On the role of language membership information during word recognition in bilinguals: Evidence from flanker-language congruency effects

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Abstract

According to some bilingual language comprehension models (BIA), language membership information has a direct influence on word processing. However, this idea is not shared by all models (BIA+). To investigate this matter, we manipulated the language membership of irrelevant flanking words while French-English bilinguals performed a lexical decision task on centrally located target words and nonwords. The target words were either French or English words, flanked by words that were either in the same language as the target (language congruent) or in the other language (language incongruent). We found that lexical decisions to target words were harder in the language-incongruent condition, indicating that language membership information was extracted from flanking words and that this affected identification of central target words, as predicted by the architecture of the BIA model.

(words: 129)

Key words: bilingualism, language membership, word recognition, flanker task

In order to produce a word in a given language, bilinguals need to know which of their two languages should be used on that particular occasion. One means of achieving this is via language tags (Green, 1998) or language nodes (Grainger & Dijkstra, 1992) that encode language membership information, such that the conjoint activation of a given language tag/node (e.g., "English") and a given concept (e.g., "domestic animal that barks") leads to activation of the appropriate phonological word-form (/dog/) and preparation of the corresponding articulatory output. While language membership information is a necessary prerequisite for language production, this is not the case for language comprehension in bilinguals given that most words have language-specific phonological and orthographic representations, and that context can be used for disambiguation when this is not the case.

The concept of language membership during bilingual language comprehension is captured in two seminal models, the Bilingual Interactive Activation (BIA) model (Grainger & Dijkstra, 1992) on the one hand and the BIA+ (Dijkstra & van Heuven, 2002) on the other. According to the BIA model, there is an influence of language membership information on language comprehension in bilinguals. More specifically, language nodes are automatically activated upon presentation of a word in a given language, or a non-linguistic stimulus that is associated with a specific language, and language node activity modulates the relative activation level of lexical representations in each language (see Grainger, Midgley, & Holcomb, 2010, for more detailed discussion).

On the other hand, the BIA+ model cannot capture such automatic influences of language membership on word recognition because language nodes do not feedback information to lexical representations in this model.[1] Language node activity can only influence performance via decision-level mechanisms in the BIA+ model. It is therefore not immediately obvious how the

BIA+ model can capture effects of language membership in tasks where such information is irrelevant for the task being performed. The removal of feedback from language nodes to lexical representations in the BIA+ was motivated by experiments using language-specific lexical decision with interlingual homographs that vary in their language-specific frequency (e.g., Dijkstra, Timmermans, & Schriefers, 2000). The key finding was that homographs that have a low frequency in the target language and high frequency in the non-target language (an example English target word for a Dutch-English bilingual would be "list" which means "ruse" in Dutch) are often not recognized as being a word in the target language (Dijkstra et al., 2000), suggesting that language node activity was not used to recover the appropriate interpretation of these interlingual homographs (see Dijkstra & van Heuven, 2002, for further discussion). However, this finding can be captured by models that integrate feedback from language nodes to lexical representations, such as the BIA model, by assuming that the stronger activation of the high-frequency non-target interpretation of the interlingual homograph (i.e., language-specific associations between orthography, phonology, and semantics) provides sufficient input to the non-target language node for it to dominate processing on those specific trials.

Moreover, there is evidence that language membership information is automatically activated during language comprehension in bilinguals, and can have a direct influence on word recognition processes. A primary example of such automatic effects of language membership are the language switch costs that have been found in experiments where language membership information is not necessary to perform the task: In a generalized lexical decision experiment (respond "word" if the letter string is a real word independently of which language it belongs to) Grainger and Beauvillain (1987) found that performance was worse when a word from the other language was the target on the preceding trial (a language switch) compared with trials with no change in language (see also e.g., Thomas & Allport, 2000). Hence, language membership of the preceding trial could affect word processing in the current trial, even when language membership is irrelevant for the task. Similar language-switch costs have been observed with tasks other than generalized lexical decision, such as semantic categorization (e.g., Macizo, Bajo, & Paolieri, 2012) and number categorization (e.g., Hirsch, Declerck, & Koch, 2015; for a review, see Declerck & Philipp, 2015).

More recently it has been shown that even non-linguistic cues to language membership can affect language comprehension in bilinguals. For example, interlocutor identity has been found to have an influence, to the extent that such information generates expectations as to which language will be heard (Martin, Molnar, & Carreiras, 2016; Molnar, Ibáñez-Molina, & Carreiras, 2015). Most important, however, is the finding that non-linguistic cues can influence language comprehension even when the cues are not informative with respect to either the process of comprehension or the specific task being performed. Grainger, Declerck, and Marzouki (2017) presented pictures of the French or UK national flags along with French and English words to be classified in a generalized lexical decision task. The flag stimuli neither predicted the language of the word nor the lexical decision response, yet a flag-language congruency effect was found, with lexical decision responses being facilitated in the presence of the flag associated with the language of the target word.

