Running-head: Prediction in L2 and L1 listening

Prediction and integration of semantics during L2 and L1 listening*

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Abstract

Using the visual world paradigm, we tested whether Dutch-English bilinguals predict upcoming semantic information in auditory sentence comprehension to the same extent in their native (L1) and second language (L2). Participants listened to sentences in L1 and L2 while their eye-movements were measured. A display containing a picture of either a target word or a semantic competitor, and three unrelated objects was shown before the onset of the auditory target word in the sentence. There were more fixations on the target and competitor pictures relative to the unrelated pictures in both languages, before hearing the target word could affect fixations. Also, semantically stronger related competitors attracted more fixations. This relatedness effect was stronger, and it started earlier in the L1 than in the L2. These results suggest that bilinguals predict semantics in the L2, but the spread of semantic activation during prediction is slower and weaker than in the L1.

Prediction and integration of semantics during L2 and L1 listening

Smooth and efficient language comprehension involves prediction of upcoming information. Context information affects the language comprehension system before new bottom-up input is encountered, and this may involve pre-activation of linguistic information (see Kuperberg & Jaeger, 2016 for a recent review; but also see Nieuwland et al., 2017 for a multilab failure to replicate pre-activation of phonology). Linguistic predictions are made on the basis of cues from the linguistic (e.g. Altmann & Kamide, 1999; Otten, Nieuwland, & Van Berkum, 2007) and non-linguistic context information (Chambers, Tanenhaus, & Magnuson, 2004; Salverda, Brown, & Tanenhaus, 2011). The content of predictions also varies greatly. Predictions can consist of semantic properties of upcoming words (including object shape) (e.g., Altmann & Kamide, 1999, 2007; Rommers, Meyer, Praamstra, & Huettig, 2013), syntactic information (e.g., Arai & Keller, 2013), and possibly word form information (e.g., Dikker, Rabagliati, Farmer, & Pylkkänen, 2010; Ito, Pickering, & Corley, 2018). Predictive language processing is not an all-or-nothing phenomenon but rather something that occurs in a graded manner (Kuperberg & Jaeger, 2016). Several word candidates for prediction are activated in parallel, depending on how likely they are given the context. Here, we tested whether prediction of target word semantics by bilinguals, and spreading semantic activation to competitors with varying degrees of semantic associatedness, is equally strong in both of their languages.

How much or how strongly a person predicts seems to be affected by processing speed (Huettig & Janse, 2016), language experience (Foucart, 2015; Kaan, 2014; Kuperberg & Jaeger, 2016; Peters, Grüter, & Borovsky, 2015; Phillips & Ehrenhofer, 2015), and the availability of cognitive resources. Each of these factors is likely to differ between native language (L1) and second language (L2) processing, and can therefore potentially affect predictive language processing in each language differently. For example, increased lexical competition due to cross-lingual word coactivation affects speed of lexical acces in bilinguals

(Duyck, Van Assche, Drieghe, & Hartsuiker, 2007; Lagrou, Hartsuiker, & Duyck, 2013), particularly in the L2 (Weber & Broersma, 2012). Bilingual language users usually have much less experience using their L2 than their L1. This may result in weaker links between word forms and semantics (Gollan, Montoya, Cera, & Sandoval, 2008; Gollan et al., 2011) and this may in turn again result in slower or weaker retrieval of linguistic representations. Less use may also result in lower quality of linguistic representations and different frequency biases for prediction, because a particular continuation for a prior context may have been encountered less often (Kaan, 2014). Furthermore, prior knowledge and new input may be considered less reliable in a less familiar L2, and this may affect the degree of predictive processing (Kuperberg & Jaeger, 2016). Finally, L2 processing may tax working memory more than L1 processing (Francis & Gutiérrez, 2012; McDonald, 2006). Therefore, if working memory resources are required for predictive processing (e.g., Huettig & Janse, 2016), then prediction may be less efficient in L2 than in L1. In sum, less efficient retrieval of representations in L2 processing may hinder the construction of higher-level meaning (such as sentence meaning) used for generating a prediction. In addition, the L2 representation of the target for prediction itself may be retrieved less efficiently, leading to slower, weaker, and/or less accurate predictions.

In a recent theoretical account of predictive processing, Pickering and Gambi (2018) postulate two routes for prediction. The first one is based on spreading activation between associated representations. This 'prediction-by-association' route is relatively automatic and not targeted. This entails that it should be mostly intact in populations with limited resources, such as L2 comprehenders. The second route to prediction uses covert imitation of the input, constructs a representation of speaker intention, and engages the production system to generate a targeted prediction (see Dell & Chang, 2013; Huettig, 2015; Pickering & Garrod, 2013, for other accounts assuming involvement of production). The authors hypothesize that this 'prediction-by-production' route is optional and that its use depends on the availability of

sufficient time and cognitive resources. Therefore, prediction-by-production is likely used less or fails more often in cognitively more demanding contexts, such as L2 comprehension.

Differences between prediction in L1 and L2 comprehension have been found when a language-specific morpho-syntactic or phonotactic rule needs to be applied quickly and accurately in order to pre-activate a target for prediction or when the target for prediction is a word form (Hopp, 2013, 2015; Ito et al., 2018; Martin et al., 2013; Mitsugi & Macwhinney, 2015). For example, in Martin et al.'s (2013) ERP study, native speakers of English and late Spanish-English bilinguals read English sentences with a predictable or unpredictable sentence ending (e.g. *Since it is raining, it is better to go out with an umbrella [EXPECTED]/ a raincoat [UNEXPECTED]*). The article preceding the sentence final noun was always congruent with the final noun, but not always congruent with the expected noun. Martin et al. found an N400-effect on the processing of incongruent versus congruent articles for L1 readers, but not for L2 readers. The sentence-final noun elicited an N400-effect as well, in both groups, but the effect was larger for L1 than for L2 readers. Thus, the N400 elicited by the article showed that bilinguals reading in the L2 did not anticipate upcoming word forms like native readers did, but the noun-elicited N400 might indicate that target word integration was easier in both languages when the target word was predictable. Alternatively, the effect could be attributed to slower prediction in the L2. The two interpretations cannot be dissociated because the effect was not found before target word onset.

Ito et al. (2018) studied prediction of word form using a visual world paradigm. Japanese-English bilinguals and native English controls listened to constraining sentences such as "*The tourists expected rain when the sun went behind the …*". Visual displays contained a predictable target object (*cloud*; in Japanese: *Kumo*), a phonological competitor of the target object in English (*clown*), a phonological competitor of the target object in Japanese (bear; *kuma*), or an unrelated object (*globe*; *tikyuugi*). The bilinguals predictively looked at target objects, but slower than native listeners). They did not look more at English

or Japanese phonological competitors than at unrelated objects. This finding suggests that the bilinguals predicted target word semantics when listening in their L2, but not word form. Native listeners fixated both target objects and English phonological competitors more than unrelated objects before hearing the target could affect fixations.

Hopp (2015) contrasted prediction based on morpho-syntactic cues and lexico-semantic cues. In a visual world paradigm study, Native German listeners and English-German bilinguals looked at picture displays including three possible actors and a control object while they listened to SVO (e.g. *The$_{NOM}$ wolf kills soon the$_{ACC}$ deer*) or OVS (e.g., *The$_{ACC}$ wolf kills soon the$_{NOM}$ hunter*) sentences in German. The native listeners looked at expected patients (*the deer)* before the onset of the second noun phrase in SVO sentences and at expected agents (*the hunter*) in OVS sentences. The bilinguals were more likely to look at patient objects before the onset of the second noun phrase, irrespective of first noun phrase case marking (nominative or accusative). Thus, even though Hopp found evidence for prediction based on lexical-semantic cues (verb information) in the L2, no prediction based on morpho-syntactic (case marking) information was found in the L2. Participants' knowledge of the German case marking system was not assessed separately, but German proficiency of the bilingual participants did not affect the pattern of results. Similarly, Mitsugi and MacWhinney (2015) found that English-Japanese bilinguals were unable to use case marking information as a cue for prediction in Japanese, even though the bilinguals' had good offline knowledge of the Japanese case marking system.

The findings of Ito et al. (2018) and Hopp (2015) suggest that semantic prediction is relatively intact in L2 comprehension. Indeed, when no application of a language-specific (morpho-)syntactic rule is required for prediction (Dijkgraaf et al., 2017; Hopp, 2015; Ito et al., 2017), or when the same rule exists in the participants' L1 (Foucart, Martin, Moreno, & Costa, 2014; Foucart, Ruiz-Tada, & Costa, 2015; van Bergen & Flecken, 2017), L2 listeners often do show prediction effects, like in L1. Dijkgraaf et al. (2017), for example, compared

prediction between the L1 and the L2 of the same participants using an eye-tracking paradigm based on Altmann and Kamide (1999). Participants listened to simple SVO sentences with either a constraining (e.g., *Mary knits a scarf*) or a neutral verb (e.g., *Mary loses a scarf*). The visual display showed four objects that could all be lost, but only one that could be knitted (a scarf). Dutch-English participants listening to sentences in Dutch or English were more likely to fixate on the target object in the constraining condition than in the neutral condition, before exposure to the auditory target word could influence fixations. The bias in target fixations did not differ between the L1 and L2. Likewise, using a between-subject comparison, Ito et al. (2017) found that bilinguals listening to constraining and neutral sentences in their L2 (English; various L1 languages) showed similar predictive looking behaviour as L1 listeners. Adding a cognitive load during the listening task (remembering 5 words) affected prediction, but in a similar way for L1 and L2 listeners. These findings indicate that at least under some circumstances, L2 listeners predict upcoming semantic information.

However, as Pickering and Gambi note, spreading activation in semantic prediction depends on the number and strength of links between representations (2018), which is in turn shaped by (linguistic) experience, and could therefore differ between L2 and L1. Different theories of bilingual lexicosemantic memory indeed assume that the mapping of words onto semantic memory is different in the L2 than in the L1. Specifically, L1 words may be semantically richer than L2 words (Finkbeiner, Forster, Nicol, & Nakamura, 2004; Schoonbaert, Duyck, Brysbaert, & Hartsuiker, 2009). Schoonbaert et al. based their model on the distributed feature model (Van Hell & De Groot, 1998) and suggested that L2 words have fewer semantic features than L1 words. Therefore, two words that share features in the L1 may have no, or fewer, shared features in the L2. Thus, even though bilinguals are able to make semantic predictions based on lexical-semantic information from the sentence context in the L2, perhaps they do not do so as strongly and quickly as monolinguals do. This should

be the case especially when the semantic associations between the sentence content and the predicted information is weaker, or when remote spreading of activation to concepts semantically associated with the predicted concept is tested. Also the strength of the links between word forms and semantics may be weaker in L2 than in L1 (Gollan et al., 2008, 2011), which may similarly affect strength and speed of semantic pre-activation.

In line with this hypothesis, Japanese-English bilinguals listening to predictable sentences anticipated a predictable target object later than English native speakers (e.g., *cloud*, when listening to *The tourists expected rain when the sun went behind the . . .*) (Ito et al., 2018). Also, using ERPs, Ito, Martin and Nieuwland (2017) found no evidence of pre-activation of a semantic competitor of the predictable target word in non-native speakers, whereas such an effect was found in native speakers (Ito, Corley, Pickering, Martin, & Nieuwland, 2016). Similarly, Foucart, Moreno, Martin, and Costa (2015) found that value-inconsistent statements as compared to value-consistent statements (e.g., *Nowadays, paedophilia should be prohibited/tolerated across the world*) triggered an N400 response in native speakers but not in non-native speakers. One possible interpretation of this finding is that the valence of a concept is not retrieved from the word as efficiently in the L2 as in the L1, and that therefore, the L2 speakers did not generate predictions based on concept valence.

Peters, Grüter, and Borovsky (2015) showed that highly proficient bilinguals pre-activated target word semantics faster than low proficient bilinguals. For instance, they fixated pictures of a *ship* faster when listening to the sentence *The pirate chases the ship.* In contrast, low-proficient bilinguals were more likely to fixate competitors that were locally related to the action verb, but not necessarily consistent with the sentence meaning (e.g. looking at a *cat* after hearing the verb *chases* in the above sentence. Finally, Kohlstedt and Mani (2018) presented discourse information in a visual world paradigm. When presententing two sentences in which the first contained a semantically associated or a neutral prime for a target in the second, predictive fixations were found in L1 listeners, but not in L2

listeners when analyzing each group seperately. However, in an overall analysis the effect of context (biasing or neutral) on target fixations did not differ significantly between groups (bilinguals in L2 vs. native speakers).

In sum, bilinguals can predict upcoming information during L2 processing in some circumstances, but they do not always do so to a similar extent as native speakers when application of a language specific morpho-syntactic or phonotactic rule is required. In addition, even though some research suggests that lexical-semantic prediction is intact in bilinguals, there is also evidence suggesting that lexical-semantic prediction is weaker or later in bilinguals comprehending L2 input. We hypothesize that even though lexical-semantic prediction can occur in L2 comprehension, the inconsistent findings above may be due to differences in spreading semantic activation and/or temporal dynamics between L1 and L2, with differences especially arising in more challenging contexts. Here, we will investigate when and how prediction in L2 differs from L1, using targets that vary in predictability, and how spreading semantic activation evolves differently when listening in different languages. More specifically, we expect pre-activation of semantic competitors of expected words to be weaker and/or slower in the L2 than in the L1, especially when the semantic distance between expected words and semantic competitors is larger. That is, we expect prediction to be semantically narrower in the L2. If L2 words are indeed mapped onto fewer semantic features than L1 words (Schoonbaert et al., 2009), they also activate fewer features shared with semantically associated concepts, which should trigger less activation spreading to those concepts in L2.

The Present Study

In the present experiment, we used the visual world paradigm to test whether prediction of semantic information during auditory speech recognition, based on lexical-semantic information from the sentence context, is weaker and/or slower in the L2 than in the L1. Dutch-English bilinguals listened to sentences in Dutch and in English while they looked

at four-picture displays on a screen in front of them. The picture display included three items that were unrelated to the target word and an experimental image: either a depiction of the target word or of a semantically related competitor. The semantic distance between the target word and the semantic competitor varied. This way, we were able to test in a more refined way whether prediction in the L1 vs. the L2 leads to a different degree of spreading semantic activation. If this were the case, one would expect a different effect of semantic distance between targets and competitors in each language. Ito et al. (2017) also included a semantic competitor in a visual world paradigm experiment in which they compared prediction in the L1 and L2. However, no pre-activation of the semantic competitor was found in either the L1 or the L2. The absence of an effect of pre-activation may have been caused by the fact that the picture displays in that study included both a target object and a semantic competitor, so that the target object attracted looks so strongly that it prevented any looks to the competitor object (Huettig & Altmann, 2005; Huettig, Rommers, & Meyer, 2011). As a more sensitive measure of competitor activation, we therefore opted for a design in which either the target object or the semantic competitor object was present in the display.

Many studies on predictive language processing in the L2 focused on prediction during sentence reading (Foucart et al., 2014; Ito, Martin, et al., 2016; Martin et al., 2013; Molinaro, Giannelli, Caffarra, & Martin, 2017). However, predictive processing may be particularly challenging for non-native speakers in the auditory modality. Speech unfolds over time and therefore a listener cannot go back to the beginning of a sentence like in reading, where the information remains available. Also, misperceptions and misrepresentations of non-native phonemes, a problem that doesn't exist for bilingual reading in the same alphabet, may increase lexical competition during listening comprehension (Weber & Broersma, 2012). Like Dijkgraaf et al. (2017), Foucart et al. (2015), Ito et al. (2017) and Hopp (2015), the current experiment therefore studied predictive processing in the auditory modality.

It is important to note that a comparison of L1 and L2 listening leaves two options: the first is that native listeners are compared with other subjects that listen in the same language, which is however their L2 (e.g. Ito et al., 2017). Even when participant groups are matched on a number of variables such as age, education level and socio-economic status, they may have very different cultural, educational, and linguistic backgrounds. Thus, any differences found between groups may be due to such variables, rather than the experimental factor Language.

The other option is to compare listening in different languages, within the same subjects. Here, we compared listening between L1 and L2 within the exact same Dutch-English bilingual participants. This way, we eliminated confounding effects of individual cognitive differences that may affect prediction such as working memory capacity, processing speed (Huettig & Janse, 2016), age (Federmeier & Kutas, 2005), and verbal fluency (Rommers, Meyer, & Huettig, 2015). This also eliminated the high inter-individual variability that characterizes eye movements (Bargary et al., 2017; Rayner, 1998) and which may confound between-group differences in visual world paradigms. To account for differences between the two languages used in this within-subject design, we included linguistic factors of stimuli such as sentence length, phoneme count, word frequency, and semantic distance measures in our analyses.

Method

Participants

Bilinguals. 50 native speakers of Dutch took part in the experiment (11 men and 39 women, mean age 19 years, *SD*=2.85). They were Ghent University students participating for course credit. Dutch was the participants' dominant and most proficient language, and English was their second (49 participants) or third (1 participant) language. On average, participants started acquiring English at age 11 (*SD*=2.46), mainly in school, on holiday or

through (online) media. None of the participants had spent time living in an English-dominant country. The participants reported to be exposed to Dutch an average of 73% of the time, and to English 22% of the time. Forty-seven participants also had knowledge of French, and 24 participants had knowledge of German. Nine participants had knowledge of Spanish, two knew Arabic, one Portuguese, and one Italian (all late learners). Language proficiency in English and Dutch was assessed with the LexTALE vocabulary knowledge test (Lemhöfer & Broersma, 2012) and with self-ratings. The LexTALE is a 60-item lexical decision task (unspeeded). It indicates word knowledge and general language proficiency (Lemhöfer & Broersma, 2012). The bilinguals' mean LexTALE scores and self-ratings are reported in Table 1. The participants were significantly less proficient in their L2 than in their L1.

Table 1

Participants' Mean (SD) L1 and L2 LexTALE Scores and Self-ratings

	L1 DUTCH	**L2 ENGLISH**	**P-VALUE** [c]
Lextale[a]	88.72 (7.25)	70.05 (10.59)	<0.001
Rating listening[b]	4.98 (.14)	4.00 (.54)	<0.001
Rating speaking[b]	4.94(.32)	3.36 (.60)	<0.001
Rating reading[b]	4.94(.24)	3.78 (.55)	<0.001
Rating general[b] proficiency	4.94 (.24)	3.64 (.55)	<0.001
Category fluency	23.46 (5.23)	14.19 (3.96)	<0.001

[a] Scores consist of percentage correct, corrected for unequal proportion of words and nonwords (Lemhöfer & Broersma, 2012). Due to technical problems one participant's score is missing.

[b] Means of self-assessed ratings on a scale of 1 to 5 (1=not at all, 5=perfect/mother tongue) for listening, speaking, reading and general proficiency.

[c] Reported p-values indicate significance levels of dependent samples t-tests between scores for Dutch and English in bilinguals. Df of t-test on LexTALE scores= 48, Df of t-test on Category Fluency=47 (due to technical problems one participant's LexTALE score and two participants' Fluency scores are missing). Df of all t-tests on ratings= 49.

Materials and Design

Three hundred sixty-two trials were included in the experiment. On each trial, participants listened to a sentence and saw a four-item picture display. Fifty further participants filled out a cloze probability test for an initial set of 871 candidate sentences,[1] with the dual purposes of (a) sentence selection and (b) measuring predictability of sentence-final (target) words. The candidate sentences were constructed so that word order was as similar as possible in Dutch and English. Sentences were excluded from the final sentence set if the Dutch and English target provided by the participants were not translation equivalents, and if the provided target word was not depictable or a picture of the word was not included in the normed picture set that we used (Severens, Lommel, Ratinckx, & Hartsuiker, 2005). Also, only one pair of sentences (translation equivalents in Dutch and English) was selected for each target picture. All English sentences were checked for grammaticality by a native speaker of American English. Like the participants in the main experiment, the participants were Ghent University students with knowledge of Dutch (L1) and English (L2). Half of the participants filled out the cloze test for the sentences in Dutch and the other half of the participants filled out the test in English. In the cloze test, participants read each sentence without the sentence-final word and were asked to complete each sentence with the first word that came to mind. For each sentence, the highest cloze probability target was selected in English and in Dutch. The final sentences had varying cloze probabilities (see Figure 1 panel A). The mean cloze probability was .71 (*SD*=.23) in Dutch (L1) and .68 (*SD*=.24) in English (L2).

