference waves of English words with low Dutch Family Size compared to English words with high Dutch Family Size, for 50 ms time windows.

TABLE 6
Main effect of Family Size (MFS) and Interaction effect of MFS by Site as reported by F-values on the within-subjects test on the midline and lateral columns in L2 processing (Experiment 4) in time windows of 50 ms

Column	*100–150*	*150–200*	*200–250*	*250–300*	*300–350*	*350–400*	*400–450*	*450–500*	*500–550*	*550–600*	*600–650*	*650–700*	*700–750*	*750–800*
MFS														
Midline	2.6	3.8	<1	<1	<1	**6.6**	**10.2**	2.2	2.3	1.6	<1	1.9	<1	1.4
C1	3.9	4.3	1.9	1.8	<1	**7.2**	**14.7**	**5.0**	3.9	4.3	1.9	3.5	<1	1.9
C2	<1	<1	<1	<1	<1	**5.9**	**5.5**	1.4	<1	2.8	<1	1.8	<1	1.2
C3	<1	1.1	<1	<1	<1	**9.2**	3.2	1.9	1.4	2.0	1.8	2.9	<1	1.5
MFS*Site														
Midline	4.3	3.6	**3.3**	4.9	1.9	2.7	6.1	7.4	8.5	**4.7**	**8.8**	3.4	2.1	1.6
C1	2.2	<1	1.5	<1	<1	<1	2.0	1.5	1.7	1.6	<1	<1	<1	3.5
C2	1.2	4.0	1.9	**8.0**	4.5	5.3	4.8	**7.2**	7.5	4.3	**15.9**	**7.5**	3.4	1.2
C3	<1	3.3	1.9	3.3	2.8	**6.8**	5.2	7.7	6.9	5.6	**10.6**	**4.1**	2.4	1.5
MFS*Hemisphere														
C1	<1	<1	1.3	<1	1.2	<1	<1	<1	<1	<1	<1	2.2	2.7	1.4
C2	<1	<1	<1	<1	<1	<1	<1	2.3	2.7	<1	1.1	<1	<1	<1
C3	<1	<1	<1	<1	2.1	<1	<1	<1	<1	2.6	<1	<1	<1	1.1

Note: Underlined $p < .1$, bold $p < .05$, and bold underlined $p < .01$. The F-values are only marked as significant or marginally significant in the within-subject test when the effects were also significant in the multivariate tests. In cases in which an effect was (marginally) significant in the within-subjects test but had a p-value larger than .05 in the multivariate test, the F-value of the within-subjects test is not underlined as (marginally) significant.

200 and 250 ms on the midline, and between 250 and 300 ms in Column 2. Finally, this interaction was found to be marginally significant in Column 3 between 250 and 300 ms. Follow-up t-tests show less positive amplitudes for words from a high Family Size compared to words with a low Family Size in the most frontal electrode site, but more positive amplitudes compared to words with a low Family Size in the other sites. No significant interactions between Family Size and hemisphere were observed.

Finally, the ANOVA with Stimulus Category, Site, and Hemisphere as within-subject factors run to determine whether there were any effects of cognate status revealed no main effect of Stimulus Category and no significant interactions with Site or Hemisphere neither on the midline nor on the lateral columns. However, a marginally significant three-way interaction between Stimulus Category, Site and Hemisphere were observed for Column 1 [$F(1.9, 22.6) = 2.90$, $MSE = 0.076$, $p = .08$], revealing more positive amplitudes in the left hemisphere compared to the right hemisphere for cognates in the central electrode site.

300–500 ms time window

The midline analysis revealed a significant main effect of Family Size [$F(1, 12) = 5.88$, $MSE = 7.56$, $p < .05$]. Words with a high Family Size had less negative amplitudes than words with a low Family Size. A significant interaction was observed between Site and Family Size [$F(2.3, 27.4) = 5.22$, $MSE = 1.84$ $p < .01$]. The interaction showed that the effect was reversed in the frontal electrode site of the midline column: Words with a high Family Size had more negative amplitudes compared to words with a low Family Size in the most frontal site, while being less negative in the other electrode sites. Follow-up t-tests revealed this effect of Family Size was not significant in the frontal electrode site [Fz: $t < 1$], but was significant or marginally significant in the other columns [FCz: $t(1, 12) = 2.80$, $MSE = 0.67$, $p < .05$; Cz: $t(1, 12) = 2.39$, $MSE = 0.68$, $p < .05$; Pz: $t(1, 12) = 2.57$, $MSE = 0.66$, $p < .05$; Oz: $t(1, 12) = 1.97$, $MSE = 0.52$, $p = .07$].

