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A different perspective on domain-general language control using the flanker task☆

Mathieu Declerck[a,*], Charlotte Eben[b], Jonathan Grainger[a]

[a] *Laboratoire de Psychologie Cognitive, Aix-Marseille Université and Centre National de la Recherche Scientifique, Marseille, France*
[b] *Department of Experimental Psychology, Ghent University, Ghent, Belgium*

A B S T R A C T

Bilingual models diverge in whether they assume that language control is domain general. Most studies that investigated this claim focused on bilingual language production and relied on the comparison between language switching and task switching. In the current study, we set out to investigate whether language control is domain general in a different context (i.e., bilingual language comprehension) and with a different paradigm (i.e., the flanker task). To this end, we let French-English bilinguals perform a bilingual (flankers are words from the same or different language as the target word) and a non-linguistic (numerical magnitude with digits) flanker task. The results showed that there was no difference in the language congruency effect between participants with a high and low non-linguistic congruency effect. These results indicate that there is no substantial overlap in the mechanisms involved in comprehension-based language control and executive control.

1. Introduction

Bilingual language control, which is the process that makes it more likely that words are processed in the target language, has been extensively investigated in recent years. One hot topic in this field is whether language control is domain general. Several, but not all (e.g., Declerck, Koch, & Philipp, 2015; Grainger & Dijkstra, 1992; Grainger, Midgley, & Holcomb, 2010), bilingual models have proposed that language control is part of general executive control (e.g., Dijkstra & van Heuven, 2002; Green, 1998; Schwieter & Sunderman, 2008). Studies investigating this connection have, almost without exception, been bilingual production studies that compared performance in language switching, as a paradigm to investigate language control (for a review, see Declerck & Philipp, 2015), and task switching, as a paradigm to investigate executive control (for a review, see Kiesel et al., 2010). In the current study, we wanted to test whether language control is domain general in a different setting (i.e., bilingual language comprehension) and with a different paradigm (i.e., the flanker task).

The literature on whether language control is domain general is divided. There are several bilingual language production studies that did not observe an overlap between language control and executive control (e.g., Calabria, Branzi, Marne, Hernández, & Costa, 2015; Segal, Stasenko, & Gollan, 2019). Calabria et al. (2015), for example, found that the cost to switch between tasks, which is a measure of executive control (e.g., Kiesel et al., 2010), increases with age. However, the same bilingual participants did not show such an age effect on the cost to switch between languages, which is a measure of language control (e.g., Declerck & Philipp, 2015).

However, there is also evidence for an overlap between production-based language control and executive control (e.g., Declerck, Grainger, Koch, & Philipp, 2017; Prior & Gollan, 2011). Prior and Gollan (2011), for example, showed that Spanish-English bilinguals, who switched languages often in daily life, not only had smaller language-switch costs but also smaller task-switch costs than Mandarin-English bilinguals, who switched languages less often in daily life. This finding indicates that intensive practice with language switching influences control processes implemented during both language and task switching. Consequently, language control and non-linguistic executive control might rely on a common mechanism according to this study.

The studies discussed so far focused on the connection between production-based language control and executive control. In contrast, two recent studies focused on whether comprehension-based language control is domain general (e.g., Jylkkä et al., 2018; Struys, Woumans, Nour, Kepinska, & Van den Noort, 2019). Jylkkä et al. (2018) tested 51 Finnish-English bilinguals with a Simon, flanker, and task switching paradigm to measure executive control, and a comprehension-based language switching paradigm to measure language control. The prediction in this study was that if language control is domain general then

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* Corresponding author at: Aix-Marseille Université, Centre St. Charles, 3 place Victor Hugo, 13331 Marseille, France.
E-mail address: mathieu.declerck@univ-amu.fr (M. Declerck).

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the cost to switch languages should be higher if these bilinguals also show worse performance on the measures of executive control. The results showed no connection between the Simon effect, flanker effect, or task-switch costs and language-switch costs.[1]

Struys et al. (2019) tested 32 Dutch-French bilinguals with a Simon paradigm and a comprehension-based language switching paradigm. This study focused on correlation analyses to examine whether language control is domain general. The results showed no correlation between the Simon effect and language-switch costs, in line with Jylkkä et al. (2018). Additionally, these authors also investigated switching between congruent and incongruent trials in the Simon paradigm. They found that the cost associated with switching to an incongruent trial had a positive correlation with language-switch costs. The latter finding could be seen as evidence for some overlap between language control and executive control. Yet, no such correlation was observed between language-switch costs and the cost associated with switching to a congruent trial or with overall congruency switching.