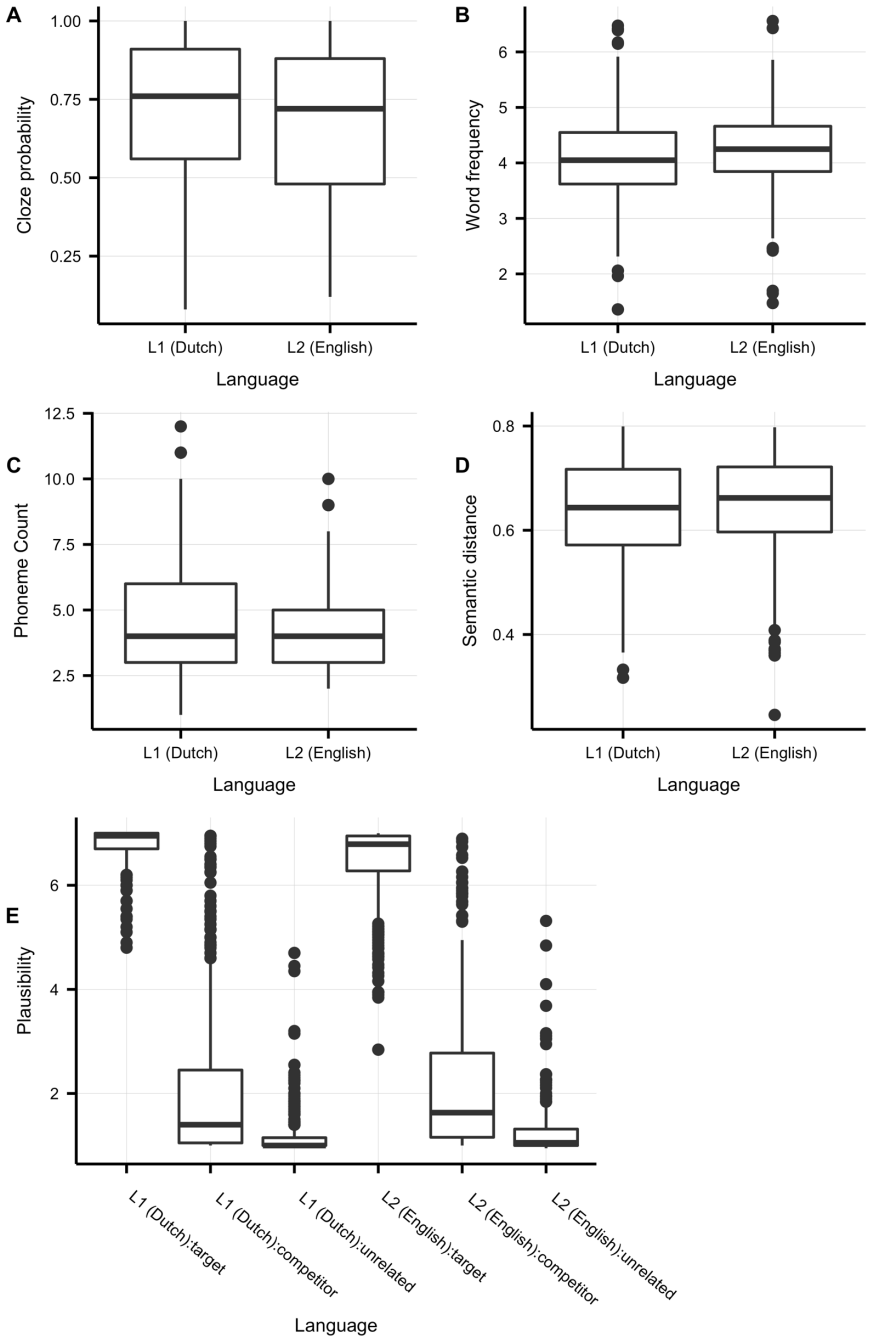


Figure 1. Stimulus information. A. Stimulus Sentence Cloze Probability. B. Target word frequency. Zipf value (log10(frequency per million*1000)) retrieved from the SUBTLEX-UK and SUBTLEX-NL databases (Keuleers, Brysbaert, & New, 2010; Van Heuven, Mandera, Keuleers, & Brysbaert, 2014). Please note that for six compound nouns no frequency score was available for English. C. Target word phoneme count retrieved from CELEX database (Baayen, Piepenbrock, & Gulikers, 1995). D. Semantic Distance Target-

Competitor Pairs Extracted From SNAUT (Mandera et al., 2017). E. Plausibility ratings of target, competitors, and unrelated words as sentence endings. Ratings were given on a 7 point scale ranging from 'not likely at all as sentence ending' to 'very likely as sentence ending'.

Figure 1 panels B and C show the frequency and phoneme count information of the Dutch and English final set of target words (Baayen, Piepenbrock, & Gulikers, 1995; Keuleers, Brysbaert, & New, 2010; van Heuven, Mandera, Keuleers, & Brysbaert, 2014). The translation equivalents of the words were mostly phonologically dissimilar in English and Dutch (normalized phonological Levenshtein distance ≤.50, *M*=.25, *SD*=.25),[2] but cognates were also included (e.g. L2-L1: *tent-tent, wheel-wiel, nest-nest*), because Dutch and English are related languages and excluding all cognates would lead to unrepresentative word selections. As phonological similarity between the target word and its translation equivalent may affect looking behaviour, target Levenshtein distance was included as a factor in the analyses and we also confirmed that the data excluding all cognates yielded a similar pattern of results.[3] Levenshtein distance between the unrelated picture names and translation equivalents, and between the (auditory) words in the sentences and translation equivalents of each trial may also affect looking behaviour. Given the many English-Dutch cognates and restrictions that had to be taken into account during item construction, we were unable to control for this factor. However, to account for differences in looking behaviour for each item, a random intercept of item was added to the linear mixed models in our analyses.

The pictures in the displays accompanying the sentences were line drawings from the normed database by Severens et al. (2005). Each display accompanying a sentence consisted of either a target picture (the last word in the sentence) or a semantic competitor (a word semantically related to the target word), and three pictures unrelated to the target word. Whether a sentence was accompanied by a target or competitor image was counterbalanced across participants. To ensure that target pictures did not inherently draw more overt visual

attention than competitors or unrelated pictures, each of the 362 target pictures was included as a competitor picture for another sentence and as unrelated picture in three other sentences. The 362 experimental sentences thus belonged to 181 sentence pairs. For each sentence pair the target of one sentence was the competitor of the other and vice versa.[4] The display of an experimental trial never included the same picture more than once.

The competitor picture for each target word was selected based on semantic distance scores extracted from the SNAUT database (Mandera, Keuleers, & Brysbaert, 2017).[5] The distance score is based on word co-occurences in large text corpora.[6] The smaller the semantic distance score for a word pair, the more related they are. The score varies between 0 and 1. We included a large range of distance scores for the semantic competitors (see Figure 1 panel D), but the distance score for target-competitor pairs was always smaller than .8. The target-unrelated pairs always had a distance score of more than .8. This cut-off point was chosen because we required a large range of semantic distance scores, and because it was the lowest cut-off point for which it was still possible to pair each target word with the same competitor word in Dutch and in English. Mean semantic distance score was .63 in Dutch (*SD*=.11) and .64 in English (*SD*=.10). Mean cloze probability for the competitors was *M*=.01, *SD*=.03 in the L1 and *M*=.01, *SD*=.03 in the L2. The competitor word never occured in the accompanying sentence.[7] Target and competitor words never started with the same phoneme (except for one pair in Dutch, *orange-lemon*, *sinaasappel-citroen*). There were the target trials where a target and three unrelated pictures were presented, and there were competitor trials where a competitor was presented instead of the target, leading to five possible picture 'positions' (target, competitor, unrelated 1, unrelated 2, unrelated 3). As the picture set was limited and each picture had to be used once in every position, it was not possible to take phonetic overlap between unrelated and experimental pictures into account when contructing the picture sets.

Plausibility ratings were generated by 40 further unbalanced Dutch-English bilingual participants (20 in English and 20 in Dutch) for each sentence ending with a target word, a competitor word, and with an unrelated word (L1 target: *M*=6.8, *SD*=.33, L1 competitor: *M*=2.08, *SD*=1.51, L1 unrelated: *M*=1.19, *SD*=.48, L2 target: *M*=6.46, *SD*=.75, L2 competitor: *M*=2.20, *SD*=1.40, L2 unrelated: *M*=1.25, *SD*=.49 on a 7 point scale ranging from 'not likely at all as sentence ending' to 'very likely as sentence ending', see Figure 1, panel E).[8] The participants were recruited from the same Ghent University participant pool, but none of them participated in the cloze probability test nor in the actual experiment. Plausibility was measured after targets were paired with competitors and did not play a role in competitor selection. Competitor plausibility was taken into account in the analyses. Figure 2 shows an example stimulus set, and Appendix A contains the sentences and object names of the target and competitor pictures for each stimulus set.

Every twelve experimental sentences were followed by a visually presented simple yes/no question about the preceding sentence to ensure the participants would continue to pay attention to the sentences. To ensure that there were no carry-over effects from answering the question in the data for analysis and to ensure that not every trial would have a target or competitor in the display, we added a filler sentence after each question. The four pictures shown on a filler trial never included a picture of the target word of the accompanying sentence. Unlike the experimental sentences, the filler trials were presented to each participant in Dutch (mean cloze probability=.64) and in English (mean cloze probability=.57). There was no significant difference between the cloze probabilities of the Dutch and English fillers ($t(11)=1.08$, $p=.30$). The sentences were selected from the same initial candidate sentences as the experimental sentences. The pictures used for the filler trials were not used for the experimental trials.

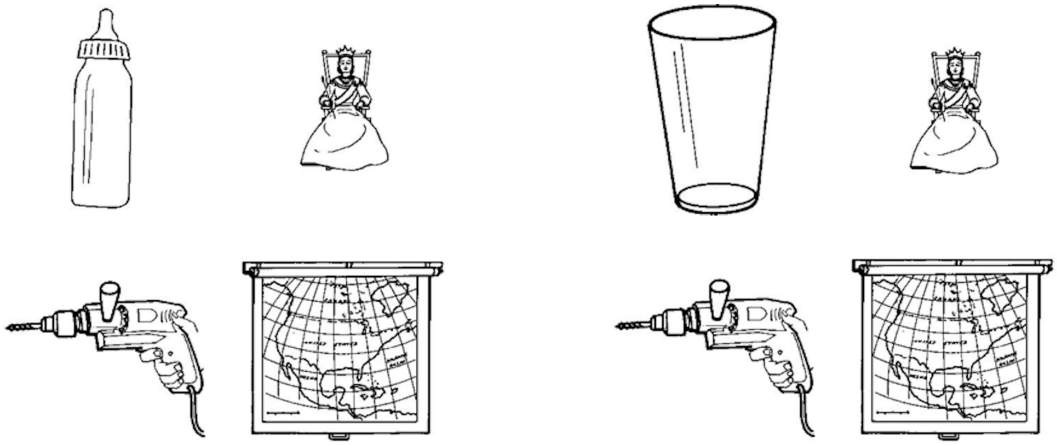


Figure 2. Example stimulus displays. Each participant was presented with one of these two displays with the sentence *'Her baby doesn't like drinking from a bottle'*. The left display includes a picture of the target word for prediction (*bottle*) and the right display includes a picture of a semantic competitor (*glass*). Each display also included 3 unrelated images.

Recordings. The sentences for the experiment were recorded in a sound attenuating room. A Dutch-English bilingual (female, 21 years old) from Flanders who had lived in England from age five to twelve recorded the sentences. The participants in the experiment rated her accent in English as 3.6 and her accent in Dutch as 4.6 on a scale from 1 (very foreign accent) to 5 (native accent). The speaker was asked to pronounce the sentences clearly at a relaxed but natural rate. Each sentence was recorded three times (sampling frequency 48 kHz); the recording that we judged to have the clearest pronunciation and most neutral prosody was selected for the experiment. The average speech rate was 220 words per minute.

The target word onset in each sentence was marked using Praat (Broersma & Weenink, 2014). The average target length was 507 ms (range 224-942 ms) in English and 511 (240-1168 ms) in Dutch. The mean length of the sentence leading up to the target word was 1977 ms in English (range 708-4557 ms) and 2164 ms in Dutch (range 764-4764 ms). Sentence length up to the target was included as factor in the analyses.

Procedure

Participants followed written and oral instructions to listen carefully to Dutch and English sentences and to look at pictures on the screen. They were instructed to look wherever they wanted as long as their gaze did not leave the screen (Huettig & Altmann, 2005; McQueen & Huettig, 2012). In addition, participants were asked to answer the occasional yes/no question about a preceding sentence by pressing "j" for yes and "f" for no. The questions were included to ensure participants continued to listen to the sentences attentively. Participants were presented with 24 questions throughout the experiment (twelve in Dutch and twelve in English). Eye movements were recorded from the right eye with an Eyelink 1000 eye-tracker (SR Research) (1000 Hz) in tower mount.

A fixation cross appeared on the screen for 500 ms, followed by the presentation of a sentence over headphones. Following the procedure in Rommers et al. (2013), the four pictures were presented only 500 ms before the onset of the target word in the sentence. This was done to avoid visual priming of the target or competitor word semantics by the target or competitor picture. Picture location was randomized. After sentence offset, the pictures remained on the screen for 1000 ms. After drift check the next trial started.

The sentence pairs (where one sentence's target was the other sentence's competitor and vice versa) were split into two lists (list A and list B). Each sentence could be presented in Dutch and in English with either a target or a competitor picture. The participants were presented with one block in English and one in Dutch, with each block consisting of a list of 181 sentences (and 12 fillers). Language order, list (A or B), and condition (target or competitor) were counterbalanced, resulting in eight presentation lists with a fixed random order. Between the two blocks, eye-tracker calibration was repeated. The eye-tracking part of the experiment took approximately one hour.

After the eye-tracking experiment, participants completed the following additional tests: a digit span task, a verbal fluency task, LexTALE Dutch, LexTALE English (Lemhöfer

& Broersma, 2012) (see Table 1 for results), and a language background questionnaire based on LEAP-Q (Marian, Blumenfeld, & Kaushanskaya, 2007). The verbal fluency task was performed in Dutch and in English. The participants were asked to name as many words as they could within the categories 'food' and 'animals' within 1 minute. The categories were counterbalanced across languages between participants. Completion of the additional tests took approximately 40 minutes.

Analyses

Our data set was analyzed with linear mixed effects models in R (3.3.2) (R Core Team, 2013) with lme4 (version 1.1-12) (Bates, Mächler, Bolker, & Walker, 2015). The p-values for the fixed effects in our models were obtained using the lmerTest package (version 2.0-33) (Satterthwaite degrees of freedom approximation) (Kuznetsova, Brockhoff, & Christensen, 2016). Post-hoc contrasts were performed with the lsmeans package (Kenward-Roger's approximation to degrees of freedom). Our dependent variable was the empirical logit (a quasi-logit transformation suitable for probabilities that are near 0 or 1) of the proportion of eye-data samples in which there was a fixation to a picture over the total number of samples (Barr, 2008). The proportions of looks to the three unrelated pictures were averaged. We ran separate analyses for the trials in which the display featured the target, and trials in which the display featured a competitor. This was done because the competitor model included the semantic distance factor (semantic distance between the competitor picture name and the target for prediction), whereas the target model did not. We also added an analysis of the combined data set, excluding the semantic distance factor.

We first analyzed the data of the prediction time frame, without taking into account the time course for prediction. As planning and executing a saccade takes approximately 200 ms (Matin, Shao, & Boff, 1993; Saslow, 1967) the prediction time frame included the eye-data samples starting from 200 ms after the onset of the picture display, to 200 ms after target word onset. We also analyzed the data in the time frame starting 200 ms after display onset

and ending 1000 ms after target offset (display time frame) to see whether any differences in semantic activation between languages persisted after hearing the target word of the sentence. For these analyses, we first constructed a full model including all theoretically relevant fixed effects and interactions for the prediction time frame (Table 2). The model also included random intercepts of participant and item. All continuous predictors were scaled and centered. We then used a backward fitting procedure for the fixed effects, followed by forward fitting the random slopes and then backward fitting fixed effects again to find the optimal model (following Cop, Keuleers, Drieghe, & Duyck, 2015; Dirix & Duyck, 2017). To be more specific, we started backward fitting by excluding the fixed model term that was contributing the least to the goodness of fit of the current model. Then we used model comparisons to confirm that the newly constructed model was not significantly lower in goodness of fit than the previous model. We always kept the fixed effects of main experimental interest in the model (see Table 2). When arriving at the restricted model, we added random slopes starting with the factor with the largest t-value. We tested the contribution of each of the random slopes with model comparisons. We used this data-driven approach for determining the random effects structure because the maximal random effects structure (Barr, Levy, Scheepers, & Tily, 2013) resulted in convergence errors. After adding all of the contributing random slopes, we again excluded non-significant fixed interaction effects one by one, until we arrived at the optimal model. An effect or interaction was excluded if a Chi-square test comparing the model with and without the effect was not significant. Backward and forward fitting were performed in the order of the lowest or highest t-value of the model terms, respectively. We report the results for the optimal model. The optimal models we found for the full prediction time frame for the target and competitor data were then used for a time course analysis, in which we fitted the model for each 50ms time bin in the display time frame (200 ms after display onset up to 1000 ms after target word

offset). The data sets and scripts used for the analyses are available online at Open Science Framework (https://osf.io/wy9tm/).

Table 2

Factors and interactions included in the full model for the Target trials and Competitor trials

Fixed factors	**Two-way interactions**	**Three-way interactions**
Language (L1 Dutch vs. L2 English)	*Language : Image type*	Language: Image type: Target word onset time
	Language : Target word onset time	Language: Image type: Cloze probability
	Language : Cloze probability	Language : Image type : English LexTALE score
	Language : English LexTALE score	
Image type (experimental vs. unrelated)	Image type : Target word onset time	
	Image type : Cloze probability	
	Image type : English LexTALE score	
	Image type : experimental image frequency	
	Image type : experimental image phoneme count	
	Image type : experimental image phonetic levenshtein distance	
Target word onset time (sentence length upto the target word in ms)		
Cloze probability		
Presentation list		
English LexTALE score		
Experimental image frequency		
Experimental image phoneme count		
Experimental image phonetic levenshtein distance (between L1 and L2 translation equivalents)		
Additional terms competitor model		
Fixed factors	**Two-way interactions**	**Three-way interactions**
Semantic distance (between competitor and target, continuous variable)	*Language: Semantic distance*	*Image type : Language : Semantic distance*
	Image type : Semantic distance	
Plausibility (plausibility rating of competitor word as sentence ending)	Image type : Plausibility	

Note. Main experimental terms that were never excluded from the model during backward fitting are printed in italics.

Results

Figure 3 shows the time-course of fixations to target, competitor, and unrelated pictures in L1 (Dutch) and L2 (English). The graph shows raw fixation proportions.