ANOVAs with Family Size, Site, and Hemisphere as within-subject factors on the lateral columns revealed a significant main effect of Family Size for Column 1 [$F(1, 12) = 8.49$, $MSE = 12.45$, $p < .05$], and a marginally significant effect in Column 2 [$F(1, 12) = 3.84$, $MSE = 6.08$, $p = .07$]. Again, words with a high Family Size induced less negative amplitudes. A significant interaction between Family Size and Site was obtained for Column 2 [$F(1.5, 18.2) = 7.01$, $MSE = 2.38$ $p. < .01$] and Column 3 [$F(1.4, 17.1) = 8.15$, $MSE = 2.46$, $p < .01$], showing more negative amplitudes for words with a high Family Size in the most frontal sites but less negative in the other sites. Follow-up t-tests revealed significant effects of Family Size mainly in the non-frontal sites of Column 2 and in all sites of Column 3 [column 2: F3/F4: $t(1, 25) = -1.06$, $p = .30$; FC5/FC6: $t(1, 25) = 1.17$, $p = .25$; CP5/CP6: $t(1, 25) = 3.81$, $MSE = 0.35$, $p < .01$; P3/P4: $t(1, 25) = 3.27$, $MSE = 0.39$, $p < .01$; column 3: FP1/FP2: $t(1, 25) = -2.12$, $MSE = 0.34$, $p < .05$; T7/T8: $t(1, 25) = 3.18$, $MSE = 0.28$, $p < .01$; P7/P8: $t(1, 25) = 2.96$, $MSE = 0.34$, $p < .01$; O1/O2: $t(1, 25) = 2.89$, $MSE = 0.37$, $p < .01$]. Finally, a three-way interaction between Family Size, Site, and Hemisphere was found to be significant in Column 2 [$F(2.1, 25.3) = 3.84$, $MSE = 0.53$, $p < .05$] and approached significance in Column 3 [$F(2.0, 24.1) = 2.67$, $MSE = 0.48$, $p = .089$]. Follow-up t-tests on the data of Column 2 revealed that words with a high Family Size had more negative amplitudes compared to words with a low Family Size in the frontal sites, and less negative amplitudes in the nonfrontal sites, expect for column FC5 in the left hemisphere, where words with a high Family Size had larger negative amplitudes [FC5: $t < 1$; FC6: $t(1, 12) = 2, 14$, $MSE = 0.42$, $p = .054$].

Additional analyses on time windows of 50 ms (see Table 6) showed a significant main effect of Family Size between 350 and 400 ms on all columns, becoming somewhat less lateral between 400 and 500 ms. Furthermore, significant interactions between Family Size and Site between 350–400 ms at Column 3 and between 450–500 ms at Column 2 show that words with a high Family Size have less negative amplitudes compared to words with a low Family Size at central and posterior sites, while the effect is reversed or absent at the utmost frontal site of the columns. Finally, no significant interaction with Hemisphere was observed.

Finally, the ANOVA including Stimulus Category, Site, and Hemisphere as within-subject factors showed no main effect of Stimulus Category. However, a significant interaction between Stimulus Category and Site was obtained for the midline: [$F(1.9, 23.8) = 3.47$, $MSE = 1.70$, $p < .05$], showing more negative amplitudes for cognates vs. noncognate control words in all sites except the most frontal site, in which the opposite effect was found. Follow-up t-tests only show a (marginally) significant effect of Stimulus Category at the two most posterior sites [Fz: $t = 1.42$, $p = .18$, FCz: $t < 1$, Cz: $t < 1$; Pz: $t(1, 12) = -2.22$, $MSE = 0.46$, $p < .05$; Oz: $t(1, 12) = -2.04$, $MSE = 0.57$, $p = .06$]. Furthermore, the interaction between Stimulus Category, Site, and Hemisphere was found to be significant in Column 1 [$F(1.7, 20.6) = 3.71$, $MSE = 0.11$, $p < .05$], and only marginally significant in Column 3 [$F(1.8, 22.5) = 3.02$, $MSE = 0.31$, $p = .07$]. Follow-up t-tests revealed only a marginally significant effect of Stimulus Category at the centro-parietal electrode site in the left hemisphere for Column 1 [CP1: $t(1, 12) = -1.98$, $MSE = 0.47$, $p = .07$], showing less positive amplitudes for cognates at this site. In Column 3, (marginally) significant effects were only observed at frontal-parietal and posterior sites in the right hemisphere [FP2: $t(1, 12) = 2.20$, $MSE = 0.37$, $p < .05$; O2: $t(1, 12) = -2.07$, $MSE = 0.43$, $p = .06$], showing less negative amplitudes for cognates relative to controls at FP2 but less positive amplitudes for cognates at O2.