In the present study we seek further evidence for an influence of language membership information on language comprehension in bilinguals, as predicted by the BIA model. To do so, we build on prior evidence from the flanker paradigm that semantic and syntactic information can be derived in parallel from target and flanker words (Snell, Declerck, & Grainger, 2017a; Snell, Meeter, & Grainger, 2017b). The key evidence has been obtained in a variant of the flanker paradigm derived from the flanking letters lexical decision task of Dare and Shillcock (2013). In this version of the flanker paradigm, target and flankers are aligned horizontally with the target on fixation and a space separating the target and the flanker stimuli located on either side. Stimulus duration is brief enough (150 - 170 ms) to discourage eye-movements to the flanking stimuli. In the Snell et al. (2017a) study, French-English bilinguals were asked to semantically categorize English target words (natural vs. artificial object), while these were flanked by their non-cognate French translation equivalent or an unrelated French control word. The results showed that semantic decisions to central target words were facilitated by translation flankers, thus indicating that semantic information had been extracted from the parafoveal flanker words. In Snell et al. (2017b), participants had to categorize central target words as being an adjective or a noun and the flanker words could be from the same syntactic category or the opposite category as the target word. Syntactic category judgments were facilitated by flankers from the same category, thus indicating that syntactic information had been extracted from the parafoveal flanker words.

This prior research suggests that other kinds of high-level linguistic knowledge, such as language membership information, could be extracted from briefly presented parafoveal flanker words. In order to examine this, we asked French-English bilinguals to indicate whether a centrally located string of letters was a word or a nonword (generalized lexical decision), while we manipulated the language congruency of semantically and orthographically unrelated flanking words. More specifically, every target was flanked by a word from the same language (language congruent; e.g., talk dice talk) or from the other language (language incongruent; e.g., loup dice loup). We predicted that language membership information would be automatically extracted from the flanker words and that this would influence lexical decisions to the central target words, even if language membership information is irrelevant for the task (i.e., generalized lexical decision).

Such a finding would be compatible with the architecture of the BIA model, but not the BIA+ model.

Method

Participants

24 French-speaking participants that spoke English as their second language (8 male, mean age = 20.7) took part in this experiment. Prior to the experiment, the participants filled in a questionnaire about their French and English proficiency and completed a French (Brysbaert, 2013) and English (Lemhöfer & Broersma, 2012) vocabulary test. The questionnaire consisted of questions about their age-of-acquisition, the average percentage of current language use, and their level of speaking and reading skills in French and English on a 7-point scale, with one being very bad and seven being very good (see Table 1).

-Table 1-

Apparatus, Materials and task.

In the current study, French-English bilinguals were presented words and nonwords with OpenSesame (Mathôt, Schreij, & Theeuwes, 2012), using a 1920x1080 px, 150 Hz computer monitor. It was the French-English bilinguals' task to categorize the central target string of letters as a word in either language or nonword.

We retrieved 60 4-letter English target words (frequency: 5.37 Zipf) from the British Lexicon Project lexicon (Keuleers, Lacey, Rastle, & Brysbaert, 2012), and 60 4-letter French target words (5.65 Zipf) from the French Lexicon Project lexicon (Ferrand et al., 2010). All targets contained no diacritics, and were not inflected forms.

We coupled each target to a semantically and orthographically unrelated 4-letter English word and a 4-letter French word, both of which would serve as flankers. Hence, each target was presented in both flanker conditions across participants: once with the flankers in the same language being presented left and right of the target (targets and flankers were separated by one character space on each side), and once with the flankers in the other language. The average frequency was kept equal between the English (5.45 Zipf) and French flankers (5.56 Zipf).

In a similar manner we retrieved 120 nonword targets (60 ‘English’ nonwords and 60 ‘French’ nonwords) from the respective pseudoword counterparts of the English and French lexicons. These nonword targets were also coupled to both an ‘English’ and a ‘French’ nonword flanker.

Procedure

Prior to the experiment, the instructions were presented both orally and visually, and participants were instructed to respond as rapidly and as accurately as possible. Then, the participants performed two experimental blocks, consisting of 120 trials each, one with French target words and the other with English target words. Half the trials would consist of target words, whereas the other half would consist of target nonwords. The nonwords were always flanked by nonwords, whereas target words would be flanked with words consisting of the same language (i.e., language congruent) for 50% of the trials, and in the other trials with words of the other language (i.e., language incongruent). The order of the language congruent, language incongruent and nonword trials was completely random. Both of these experimental blocks were preceded by a practice block of twelve trials.