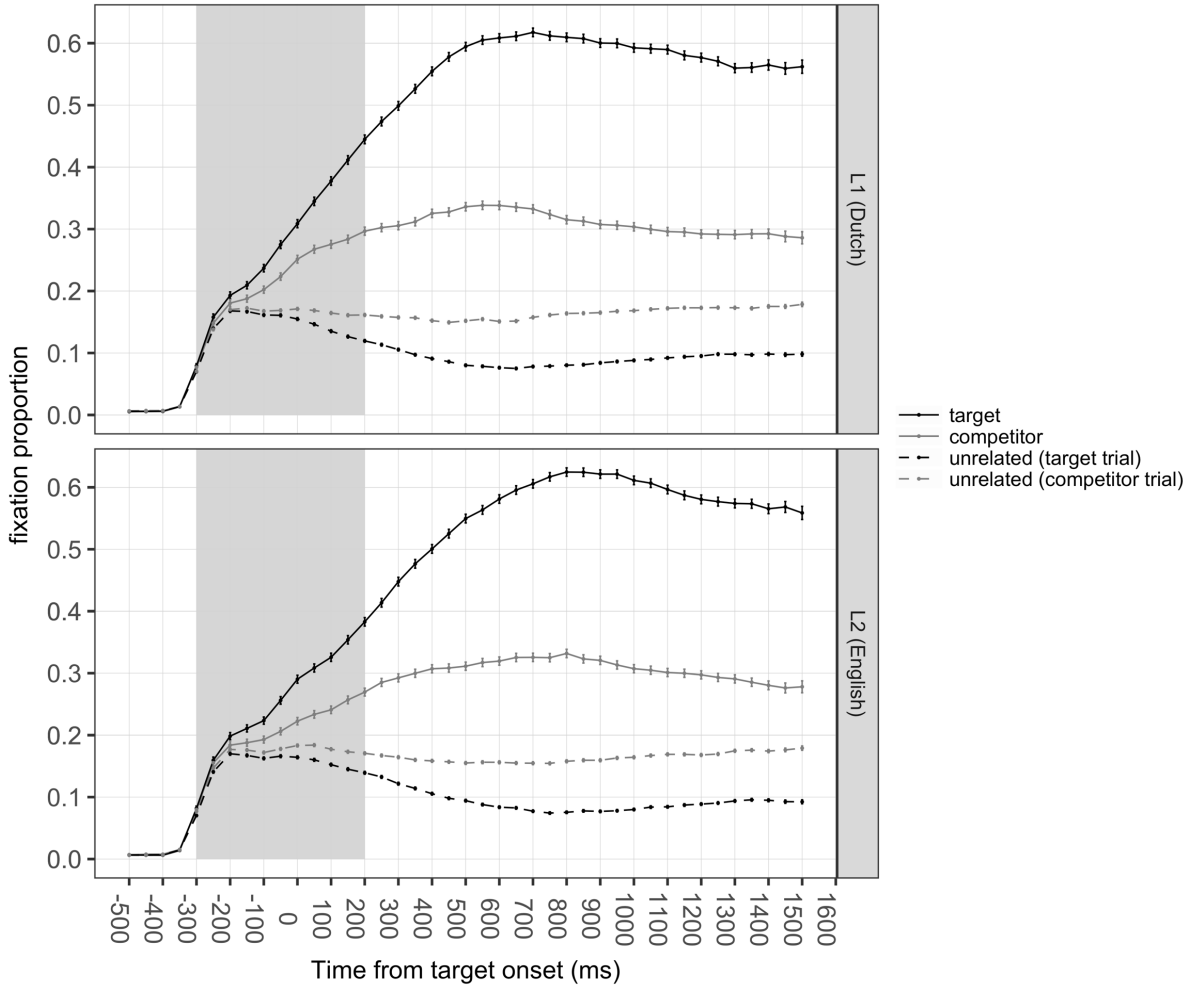


Figure 3. Time course of fixations to target, competitor, and unrelated pictures in the L1 (Dutch) and the L2 (English) relative to target onset. Display onset was 500 ms before target onset. Proportions are based on proportion of samples in which there was a fixation to the picture, aggregated in 50 ms time bins. Proportions for unrelated images were averaged. The area shaded grey is the prediction time frame, in which bottom-up information from the target word could not yet affect looking behaviour (but top-down information from the preceding sentence could). The prediction time frame included the eye-data samples starting from 200 ms after the onset of the picture display to 200 ms after target onset. Whiskers indicate the mean ± standard error.

Visual inspection of the graph suggests that participants were more likely to fixate on target objects than on competitor objects, and also more likely to fixate on competitor objects than on unrelated objects. Fixation proportions for the target, competitor, and unrelated pictures started to diverge well before the target word onset time both in Dutch and in English.

Analyses full prediction time frame

Target trials. The optimal model for the prediction time frame (200 ms after the onset of the picture display to 200 ms after target word onset) included the factors language, image type (target versus unrelated), target word onset time (sentence length upto the target word in ms), and presentation list, as well as the interaction between image type and language, and the interaction between image type and target word onset. A random slope of image type was included for each participant and sentence (full results are presented in Table B1 of Appendix B). There was a significant effect of image type (Figure 4, panel A). Importantly, image type also interacted with language. During the prediction time frame, participants were more likely to fixate target images than unrelated images in both the L1 (target raw fixation probability: *M*=.26 *SD*=.30, unrelated raw fixation probability: *M*=.14, *SD*=.10) and the L2 (target raw fixation probability: *M*=.24 *SD*=.29, unrelated raw fixation probability: *M*=.15, *SD*=.11), and this effect was larger in the L1 than in the L2 (β = .26, *SE* = .08, *t* = 3.40, $p <$ .001).

The interaction between image type and target word onset time was also significant (β = -.38, *SE* = .09, *t* = -4.42, p < .0001). As the length of the sentence leading up to the target word increased, so did the difference between fixations to the target and unrelated images. The interaction between image type and cloze probability did not contribute significantly to the model ($\chi^2(2)$=.28, *p*=.87), suggesting that the bias in looks toward the target picture in the prediction time frame did not increase when the cloze probability of the

sentence increased. Also, the interaction between L2 LexTALE score, language, and image type did not contribute significantly to the model ($\chi^2(4)=4.46$, $p=.35$), thus there was no evidence suggesting that relatively proficient bilinguals predicted more than less proficient bilinguals.

Competitor trials. The optimal model included the main effects of language, image type (competitor versus unrelated), semantic distance (between competitor and sentence target, as continuous factor), target word onset time, and presentation list. The model also included the two-way interactions between image type and language, image type and target word onset, image type and semantic distance, and language and semantic distance. Additionally, the model included the three-way interaction between image type, language, and semantic distance. A random slope of image type was included for each participant and sentence (full results are presented in Table B2 of Appendix B).

There was a significant main effect of image type (competitor vs. unrelated) (β = -.66, SE = .10, t = -6.35, $p < .001$). As shown in Figure 4 panel B, there was a stronger fixation bias to the competitor (versus unrelated images) when the semantic distance between target and competitor was smaller (e.g. *bottle-glass*) (β = .22, SE = .07, t = 3.04, p = .002). This interaction effect was larger in L1 than in L2 (β = -.19, SE = .08, t = -2.49, p = .013). Post-hoc tests reveal that the interaction between semantic distance and image type was significant in both languages (L1 Dutch: β = .66, SE = .10, t = 6.35, p <.0001, L2 English: β = .51, SE = .10, t = 4.97, $p < .0001$).

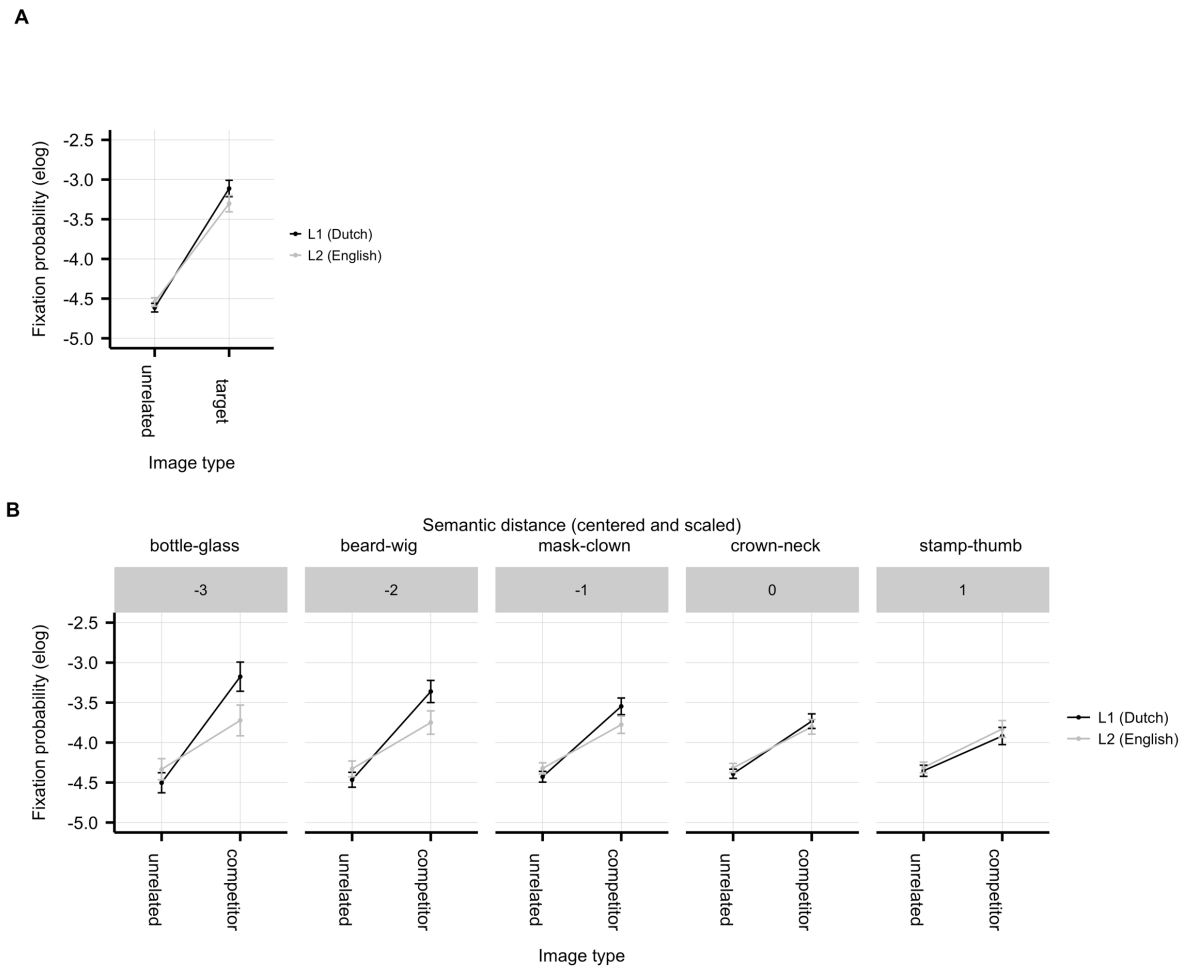


Figure 4. A. Interaction between image type and language for target trials (model predicted means). B. Interaction between image type, language and target-competitor semantic distance (model predicted means). The word pairs above each semantic distance facet are example competitor word pairs in that semantic distance category.

As in the target image data analysis, the interaction between image type and target word onset time was significant (β = -.29, SE = .08, t = -3.57, p < .001). Longer sentences before the target words yielded larger differences between fixations to the competitor and fixations to the unrelated images. As in the target image data, the interaction between image type and cloze probability did not contribute significantly to the model ($\chi^2(2)=1.33$, p=.51). Also, the interaction between L2 LexTALE score, language and image type did not contribute

significantly to the model ($\chi^2(4)=2.36$, $p=.67$), so that relatively proficient bilinguals did not predict competitors more than less proficient bilinguals.

Individual cognitive differences.

Forward digit span score ($M=9.53$, $SD=1.83$) and fluency (English and Dutch) (Table 1) and their interactions with image type and language did not contribute to the optimal model fit for the competitor and target trials (all ps >.1).[9]

Time course analyses

A time course analysis was carried out to test whether the language effects found in the analyses of the prediction time frame were caused by a delay in fixation bias in the L2 relative to the L1, rather than by an overall weaker fixation bias in L2. With this goal, the data were aggregated in 50 ms time bins starting from the prediction time frame (200 ms after the onset of the picture display). The optimal model for the target trials was run for each 50 ms time bin in the target trial data, and the optimal model for the competitor trials was run for each 50 ms time bin in the competitor trials.[10] We continued to run the models for the 50 ms time bins after the prediction frame, up to 1500 ms after target word onset (the average target word duration was 509 ms and pictures were left on screen for 1000 ms after target offset). In those time bins, looking behavior could be influenced by hearing the target word. Therefore, we do not interpret the effects in this time window as prediction effects but as effects of ease of integration of information from the auditory target and sentence and the semantic information from the picture display. This type of time-course analysis increases the likelihood of Type I errors, and therefore the differences reported here only include those differences that were found consistently in multiple (>1) time bins (following Ito, Corley, et al., 2017). In addition, we plotted the p-values in each time bin of the most relevant effects with horizontal lines indicating alpha and corrected alpha (Bonferroni style) in Figure C1 and Figure C2 of Appendix C.

Figure 5 shows the time course of fixations on the target and unrelated objects in the L1 and L2. The solid circles at the top of the graph indicate a significant interaction between language and image type ($p<.05$).

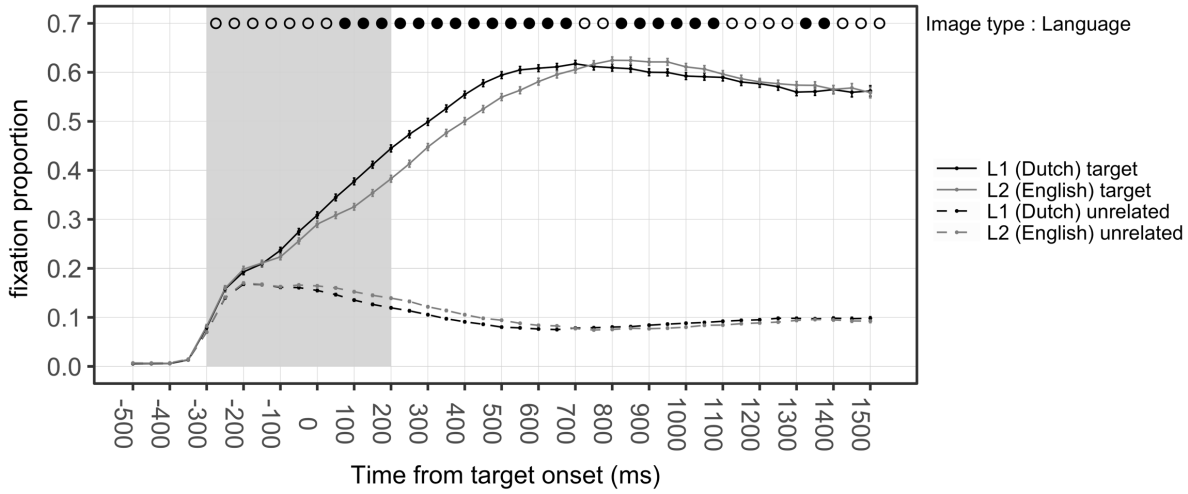


Figure 5. Time course of fixations to the target image and unrelated images in the L1 and L2 relative to target onset. Display onset was 500 ms before target onset. Proportions are based on proportion of samples in which there was a fixation to the picture, aggregated in 50 ms time bins. Proportions for unrelated images were averaged. The area shaded grey is the prediction time frame. Whiskers indicate the mean ± standard error.

In the prediction frame of the target trials, the image type by language interaction was significant only in the last three time bins (50-200 ms after target word onset). The main effect of image type (target vs. unrelated) was already significant at 250 ms before target word onset. After the prediction time frame, at 700 ms, the bias towards the target did reach the same level in the L2 as in the L1 and from 800 to 1100 ms after target word onset the bias towards the target was even larger in the L2 than in the L1.

Figure 6 shows the time course of fixations on the competitor and unrelated objects in the L1 and the L2. The solid circles at the top of the graph indicate a significance of the effects listed on the right (p<.05).

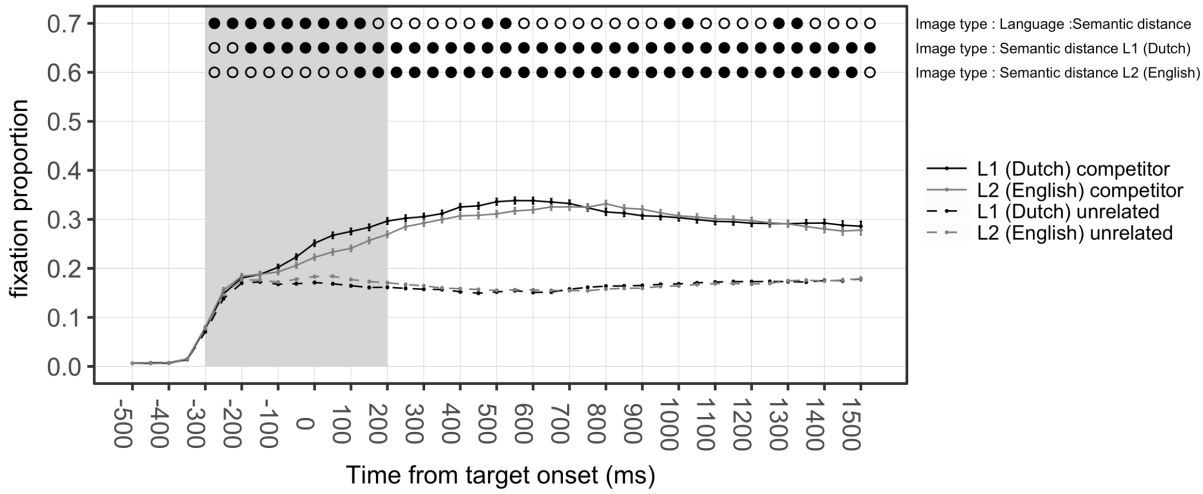


Figure 6. Time course of fixations to the competitor image and unrelated images in the L1 and the L2 relative to target onset. Display onset was 500 ms before target onset. Proportions are based on proportion of samples in which there was a fixation to the picture, aggregated in 50 ms time bins. Proportions for unrelated images were averaged. The area shaded grey is the prediction time frame. Whiskers indicate the mean ± standard error.

First, the main effect of image type became significant 100ms before target word onset in the competitor trial data set. The interaction between language and image type was significant from -50 ms to 200 ms in the prediction frame and continued to be significant for 50 ms (200-250 ms) in the post prediction time frame. The bias towards the competitor object was weaker in the L2 than in the L1. The image type effect also became significant at 100ms before target word onset in both languages separately.

Within the prediction time frame, the interaction between semantic distance and image type was modulated by language from 300 ms before target word onset until 150 ms after target word onset; the effect of semantic distance on the bias towards the competitor was

larger in the L1 than in the L2 in those time bins. Figure D1 of Appendix D shows that the interaction effect of semantic distance on the bias towards the competitor gradually increased in the L2 until the three-way interaction with language was no longer significant at 150 ms after target word onset. The effect of semantic distance on bias towards the competitor continued to grow in the L2 after the prediction time time frame, and from 450-550 ms, the three-way interaction with language was significant again. This time, the effect of semantic distance on the bias towards the competitor was larger in the L2 than in the L1. There are four more later time bins in which the the three-way interaction was significant. Again, the effect was larger in the L2 than in the L1 in those time bins. Interestingly, post-hoc tests with lsmeans show that the interaction between image type and semantic distance became significant 300 ms later in the L2 (English) data than in the L1 (Dutch) data (see Figure 6).

Overall time-course analysis

In order to compare the time-course for target and competitor pre-activation in both languages we ran an additional time bin analysis on the entire data set, including both target and competitor trials, for the bins in the prediciton time frame. All factors included in both the competitor final model and the target final model were included in the model for the overall analysis. The factor trial type (target vs. competitor) was added as well. Semantic distance was not included as factor as it applied only to the competitor trials. A random slope for image type was added by items and by participants. Further random slopes did not contribute to the model fit (as determined by model comparisons with and without each slope for the model applied to the full prediction time frame data set). The image type effect was significant from 250 ms before target word onset ($ps<.05$), and this effect was modulated by trial type from 150 ms before target word onset ($ps<.05$). The bias towards the experimental image was larger on target trials than on competitor trials. The image type effect interacted with language from time bin 0 onwards, with a larger bias towards the experimental image in L1 than in L2. The three-way interaction between image type, trial type, and language did not

reach significance until the final bin of the prediction time frame. Post-hoc tests reveal that on target trials the effect of image type became significant from 250 ms before target word onset onwards in L2, and from 200 ms before target word onset in L1. On competitor trials, the effect of image type was significant from 100 ms before target word onset onwards in both languages.

Discussion

In the present study, we tested whether prediction of meaning during speech comprehension is affected by language (native versus non-native). We found that bilinguals predicted the semantics of target words both in the L1 and the L2; participants were more likely to focus on target objects than on unrelated objects before the auditory target could affect eye-movements. We found a larger prediction effect when bilinguals listened in the L1 than when they listened in the L2. Bilinguals were also more likely to look at semantic competitor objects than at unrelated objects, in both languages. This shows that semantic pre-activation during listening in both languages is strong enough to spread to related concepts, at least when a picture of the related concept is present on the screen. The strength of the competitor fixation bias depended on the semantic distance between target and competitor (the smaller the distance, the larger the bias) and language: the effect of semantic distance on bias to competitor objects was larger in the L1 than in the L2, with an especially strong competitor effect in the L1 for the most strongly related competitors. Time-course analyses showed that there was significant prediction of target word semantics in the L1 and the L2 250 ms before target word onset, and that the prediction effect was larger in the L1 than in the L2 from 150 ms before auditory exposure to the target word could influence looking behavior. The difference remained significant for 500 ms afterwards. The effect of semantic distance on the bias to competitor objects was larger in the L1 than in the L2 throughout almost the entire prediction time frame. After the prediction time frame, the effect of

semantic distance on the bias to the competitor object was the same in the L1 and the L2, and it even became larger in the L2 than in the L1 for a brief period (6 time bins in total).

In this study, differences were found when directly comparing prediction between the L1 and the L2 of the same individuals when both the cues and information to be predicted are of a lexical-semantic nature. The results indicate that semantic prediction in the L2 does not always occur as efficiently as in the L1.