500–800 ms time window

The ANOVA on the midline revealed no significant effect of Family Size, but showed a significant interaction between Site and Family Size [$F(1.9, 23.1) = 6.98$, $MSE = 1.39$, $p < 0.01$]. Follow-up *t*-tests showed more positive amplitudes for words with a high Family Size compared to words with a low Family Size on all electrode sites except the most frontal site [Fz: $t(1, 12) = -2.21$, $MSE = 0.37$, $p < .05$; FCz: $t(1, 12) = 2.01$, $MSE = 0.63$, $p = 0.07$; Cz: $t(1, 12) = 1.75$, $p = .11$; Pz: $t(1, 12) = 2.32$, $MSE = 0.46$, $p < .05$; Oz: $t(1, 12) = 1.77$, $p = 10$]. The ANOVA with Family Size, Site, and Hemisphere as within-subject factor on the lateral columns revealed a marginal significant main effect of Family Size [$F(1, 12) = 4.29$, $MSE = 11.39$, $p = .06$] in Column 1, showing more positive amplitudes for words with a high Family Size. The interaction between Family Size and Site was significant in Column 2 [$F(1.5, 17.4) = 9.95$, $MSE = 1.73$, $p < .01$] and in Column 3 [$F(1.7, 20.1) = 9.21$, $MSE = 1.31$, $p < .01$]. Follow-up *t*-tests on these interactions revealed that words with a high Family Size revealed more positive amplitudes than words with a low Family Size in all sites but not the most frontal site [column 2: F3/F4: $t(1, 25) = -3.45$, $MSE = 0.21$, $p < .01$; FC5/FC6: $t < 1$; CP5/CP6: $t(1, 25) = 3.16$, $MSE = 0.32$, $p < .01$; P3/P4: $t(1, 25) = 2.85$, $MSE = 0.33$, $p < .01$; column 3: FP1/FP2: $t(1, 25) = -3.17$, $MSE = 0.23$, $p < .01$; T7/T8: $t(1, 25) = 2.46$, $MSE = 0.27$, $p < .05$; P7/P8: $t(1, 25) = 3.29$, $MSE = 0.28$, $p < .01$; O1/O2: $t(1, 25) = 2.74$, $MSE = 0.32$, $p < .05$]. Further a three-way interaction between Family Size, Site, and Hemisphere was obtained in Column 2 [$F(2.2, 26.3) = 11.87$, $MSE = 0.26$, $p < .001$]. Follow-up *t*-test showed significantly more positive amplitudes for words with a high Family Size in the nonfrontal sites, but not in site FC5 in the left hemisphere, where less negative amplitudes are observed [FC5: $t = 1.71$, $p = .11$].

Analysis on the 50 ms time windows (see Table 6) revealed no main effects of Family Size. However, significant interactions between Family Size and Site were observed between 600–650 and 650–700 ms on the midline and most lateral columns c2 and c3, showing more positive amplitudes for words with a higher Family Size compared to words with a smaller Family Size at all sites, except for the most frontal site. A three-way interaction between Family Size, Site, and Hemisphere was observed in Column 2 between 600–650 ms and 650–700 ms.

Finally, the ANOVA with Stimulus Category, Site, and Hemisphere as within-subject factors run on the midline and lateral columns revealed no main effect of Stimulus Category and no interactions with Site or Hemisphere.

Discussion

The most important finding of Experiment 4 was that Morphological Family Size modulated cognate processing, inducing a less negative waveform for cognates with a higher Family Size compared to cognates with a lower Family Size in the N400 time window. The direction of the Family Size effect in the ERP data was the same as in the L1 ERP data of Experiment 2. Apparently, in this task situation, L1 Family Size facilitates word processing regardless of whether Dutch L1 speakers read in their L1 Dutch or their L2 English. Interestingly, the effect of Family Size seems to emerge, though not fully significant, as early as 100 ms upon stimulus presentation, and became significant in the ERP signal from 200 ms onwards. This is comparable to what was observed in the monolingual ERP data of Experiment 2.

The negative waveform observed in the N400 time window quickly shifts into a positive component in the 500–800 ms time window. Family Size was found to significantly affect this waveform: A more positive-going waveform was observed for words with a high Family Size compared to cognates with a low Family Size. This is in line with the findings of Experiment 2. Visual inspection of the ERP suggests that this waveform is a continuation of the N400 rather than a combination of two differentiated components (N400 and LPC), as we proposed in Experiment 2, though we cannot exclude this possibility.

Interestingly, the ERP data showed larger negativities for cognates relative to noncognate controls within the N400 time window. This contrasts with the facilitation effect that was observed in Experiment 3 on the same materials. The cognate facilitation effect is a well-established effect that has been observed in a large number of behavioural studies. Moreover, in a go/no-go semantic categorisation study during which ERPs were recorded, Midgley et al. (2011) mainly observed less negative amplitudes in the N400 time window for cognates than for noncognates.