In the current study, we used the same setup as Eben and Declerck (2019) to further investigate the possibility of an overlap between comprehension-based language control and executive control. Unlike prior studies, where the focus was typically on language switching and some measure(s) of executive control, we compared performance in a bilingual flanker task (Declerck, Snell, & Grainger, 2018; Eben & Declerck, 2019) and a non-linguistic flanker task (e.g., Eriksen & Eriksen, 1974). More specifically, in the bilingual flanker task, bilingual participants had to categorize a centrally presented word as belonging to one language or the other (i.e., a language decision task). This central word was flanked on either side by another completely unrelated word that could either be in the same language as the central target word or in the other language. Two prior studies have shown that performance is worse when the central and flanker words are in a different language (Declerck et al., 2018; Eben & Declerck, 2019). Similar to prior flanker studies (e.g., Rey-Mermet & Gade, 2018; Salthouse, 2010), this effect was interpreted as evidence for inhibitory control instigated by the language of the flanker word. Hence, the language congruency effect was the measure of language control in our study.

In the non-linguistic flanker, a similar setup was used to maximize the comparability, but the stimuli were non-linguistic (i.e., digits) and the task was to classify the central target digit as being smaller or larger than five. The non-linguistic congruency effect, and thus our measure of executive control, depended on whether the flanking digit was part of the same (congruent) or the alternative (incongruent) category (i.e., smaller or larger than five) as the central target digit.

If language control and executive control rely on the same underlying mechanism, one would expect that participants with a greater ability to implement non-linguistic control should also have a greater ability to implement language control. Put differently, participants with a large non-linguistic congruency effect would show a larger language congruency effect than those participants with a small non-linguistic congruency effect. If language control and executive control rely on different underlying mechanisms, on the other hand, there should be no influence of the non-linguistic congruency effect on the language congruency effect.

2. Method

2.1. Participants

50[2] French-speaking participants took part that spoke English as their second language (7 male, mean age = 21.8). Prior to the experiment, the participants filled in a questionnaire about their French and English proficiency (see Table 1).

These French-English bilingual participants were divided in two groups: a high and low non-linguistic congruency group (cf. Liu, Rossi, Zhou, & Chen, 2014). This division was done based on a non-linguistic flanker task (see below for more details), where the 25 bilinguals with the highest non-linguistic congruency effect were put in the high non-linguistic congruency group, and the 25 bilinguals with the lowest non-linguistic congruency effect were put in the low non-linguistic congruency group. The groups differed significantly from each other with respect to non-linguistic congruency, $b = 0.098$, SE = 0.025, $t = 3.911$, with the high non-linguistic congruency group showing a substantially higher non-linguistic congruency effect (608 ms vs. 571 ms, $b = 0.074$, SE = 0.018, $t = 4.152$) than the low non-linguistic congruency group (543 ms vs. 556 ms, $b = 0.0024$, SE = 0.016, $t = 1.540$). Additionally, there was no significant difference between the two groups on any of the language questionnaire items, $ts < 1.7$.

2.2. Materials and task

In the bilingual flanker task, 60 four-letter English target words (frequency: 5.37 Zipf; for information on Zipf, see van Heuven, Mandera, Keuleers, & Brysbaert, 2014) from the British Lexicon Project (Keuleers, Lacey, Rastle, & Brysbaert, 2012) and 60 four-letter French target words (5.65 Zipf) from the French Lexicon Project (Ferrand et al., 2010) were used. Each of these words were not inflected forms nor did they contain diacritics. Every word was paired with another four-letter English and French word, which served as flankers. These flanker words did not semantically overlap with the target word, and orthographic overlap was controlled for across conditions (for an example of a congruent and incongruent trial, see Fig. 1).

In the bilingual flanker task, the bilingual participants had to categorize the central target word as French, for which they had to press “Q” on an azerty keyboard, or as English, for which they had to press “L” on an azerty keyboard. Each word was only presented once to each participant, and was flanked by either a language congruent or language incongruent word.

In the numerical flanker task, digits 1–9, without 5, were used. These served as both targets and flankers. In this flanker task, participants had to perform a magnitude task (i.e., is the digit smaller than 5, for which they had to press “Q”, or larger than 5, for which they had to press “L”). The flanking digit could either elicit the same response (congruent) or the alternative response (incongruent).

2.3. Procedure

Both flanker tasks contained a practice block with 16 trials and three experimental blocks with 40 trials each. Within a block, half of the trials were French target words/digits smaller than 5, and the other half of the trials were English words/digits larger than 5. Moreover, there was an equal number of congruent and incongruent trials in each block. The order of the bilingual and numerical flanker task was counterbalanced over the participants.

Each trial began with a blank screen, which was followed by the target and flanking stimuli after 600 ms. These stimuli appeared central on the screen and were separated by one space. All three stimuli stayed on the screen until a response was registered, after which the next trial started.

[1] Some divergent effects were observed between the measures of executive control and language-mixing costs in this study. However, the authors indicate that it is not clear whether language-mixing costs are a measure of language control or language monitoring.