Target prediction

The finding that the effect of pre-activation of the target was smaller in the L2 than in L1 could be due to weaker and/or slower pre-activation in L2. Target pre-activation became significant at approximately the same time in English and Dutch, suggesting that predictive pre-activation of the target was weaker, rather than slower in L2 than in L1. However, these two explanations cannot be teased apart enequivocally in this paradigm. The finding that the effect of pre-activation of the target was smaller in the L2 than in L1 differs with earlier findings on semantic prediction in the L2 (Dijkgraaf et al., 2017; Hopp, 2015; Ito et al., 2017). Dijkgraaf et al. directly compared predictive looking behaviour in the L1 and the L2 in bilinguals and found no significant difference. Hopp found predictive looking behaviour in L2 like in L1, but only when the cues used for prediction were lexico-semantic and not when predictions were to be based on case-marking information. No direct comparison of prediction in the L1 and L2 was reported for lexico-semantic prediction. Ito et al. found predictive looking behaviour in the L1 and the L2 but they did not report a direct comparison of the strength of the prediction effect in each language. Instead, they reported a similar effect of cognitive load on predictive processing in the L1 and L2.

It is of course possible that the difference between our findings and previous findings is driven by the greater statistical power in the current study. After all, we had 4525 observations per condition in the current study, 270 in Dijkgraaf et al. (2017), 768 in Ito et al. (2017) (ignoring the cognitive load factor), and 360 and 96 observations for the L2 and L1

groups in Hopp (2015) respectively. But more interestingly, the differences between our findings and the findings of Dijkgraaf et al, Ito et al. and Hopp can be attributed to contextual factors or to individual differences between our participants and theirs. The sentences used in the current experiment were longer and often syntactically more complex (e.g., compound sentences) than the simple sentences used in previous studies. This may have lead the participants to use the routes to prediction to a different extent. Specifically, as predictions in Dijkgraaf et al., Ito et al., and Hopp were based mainly on information from only one word (the verb), low-level lexical associations may have played a large role. The present study used longer, more naturalistic sentences and therefore predictions were likely at least partly based on higher level meaning. The latter may require more cognitive resources unavailable to the L2-comprehenders than prediction via low level lexical associations (e.g., Huettig, 2015; Pickering & Gambi, 2018), hence the diverging findings. In line with this hypothesis Ito et al. (2018) also found a L2 disadvantage in semantic prediction, similar to the current study. These authors also used longer, more naturalistic sentences (e.g., *The tourists expected rain when the sun went behind the* ***cloud***). Both English native speakers and Japanese-English bilinguals showed anticipatory eye-movements to predictable targets (e.g., *cloud*), but the L2-listeners did so later than the L1-listeners.

Further, in Dijkgraaf et al. (2017), Hopp (2015), and Ito et al. (2017) the picture display appeared before sentence onset. Pre-activation of target word semantics may have been increased greatly because of the visual presence of a plausible target object. This may be especially true for bilinguals, as they may rely strongly on visual information during language processing (Navarra & Soto-Faraco, 2007). Therefore, in order to maximize sensitivity for language differences in the current experiment, the pictures appeared only 500 ms before the onset of the target word. This was also done to minimize effects of priming by the visual context.

Besides task and stimulus differences, individual differences could also contribute to differences across studies, but this does not seem to be the case here. For example, prediction in the L2 is thought to approach prediction in the L1 as L2 proficiency increases (Kaan, 2014). However, participants in Ito et al. (2017), and Dijkgraaf et al. (2017) were highly proficient like the participants in the current experiment, which makes proficiency an unlikely explanation for the diverging results. Also, like in Ito et al., Hopp (2015) and Dijkgraaf et al., no effect of proficiency on semantic prediction in L2 was found in the current experiment. The range of proficiencies was possibly too small to detect such an effect.

Competitor prediction

Our finding that the semantic distance effect on competitor prediction was smaller in the L2 than in the L1 in the prediction time frame indicates that spread of semantic activation started later in the L2 than in the L1, that activation spreading was weaker (especially for the most strongly related concepts), or both. The first explanation receives support from the time-course analyses of competitor trials, which indicated that the effect of spread of semantic activation became significant later in the L2 than in the L1. When we compared looking behavior in the L1 and L2 in later time bins (including time bins where hearing the target word could affect looking behaviour) the effect of semantic distance on the bias to the competitor was the same in both languages, or even bigger in the L2. The later significant effect in the L2 suggests a delay in activation. This would be consistent with the temporal delay assumption of the BIA+ model of bilingual visual word recognition (Dijkstra & van Heuven, 2002). This assumption states that due to lower subjective L2 word frequency, activation of word forms and, as a consequence, semantic codes is somewhat delayed in the L2 compared to the L1, while activation patterns themselves are the same.

We also obtained evidence supporting the second explanation above, namely that of weaker lexico-semantic activation in the L2. We observed that the semantic distance effect in

the competitor trials was stronger in the L1 than the L2, even though the prediction effect itself became significant in the same time bin in both languages. We predicted such an effect from the assumption that L2 words are mapped onto fewer semantic features than L1 words (Schoonbaert et al., 2009; Van Hell & De Groot, 1998), and that therefore spreading semantic activation should be narrower in the L2 than in the L1. We expected that the difference between the L1 and L2 would be particularly large for less strongly related competitors, because L2 concepts should map onto the core semantic features (shared by strongly related concepts), but perhaps not onto the more remote ones (shared by weakly related concepts). Somewhat surprisingly, the difference between the competitor effects in L1 and L2 was most pronounced for the most strongly related competitors, with very strong semantic pre-activation of closely related concepts especially from L1 words. This suggests that stronger spreading semantic activation for the L1 is determined by the strength of mappings between word forms and semantics, rather than by the number of mapped semantic features. Our interaction effect between language, image type, and semantic distance suggests that L1 words have stronger links with the underlying concepts than L2 words, which then leads to stronger semantic pre-activation for very related concepts. Such an explanation is consistent with for instance the weaker links account, which assumes that divided language practice across languages leads to weaker links between representations in the bilingual language system (Gollan et al., 2008; Gollan, Montoya, Fennema-Notestine, & Morris, 2005). Because L2 exposure is far less frequent for our bilinguals, mappings from L2 word forms onto semantics are weaker.

Finally, in this paradigm, we cannot distinguish between competitor activation through target word pre-activation, followed by spreading activation to the competitor on the one hand, and competitor activation via passive resonance of the semantics of semantically related words in the sentence on the other hand. Both mechanisms may also be additive. Future studies could be aimed at pinpointing the exact locus of the delay in/weaker effect of

spreading semantic activation in L2 compared to L1. In any case, the present results show that L2 yields slower and/or weaker semantic prediction overall.

Other potential modulating factors

As less cognitive resources may be available during L2 than during L1 processing (e.g., Francis & Gutiérrez, 2012; McDonald, 2006) we expected that participants with a larger working memory capacity would have less of a disadvantage in L2 prediction. However, we found no effects of working memory span (forward digit span) on prediction in L1 and L2, suggesting that working memory resources may not drive the current differences between L1 and L2. Consistent with our finding, Ito et al. found that a cognitive load during speech comprehension affects prediction in L1 and L2 to the same extent. On the other hand, the sample of 50 participants in our study may not have been large enough to detect an effect of individual differences in working memory capacity, or there may not have been sufficient variation in resources given that all participants were university students. Future research using a more sensitive design could be aimed at testing whether working memory resource limitations in L2 may underlie the L2 disadvantage in prediction.

For both the target and the competitor data we found that target word onset time (the length of the sentence leading up to the target word) affected prediction. The longer the sentence, the larger the prediction effect. This may be due both to the increased time for pre-activation in longer sentences and the increased amount of context information to serve as cue for prediction. The effect of sentence length on predictive looking behavior was not modulated by language (L1 vs. L2). Apparently, even though semantic pre-activation was weaker in the L2 than in the L1, the length of the sentence did not differentially affect pre-activation in the L1 and the L2. A limitation of the current study is that the Dutch sentences were slightly longer than the English sentences, possibly contributing to the L2 disadvantage in prediction.

Somewhat unexpectedly, we found no effect of sentence cloze probability on target or competitor pre-activation, even though we included sentences with a rather large range of cloze probabilities (0.08-1). The cloze probability test was filled out with the sentences as context only. The presence of a picture display with a target or competitor word may have increased the probability of the sentence ending with the target word, thereby eliminating the cloze probability effect. Furthermore, participants listened to 362 experimental sentences with an average cloze probability of .68 for English and .71 for Dutch. The exposure to so many predictable sentences may have further enhanced the likelihood of predictive behavior overall (Lau, Holcomb, & Kuperberg, 2013), and thereby reduced the chances of finding an effect of cloze probability.

Conclusion

In sum, even in an experimental setting with many relatively high cloze sentences and additional visual information, we find differences in the strength and time-course between L1 and L2 semantic prediction. Therefore, language dominance (L1 versus L2) can not only affect prediction based on (morpho-)syntactic cues but also prediction of semantic information based on semantic context information, if more fine-grained measures of semantic activation are targeted. The difference between prediction in the L1 and the L2 is compatible with the hypothesis that lexico-semantic mappings are weaker for L2 than for L1 (Gollan et al., 2008, 2005), and with slower word form activation and, as as a consequence, slower spread of semantic activation in L2 than in L1, due to smaller subjective word frequency in the L2 (Dijkstra & van Heuven, 2002). As working memory (digit span score) did not affect prediction, an explanation in terms of limited cognitive resources in L2 (Francis & Gutiérrez, 2012; McDonald, 2006) is less likely. We suggest that there is no qualitative difference between lexico-semantic prediction in the L2 and the L1, but that subtle quantitative differences arise when graded semantic relations are assessed, like in the present paradigm. The differences between our findings and previous research in which no language

effect on semantic prediction was found, illustrate again that prediction during language comprehension is a highly flexible process. Future studies should be aimed at testing which exact contextual factors and individual differences, best explain the diverging findings on predictive behavior in L2 comprehension.

Disclosure of interest

The authors report no conflict of interest.

References

Altmann, G. T. M., & Kamide, Y. (1999). Incremental interpretation at verbs: restricting the domain of subsequent reference. *Cognition*, *73*(3), 247–264. https://doi.org/10.1016/S0010-0277(99)00059-1

Altmann, G. T. M., & Kamide, Y. (2007). The real-time mediation of visual attention by language and world knowledge: Linking anticipatory (and other) eye movements to linguistic processing. *Journal of Memory and Language*, *57*(4), 502–518. https://doi.org/10.1016/j.jml.2006.12.004

Arai, M., & Keller, F. (2013). The use of verb-specific information for prediction in sentence processing. *Language and Cognitive Processes*, *28*(4), 525–560. https://doi.org/10.1080/01690965.2012.658072

Baayen, H., Piepenbrock, R., & Gulikers, L. (1995). *The CELEX Lexical Database. Release 2 (CD-ROM)*. Linguistic Data Consortium, University of Pennsylvania.

Bargary, G., Bosten, J. M., Goodbourn, P. T., Lawrance-Owen, A. J., Hogg, R. E., & Mollon, J. D. (2017). Individual differences in human eye movements: An oculomotor signature? *Vision Research*, *141*, 157–169. https://doi.org/10.1016/j.visres.2017.03.001

Barr, D. J. (2008). Analyzing 'visual world' eyetracking data using multilevel logistic regression. *Journal of Memory and Language*, *59*(4), 457–474. https://doi.org/10.1016/j.jml.2007.09.002

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, *68*(3), 255–278. https://doi.org/10.1016/j.jml.2012.11.001

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, *67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Block, C. K., & Baldwin, C. L. (2010). Cloze probability and completion norms for 498 sentences: Behavioral and neural validation using event-related potentials. *Behavior Research Methods*, *42*(3), 665–670. https://doi.org/10.3758/BRM.42.3.665

Broersma, P., & Weenink, D. (2014). Praat: doing phonetics by computer (Version 5.3.78). Retrieved from www.praat.org

Chambers, C. G., Tanenhaus, M. K., & Magnuson, J. S. (2004). Actions and Affordances in Syntactic Ambiguity Resolution. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*(3), 687–696. https://doi.org/10.1037/0278-7393.30.3.687

Cop, U., Keuleers, E., Drieghe, D., & Duyck, W. (2015). Frequency effects in monolingual and bilingual natural reading. *Psychonomic Bulletin & Review*, *22*(5), 1216–1234. https://doi.org/oi: 10.3758/s13423-015-0819-2

Dell, G. S., & Chang, F. (2013). The P-chain: relating sentence production and its disorders to comprehension and acquisition. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *369*(1634), 20120394–20120394. https://doi.org/10.1098/rstb.2012.0394

Dijkgraaf, A., Hartsuiker, R. J., & Duyck, W. (2017). Predicting upcoming information in native-language and non-native-language auditory word recognition. *Bilingualism:*

Language and Cognition, *20*(5), 917–930. https://doi.org/10.1017/S1366728916000547

Dijkstra, T., & van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition*, *5*(03), 175–197. https://doi.org/10.1017/S1366728902003012

Dikker, S., Rabagliati, H., Farmer, T. A., & Pylkkänen, L. (2010). Early Occipital Sensitivity to Syntactic Category Is Based on Form Typicality. *Psychological Science*, *21*(5), 629–634. https://doi.org/10.1177/0956797610367751

Dirix, N., & Duyck, W. (2017). The first- and second-language age of acquisition effect in first- and second-language book reading. *Journal of Memory and Language*, *97*, 103–120. https://doi.org/10.1016/j.jml.2017.07.012

Duyck, W., Assche, E. V., Drieghe, D., & Hartsuiker, R. J. (2007). Visual word recognition by bilinguals in a sentence context: Evidence for nonselective lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*(4), 663–679. https://doi.org/10.1037/0278-7393.33.4.663

Federmeier, K. D., & Kutas, M. (2005). Aging in context: Age-related changes in context use during language comprehension. *Psychophysiology*, *42*(2), 133–141. https://doi.org/10.1111/j.1469-8986.2005.00274.x

Ferraresi, A., Zanchetta, E., Baroni, M. G., & Bernardini, S. (2008). Introducing and evaluating ukWaC, a very large web-derived corpus of English. In *Proceedings of the 4th Web as Corpus Workshop (WAC-4)* (pp. 47–54).

Finkbeiner, M., Forster, K., Nicol, J., & Nakamura, K. (2004). The role of polysemy in masked semantic and translation priming. *Journal of Memory and Language*, *51*(1), 1–22. https://doi.org/10.1016/j.jml.2004.01.004

Foucart, A. (2015). Prediction is a question of experience. *Linguistic Approaches to Bilingualism*, *5*(4), 465–469. https://doi.org/10.1075/lab.5.4.04fou

Foucart, A., Martin, C. D., Moreno, E. M., & Costa, A. (2014). Can bilinguals see it coming? Word anticipation in L2 sentence reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *40*(5), 1461–1469. https://doi.org/10.1037/a0036756

Foucart, A., Moreno, E., Martin, C. D., & Costa, A. (2015). Integration of moral values during L2 sentence processing. *Acta Psychologica*, *162*, 1–12. https://doi.org/10.1016/j.actpsy.2015.09.009

Foucart, A., Ruiz-Tada, E., & Costa, A. (2015). Anticipation processes in L2 speech comprehension: Evidence from ERPs and lexical recognition task. *Bilingualism: Language and Cognition*, 1–7. https://doi.org/10.1017/S1366728915000486

Francis, W. S., & Gutiérrez, M. (2012). Bilingual recognition memory: Stronger performance but weaker levels-of-processing effects in the less fluent language. *Memory & Cognition*, *40*(3), 496–503. https://doi.org/10.3758/s13421-011-0163-3

Gollan, T. H., Montoya, R. I., Cera, C., & Sandoval, T. C. (2008). More use almost always means a smaller frequency effect: Aging, bilingualism, and the weaker links hypothesis. *Journal of Memory and Language*, *58*(3), 787–814. https://doi.org/10.1016/j.jml.2007.07.001

Gollan, T. H., Montoya, R. I., Fennema-Notestine, C., & Morris, S. K. (2005). Bilingualism affects picture naming but not picture classification. *Memory & Cognition*, *33*(7), 1220–1234. https://doi.org/10.3758/BF03193224

Gollan, T. H., Slattery, T. J., Goldenberg, D., Van Assche, E., Duyck, W., & Rayner, K. (2011). Frequency drives lexical access in reading but not in speaking: The frequency-lag hypothesis. *Journal of Experimental Psychology: General*, *140*(2), 186–209. https://doi.org/10.1037/a0022256

Hamberger, M. J., Friedman, D., & Rosen, J. (1996). Completion norms collected from younger and older adults for 198 sentence contexts. *Behavior Research Methods, Instruments, & Computers*, *28*(1), 102–108. https://doi.org/10.3758/BF03203644

Hopp, H. (2013). Grammatical gender in adult L2 acquisition: Relations between lexical and syntactic variability. *Second Language Research*, *29*(1), 33–56. https://doi.org/10.1177/0267658312461803

Hopp, H. (2015). Semantics and morphosyntax in predictive L2 sentence processing. *International Review of Applied Linguistics in Language Teaching*, *53*(3), 277–306. https://doi.org/10.1515/iral-2015-0014

Huettig, F. (2015). Four central questions about prediction in language processing. *Brain Research*, *1626*, 118–135. https://doi.org/10.1016/j.brainres.2015.02.014

Huettig, F., & Altmann, G. T. M. (2005). Word meaning and the control of eye fixation: semantic competitor effects and the visual world paradigm. *Cognition*, *96*(1), 23–32. https://doi.org/10.1016/j.cognition.2004.10.003

Huettig, F., & Janse, E. (2016). Individual differences in working memory and processing speed predict anticipatory spoken language processing in the visual world. *Language, Cognition and Neuroscience*, *31*(1), 80–93. https://doi.org/10.1080/23273798.2015.1047459

Huettig, F., Rommers, J., & Meyer, A. S. (2011). Using the visual world paradigm to study language processing: A review and critical evaluation. *Acta Psychologica*, *137*(2), 151–171. https://doi.org/10.1016/j.actpsy.2010.11.003

Ito, A., Corley, M., & Pickering, M. J. (2017). A cognitive load delays predictive eye movements similarly during L1 and L2 comprehension. *Bilingualism: Language and Cognition*, *21*(2), 251–264. https://doi.org/10.1017/S1366728917000050

Ito, A., Corley, M., Pickering, M. J., Martin, A. E., & Nieuwland, M. S. (2016). Predicting form and meaning: Evidence from brain potentials. *Journal of Memory and Language*, *86*, 157–171. https://doi.org/10.1016/j.jml.2015.10.007

Ito, A., Martin, A. E., & Nieuwland, M. S. (2017). On predicting form and meaning in a second language. *Journal of Experimental Psychology: Learning, Memory, and Cognition.*, *43*(4), 635–652. https://doi.org/10.1037/xlm0000315

Ito, A., Pickering, M. J., & Corley, M. (2018). Investigating the time-course of phonological prediction in native and non-native speakers of English: A visual world eye-tracking study. *Journal of Memory and Language*, *98*, 1–11. https://doi.org/10.1016/j.jml.2017.09.002

Kaan, E. (2014). Predictive sentence processing in L2 and L1: What is different? In *Linguistic Approaches to Bilingualism* (pp. 257–282).