Every trial would start with two centrally positioned vertical fixation bars (see Figure 1). After 600 ms, the target appeared between these fixation bars, with flanking stimuli to its left and right side, (targets and flankers were separated by one character space on each side). After 170 ms, the target and flankers disappeared, and participants had a maximum of 2000 ms to indicate whether they had recognized the target as being a word or not. This was done with a left- or right-sided button press ('w' and '!' respectively on an azerty keyboard), with the right button always corresponding to 'word'. A green or red dot was then briefly shown (600 ms) at the center of the screen, depending on whether the participant's response was correct or incorrect respectively, after which the next trial would start.

-Figure 1-

Analysis. For the reaction time (RT) analysis, errors were discarded, as were RTs that were above or below two standard deviations from the mean (per participant). Overall this resulted in the exclusion of 14.2% of the RT data.

The RT data were analyzed using mixed-effects models (Baayen, Davidson, & Bates, 2008). The error data were analyzed using a logistic mixed model (Jaeger, 2008). Both participants and items were considered random factors, with all fixed effects (i.e., language [French vs. English], language congruency between target and flankers [congruent vs. incongruent], and their interaction) varying by all random factors (Barr, Levy, Scheepers, & Tily, 2013). In the error analysis the full random effects model did not converge. This was resolved by using a model that contained the intercept for both participants and items, but only contained the by-participant random slope for language.[2]

Results

As can be seen in Table 2, the RT data revealed a significant main effect of language, with English trials (633 ms) being slower than French trials (596 ms). Importantly, the main effect of language congruency was also significant, with incongruent language trials (619 ms) being slower than congruent trials (608 ms).[3] There was no significant interaction.

-Table 2-

As can be seen in Table 3, there was only a significant main effect of language in the error data, with a higher error rate in English trials (14.9%) than in French trials (6.8%; see Table 4).

-Table 3-

-Table 4-

Discussion

In the present study, we investigated the role of language membership information during language comprehension in bilinguals. To this end, we implemented a bilingual flanker task, in which the flanking words could either be presented in the same language as the target word (language congruent) or in the other language (language incongruent). The language of the flanking words was irrelevant for the task being performed (generalized lexical decision on central targets), yet our results showed better performance when the language of the flanker and the target word was congruent (for a replication of the data, see footnote 3).

This language-congruency effect suggests that language membership information can directly influence word recognition in bilinguals. Language membership information would be automatically extracted from the irrelevant flanker words and this information would either help or hinder the processing of central target words depending on whether or not target and flankers are from the same language. The original BIA model implements a specific mechanism for the automatic activation of language membership information and the influence of such activation on word recognition in bilinguals. The language nodes of the BIA model receive input from language-specific stimuli, and this activation is used to regulate the relative activation level of lexical representations in each language. Thus, when the flankers were French words this would lead to activation of the French language node and the subsequent inhibition of all English words, making it harder to process an English target word in the incongruent condition. The English language node would of course be activated by the English target word, but it is the overall activation of both language nodes that determines the level of inhibition directed at lexical representations in one or the other language.

According to the BIA+ model, on the other hand, activity in language nodes cannot directly affect word recognition. Hence, this model predicted no impact of language congruency between flanker words and the target word, a prediction that is contradicted by our findings. It could be argued, however, that our results might be driven by flanker language congruency affecting executive control processes (i.e., task/decision system) in the BIA+ model, by changing the criterion used for making a lexical decision response. Exactly how this might occur is not at all obvious, and there is one finding from our laboratory that speaks against any role for adjustments in decision criteria as a cause of flanker effects in general (see supplementary materials). In a simple monolingual lexical decision flanker experiment, we found that flanker lexicality (word vs. pseudoword vs. nonword) did not significantly influence lexical decision responses to central target words. This suggests that the flanker paradigm is a good reflection of the linguistic information processing that occurs prior to the involvement of decision mechanisms.

As well as their implications for bilingual language comprehension, our results also speak to the hotly debated issue of serial versus parallel word processing during reading. The observation that the language of parafoveal flanker words has an influence on the processing of the foveal target word provides further evidence in favor of the idea that higher-order processing can occur for multiple words in parallel, at least to the extent that the representation of language membership is considered to be a high-level phenomenon. We of course acknowledge the possibility that language membership information can be activated via sublexical cues (e.g., Casaponsa, Carreiras, & Duñabetia, 2014; Van Kesteren, Dijkstra, & de Smedt, 2012), but we would argue that the same representation of language membership information, such as the language nodes in the BIA model, receives input from both sublexical and lexical activity associated with a given language, and that therefore the influence of such language membership information necessarily involves post-lexical processing.