However, Midgley et al. also observed more negative amplitudes for cognates than for controls at more posterior sites (Oz and Pz) of the midline column between 300 and 400 ms in the L2 block of the experiment. Interestingly, follow-up *t*-tests on our data show that the cognate effect was also only significant or marginally significant at these same posterior sites. Midgley et al. argued that the reversed cognate effect might reflect a conflict in the mapping of orthography to phonology that is exaggerated in the case of cognates due to the fact that the orthography maps onto two phonological representations. Future research should further investigate this issue.

However, from 400 ms onwards, Midgley et al. predominantly found less negative amplitudes for cognates relative to controls. The difference between the direction of the effect in the present study and the study of Midgley et al. (2011) might be attributed to task-related effects. In the latter study, participants had to read lists of words for meaning while making occasional button presses to probes belonging to a specific semantic category. No button presses to the cognate items were required, and the semantic go/no-go paradigm ensured semantic processing. In the go/no-go lexical decision task, participants were told not to press a button when they saw an English word, but only to press a button when they saw a pseudo-word. Participants were explicitly asked to judge the lexical status of the presented item in the target language and may have applied a response strategy consisting of detecting non-English cues rather than focusing on the actual lexical status of the stimulus. Any non-English lexical activation may then feed the inappropriate no-response. Thus, in the case of seeing an English–Dutch cognate, a response conflict may have arisen, because participants may have initially been inclined to press the button because the item was a correct Dutch word, but then had to inhibit this button press because the word was an existing English word as well. In the study of Midgley et al., this response competition was fully absent because the language membership of the items was not questioned.

Task differences have been observed to result in different cognate effects. For instance, in studies using the language decision paradigm, in which a participant is asked to determine whether the stimulus is a word in one language or the other, cognate inhibition effects were observed (cf. Dijkstra et al., 2010). With different experimental manipulations or designs, these studies suggest that cognate inhibition can arise when lexical information in the target language must be retrieved. Further research should show whether or not our explanation of the observed cognate inhibition effect in terms of response competition holds.

GENERAL DISCUSSION

Behavioural (e.g., Schreuder & Baayen, 1997) and MEG (Pylkkänen et al., 2004) studies on Morphological Family Size have shown that this variable influences lexical processing. The behavioural studies suggest that the Family Size effect is mainly semantically driven (e.g., De Jong et al., 2000; Schreuder & Baayen, 1997). Our study addressed the role of Morphological Family Size in L1 and L2 word processing. The aim of this study was two-fold. First, we wanted to show, for the first time, that also the ERP signal is sensitive to Morphological Family Size effects. Second, we wanted to investigate if this sensitivity to L1 Family Size is restricted to L1 processing, or whether L2 processing can be influenced by it as well. There is ample evidence that in an L2 context, L1 lexical items become activated (see for an overview, Dijkstra & Van Heuven, 2002). In the present study, we investigated if this activation of the nontarget language is restricted to the level of representation of the lemma itself, or whether activation is spread beyond the lemma level, to the morphological family of the activated lemma. This was done by examining Family Size effects in bilingual processing using both behavioural and electrophysiological measures. We investigated, if and when, during L2 cognate processing, the family members of the activated L1 cognates also become activated.

To set the stage for cross-language Family Size effects in L2 processing, Experiments 1 and 2 investigated Family Size effects in L1 processing. Experiment 1, a Dutch (L1) lexical decision task with Dutch (L1)-English (L2) bilinguals, replicated previous monolingual studies showing faster response latencies in lexical decision for Dutch words with a high Family Size. Exactly the same materials were used in a go/no-go lexical decision task (Experiment 2) while ERPs were recorded. As predicted, the ERP data showed an effect of Family Size in the N400 time window: Less negative amplitudes were observed for Dutch words with a high Family Size compared to words with a low Family Size. This effect persisted in the 500–800 ms time window with more positive amplitudes for words with a high Family Size. Interestingly, Family Size was also found to affect early processing stages as was reflected by a significant interaction between Family Size and Hemisphere showing that the effect of Family Size is left-lateralised. This experiment shows, for the first time, that the ERP signal is sensitive to differences in Family Size.