Keuleers, E., Brysbaert, M., & New, B. (2010). SUBTLEX-NL: A new measure for Dutch word frequency based on film subtitles. *Behavior Research Methods*, *42*(3), 643–650. https://doi.org/10.3758/BRM.42.3.643

Kohlstedt, T., & Mani, N. (2018). The influence of increasing discourse context on L1 and L2 spoken language processing. *Bilingualism: Language and Cognition*, *21*(01), 121–136. https://doi.org/10.1017/S1366728916001139

Kuperberg, G. R., & Jaeger, T. F. (2016). What do we mean by prediction in language comprehension? *Language, Cognition and Neuroscience*, *31*(1), 32–59. https://doi.org/10.1080/23273798.2015.1102299

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2016). *lmerTest: Tests in Linear Mixed Effects Models*. Retrieved from https://CRAN.R-project.org/package=lmerTest

Lagrou, E., Hartsuiker, R. J., & Duyck, W. (2013). Interlingual lexical competition in a spoken sentence context: Evidence from the visual world paradigm. *Psychonomic Bulletin & Review*, *20*(5), 963–972. https://doi.org/10.3758/s13423-013-0405-4

Lau, E. F., Holcomb, P. J., & Kuperberg, G. R. (2013). Dissociating N400 effects of prediction from association in single-word contexts. *Journal of Cognitive Neuroscience*, *25*(3), 484–502. https://doi.org/10.1162/jocn_a_00328

Lemhöfer, K., & Broersma, M. E. (2012). Introducing LexTALE: A quick and valid Lexical Test for Advanced Learners of English. *Behavior Research Methods*, *44*(2), 325–343. https://doi.org/10.3758/s13428-011-0146-0

Mandera, P., Keuleers, E., & Brysbaert, M. (2017). Explaining human performance in psycholinguistic tasks with models of semantic similarity based on prediction and counting: A review and empirical validation. *Journal of Memory and Language*, *92*, 57–78. https://doi.org/10.1016/j.jml.2016.04.001

Marian, V., Blumenfeld, H. K., & Kaushanskaya, M. (2007). The Language Experience and Proficiency Questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals. *Journal of Speech, Language, and Hearing Research*, *50*(4), 940–967. https://doi.org/10.1044/1092-4388(2007/067)

Martin, C. D., Thierry, G., Kuipers, J.-R., Boutonnet, B., Foucart, A., & Costa, A. (2013). Bilinguals reading in their second language do not predict upcoming words as native readers do. *Journal of Memory and Language*, *69*(4), 574–588. https://doi.org/10.1016/j.jml.2013.08.001

Matin, E., Shao, K. C., & Boff, K. R. (1993). Saccadic overhead: Information-processing time with and without saccades. *Perception & Psychophysics*, *53*(4), 372–380. https://doi.org/10.3758/BF03206780

McDonald, J. L. (2006). Beyond the critical period: Processing-based explanations for poor grammaticality judgment performance by late second language learners. *Journal of Memory and Language*, *55*(3), 381–401. https://doi.org/10.1016/j.jml.2006.06.006

McQueen, J. M., & Huettig, F. (2012). Changing only the probability that spoken words will be distorted changes how they are recognizeda). *The Journal of the Acoustical Society of America*, *131*(1), 509–517. https://doi.org/10.1121/1.3664087

Mitsugi, S., & Macwhinney, B. (2015). The use of case marking for predictive processing in second language Japanese. *Bilingualism: Language and Cognition*, *19*(01), 19–35. https://doi.org/10.1017/S1366728914000881

Navarra, J., & Soto-Faraco, S. (2007). Hearing lips in a second language: visual articulatory information enables the perception of second language sounds. *Psychological Research*, *71*(1), 4–12. https://doi.org/10.1007/s00426-005-0031-5

Nieuwland, M., Politzer-Ahles, S., Heyselaar, E., Segaert, K., Darley, E., Kazanina, N., … Huettig, F. (2017). Limits on prediction in language comprehension: A multi-lab failure to replicate evidence for probabilistic pre-activation of phonology. *BioRxiv*, 111807.

Oostdijk, N., Reynaert, M., Hoste, V., & van den Heuvel, H. (2013). *SoNaR user documentation*. Retrieved from https://ticclops.uvt.nl/SoNaR_end-user_documentation_v.1.0.4.pdf

Otten, M., Nieuwland, M. S., & Van Berkum, J. J. (2007). Great expectations: Specific lexical anticipation influences the processing of spoken language. *BMC Neuroscience*, *8*(1), 89. https://doi.org/10.1186/1471-2202-8-89

Peters, R., Grüter, T., & Borovsky, A. (2015). Anticipatory and Locally Coherent Lexical Activation Varies as a Function of Language Proficiency. In *Proceedings of the 37th Annual Meeting of the Cognitive Science Society* (pp. 1865–1870). Austin, TX.

Phillips, C., & Ehrenhofer, L. (2015). The role of language processing in language acquisition. *Linguistic Approaches to Bilingualism*, *5*(4), 409–453. https://doi.org/10.1075/lab.5.4.01phi

Pickering, M. J., & Gambi, C. (2018). Predicting while comprehending language: A theory and review. *Psychological Bulletin*, *144*(10), 1002–1044. https://doi.org/10.1037/bul0000158

Pickering, M. J., & Garrod, S. (2013). An integrated theory of language production and comprehension. *Behavioral and Brain Sciences*, *36*(04), 329–347. https://doi.org/10.1017/S0140525X12001495

R Core Team. (2013). *R: A language and environment for statistical computing.* Vienna, Austria.: R Foundation for Statistical Computing,. Retrieved from http://www.R-project.org/.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin*, *124*(3), 372–422. http://dx.doi.org/10.1037/0033-2909.124.3.372

Rommers, J., Meyer, A. S., Praamstra, P., & Huettig, F. (2013). The contents of predictions in sentence comprehension: Activation of the shape of objects before they are referred to. *Neuropsychologia*, *51*(3), 437–447. https://doi.org/10.1016/j.neuropsychologia.2012.12.002

Salverda, A. P., Brown, M., & Tanenhaus, M. K. (2011). A goal-based perspective on eye movements in visual world studies. *Acta Psychologica*, *137*(2), 172–180. https://doi.org/10.1016/j.actpsy.2010.09.010

Saslow, M. G. (1967). Latency for Saccadic Eye Movement*. *JOSA*, *57*(8), 1030–1033. https://doi.org/10.1364/JOSA.57.001030

Schepens, J., Dijkstra, T., Grootjen, F., & van Heuven, W. J. B. (2013). Cross-Language Distributions of High Frequency and Phonetically Similar Cognates. *PLoS ONE*, *8*(5), e63006. https://doi.org/10.1371/journal.pone.0063006

Schoonbaert, S., Duyck, W., Brysbaert, M., & Hartsuiker, R. J. (2009). Semantic and translation priming from a first language to a second and back: Making sense of the findings. *Memory & Cognition*, *37*(5), 569–586. https://doi.org/10.3758/MC.37.5.569

Severens, E., Lommel, S. V., Ratinckx, E., & Hartsuiker, R. J. (2005). Timed picture naming norms for 590 pictures in Dutch. *Acta Psychologica*, *119*(2), 159–187. https://doi.org/10.1016/j.actpsy.2005.01.002

Van Bergen, G., & Flecken, M. (2017). Putting things in new places: Linguistic experience modulates the predictive power of placement verb semantics. *Journal of Memory and Language*, *92*, 26–42. https://doi.org/10.1016/j.jml.2016.05.003

Van Hell, J. G., & De Groot, A. M. B. (1998). Conceptual representation in bilingual memory: Effects of concreteness and cognate status in word association. *Bilingualism: Language and Cognition*, *1*(3), 193–211. https://doi.org/10.1017/S1366728998000352

Van Heuven, W. J. B., Mandera, P., Keuleers, E., & Brysbaert, M. (2014). SUBTLEX-UK: a new and improved word frequency database for British English. *Quarterly Journal of Experimental Psychology (2006)*, *67*(6), 1176–1190. https://doi.org/10.1080/17470218.2013.850521

Weber, A., & Broersma, M. E. (2012). Spoken word recognition in second language acquisition. In C. Chapelle (Ed.), *The Encyclopedia of Applied Linguistics*. Hoboken, NJ, USA: John Wiley & Sons, Inc. Retrieved from http://doi.wiley.com/10.1002/9781405198431

[1] Out of the 871 sentences, 54 were from the Block and Boldwin (2010) sentence set, and 31 from Hamberger, Friedman & Rosen (1996). Another 39 were adapted from Block and Boldwin, and 31 were adapted from Hamberger, Friedman and Rosen. These sentences were adapted so that they could be translated to Dutch without changing the sentence final word.

[2] 0=no overlap, 1=identical (Schepens, Dijkstra, Grootjen, & van Heuven, 2013).

[3] We applied the optimal models to the prediction time frame data excluding trials in which the experimental image was a cognate (phonological levenshtein distance >.5, following Schepens et al., 2013). For the target, the language by image type interaction remained significant (β = 35, *SE* = .08, *t* = 4.19, *p* < .001). For the competitor data, the threeway interaction between language, image type and semantic distance also remained significant (β = -.21, *SE* = .08, *t* = -2.54, *p* = .01)

[4] The target/competitor words sometimes had false friends in the other language (e.g. *map*, meaning *folder* in Dutch). We applied the optimal models to the prediction time frame data excluding trials in which the experimental image (target or competitor) had (identical) false friends in the other language. Both words with identical orthographic false friends (85 out of 724 words) and words with identical phonological false friends (25 out of 724 words) were excluded (106 in total). For the target, the language by image type interaction remained significant (β = .24, *SE* = .09, *t* = 2.77, *p* =.006). As for the competitor, competitor semantic distance still interacted with image type (β = .28, *SE* = .08, *t* = 3.49, *p* <.001), but the three-way interaction with language was no longer significant (β =- .13, *SE* = .09, *t* = -1.54, *p* =.12). To investigate whether the three-way interaction disappeared because of loss of power or because false friend status actually affected looking behavior we compared the final model with the final model plus the factor false friend status (false friend in the other language yes

or no) and the interaction between false friend status and image type. False friend status did not contribute to the model fit ($\chi(2)=1.73$, $p=.42$).

[5] Competitors were sometimes ungrammatical as sentence ending (e.g. because of a gender mismatch with the preceding determiner) and/or they could violate a phonotactic rule (due to a mismatch with preceding indefinite article *a* or *an*). To test whether competitor grammaticality affected our results we applied the optimal models to the prediction frame data excluding trials in which the competitor was ungrammatical or violated a phonotactic rule. Fifty (out of 362) English sentences and 43 (out of 362) Dutch sentences were excluded. For the target, the language by image type interaction remained significant (β = .25, *SE* = .09, t = 2.89, p =.004). For the competitor data, the twoway language by image type interaction remained significant (β =.22, *SE* = .08, t = 2.68, p =.007), as did the interaction between image type and semantic distance (β =.27, *SE* = .08, t = 3.45, p < .001). The threeway interaction between language, image type and semantic distance approached significance (β = -.15, *SE* = .08, t = -1.87, p = .06). In addition, adding competitor grammaticality and the interaction between grammaticality and image type to the optimal model for the prediction time frame (competitor data set) did not improve the model fit ($\chi(2)=1.63$, $p=.44$).

[6] The English corpora used were UKWAC (Ferraresi, Zanchetta, Baroni, & Bernardini, 2008) (containing texts from the .uk internet domain) and a subtitle corpus (Mandera, Keuleers, & Brysbaert, 2017) (downloaded from http://opensubtitles.org). For Dutch Sonar-500 text corpus (Oostdijk, Reynaert, Hoste, & van den Heuvel, 2013) (texts from conventional and new media) and another subtitle corpus (Mandera et al., 2017) were used.

[7] In 8 sentences (out of 362 Dutch and 362 English sentences) either the target word or the competitor word was present in the sentence, either with the same meaning or a slightly different meaning (e.g. *She locked her bicycle to a fence with a lock*, *Ivory is derived from an elephant or a rhino*-> competitor: *elephant*). A picture of the target or competitor word also

present in the sentence was likely to attract more fixations in these sentences than in other sentences. The random slope for item in the analyses ensured that this possible confound did not affect the results. In addition, an analysis of the target and competitor data of the full prediction time frame without these 7 sentences did not change the results.

[8] Due to an error in the test plausibility ratings for three (out of 724 sentences) were missing.

[9] Due to technical problems the scores for fluency (Dutch and English) is missing for two participants, and the score for digit span is missing for one participant.

[10] It is possible that any of the factors excluded from the final models had a significant effect in some of the time bins. We used the final model for the time bin analyses in order to investigate whether different languages showed a different time course of effects of the relevant variables, as observed in the full prediction time frame analysis. The alternative of running a separate backfitting procedure for each time bin could not fulfill this goal, as this would lead to models with different factors in each bin, so that the results for each time bin would not have been directly comparable.

Appendix A Sentences with targets and competitors

Stimulus set	English sentence	Dutch sentence	Target English	Target Dutch	Competitor English	Competitor Dutch	Association strength L2	Association strength L1
1	The man went sailing on his	De man ging zeilen op zijn	boat	boot	anchor	anker	0.57	0.49
1	The sailor had a tattoo depicting an	De zeeman had een tattoo van een	anchor	anker	boat	boot	0.57	0.49
2	Eric had beautiful guppies and a turtle in his	Erik had prachtige guppy's en een schildpad in zijn	aquarium	aquarium	shark	haai	0.60	0.48
2	Surfers are scared of getting bitten by a	Surfers zijn bang om gebeten te worden door een	shark	haai	aquarium	aquarium	0.60	0.48
3	An insect crawled over her	Een insect kroop over haar	arm	arm	leg	been	0.25	0.33
3	During his last skiing trip he broke his	Tijdens zijn laatste skireisje brak hij zijn	leg	been	arm	arm	0.25	0.33
4	The policeman collected all the documents and put them in a	De politie verzamelde alle documenten en stopte ze in een	folder	map	backpack	rugzak	0.72	0.70
4	The hiker put his water bottle in his	De wandelaar stopte zijn waterfles in zijn	backpack	rugzak	folder	map	0.72	0.70
5	Santa Claus put a present in his	De Kerstman stopte een cadeautje in zijn	bag	zak	wallet	portefeuille	0.36	0.57
5	He took a euro out of his leather	Hij nam een euro uit zijn leren	wallet	portefeuille	bag	zak	0.36	0.57
6	The monkey peeled a	De aap pelde een	banana	banaan	pineapple	ananas	0.55	0.47
6	The Hawaiian pizza was topped with slices of ham and	De pizza Hawaï was belegd met plakjes ham en	pineapple	ananas	banana	banaan	0.55	0.47
7	He always sang in the	Hij zong altijd onder de	shower	douche	bath	bad	0.36	0.38
7	To relax her muscles she took a	Om haar spieren te ontspannen nam ze een	bath	bad	shower	douche	0.36	0.38
8	He rested his head on a	Hij liet zijn hoofd rusten op een	pillow	kussen	bed	bed	0.37	0.40
8	He was tired so went to	Hij was moe dus ging hij naar	bed	bed	pillow	kussen	0.37	0.40
9	He drove to the garage for a new	Hij reed naar de garage voor een nieuwe	car	auto	bike	fiets	0.46	0.51
9	He rode to school on a	hij reed naar school op de	bike	fiets	car	auto	0.46	0.51
10	The biologist studied the cells through a	De bioloog bestudeerde de cellen door een	microscope	microscoop	binoculars	verrekijker	0.62	0.60
10	He studied the rare bird through his	Hij bestudeerde de zeldzame vogel door zijn	binoculars	verrekijker	microscope	microscoop	0.62	0.60
11	The dog barked at a	De hond blafte naar een	cat	kat	bird	vogel	0.61	0.47
11	She heard the sound of a	Ze hoorde het geluid van een	bird	vogel	cat	kat	0.61	0.47
12	The equipment was sent to the planet in a	De apparatuur werd naar de planeet gestuurd in een	rocket	raket	bomb	bom	0.62	0.52
12	In his backpack the terrorist had a	In zijn rugzak had de terrorist een	bomb	bom	rocket	raket	0.62	0.52
13	Her baby doesn't like drinking from a	Haar baby drinkt niet graag uit een	bottle	fles	glass	glas	0.41	0.37
13	He poured some lemonade into a	Hij schonk wat limonade in een	glass	glas	bottle	fles	0.41	0.37
14	Derrick collects magnets to put on his	Derrick verzamelt magneten voor op zijn	fridge	koelkast	bottle	fles	0.56	0.56
14	He poured a glass of wine and put the cork back in the	Hij schonk een glas wijn in en stopte de kurk terug in de	bottle	fles	fridge	koelkast	0.56	0.56

15	The bird sat on a broken	De vogel zat op een gebroken	branch	tak	pickaxe	houweel	0.78	0.80
15	Coal was extracted with a shovel and a	Steenkool werd gewonnen met een schop en een	pickaxe	houweel	branch	tak	0.78	0.80
16	The janitor cleaned the floor with his bucket and his	De conciërge boende de vloer met zijn emmer en zijn	mop	dweil	brush	borstel	0.60	0.48
16	She sat on her knees and scrubbed the floor with a	Ze zat op haar knieën en schrobde de vloer met een	brush	borstel	mop	dweil	0.60	0.48
17	He ran to the station but missed the	Hij rende naar het station maar miste de	train	trein	bus	bus	0.41	0.38
17	In the USA children are brought to school by	In VS worden kinderen naar school gebracht met een	bus	bus	train	trein	0.41	0.38
18	The Arab rode into the desert on a	De Arabier reed de woestijn in op een	camel	kameel	donkey	ezel	0.57	0.45
18	To bring the goods down from the mountain. he put them on the back of a	Om de goederen de berg af te brengen legde hij ze op de rug van een	donkey	ezel	camel	kameel	0.57	0.45
19	The floor in the Persian Palace was covered with a	De vloer in het Perzische paleis was bedekt met een	carpet	tapijt	chair	stoel	0.69	0.63
19	He came in and threw his bag on a	Hij kwam binnen en gooide zijn tas op een	chair	stoel	carpet	tapijt	0.69	0.63
20	The romantic boy was very old-fashioned. He collected songs and recorded them for her on a	De romantische jongen was erg ouderwets. Hij verzamelde liedjes en nam die voor haar op op een	cassette	cassette	radio	radio	0.62	0.75
20	We listened to the morning news on the	We luisterden naar het ochtendnieuws op de	radio	radio	cassette	cassette	0.62	0.75
21	The mouse ate the	De muis at de	cheese	kaas	sandwich	boterham	0.43	0.49
21	In her lunchbox Mary found fruit and a	In haar lunchtrommel vond Marie fruit en een	sandwich	boterham	cheese	kaas	0.43	0.49
22	The nun listened to the sermon in the	De non luisterde naar de preek in de	church	kerk	priest	priester	0.47	0.32
22	He was baptized by a	Hij werd gedoopt door een	priest	priester	church	kerk	0.47	0.32
23	He wanted to marry her. so he gave her a	Hij wilde met haar trouwen dus gaf hij haar een	ring	ring	clock	klok	0.77	0.77
23	Rob was in a hurry and kept watching the	Rob had haast en bleef maar kijken naar de	clock	klok	ring	ring	0.77	0.77
24	It doesn't matter whether you seal a wine bottle with a cap or a	Het maakt niet uit of je een wijnfles afsluit met een dop of een	cork	kurk	grapes	druiven	0.74	0.60
24	Wine is made of	Wijn wordt gemaakt van	grapes	druiven	cork	kurk	0.74	0.60
25	He cut her hair with the	Hij knipte haar haar met de	scissors	schaar	corkscrew	kurkentrekker	0.73	0.63
25	He opened the wine bottle with a	Hij opende de wijnfles met een	corkscrew	kurkentrekker	scissors	schaar	0.73	0.63
26	The magician pulled the rabbit out of his	De goochelaar trok een konijn uit zijn	hat	hoed	cowboy	cowboy	0.56	0.53
26	His granddad told him stories about an indian and a	Zijn opa vertelde hem een verhaal over een indiaan en een	cowboy	cowboy	hat	hoed	0.56	0.53
27	The guppy was eaten by a large	De guppy werd opgegeten door een grote	fish	vis	shell	schelp	0.73	0.60
27	The mussel closed its	De mossel sloot zijn	shell	schelp	fish	vis	0.73	0.60
28	He heard someone knocking. so he opened the	Hij hoorde iemand kloppen dus hij opende de	door	deur	cupboard	kast	0.59	0.53
28	He put the clean plates back in the	Hij zette de schone borden terug in de	cupboard	kast	door	deur	0.59	0.53
29	The doctor listened to his heart with a	De dokter luisterde naar zijn hart met een	stethoscope	stethoscoop	dentist	tandarts	0.73	0.64