In sum, our results indicate that the language of unattended flanker words can influence the processing of central target words during bilingual language comprehension. This is in line with models of bilingual word recognition that assume that the mechanism used to represent language membership information is also used to regulate the relative activation of lexical representations in each language, as is the case in the BIA model.

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Footnotes

[1] This follows the tradition of modularist theories of linguistic information processing whereby evidence for top-down feedback is captured by complex decision-level mechanisms (e.g., Norris, McQueen, & Cutler, 2000).

[2] Comparing the fit of our reduced model (AIC: 1705) with a full random effects model (AIC: 1722) showed no significant difference (p = .54). Thus, the observed effects were not due to variability that was not captured by the model.

[3] We replicated this effect with a new sample of 24 French-English bilinguals from the same participant pool. The setup of this experiment was identical to that of the main experiment, except that there were two additional mixed language blocks (French and English), next to the two pure language blocks (French or English). The results showed a main effect of language congruency, b = 21.3, SE = 9.6, t = 2.2, with slower responses in incongruent (620 ms) than congruent language trials (608 ms). Language congruency did not interact with the type of block, b = 21.2, SE = 12.9, t = 1.6 (17 ms congruency effect in pure language blocks and 23 ms in mixed language blocks).

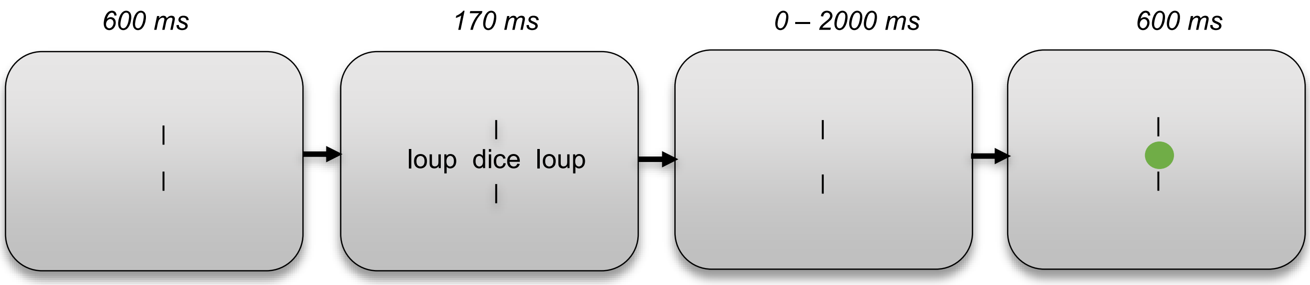

Figure 1. Overview of the trial procedure. The size of stimuli relative to the screen is exaggerated in this example.

Table 1. Overview of the demographic information (SD in brackets). The information consists of the average age-of-acquisition of both languages and the average percentage of time the participants spoke currently. Furthermore, the average self-rated scores for speaking and reading both languages is given, as is the average LexTALE scores for both languages.

	French	English
Age-of-acquisition	0.5 (1.4)	8.4 (3.0)
Currently used	70.8 (22.1)	29.2 (22.1)
Speaking	6.4 (0.7)	4.3 (1.0)
Reading	6.5 (0.7)	5.1 (1.0)
LexTALE	88.8 (4.7)	71.5 (10.7)

Table 2. *b*-, *t*-values, and standard errors of RT analyses.

Effects	*b*-value	Standard error	*t*-value
Intercept	461.0	14.1	32.6***
Congruency	18.6	8.6	2.2*
Language	38.2	11.6	3.3**
Congruency x Language	7.3	10.8	0.7

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

Table 3. *b*-, *z*-values, and standard errors of error analyses.

Effects	*b*-value	Standard error	*z*-value
Intercept	-2.5	0.3	9.1***
Congruency	0.1	0.2	0.5
Language	0.9	0.4	2.4*
Congruency x Language	0.4	0.3	1.3

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

Table 4. Overall RT in ms and percentage of errors (SD in parentheses) as a function of language congruency (congruent vs. incongruent), and language (French vs. English).

	Congruent	Incongruent
RT		
French	591 (65)	600 (73)
English	627 (64)	639 (72)
Error rates		
French	6.0 (5.6)	7.6 (7.0)
English	15.3 (8.8)	14.6 (10.6)