Experiments 3 and 4 investigated L1 Family Size effects in L2 processing, again using both behavioural and ERP measures. To study L1 Family Size effects in L2 cognate processing, the L1 Family Size was manipulated while the Family Size of the target (L2) language was controlled for. Importantly, the contrast in Dutch Family Size in Experiments 3 and 4 was comparable to those of Experiments 1 and 2. Experiment 3 showed facilitation for cognates compared to controls in terms of response speed. Family Size was found to modulate cognate processing: Faster RTs arose for cognates with high Family Size compared to cognates with low Family Size. This result suggests that activation of the nontarget language spreads beyond the activated lemma itself, even activating family members of this nontarget word. Experiment 4 revealed the same modulation of Family Size on cognate processing: Cognates with a higher Family Size showed less negative amplitudes than cognates with a lower Family Size in the N400 time window. The effects arose in the ERP signal significantly from 200 ms onwards. Again, the Family Size effect persisted in later time windows. Thus, similar to what was observed Experiment 3, Family Size facilitated word processing. These experiments show that Family Size of the L1 affects word processing even if the L1 is not the target language at that moment.

In the introduction of this paper, we argued that the direction of the Family Size effect in the N400 time window could differ along two hypotheses. First, more negative-going waveforms could be observed for words with a high Family Size compared to words with a low Family Size because more semantic information is activated. This would be in line with the findings of Holcomb et al. (2002) and Müller et al. (2010), who observed that words with a large number of orthographic neighbours elicit larger (i.e., more negative-going) N400 amplitudes compared to words with a smaller number of neighbours. Furthermore, Müller et al. showed that the same pattern in the N400 effect could be observed for words with a large or small number of semantic associates.

The alternative hypothesis was that the kind of the semantic information would influence the N400 effect. Arguing that the semantics of family members are convergent with that of the target, words with a high number of family members should be easier to process than words with a lower Family Size, given that more activation maps onto the same semantics. This should then translate into less negative N400 amplitudes for words with a high Family Size.

In the present study, we found evidence for this second hypothesis. In both the L1 and L2 ERP data, words with a large number of morphological relatives elicited more negative amplitudes in the N400 time window compared to words with a smaller Family Size. The discrepancy in direction of the N400 effect for Morphological Family Size on the one hand, and orthographic and associative neighbourhood size on the other hand, raises an interesting point. The difference in direction of the N400 effect could reflect the sensitivity of this component to semantic convergence between target and activated items. While activating either a large number of orthographic neighbours and morphological family members should both generate a large amount of semantic activation, the activated semantics of the two types of words have a different relation to that of the target. The activated orthographic neighbours do not overlap in semantics with the target, while this is the case for family members. For example, the target *dog* does not share semantic overlap with its orthographic neighbours *fog* and *dot*, while morphological family members of this target such as *doggy*, *dog fight*, *bulldog* do map on similar semantics. Thus, words with many orthographic neighbours show a larger N400 compared to words with few neighbours because more conflicting semantic information relative to the target is activated.[3] Family members, on the other hand, activate more overlapping semantic information than orthographic neighbours because they contain the target. As a consequence, they feed the activation of semantic representation of the target, hence increasing the activation level of the target word. This will result in less negative N400 amplitudes for words with a large number of family members, because the target is processed more easily based on more semantic evidence feeding this target.

The observed larger N400 for words with a large number of semantic associative neighbours compared to words with a smaller number of semantic associates is particularly interesting, because these activated items overlap, just like morphological family members, in semantics with the target, while not being form-related to the target (as is the case for family members). For instance, the target *dog* should very likely activate semantic associates such as *animal*, *cat,* or *pet.* Though these associates

[3] This assumption does not imply that neighborhood size effects due to conflicting semantics should lead to inhibitory effects in behavioral experiments such as lexical decision. The commonly observed facilitation effects for orthographic neighbourhood size could be based on global lexical activation, feeding the positive response to a given target.

converge, just like family members, with the target on a common concept, it is clear that the semantic relationship between these items and the target is much more diverse. The part of the semantic representation of the associate that overlaps with the target does not encompass the whole semantics of the target but just a small part of it. As a consequence, activating a large number of semantic associates will activate a large amount of irrelevant semantic information.

For activated family members, the semantic relationship they share with the target is in part always the same, because a part of their form overlaps completely or almost completely with that of the target (e.g., *dog fight* contains the target *dog*). This means that a part of the semantics that is activated by the family members corresponds directly to the complete semantic representation of the target. This might boost the activation level of the target considerably. Just because of their formal overlap with the target, the activated semantics of the family members themselves are always more overlapping with that of the target than is the case for semantic associates.

The reason that associate neighbourhood size generates a different N400 effect than Morphological Family Size should, therefore, reside in the fact that semantic associates, while partly feeding the semantic activation of the target, also activate a large amount of semantic information that is not overlapping with the semantics of the target. For example, a large part of the activated semantics of the associated word *cat* of the target *dog* is not dog-related at all. Therefore, activating a target with many semantic associates will generate a large amount of conflicting semantic information, which will generate a large N400 for these targets. Family members will always directly map on and hence feed the semantic representation of the target, just because they contain an element that overlaps in form with the target. A target with many family members will therefore generate a large amount of converging semantic activation and elicit a less negative N400 amplitude compared to targets with few family members.