29	He had a painful molar so he went to see a	Hij had een pijnlijke kies dus hij ging naar een	dentist	tandarts	stethoscope	stethoscoop	0.73	0.64
30	It is a nice ring with a small	Het is een mooie ring met een kleine	diamond	diamant	necklace	ketting	0.45	0.64
30	She put the ring on her finger and the bracelet around her wrist. Around her neck she wore a	Ze deed de ring om haar vinger en een armband om haar pols. Om haar nek droeg zij een	necklace	ketting	diamond	diamant	0.45	0.64
31	The young mother bought a new brand of diapers for her	De jonge moeder kocht een nieuw merk luiers voor haar	baby	baby	doctor	dokter	0.60	0.61
31	I wish my daughter had married a lawyer or a	Ik wou dat mijn dochter getrouwd was met een advocaat of een	doctor	dokter	baby	baby	0.60	0.61
32	He put a carrot in the cage of his	Hij legde een wortel in het hok van zijn	rabbit	konijn	dog	hond	0.55	0.57
32	Lola would adopt a cat rather than a	Lola adopteert liever een kat dan een	dog	hond	rabbit	konijn	0.55	0.57
33	A Scottish kilt is a kind of	Een Schotse kilt is een soort	skirt	rok	dress	jurk	0.39	0.39
33	At the prom she wore a blue	Op het gala droeg zij een blauwe	dress	jurk	skirt	rok	0.39	0.39
34	He had a bad cold so he blew his	Hij was erg verkouden dus hij snoot zijn	nose	neus	ear	oor	0.51	0.56
34	She whispered something in his	Ze fluisterde iets in zijn	ear	oor	nose	neus	0.51	0.56
35	The circus owned a tiger and a huge grey	Het circus had een tijger en een enorme grijze	elephant	olifant	rhino	neushoorn	0.50	0.40
35	Ivory is derived from an elephant or a	Ivoor is afkomstig van een olifant of een	rhino	neushoorn	elephant	olifant	0.50	0.40
36	The goods were transported in a	De goederen werden vervoerd in een	truck	vrachtwagen	factory	fabriek	0.67	0.75
36	The clothing was made in a large	De kleding werd gemaakt in een grote	factory	fabriek	truck	vrachtwagen	0.67	0.75
37	The king wore his golden	De koning droeg zijn gouden	crown	kroon	neck	hals	0.71	0.72
37	She wore a colorful scarf around her	Ze droeg een kleurrijke sjaal om haar	neck	hals	crown	kroon	0.71	0.72
38	The natives danced around the	De inboorlingen dansten rond het	fire	vuur	smoke	rook	0.50	0.49
38	The chimney was clogged. so the house was full of	De schoorsteen zat verstopt dus het huis stond vol	smoke	rook	fire	vuur	0.50	0.49
39	The cat was saved from the tree by a	De kat werd uit de boom gered door een	fireman	brandweerman	ladder	ladder	0.72	0.66
39	He was cleaning the windows of the upper floor on a	Hij waste de ruiten van de bovenverdieping op een	ladder	ladder	fireman	brandweerman	0.72	0.66
40	At the villa. he wanted to go swimming in a	Hij wilde bij de villa gaan zwemmen in een	pool	zwembad	fountain	fontein	0.60	0.62
40	He threw a penny into the	Ze gooide een muntje in de	fountain	fontein	pool	zwembad	0.60	0.62
41	He is as clever as a	Hij is zo sluw als een	fox	vos	deer	hert	0.57	0.76
41	He took his gun and shot a	Hij nam zijn geweer en schoot een	deer	hert	fox	vos	0.57	0.76
42	Besides cheese of cow's milk the farmer often makes cheese from the milk of his	Naast kaas van koeienmelk maakt de boer vaak kaas van de melk van zijn	goats	geiten	pig	varken	0.45	0.51
42	Spanish ham is meat from a special kind of	Spaanse ham is vlees van een speciaal soort	pig	varken	goats	geiten	0.45	0.51
43	The rock star put new strings on his	De rockster zette nieuwe snaren op zijn	guitar	gitaar	piano	piano	0.37	0.40
43	With such long fingers. you must play the	Met zulke lange vingers speelt u vast	piano	piano	guitar	gitaar	0.37	0.40

44	The mobster played Russian roulette with his	Het maffialid speelde Russische roulette met zijn	gun	geweer	knife	mes	0.47	0.48
44	He cut his food with a	Hij sneed zijn eten met een	knife	mes	gun	geweer	0.47	0.48
45	The hungry woman ordered a coke. fries. and a	De hongerige vrouw bestelde een cola. friet en een	hamburger	hamburger	icecream	ijsje	0.59	0.60
45	It was a warm day so the spoiled child wanted an	Het was een warme dag dus het verwende kind wilde een	icecream	ijsje	hamburger	hamburger	0.59	0.60
46	The boy dressed up as a train conductor and wore a whistle and a	De jongen verkleedde zich als conducteur en droeg een fluitje en een	hat	pet	basket	mand	0.67	0.77
46	She put the food for the picnic in a	Ze deed het eten voor de picknick in een	basket	mand	hat	pet	0.67	0.77
47	The farmer milked a	De boer melkte een	cow	koe	hay	hooi	0.72	0.68
47	The stable boy took a bale of	De stalknecht nam een baal	hay	hooi	cow	koe	0.72	0.68
48	The doctor held the stethoscope against his	De dokter hield de stethoscoop tegen zijn	chest	borst	heart	hart	0.52	0.50
48	He was in love with her. so he gave her a box of chocolates in the shape of a	Hij was verliefd op haar dus hij gaf haar een doos bonbons in de vorm van een	heart	hart	chest	borst	0.52	0.50
49	Santa Claus travels to the North Pole on a	De Kerstman reist naar de Noordpool op een	sled	slee	rope	touw	0.68	0.64
49	The pirate tied the prisoner's hands with a	De piraat bond de handen van zijn gevangene vast met een	rope	touw	sled	slee	0.68	0.64
50	He buried his head in the sand like an	Hij stak zijn kop in het zand als een	ostrich	struisvogel	kangaroo	kangoeroe	0.63	0.48
50	When he was in Australia. he saw a young joey in the pouch of a	Toen hij in Australië was zag hij een jong in de buidel van een	kangaroo	kangoeroe	ostrich	struisvogel	0.63	0.48
51	The politician kept the secret document and the money in a	De politicus bewaarde het geheime document en het geld in een	safe	kluis	key	sleutel	0.62	0.46
51	He quickly opened the lock with his	Hij opende vlug het slot met zijn	key	sleutel	safe	kluis	0.62	0.46
52	The knight saw his enemy and drew his	De ridder zag zijn vijand en trok zijn	sword	zwaard	king	koning	0.65	0.54
52	He was the prince and his father was	Hij was de prins en zijn vader was een	king	koning	sword	zwaard	0.65	0.54
53	The dragon was slain by the courageous	De draak werd gedood door de dappere	knight	ridder	wizard	tovenaar	0.66	0.62
53	The head of the school of magic was a	Het hoofd van de toverschool was een	wizard	tovenaar	knight	ridder	0.66	0.62
54	He hated the sour taste of	Hij haatte de zure smaak van	lemon	citroen	orange	sinaasappel	0.50	0.39
54	She squeezed the delicious fresh juice from the	Ze perste het heerlijke verse sap uit de	orange	sinaasappel	lemon	citroen	0.50	0.39
55	It is so dark I can barely read. I would like a better	Het is hier zo donker dat ik bijna niet kan lezen. Ik wil graag een betere	light	lamp	candle	kaars	0.49	0.58
55	In church we saw the flickering light of a	In de kerk zag hij het flikkerende licht van een	candle	kaars	light	lamp	0.49	0.58
56	The circus performer tamed a	De circusartiest temde een	lion	leeuw	dragon	draak	0.51	0.55
56	He heard that the beast had two heads and breathed fire. It must have been a	Hij hoorde dat het beest twee koppen had en vuur spuwde. Het was zeker een	dragon	draak	lion	leeuw	0.51	0.55
57	Alexandra put her new clothes on a shelf in her	Alexandra legde haar nieuwe kleding op een plank in haar	closet	kast	lock	slot	0.64	0.57
57	She locked her bicycle to a fence with a	Zij zette haar fiets vast aan een hek met een	lock	slot	closet	kast	0.64	0.57
58	The thief was caught and had to go to	De dief werd gepakt en moest naar de	jail	gevangenis	man	man	0.58	0.60

58	She fell in love with a handsome	Ze werd verliefd op een knappe	man	man	jail	gevangenis	0.58	0.60
59	When you drive. you keep your eyes on the	Als je rijdt houd je je ogen op de	road	weg	map	kaart	0.71	0.63
59	Could you show me where the village is on a	Kun je me laten zien waar het dorpje ligt op een	map	kaart	road	weg	0.71	0.63
60	I saw myself in the	Ik zag mezelf in de	mirror	spiegel	eyes	ogen	0.58	0.49
60	Without her sunglasses. the sun hurt Erika's	Zonder haar zonnebril deed de zon Erika pijn aan haar	eyes	ogen	mirror	spiegel	0.58	0.49
61	The adventurer started to climb a	De avonturier begon aan de beklimming van een	mountain	berg	rock	steen	0.65	0.68
61	The little frog sat on a	Het kleine kikkertje zat op een	rock	steen	mountain	berg	0.65	0.68
62	The cat killed a	De kat doodde een	mouse	muis	cage	kooi	0.64	0.60
62	He petted his parrot and then put it back in its	Hij aaide zijn papegaai en zette hem toen terug in zijn	cage	kooi	mouse	muis	0.64	0.60
63	The strongest finger on your hand is your	De sterkste vinger aan je hand is je	thumb	duim	stamp	postzegel	0.77	0.80
63	He mailed the letter without a	Hij verstuurde de brief zonder een	stamp	postzegel	thumb	duim	0.77	0.80
64	The chicken laid an	De kip legde een	egg	ei	nest	nest	0.54	0.59
64	In spring the birds built a	In het voorjaar bouwden de vogels een	nest	nest	egg	ei	0.54	0.59
65	The little boy marched like a	Het kleine jongetje marcheerde als een	soldier	soldaat	nurse	verpleegster	0.66	0.71
65	During the war. she worked at the hospital as a	Tijdens de oorlog werkte zij in een ziekenhuis als	nurse	verpleegster	soldier	soldaat	0.66	0.71
66	To protect her fingers from the cold she wore a	Om haar vingers tegen de kou te beschermen droeg ze een	glove	handschoen	package	pakketje	0.75	0.74
66	This morning. someone delivered us a	Vanochtend bezorgde iemand ons een	package	pakketje	glove	handschoen	0.75	0.74
67	Clara put the flowers in an expensive	Clara zette de bloemen in een dure	vase	vaas	painting	schilderij	0.58	0.61
67	The artist took his brush and made a	De kunstenaar pakte zijn kwast en maakte een	painting	schilderij	vase	vaas	0.58	0.61
68	He had a hole in his	Hij had een gat in zijn	pants	broek	sweater	trui	0.49	0.51
68	For Christmas. she knitted her son a	Voor kerst breidde ze voor haar zoon een	sweater	trui	pants	broek	0.49	0.51
69	Dick wrote a chapter in the	Dick schreef een hoofdstuk in het	book	boek	paper	papier	0.60	0.65
69	Jot it down on a piece of	Noteer het op een stuk	paper	papier	book	boek	0.60	0.65
70	The boy at the zoo brought bananas to feed a	De jongen in de dierentuin bracht bananen mee om te voeren aan een	monkey	aap	parrot	papegaai	0.61	0.57
70	The colorful bird that repeats your words is called a	De kleurrijke vogel die je woorden herhaalt heet een	parrot	papegaai	monkey	aap	0.61	0.57
71	The clown sold her father a	De clown verkocht haar vader een	balloon	ballon	plane	vliegtuig	0.66	0.60
71	The pilot entered the cockpit of the	De piloot betrad de cockpit van het	plane	vliegtuig	balloon	ballon	0.66	0.60
72	It was his birthday and his mother baked a	Hij was jarig en zijn moeder bakte een	cake	taart	potato	aardappel	0.71	0.69
72	Max wanted to help his mother in the kitchen. so he peeled a	Max wilde zijn moeder helpen in de keuken. dus schilde hij een	potato	aardappel	cake	taart	0.71	0.69
73	The ceremony was attended by the king and	De ceremonie werd bijgewoond door de koning en	queen	koningin	witch	heks	0.73	0.58

73	She was burned in the middle ages because they thought she was a	Ze werd in de middeleeuwen verbrand want ze hielden haar voor een	witch	heks	queen	koningin	0.73	0.58
74	He worked on a ship as a	Hij werkte op een schip als	sailor	matroos	raft	vlot	0.73	0.70
74	To leave the deserted island. they built a	Om van het onbewoonde eiland af te komen bouwden ze een	raft	vlot	sailor	matroos	0.73	0.70
75	I got sick from eating a poisonous	Ik werd ziek door het eten van een giftige	mushroom	paddenstoel	rose	roos	0.74	0.72
75	She removed the thorns from the red	ze verwijderde de doorns van de rode	rose	roos	mushroom	paddenstoel	0.74	0.72
76	He is so good at horseback riding. He doesn't even use a	Hij is zo goed in paardrijden. Hij gebruikt niet eens een	saddle	zadel	helmet	helm	0.71	0.69
76	He rides a motorbike but he never wears a	Hij rijdt motor maar hij draagt nooit een	helmet	helm	saddle	zadel	0.71	0.69
77	The captain decided to stay with the sinking	De kapitein besloot om te blijven op het zinkende	ship	schip	bridge	brug	0.66	0.50
77	To get to the other side of the river you have to cross a	Om aan de andere kant van de rivier te komen moet je over een	bridge	brug	ship	schip	0.66	0.50
78	The boy enjoyed himself in the pool. He loved going down the	De jongen vermaakte zich in het zwembad. Hij ging graag van de	slide	glijbaan	tripod	statief	0.74	0.64
78	To keep the camera steady. he put it on a	Om de camera recht te houden zette hij hem op een	tripod	statief	slide	glijbaan	0.74	0.64
79	The treasure map was made by a	De schatkaart werd gemaakt door een	pirate	piraat	submarine	duikboot	0.71	0.64
79	To research The Titanic. the research team used a	Om de titanic te bereiken gebruikte het onderzoeksteam een	submarine	duikboot	pirate	piraat	0.71	0.64
80	The player’s cap protected him from the	De pet van de speler beschermde hem tegen de	sun	zon	rain	regen	0.53	0.54
80	He walked outside in the wind and the	Hij liep buiten in de wind en de	rain	regen	sun	zon	0.53	0.54
81	That night he slept at the festival in a	Die nacht sliep hij op het festival in een	tent	tent	house	huis	0.69	0.64
81	He placed a new kitchen in his	Hij plaatste een nieuwe keuken in zijn	house	huis	tent	tent	0.69	0.64
82	He hung the sock on the line with a	Hij hing de sok aan de lijn met een	clothespin	wasknijper	thread	draad	0.68	0.71
82	I sewed on the button with a needle and	Ik naaide de knoop eraan met naald en	thread	draad	clothespin	wasknijper	0.68	0.71
83	The little girl needed to pee. so she went to the	Het kleine meisje moest plassen dus ze ging naar het	toilet	toilet	sink	gootsteen	0.60	0.45
83	She washed the dirty dishes in the	Ze deed de afwas in de	sink	gootsteen	toilet	toilet	0.60	0.45
84	Ron was shocked by the environmental pollution. The whole beach was full of	Ron was geschrokken van de milieuvervuiling. Het hele strand lag vol met	garbage	afval	diaper	luier	0.71	0.79
84	She picked up her baby. It was time to change his	Ze pakte haar baby op. Het was tijd voor het verschonen van zijn	diaper	luier	garbage	afval	0.71	0.79
85	It was raining heavily so Jenny went outside with her	Het regende erg hard dus Jennie ging naar buiten met haar	umbrella	paraplu	torch	fakkel	0.73	0.78
85	To show us the murals in the cave. he lit up a	Om ons de muurschildering in de grot te laten zien ontstak hij een	torch	fakkel	umbrella	paraplu	0.73	0.78
86	He did not want to spill anything so he poured the lemonade through a	Hij wilde niets morsen dus schonk hij de limonade door een	funnel	trechter	volcano	vulkaan	0.78	0.78
86	Lava is the molten rock expelled by a	Lava is gesmolten gesteente dat wordt uitgestoten door een	volcano	vulkaan	funnel	trechter	0.78	0.78
87	The dog looked outside through a	Het hondje keek naar buiten door een	window	raam	roof	dak	0.54	0.53
87	He climbed on top of his house and sat down on the	Hij klom op zijn huis en ging zitten op het	roof	dak	window	raam	0.54	0.53

88	The sommelier handed her the glass and she took a sip of	De sommelier gaf haar het glas en ze nam een slokje	wine	wijn	table	tafel	0.63	0.72
88	He put the chair under a	Hij zette de stoel onder een	table	tafel	wine	wijn	0.63	0.72
89	The dog wagged its	Het hondje kwispelde met zijn	tail	staart	wing	vleugel	0.70	0.74
89	The bird couldn't fly because he had a broken	Het vogeltje kon niet vliegen want hij had een gebroken	wing	vleugel	tail	staart	0.70	0.74
90	The squirrel ate an	De eekhoorn at een	acorn	eikel	tree	boom	0.78	0.67
90	The dog chased our cat up a	De hond joeg onze kat in een	tree	boom	acorn	eikel	0.78	0.67
91	Floris is as slow as a	Floris is zo traag als een	snail	slak	ant	mier	0.72	0.55
91	The insect that can carry fifty times its own weight is called an	Het insect dat vijftig keer zijn eigen gewicht kan dragen heet een	ant	mier	snail	slak	0.72	0.55
92	On Halloween he carved a face out of a	Met Halloween sneed hij een gezicht uit een	pumpkin	pompoen	apple	appel	0.65	0.69
92	Snow White took a bite of her	Sneeuwwitje nam een hap van haar	apple	appel	pumpkin	pompoen	0.65	0.69
93	The Indian carried a bow and an	De indiaan droeg een boog en een	arrow	pijl	needle	naald	0.73	0.78
93	She repaired the skirt with thread and	Ze repareerde de rok met draad en	needle	naald	arrow	pijl	0.73	0.78
94	He tossed the empty plastic cup in a	Hij gooide het lege plastic bekertje in een	trashcan	vuilbak	ashtray	asbak	0.66	0.57
94	He put the cigarette out in the	Ze maakte de sigaret uit in de	ashtray	asbak	trashcan	vuilbak	0.66	0.57
95	The lumberjack chopped wood with his	De houthakker hakte hout met zijn	axe	bijl	hammer	hamer	0.56	0.59
95	He slammed the nail into the wall with a	Hij sloeg de spijker in de muur met een	hammer	hamer	axe	bijl	0.56	0.59
96	The cashier put the groceries into a	De caissière stopte de boodschappen in een	bag	tas	zipper	rits	0.65	0.68
96	This coat has buttons. but I prefer a	Deze jas heeft knopen maar ik verkies een	zipper	rits	bag	tas	0.65	0.68
97	The other player threw the	De andere speler gooide de	ball	bal	racket	tennisracket	0.61	0.66
97	Nadal bought a new	Nadal kocht een nieuw	racket	tennisracket	ball	bal	0.61	0.66
98	He eats out because he is a lousy	Hij gaat uiteten want hij is een slechte	cook	kok	barbecue	barbecue	0.61	0.70
98	He liked to grill meat in summer so he put coals in his	Hij hield ervan 's zomers vlees te grillen en legde kolen in zijn	barbecue	barbecue	cook	kok	0.61	0.70
99	The student repaired his tire and filled it using a	De student plakte zijn band en vulde hem met een	pump	fietspomp	barrel	vat	0.70	0.76
99	Wine is often stored in a wooden	Wijn wordt vaak opgeslagen in een houten	barrel	vat	pump	fietspomp	0.70	0.76
100	He was afraid to catch a cold. so he wore a	Hij was bang verkouden te worden dus hij droeg een	scarf	sjaal	towel	handdoek	0.67	0.68
100	She dried her wet feet with a	Zij droogde haar natte voeten met een	towel	handdoek	scarf	sjaal	0.67	0.68
101	He hit the burglar in the face with a	Hij sloeg de inbreker in het gezicht met een	bat	knuppel	fist	vuist	0.76	0.66
101	He wanted to hit him in the face. so he made a	Hij wilde hem in het gezicht slaan. dus hij maakte een	fist	vuist	bat	knuppel	0.76	0.66
102	The hare will always be faster than the	De haas zal altijd sneller zijn dan de	turtle	schildpad	bat	vleermuis	0.68	0.63
102	High up in the cave they saw a	Hoog boven in de grot zagen ze een	bat	vleermuis	turtle	schildpad	0.68	0.63

103	The colorful bird cracked a nut with its	De gekleurde vogel kraakte een noot met zijn	beak	bek	worm	worm	0.71	0.71
103	The bird ate a big fat	De vogel at een grote dikke	worm	worm	beak	bek	0.71	0.71
104	The boy looked at the long neck of the	De jongen keek naar de lange nek van de	giraffe	giraf	bear	beer	0.64	0.56
104	The child could not sleep without his brown	Het kind kon niet slapen zonder zijn bruine	bear	beer	giraffe	giraf	0.64	0.56
105	He grabbed a razor and shaved his	Hij pakte een scheermes en scheerde zijn	beard	baard	wig	pruik	0.49	0.49
105	She lost her hair so now she wears a	Ze verloor haar haar dus nu draagt ze een	wig	pruik	beard	baard	0.49	0.49
106	The flower was pollinated by a	De bloem werd bestoven door een	bee	bij	girl	meisje	0.77	0.63
106	The boy kissed a	De jongen kuste een	girl	meisje	bee	bij	0.77	0.63
107	The angry driver used his	De boze automobilist gebruikte zijn	horn	claxon	bell	bel	0.70	0.72
107	When it was time to go back to class the students would hear the sound of a	Wanneer het tijd was om terug naar de klas te gaan hoorden de leerlingen het geluid van een	bell	bel	horn	claxon	0.70	0.72
108	The policeman attached him to the fence with	De agent bond hem aan het hek met	handcuffs	handboeien	belt	riem	0.66	0.61
108	To keep up his pants he used a	Om zijn broek op te houden gebruikte hij een	belt	riem	handcuffs	handboeien	0.66	0.61
109	Cinderella scrubbed the	Assepoester boende de	floor	vloer	bench	bank	0.73	0.66
109	The old man in the park sat on a	De oude man in het park ging zitten op een	bench	bank	floor	vloer	0.73	0.66
110	Nikkie hung the colorful painting up on the	Nikkie hing het kleurrijke schilderij aan de	wall	muur	block	blok	0.60	0.70
110	To start building a tower the little boy picked up a wooden	Om te beginnen een toren te bouwen pakte de kleine jongen een houten	block	blok	wall	muur	0.60	0.70
111	Walking through the dark room. I accidentally stubbed my	Rondlopend in het donker stootte ik per ongeluk mijn	toe	teen	feather	veer	0.75	0.70
111	Before there were pens. people wrote with a	Voordat er pennen waren schreef men met een	feather	veer	toe	teen	0.75	0.70
112	The knight took his sword and mounted his	De ridder nam zijn zwaard en besteeg zijn	horse	paard	bow	strik	0.73	0.68
112	He tied the ribbon into a	Hij knoopte het lint in een	bow	strik	horse	paard	0.73	0.68
113	He couldn't see without his	Hij kon niet zien zonder zijn	glasses	bril	bowl	kom	0.70	0.69
113	He poured the soup into a	Hij schonk de soep in een	bowl	kom	glasses	bril	0.70	0.69
114	Bob took all the toys and put them in a	Bob pakte al het speelgoed en deed het in een	box	doos	drawer	lade	0.55	0.61
114	We keep the forks and knives in a	We bewaren de vorken en messen in een	drawer	lade	box	doos	0.55	0.61
115	He already had two girls so this time he hoped for a	Hij had al twee meisjes dus deze keer hoopte hij op een	boy	jongen	woman	vrouw	0.52	0.57
115	He left his wife for another	Hij verliet zijn echtgenote voor een andere	woman	vrouw	boy	jongen	0.52	0.57
116	There was a hole in the sole of the	Er zat een gat in de zool van de	shoe	schoen	bra	beha	0.64	0.65
116	She was a feminist in the sixties and she burned her	Ze was een feministe in de jaren 60 en verbrandde haar	bra	beha	shoe	schoen	0.64	0.65
117	The kids fed the ducks some	De kinderen voerden de eendjes wat	bread	brood	cookie	koekje	0.69	0.64

117	Before going to bed. the boy had milk and a	Voordat hij naar bed ging kreeg het jongetje melk en een	cookie	koekje	bread	brood	0.69	0.64
118	Santa Claus enters your house through the	De Kerstman komt je huis binnen door de	chimney	schoorsteen	bricks	bakstenen	0.72	0.72
118	The house was made of red	Het huis was gemaakt van rode	bricks	bakstenen	chimney	schoorsteen	0.72	0.72
119	The old witch flew off on a	De oude heks vloog weg op een	broom	bezem	wheelbarrow	kruiwagen	0.69	0.68
119	The gardener moved the heavy rocks in a	De tuinman verplaatste de zware stenen in een	wheelbarrow	kruiwagen	broom	bezem	0.69	0.68
120	The lawn was very dry so he watered it with a	Het gazon was erg droog dus hij besproeide het met een	hose	tuinslang	bucket	emmer	0.66	0.56
120	He played in the sand with a shovel and a	Hij speelde op het zand met een schepje en een	bucket	emmer	hose	tuinslang	0.66	0.56
121	He lost his legs so now he has a	Hij verloor zijn benen dus nu heeft hij een	wheelchair	rolstoel	buggy	buggy	0.64	0.61
121	She walked through the zoo with the toddler in a	Ze wandelde door de dierentuin met de peuter in een	buggy	buggy	wheelchair	rolstoel	0.64	0.61
122	The farmer gave them a fresh egg from his	De boer gaf hen een vers ei van zijn	chicken	kippen	butcher	slager	0.64	0.76
122	There were no more lamb chops at the supermarket so I asked the	Er waren geen lamskoteletjes meer in de supermarkt dus ik ging naar de	butcher	slager	chicken	kippen	0.64	0.76
123	He didn't like frying things in oil so he used	Hij hield er niet van dingen te bakken in olie dus gebruikte hij	butter	boter	onion	ui	0.60	0.64
123	Mary's eyes teared up from cutting an	Maries ogen traanden van het snijden van een	onion	ui	butter	boter	0.60	0.64
124	It was raining but the sun was shining. and Maya saw a	Het regende maar de zon scheen en Maya zag een	rainbow	regenboog	butterfly	vlinder	0.72	0.74
124	His last collection included a purple	Tot zijn laatste collectie behoorde een paarse	butterfly	vlinder	rainbow	regenboog	0.72	0.74
125	The jeans closed with a zipper and a	De jeans sloot met een rits en een	button	knoop	suit	pak	0.74	0.72
125	He looked like a penguin in that	Hij zag eruit als een pinguïn in dat	suit	pak	button	knoop	0.74	0.72
126	He wasn't good with plants so he bought a	Hij was niet goed met planten dus kocht hij een	cactus	cactus	dinosaur	dinosaurus	0.77	0.77
126	In the Museum of Natural History he saw an enormous skeleton of a	In het Natuurhistorisch museum zag hij een enorm skelet van een	dinosaur	dinosaurus	cactus	cactus	0.77	0.77
127	You forgot to turn on the flash on your	Je bent vergeten de flits aan te zetten op je	camera	camera	phone	telefoon	0.69	0.63
127	She couldn't leave the house. so she called her daughter on the	Ze kon het huis niet uit en belde haar dochter met de	phone	telefoon	camera	camera	0.69	0.63
128	Ron had several blisters on his	Ron had meerdere blaren op zijn	feet	voeten	can	blik	0.70	0.75
128	She wanted to eat peas so she opened a	Ze wilde erwten eten dus ze opende een	can	blik	feet	voeten	0.70	0.75
129	The pretty girl sat at the bar on a	Het mooie meisje zat aan de bar op een	stool	kruk	cane	stok	0.76	0.59
129	To help him walk better. the man used a	Om beter te kunnen lopen gebruikte de man een	cane	stok	stool	kruk	0.76	0.59
130	The farmer tended to his field on a	De boer bewerkte zijn akker op een	tractor	tractor	caravan	caravan	0.75	0.62
130	He thought it was too cold to sleep in a tent so he went on a trip with a	Hij vond het te koud om te slapen in een tent dus hij ging op reis met een	caravan	caravan	tractor	tractor	0.75	0.62
131	Sleeping beauty pricked her finger on a	Doornroosje prikte haar vinger aan een	spinningwheel	spinnewiel	carousel	draaimolen	0.72	0.60
131	She wanted to sit on the pink horse in the	Ze wilde op het roze paard in de	carousel	draaimolen	spinningwheel	spinnewiel	0.72	0.60
132	That green soup is made of	Die groene soep wordt gemaakt van	peas	erwten	carrot	wortel	0.72	0.64

132	To improve his vision. he ate a	Om zijn zicht te verbeteren at hij een	carrot	wortel	peas	erwten	0.72	0.64
133	The knight lived in a	De ridder woonde in een	castle	kasteel	city	stad	0.73	0.67
133	He loved the countryside. but he lived in the	Hij hield van het platteland. maar hij woonde in de	city	stad	castle	kasteel	0.73	0.67
134	The playground only had a slide and a	De speeltuin had enkel een glijbaan en een	swing	schommel	catapult	katapult	0.74	0.69
134	The naughty boy shot rocks at a cat with a	De stoute jongen schoot stenen naar een poes met een	catapult	katapult	swing	schommel	0.74	0.69
135	On top of the cake she put a nice red	Bovenop de taart legde ze een mooie rode	cherry	kers	strawberries	aardbeien	0.54	0.72
135	She made a delicious jam of	Ze maakte een heerlijke jam van	strawberries	aardbeien	cherry	kers	0.54	0.72
136	The pirate found a treasure of gold coins in a	De piraat vond een schat van gouden munten in een	chest	kist	well	put	0.75	0.72
136	In the middle ages people took water from a	In de middeleeuwen haalden mensen water uit een	well	put	chest	kist	0.75	0.72
137	The Cuban smoked a	De Cubaan rookte een	cigar	sigaar	waiter	ober	0.76	0.73
137	In this restaurant you are served by a friendly	In dit restaurant word je bediend door een aardige	waiter	ober	cigar	sigaar	0.76	0.73
138	I couldn't see his face because he wore a	Ik kon zijn gezicht niet zien want hij droeg een	mask	masker	clown	clown	0.63	0.60
138	For his third birthday. his dad dressed up as a	Voor zijn derde verjaardag verkleedde zijn vader zich als	clown	clown	mask	masker	0.63	0.60
139	I heard the hissing of a venomous	Ik hoorde het gesis van een giftige	snake	slang	cock	haan	0.69	0.72
139	Early in the morning he heard the cock-a-doodle-doo of a	Vroeg in de ochtend hoorde hij het gekukeleku van een	cock	haan	snake	slang	0.69	0.72
140	He made a part in his hair with a	Hij maakte een scheiding in zijn haar met een	comb	kam	handkerchief	zakdoek	0.76	0.78
140	He blew his nose into a	Hij snoot zijn neus in een	handkerchief	zakdoek	comb	kam	0.76	0.78
141	He pretended to be with the mafia. but he was actually a	Hij deed alsof hij bij de maffia hoorde maar hij was eigenlijk een	cop	agent	desk	bureau	0.66	0.47
141	He took his textbook and sat at his	Hij nam zijn tekstboek en ging zitten aan zijn	desk	bureau	cop	agent	0.66	0.47
142	Flour for bread is usually made of	Meel voor brood wordt meestal gemaakt van	wheat	graan	corn	mais	0.39	0.78
142	Tortillas are often made of	Tortilla's worden vaak gemaakt van	corn	mais	wheat	graan	0.39	0.78
143	He checked the time on his	Hij keek hoe laat het was op zijn	watch	horloge	couch	bank	0.67	0.73
143	Martin was very lazy today and watched television on the	Martin was erg lui vandaag en keek tv op de	couch	bank	watch	horloge	0.67	0.73
144	The little girl put her savings in a	Het kleine meisje deed haar spaargeld in een	piggybank	spaarpot	wateringcan	gieter	0.73	0.78
144	He watered the flowers with a	Hij gaf de bloemen water met een	wateringcan	gieter	piggybank	spaarpot	0.73	0.78
145	The pope wore a necklace with a	De paus droeg een ketting met een	cross	kruis	flag	vlag	0.73	0.69
145	To show that he had surrendered. he waved a white	Om te laten zien dat hij zich overgaf zwaaide hij met een witte	flag	vlag	cross	kruis	0.73	0.69
146	He put the ring on her	Hij deed de ring om haar	finger	vinger	hair	haar	0.68	0.70
146	She went to the salon to color her	Ze ging naar de kapper voor een kleurtje in haar	hair	haar	finger	vinger	0.68	0.70
147	The English queen drank tea from a	De Engelse koningin dronk thee uit een	cup	kopje	toaster	broodrooster	0.72	0.70

147	Since the slice of bread was a bit old. he put it in the	Omdat de boterham wat oud was deed hij het in de	toaster	broodrooster	cup	kopje	0.72	0.70
148	It was dark so Simon closed the	Het was donker dus Simon sloot de	curtains	gordijnen	iron	strijkijzer	0.63	0.65
148	His shirt was completely wrinkled. so his mother took out her	Zijn hemd was helemaal gekreukeld dus zijn moeder pakte haar	iron	strijkijzer	curtains	gordijnen	0.63	0.65
149	The little girl played with her	Het kleine meisje speelde met haar	doll	pop	purse	handtas	0.68	0.75
149	She walked up to the mirror and took her lipstick from her	Ze liep naar de spiegel en pakte haar lipstick uit haar	purse	handtas	doll	pop	0.68	0.75
150	He made a hole in the wall for the screw with a	Hij maakte een gat in de muur voor de schroef met een	drill	boor	jack	krik	0.69	0.56
150	To replace the tire. the car was lifted with a	Om de autoband te vervangen werd de auto opgetild met een	jack	krik	drill	boor	0.69	0.56
151	To built up suspense. the circus artist beat the	Om de spanning op te bouwen sloeg the circusartiest op een	drum	trommel	kettle	waterkoker	0.75	0.64
151	She offered him tea and heated up the water in a	Ze bood hem thee aan en verwarmde het water in een	kettle	waterkoker	drum	trommel	0.75	0.64
152	The Disney character Donald is a	Het Disney-personage Donald is een	duck	eend	turkey	kalkoen	0.63	0.67
152	For our Christmas dinner. mother usually stuffed a	Voor ons kerstdiner vulde moeder gewoonlijk een	turkey	kalkoen	duck	eend	0.63	0.67
153	The American had a beautiful collection of birds of prey. but his favorite was his	De Amerikaan had een prachtige collectie roofvogels. maar zijn favoriet was zijn	eagle	arend	fly	vlieg	0.60	0.78
153	An insect that is attracted to shit is a	Een insect dat wordt aangetrokken door stront is een	fly	vlieg	eagle	arend	0.60	0.78
154	The dog buried a	De hond begroef een	bone	bot	heel	hak	0.64	0.73
154	To look taller she wore shoes with a	Om er langer uit te zien droeg ze schoenen met een	heel	hak	bone	bot	0.64	0.73
155	It is fashionable again to listen to music from a	Het is weer in de mode om muziek te luisteren van een	recordplayer	platenspeler	fan	fan	0.72	0.75
155	Messi signed the football for a	Messi tekende de voetbal voor een	fan	fan	recordplayer	platenspeler	0.72	0.75
156	The shepherd shaved a	De herder schoor een	sheep	schaap	farm	boerderij	0.58	0.66
156	They raised pigs on their	Ze fokten varkens op hun	farm	boerderij	sheep	schaap	0.58	0.66
157	Ana accidentally tripped and fell down the	Anna struikelde per ongeluk en viel van de	stairs	trap	fence	hek	0.77	0.68
157	To keep the dogs in the yard he put up a	Om de honden in de tuin te houden plaatste hij een	fence	hek	stairs	trap	0.77	0.68
158	One year after her death. Bill visited his mother's	Een jaar na haar dood bezocht Bill zijn moeders	grave	graf	flower	bloem	0.66	0.71
158	There was a butterfly on a	Er zat een vlinder op een	flower	bloem	grave	graf	0.66	0.71
159	He always looked sharp with his suit and his	Hij zag er altijd netjes uit met zijn pak en zijn	tie	das	coat	jas	0.64	0.60
159	Let me take your hat and your	Laat me je hoed aannemen en je	coat	jas	tie	das	0.64	0.60
160	Dinner was not served in a bowl but on a	De maaltijd werd niet geserveerd in een kom maar op een	plate	bord	fork	vork	0.66	0.63
160	He ate the sausage with a knife and	Hij at de worst met mes en	fork	vork	plate	bord	0.66	0.63
161	The stable boy scooped up the hay with a	De stalknecht schepte het hooi op met een	fork	hooivork	pinecone	dennenappel	0.70	0.67
161	On a branch of the needle-leaved tree grew a	Op een tak van de naaldboom groeide een	pinecone	dennenappel	fork	hooivork	0.70	0.67
162	Her right foot was cold and she took a	Haar rechtervoet was koud en ze pakte een	sock	sok	toothbrush	tandenborstel	0.74	0.62

162	Don’t forget your pajamas and your	Vergeet niet je pyjama en je	toothbrush	tandenborstel	sock	sok	0.74	0.62
163	The animal that can grow back his lost tail is called a	Het dier dat zijn verloren staart kan laten terug groeien heet een	lizard	hagedis	crab	krab	0.68	0.66
163	Surimi is not real	Surimi is geen echte	crab	krab	lizard	hagedis	0.68	0.66
164	He kept his lawn nice and tidy with his	Hij hield zijn grasveld mooi en netjes met zijn	lawnmower	grasmaaier	gas	benzine	0.70	0.71
164	I would drive. but my car is low on	Ik zou rijden. maar mijn auto heeft nog maar weinig	gas	benzine	lawnmower	grasmaaier	0.70	0.71
165	Covered with a white sheet. he looked like a	Bedekt met het witte laken zag hij eruit als een	ghost	spook	wolf	wolf	0.72	0.73
165	The three little pigs were afraid of a	De drie kleine biggetjes waren bang voor een	wolf	wolf	ghost	spook	0.72	0.73
166	He didn't own a computer. so he wrote his books on a	Hij had geen computer dus hij schreef zijn boeken op een	typewriter	typmachine	letter	brief	0.63	0.63
166	He wrote his parents a	Hij schreef zijn ouders een	letter	brief	typewriter	typemachine	0.63	0.63
167	The jockey hit his horse's flank with a	De jockey sloeg zijn paard op de flank met een	whip	zweep	lightning	bliksem	0.74	0.73
167	She was afraid of the thunder and	Ze was bang voor de donder en	lightning	bliksem	whip	zweep	0.74	0.73
168	The draftsman sharpened his	De tekenaar sleep zijn	pencil	potlood	lips	lippen	0.79	0.73
168	He kissed his lucky coin with his	Hij kuste zijn geluksmunt met zijn	lips	lippen	pencil	potlood	0.79	0.73
169	I was attracted to him like a	Ik voelde me aangetrokken tot hem als een	magnet	magneet	switch	schakelaar	0.79	0.66
169	Mohamed wanted to turn on the light but he found no	Mohamed wilde het licht aandoen maar hij vond geen	switch	schakelaar	magnet	magneet	0.79	0.66
170	The athlete won a gold	De atleet won een gouden	medal	medaille	trophy	beker	0.54	0.78
170	The team that wins the most matches receives a	Het team dat de meeste wedstrijden wint ontvangt een	trophy	beker	medal	medaille	0.54	0.78
171	The hand of the captain was eaten by a crocodile and was now replaced with a	De hand van de kapitein was opgegeten door een krokodil en was nu vervangen door een	hook	haak	knot	knoop	0.66	0.78
171	He tied the rope to the pole with a complex	Hij bond het touw aan de paal met een ingewikkelde	knot	knoop	hook	haak	0.66	0.78
172	The train conductor blew a	De conducteur blies op een	whistle	fluitje	microphone	micro	0.79	0.80
172	The audience can't hear you if you don't speak into the	Het publiek kan je niet horen als je niet spreekt door de	microphone	micro	whistle	fluitje	0.79	0.80
173	The car had a flat	De auto had een platte	tire	band	wheel	wiel	0.60	0.75
173	She took her bicycle and saw that there was a spoke missing in the	Ze pakte haar fiets en zag dat er een spaak miste in het	wheel	wiel	tire	band	0.60	0.75
174	The car had to stop at a	De auto moest stoppen bij een	trafficlight	licht	moon	maan	0.74	0.65
174	In 1969 Neil Armstrong travelled to the	In 1969 reisde Neil Armstrong naar de	moon	maan	trafficlight	licht	0.74	0.65
175	You can catch malaria if you are bitten by a	Je kunt malaria krijgen als je gestoken wordt door een	mosquito	mug	spider	spin	0.63	0.73
175	In the middle of the large web sat a	Midden in het grote web zat een	spider	spin	mosquito	mug	0.63	0.73
176	The wooden plank for the floor was made shorter with a	De houten plank voor de vloer werd korter gemaakt met een	saw	zaag	nail	spijker	0.77	0.62
176	The carpenter secured the shelf with another	De timmerman zette de plank vast met nog een	nail	spijker	saw	zaag	0.77	0.62

177	He hung his shirt in the closet on a	Hij hing zijn hemd in de kast op een	hanger	kapstok	mailbox	brievenbus	0.77	0.77
177	He found a postcard from Portugal in his	Hij vond een ansichtkaart uit Portugal in zijn	mailbox	brievenbus	hanger	kapstok	0.77	0.77
178	He filled the bucket and closed the	Hij vulde de emmer en sloot de	tap	kraan	plug	stekker	0.68	0.77
178	We cannot put the lamp there. There is no outlet for the	We kunnen de lamp daar niet neerzetten. Er is geen stopcontact voor de	plug	stekker	tap	kraan	0.68	0.77
179	The well-known artist took a block of marble and carved a	De bekende kunstenaar nam een blok marmer en hakte een	statue	beeld	puzzle	puzzel	0.80	0.78
179	It was almost finished; there was the last piece of his	Het was bijna klaar; daar was het laatste stukje van zijn	puzzle	puzzel	statue	beeld	0.80	0.78
180	The pan fell on top of a	De pan viel bovenop een	pot	pot	hand	hand	0.71	0.76
180	He held the gun in his right	Hij hield het pistool in zijn rechter	hand	hand	pot	pot	0.71	0.76
181	He is as proud as a	Hij is zo trots als een	peacock	pauw	frog	kikker	0.71	0.73
181	Close by the pond she heard the croaking of a little green	Vlakbij de vijver hoorde ze het gekwaak van een kleine groene	frog	kikker	peacock	pauw	0.71	0.73

Appendix B

Table B1

Estimates, standard errors, t-values and p-values for the fixed and random effects of the final general linear mixed effect model for the prediction time frame in the target data set.