The interpretation presented above is in line with studies that show that the N400 amplitude varies with semantic relationships between individual words in lists, when the words are attended (see for a review on characteristics of the N400, Kutas & Federmeier, 2000). Although many of these studies focus on semantic priming, they show that the N400 is sensitive to various types of semantic relationships. Importantly, the results of the present study do not contradict the interpretation of Müller et al. (2010) that more semantic activation due to the activation of orthographic neighbours or semantic associates leads to processing difficulties. Rather, the findings of this study extend the interpretation of these effects, relating it to the kind of semantic overlap between target word and activated item (cf. Carrasco-Ortiz, Midgley, & Frenck-Mestre, 2012, for an alternative explanation of differing N400 effects with respect to interlingual homophones).

Remarkably, in both data sets, significant Family Size effects arose around 150–200 ms in the time window preceding the N400 time window. In a linear regression analysis of ERP data obtained in monolingual visual lexical decision, Hauk, Davis, Ford, Pulvermüller, and Marslen-Wilson (2006) investigated the time course of different variables known to affect visual word processing. Effects of lexical frequency were observed that occurred at 110 ms and were left-lateralised. This lexical frequency effect was reported to reflect the familiarity of an individual word and its morphologically related forms. Moreover, they reported an effect of semantic coherence (as a predictor of whether words had a meaning consistent across the morphological families) around 160 ms that was observed in event-related regression coefficients. These findings suggest that early ERP effects before 200 ms might reflect word-form-related processes as well as lexical-semantic processes.

According to Hauk et al., the results of their analyses suggest that not only the semantic properties of a stimulus word per se are activated at early stages of processing, but also the morphological family of this word, together with the semantic properties of this family. Moreover, they argue that members of the family of a stimulus are at least partially activated at the semantic level. Our ERP data confirm this assumption. However, although the early effects of semantic coherence (i.e., the quantitative measure of consistency in meaning of morphologically related word forms) observed by Hauk et al. are related to the effect of Family Size (i.e., the quantitative measure of the number of morphological family members) observed in the present study, they might reflect different aspects of word processing. On the basis of our data, we cannot conclude whether the observed effects are lexical-semantic effects or rather effects that are purely word-form related. It is possible that the early effects only reflect formal aspects of word processing, such as familiarity of the letter string. Clearly, more research investigating early morphological effects is needed.

Interestingly, Pylkkänen et al. (2004) reported Family Size effects at 350 ms in the MEG signal, and argued this to be an effect affecting early stages of word processing prior to word selection. This finding is not consistent with a postlexical account of Family Size. The M350 component has been proposed to be an early subcomponent of the N400, the N400 being sensitive to both lexical and postlexical processes (cf. Pylkkänen & Marantz, 2003). In this view, the earlier effects in the N400 time window (and possibly also the effects between 250 and 300 ms) observed in the present study and the M350 effects observed by Pylkkänen et al. may reflect the same process, namely the interplay of activation between orthography, morphology, and semantics.

Furthermore, Family Size effects are observed in time windows following the N400 window, until approximately 700–750 ms in the L1 and L2 data. While in the L2 data, visual inspection suggests that these late effects of Family Size seem to be a continuation of the N400 effect of Family Size, the ERP signal in the L1 data seems to contain two distinct components (N400 and LCP) that are affected by Family Size. Whatever the case, given that mean response latencies in the lexical decision task of Experiments 1 and 3 were shorter than 600 ms (including the motor planning of the physical response), a lexical decision about the target should already have been made at this point in time, though no button press was required for word targets in this task. Apparently, the activation of morphological family members persists after the actual lexical decision has been made.

In sum, the observed early effects lead us to conclude that the Family Size effect is not a pure postlexical-semantic effect and that formal aspects might be at play, while the observed effects in the N400 time window and the 500–800 ms time window confirm earlier behavioural findings that the Family Size effect is at least partially semantic in nature. Thus, we have shown in one single experiment without response component that the Family Size effect may depend on both the form and semantic relationship between target and family member. We, therefore, conclude that it is a truly morphological effect.

What are the consequences of our findings for monolingual and bilingual models of word processing? First, the observed Family Size effects in L1 processing are in line with the MFRM model of De Jong et al. (2003). This monolingual model of morphological processing assumes that response latencies to words differ as a function of their morphological productivity (i.e., their Family Size). Family size effects are explained in terms of resonance of activation between a target word and the words that are morphologically related to this target: When a word has a high Family Size, more activation is resonated back from the activated family members to the semantic representation to which the target is linked, resulting in faster response latencies for these words compared to words with a low Family Size. Both the behavioural and ERP L1 data have shown that word processing is facilitated by an increased morphological productivity of words.

Interestingly, the observed Family Size effects in later time windows of the ERP signal, that is, after 600 ms, indicate that the process of resonance is at work even after the actual lexical decision to a target word has taken place. It suggests that the interaction between bottom-up processes and contextual information from the semantics of the target persists after the target word has been identified and selected. Because words are usually embedded in sentences and texts, activation of a wider semantic network is not unexpected in light of the fact that word meaning must be integrated in a situation model based on contextual information (cf. Van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998).

The observation that Family Size effects persist in the ERP data after the actual lexical decision has been made (without a physical response), suggests that Family Size effects are based on increased semantic activation rather than global lexical activation of family members. These two accounts could not be dissociated in lexical decision, because this paradigm always requires a response. In contrast, in a go/no-go lexical decision, no physical response to words is required, which allows us to examine any effects occurring after the lexical decision has taken place. The observed late Family Size effects that occur after 600 ms are not likely to reflect global lexical activation. Typically, Family Size effects based on global lexical activation would occur before word identification has been completed, and would not occur after the lexical decision has been made, because after word identification, activation of nonselected lexical candidates is assumed to be reset to zero (cf. Dell, 1986). In contrast, Family Size effects based on increased semantic activation could influence word processing even after the lexical decision has been made via the mechanism of resonance. This would indicate that at least the later effects are based on semantic activation. Nevertheless, this does not rule out the possibility that the actual lexical decision can still be based on global lexical activation. More research is needed to distinguish whether Family Size effects are true semantic effects and/or based on global lexical activation. While studies using progressive demasking have found no effects of Family Size, and argue that Family Size effects arise postlexically (i.e., after the target has been identified; Schreuder & Baayen, 1997), the early effects around 200 ms observed in our study suggest that the picture might be more complicated.

The observed L1 Family Size effect in the L2 data provides evidence in support of a language nonselective access account of word processing as proposed by the Bilingual Interactive Activation + model (BIA + ; Dijkstra & Van Heuven, 2002). The BIA + model assumes parallel activation of words belonging to different languages that overlap in form. The results of Experiments 3 and 4 show that, during L2 cognate processing, L1 word representations can be co-activated due to their orthographic overlap with the target word. Moreover, these experiments showed that activation spreads beyond the word level, to the morphological family members of the nontarget word. The BIA+ model does not provide a specific account for Family Size effects, but does assume interactive links within the lexicon between orthography and semantics. Cognates overlap in orthography and semantics, and are found to be processed faster than words that do not share this semantic and orthographic overlap (i.e. noncognate words like *bird*). If we apply the process of resonance as proposed by the MFRM model to the situation of cognates, this would lead to a facilitation for cognates with a high Family Size. Moreover, the net facilitatory effect of Family Size is expected to be larger for cognates than for noncognate words, because nontarget language family members of a cognate are often also semantically related and add to the facilitation. This is exactly what we observed. Thus, by extending the BIA+ model with this mechanism of resonance, the MFRM and BIA+ models can be integrated into one account on Family Size effects in bilingual word processing (see Figure 7).

The finding that L1 Family Size effects work in the same way in both L1 and L2 lexical decision suggests that information about language membership does not directly influence the Family Size effect in language specific lexical decision. Thus, when making a lexical decision, the activated language node in the mental lexicon does not restrict the contribution of activated nontarget family members in any sense, nor does it change the direction of the Family Size effect. This suggests that, at least for cognates in lexical decision, activating family members simply results in more convergent semantic activation feeding the positive response to a target word. This does not mean that language membership is not important at all for the presence and direction of Family Size effects in cognate processing. Inhibitory effects of nontarget language Family Size were observed in language decision, where the task requirements forced a clear decision about response language and Family Size fed a different response for each reading of a cognate (Mulder et al., 2012). Future research should address this sensitivity of cross-language Family Size effects to language context and task requirements in more detail.

In sum, this study has shown, by using the ERP technique, that the contribution of Morphological Family Size to word processing is substantial. Morphological Family Size influenced both response latencies and the ERP signal in both L1 and L2 processing, supporting the idea of resonance of activation between the target lemma and morphologically related family members within the lexicon. The results provide evidence for an integrated lexicon in which words within and across different languages are linked via fine-grained relationships and can be co-activated in parallel.