	Elog			
Fixed effects	β	se	t	p
Intercept	-3.478	0.148	-23.510	<.001
Language	-0.191	0.055	-3.487	<.001
Image type (target vs. unrelated)	-1.502	0.123	-12.227	<.001
Target word onset time	0.248	0.063	3.925	<.001
List2	0.599	0.154	3.896	<.001
List 3	0.401	0.155	2.595	0.012
List 4	0.276	0.154	1.789	0.080
List 5	0.341	0.154	2.219	0.031
List 6	0.464	0.178	2.601	0.012
List 7	0.736	0.160	4.597	<.001
List 8	0.112	0.160	0.699	0.488
Language:Image type	0.262	0.077	3.398	0.001
Image type: Target word onset time	-0.385	0.087	-4.424	<.001
	Variance	SD		
Random effects				
Sentence				
(intercept)	1.563	1.250		
Image type	2.924	1.710		
Participant				
(intercept)	0.242	. 0.492		
Image type	0.209	0.456		

Table B2

Estimates, standard errors, t-values and p-values for the fixed and random effects of the final general linear mixed effect model for the prediction time frame in the competitor data set.

	Elog			
Fixed effects	β	se	*t*	*p*
Intercept	-4.172	0.154	-27.177	<.001
Language	-0.071	0.054	-1.313	0.189
Image type (Competitor vs. Unrelated)	-0.658	0.104	-6.349	<.001
Semantic distance	-0.186	0.054	-3.451	0.001
Target word onset time	0.208	0.061	3.432	0.001
List2	0.629	0.179	3.515	0.001
List 3	0.500	0.180	2.784	.0.008
List 4	0.391	0.179	2.182	0.034
List 5	0.444	0.179	2.482	0.016
List 6	0.567	0.208	2.728	0.009
List 7	0.849	0.186	4.561	<.001
List 8	0.145	0.186	0.778	0.440
Language:Image type	0.144	0.076	1.895	0.058
Image type: Semantic distance	0.223	0.073	3.037	0.002
Language: Semantic distance	0.159	0.055	2.905	0.004
Image type: Target word onset time	-0.291	0.082	-3.568	<.001
Language: Image type: Semantic distance	-0.191	0.077	-2.487	0.013
	Variance	SD		
Random effects				
Sentence				
(intercept)	1.378	1.174		
Image type	2.431	1.559		
Participant				
(intercept)	.0.158	0.397		
Image type	0.063	0.251		

Appendix C

Repeated testing (in each time bin) increases the likelihood of Type I errors. To show that the pattern of results remains the same with a Bonferroni corrected alpha value we plot the p-values of the most relevant effects in each time bin. Figure C1 shows the target data p-values of the interaction between language and image type in each bin.

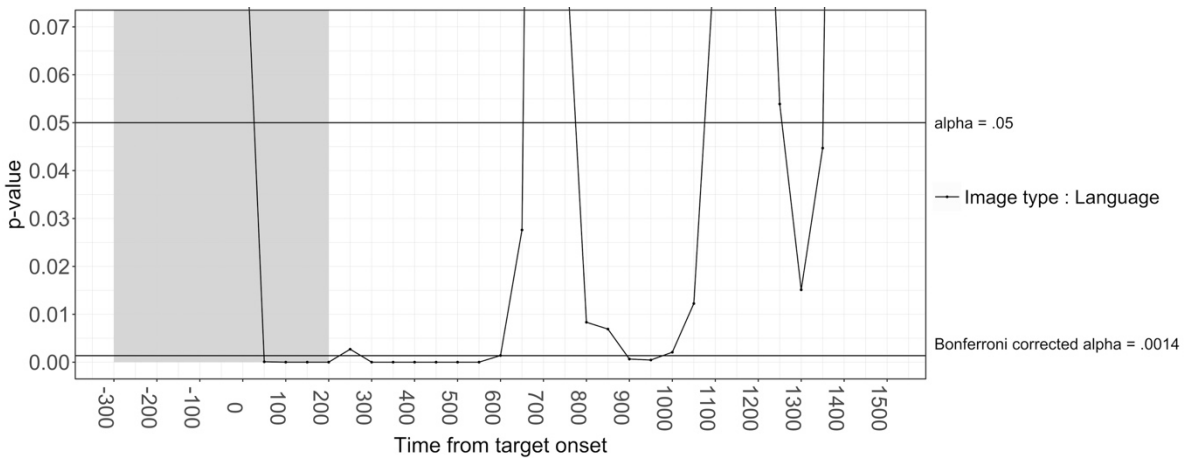


Figure C1. P-values of the language by image type interaction in each time bin (optimal model). Display onset was 500 ms before target onset. The area shaded grey is the prediction time frame. Horizontal lines indicate uncorrected alpha (0.05), and bonferroni corrected alpha (0.0014).

Figure C1 shows that the Image type by Language interaction is significant in the same time bins in the prediction time frame if we use Bonferroni corrected alpha (from 50 ms after target word onset). The interaction remains significant until the time bin of 600-650 ms after target word onset (except for 250-300 ms bin).

Figure C2 shows the competitor data p-values of the effects listed in the legend in each time bin.

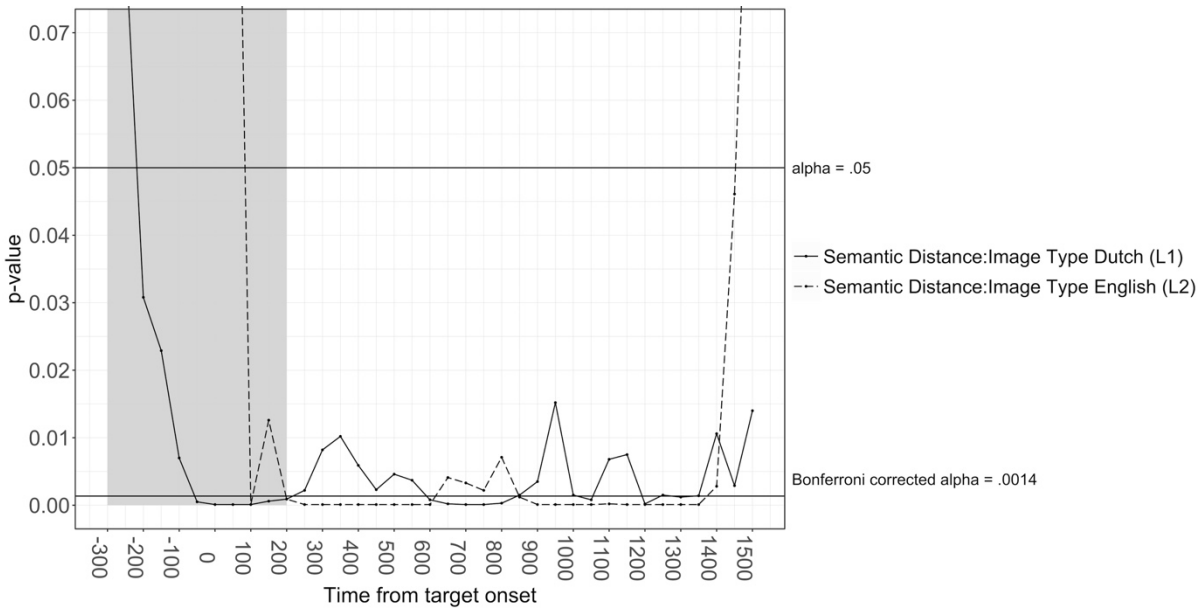
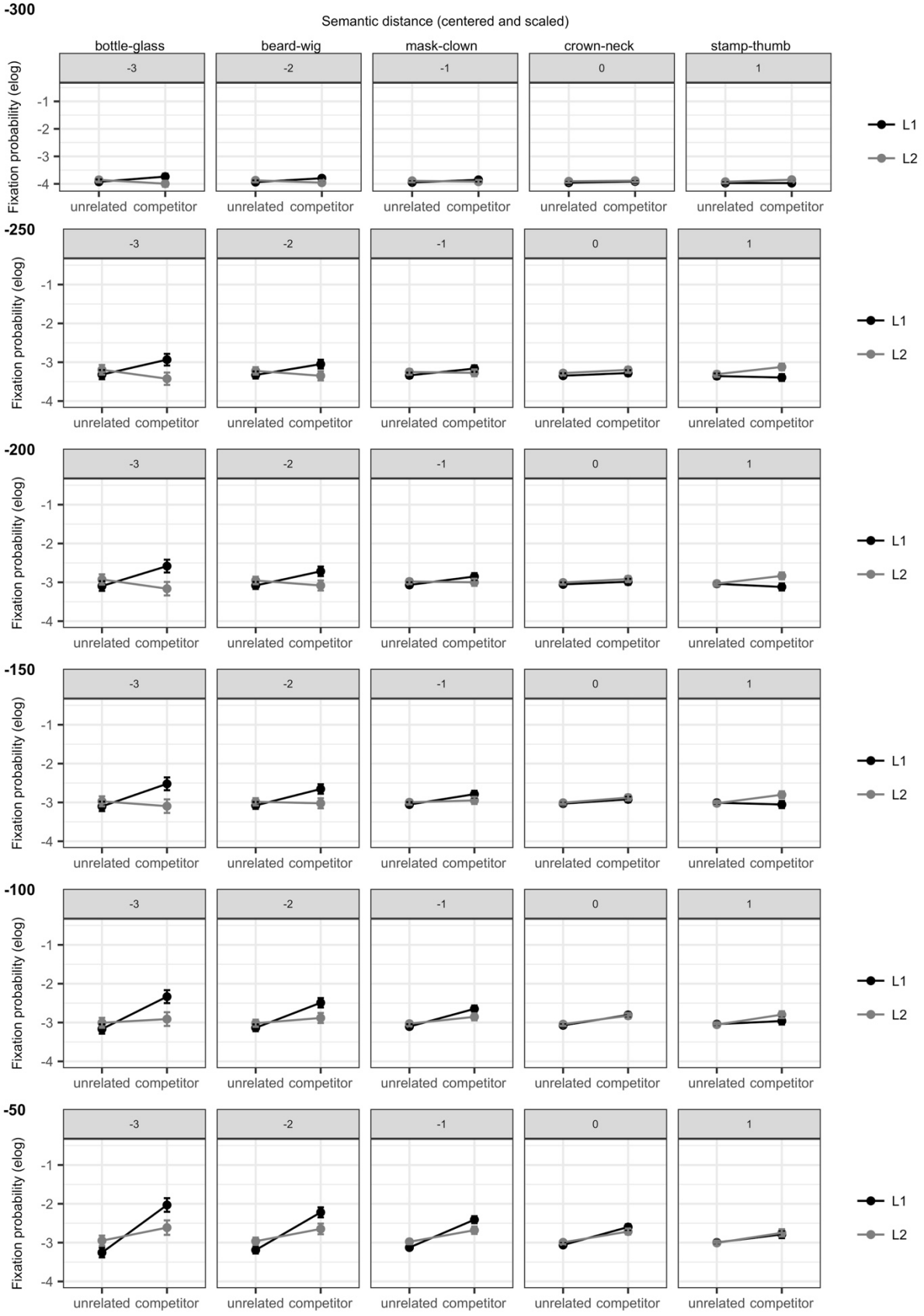
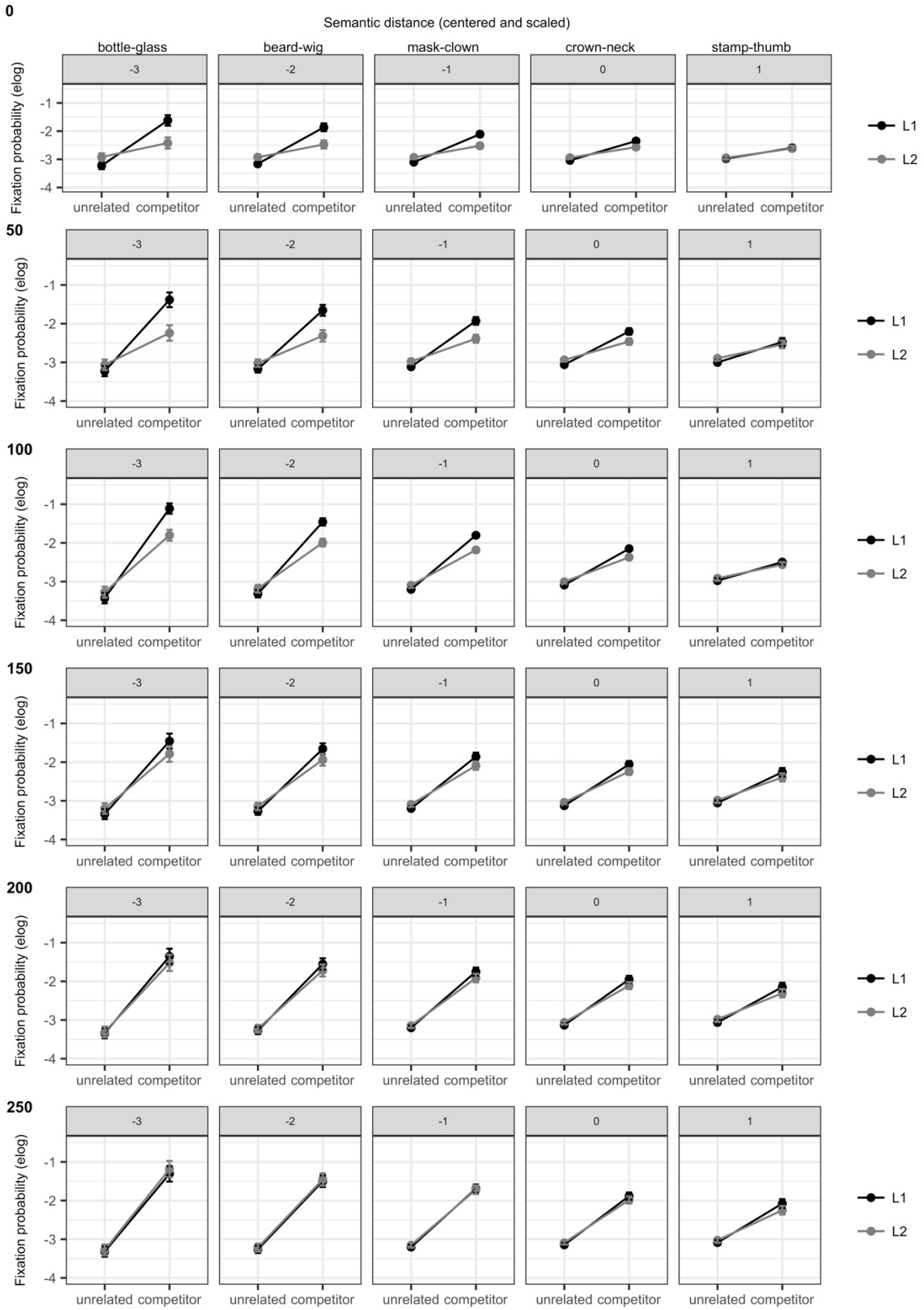


Figure C2. P-values of the effects in each time bin (optimal model). Display onset was 500 ms before target onset. The area shaded grey is the prediction time frame. Horizontal lines indicate uncorrected alpha (0.05) and Bonferroni corrected alpha (0.0014).

Figure C2 shows that the interaction between image type and semantic distance becomes significant 3 time bins later in Dutch (L1) if we use Bonferroni corrected alpha. However, in English (L2) there is still a delay of three time bins before the interaction becomes significant for the first time, and the interaction is consistently signicant from 200 ms after target word onset (after the prediction time frame). Thus, the main pattern of results found with corrected alpha is the same as the pattern found with uncorrected alpha.

Appendix D


-300
Semantic distance (centered and scaled)
bottle-glass
beard-wig
mask-clown
crown-neck
stamp-thumb
-3
-2
-1
0
1
Fixation probability (elog)
-1
-2
-3
-4
unrelated competitor
L1
L2
-250
-200
-150
-100
-50


0
50
100
150
200
250
Semantic distance (centered and scaled)
bottle-glass
beard-wig
mask-clown
crown-neck
stamp-thumb
-3
-2
-1
0
1
Fixation probability (elog)
-1
-2
-3
-4
unrelated
competitor
L1
L2

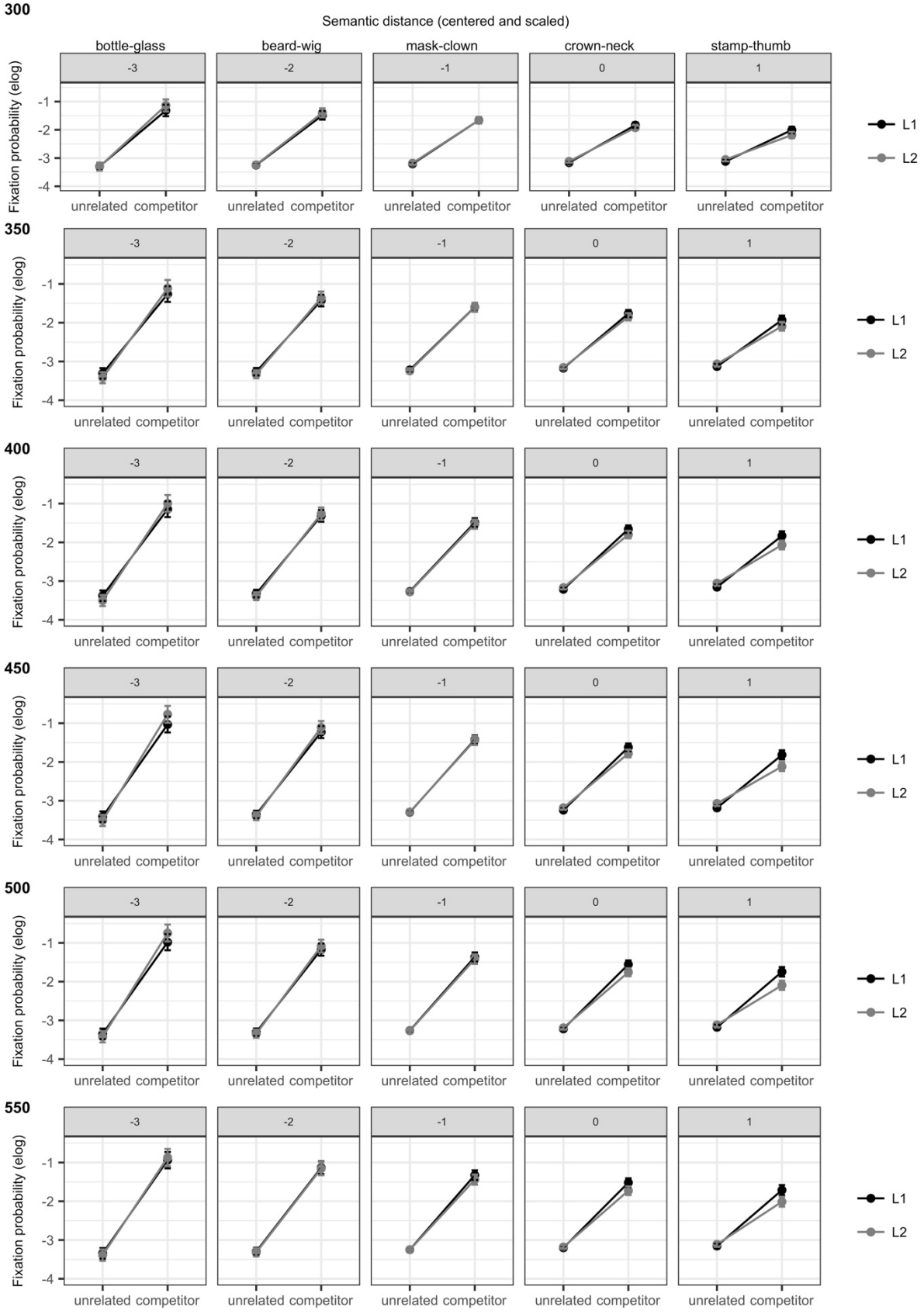


Figure D1. Three-way interaction between image type, language and semantic distance per time bin. Plot label in the left upper corner of each plot indicates time relative to target onset.

The word pairs above each semantic distance facet are example competitor-word pairs for that semantic distance score.