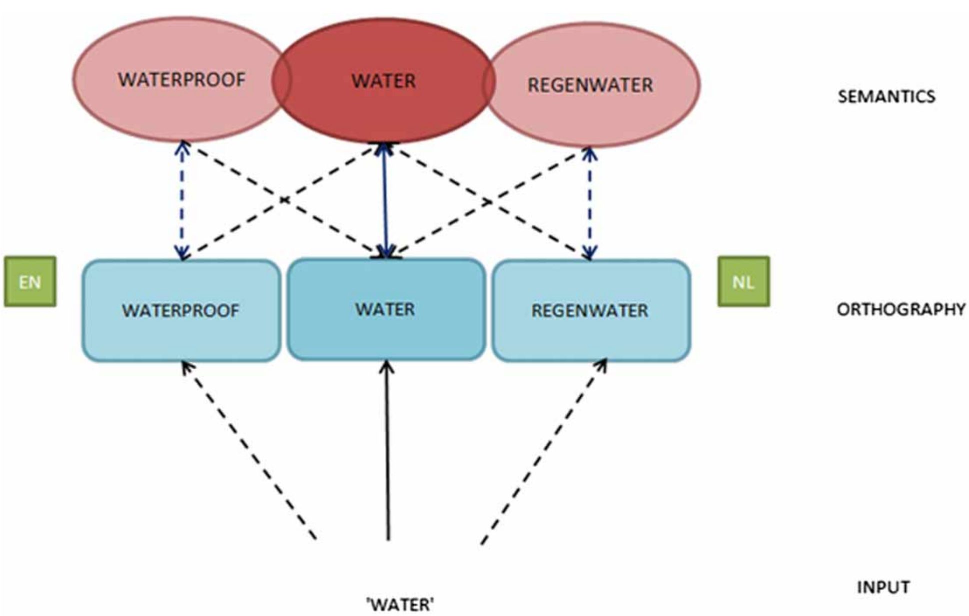

Figure 7. Schematic representation of the activation of the morphological family members of a Dutch–English cognate and the resonance between orthographic and semantic levels of representation.

The observed cross-language Family Size effects suggest that, during word processing, the language user takes into account all possible relevant information from both of his languages.

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APPENDIX 1

Experimental words used in Experiment 1 and 2

Words with a high Dutch Family Size: IJZER, KOEK, STOOM, BLOEM, KNOOP, FIETS, KOORTS, VREDE, WAND, STOK, VOGEL, WIEL, KLANK, PLICHT, POORT, VARKEN, JURK, ZENUW, HUID, NIER, BROEK, VRUCHT, MUUR, STAD, STRUIK, SCHADE, HERFST, HAAK, JACHT, HALS, CIJFER, ZAAG, MODE, APPEL, DARM, DOEK, FONDS, ZAAD, MOLEN, RENTE.

Words with a low Dutch Family Size: STIER, GRAP, HIEL, MOUW, PECH, OBER, STOEP, RUZIE, TAPIJT, KROEG, BOCHT, GROT, KEIZER, RIEM, BEKER, TANTE, STANK, PIJL, POES, TRUI, ZONDE, NEEF, BIJL, KONIJN, TEEN, TOUW, HAAST, DUIF, BROER, KEREL, REEKS,MINUUT, SPUL, DUIM, OEVER, VUIST, WANG, LEPEL, BRIL, VIJVER.

Experimental words used in Experiment 3 and 4

Cognates with a high Dutch Family Size: SPORT, TOILET, NEST, CODE, RADIO, NORM, TENT, MODEL, LAMP, WINTER, STORM, GOLD, LUNG, GRASS, SOUP, LAMB, SILVER, BIBLE, RIVER, ROSE, STEAM, CROWN, CLIMB, FLUTE, SHOE, LOAD, BREAD, APPLE, TEAM, HOTEL.

Cognates with a low Dutch Family Size: CRISIS, DRAMA, LOGIC, MENU, MILD, OPERA, FLORA, ECHO, TRUCK, FRUIT, DIRECT, TREND, ALTAR, SYMBOL, PILL, DEBATE, MYTH, FORT, FLAG, PILOT, CAMEL, HUMOUR, NEWS, IDOL, FRESH, STINK, IDEAL, NATION, PAPER, SIMPLE.

Non-cognate controls: KNIFE, TOWER, SNAKE, CRIME, FLOWER, SMOKE, HABIT, WRIST, GUARD, KIDNEY, FAME, GLORY, PRISON, PARCEL, MUSCLE, MERCY, BIKE, WIZARD, CEREAL, TAIL, DEBT, SOURCE, TORCH, ARROW, SKILL, FIRE, SKIRT, HAPPY, DAMAGE, HARM, BULLET, GHOST, FEVER, LAKE, WOOD, TRUTH, BIRD, CLOUD, FAITH, GUILT, SILK, HERB, THIGH, WING, MIRROR, CATTLE, CAVE, DONKEY, DUKE, ENGINE, DUTY, PIGEON, THROAT, EVIL, WITH, FROG, NOISE, HORSE, WIDOW, FATE.