[2] We used the data of the 32 participants of Eben and Declerck (2019), which was supplemented with an additional 18 participants to assure that both groups would have an adequate number of participants.

Table 1
Overview of demographic information (SD in brackets).

	French	English
Age of acquisition	0.3 (0.8)	9.2 (2.6)
Currently used	77.5 (15.0)	22.5 (15.0)
Speaking	6.7 (0.5)	4.4 (1.0)
Reading	6.7 (0.6)	5.0 (1.1)

The information consists of the average age of acquisition of each language, the average percentage of time the participants currently spoke each language, and the average self-rated scores for speaking and reading both languages.

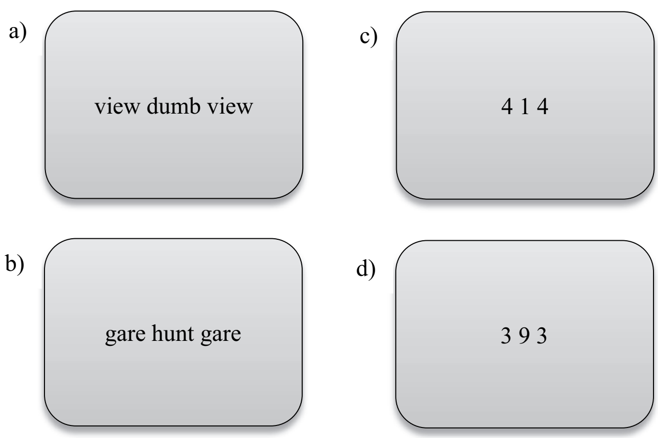

Fig. 1. Examples of (a) congruent and b) incongruent trials (*gare* meaning station in English) in the bilingual flanker task, and examples of c) congruent and d) incongruent trials in the non-linguistic flanker task.

2.4. Design

For the reaction time (RT) analyses, we excluded errors and RTs above and below 2 standard deviations from the mean per participant. Together, this resulted in the exclusion of 13.8% of the RT data.

The RT and error data were analyzed using linear or logistic mixed-effects regression modeling, respectively (Baayen, Davidson, & Bates, 2008; Jaeger, 2008). Both participants and items were considered random factors with both fixed effects (i.e. language congruency [congruent vs. incongruent] and group [high vs. low non-linguistic congruency group]) and their interaction varying by all random factors (Barr, Levy, Scheepers, & Tily, 2013).[3] *T*- and *z*-values larger or equal to 1.96 were deemed significant (Baayen, 2008). Finally, the RT data were inverse-transformed (−1000/RT) prior to analysis for the purpose of normalization.

3. Results

The RT data revealed a significant main effect of language congruency, $b = 0.030$, $SE = 0.014$, $t = 2.131$, indicating larger RTs in incongruent (822 ms) than in congruent trials (812 ms; see Table 2). There was no significant effect of group, $b = 0.028$, $SE = 0.055$, $t = 0.514$, and the interaction, $b = 0.004$, $SE = 0.016$, $t = 0.239$, was not significant.[4]

Table 2
Mean RTs (in milliseconds) and Error Rates (in percentage) of the bilingual flanker data as a function of language congruency (congruent vs. incongruent) and group (high vs. low non-linguistic congruency group). SE in brackets.

	High	Low
RT		
Congruent	838 (43)	785 (21)
Incongruent	843 (62)	803 (21)
Error rates		
Congruent	8.7 (1.0)	8.3 (0.7)
incongruent	12.9 (2.3)	10.7 (0.8)

A similar pattern was observed in the error rates as in the RT data. The main effect of language congruency was significant, $b = 0.361$, $SE = 0.180$, $z = 2.005$, with larger error rates in incongruent trials (11.8%) compared to congruent trials (8.5%; see Table 2). The main effect of group, $b = 0.033$, $SE = 0.199$, $z = 0.167$, and the interaction, $b = 0.190$, $SE = 0.197$, $z = 0.968$, were not significant.

To get a further sense of the degree of overlap between control processes in a bilingual and non-linguistic context, we also examined the correlations of the average bilingual and numerical congruency effects across all participants. The results showed no correlation between these two congruency effects for both the RTs, $r(50) = 0.140$, $p = .332$, and error rates, $r(50) = -0.070$, $p = .630$.

4. Discussion

In the present study, we investigated the overlap between comprehension-based language control and executive control. To this end, participants were presented with a bilingual and a non-linguistic flanker task. The results showed a language congruency effect. However, there was no difference of the language congruency effect for participants with a high or low non-linguistic congruency effect. There was also no substantial correlation observed between the language and non-linguistic congruency effects across all 50 French-English bilinguals.

According to some bilingual language comprehension models (e.g., Dijkstra & van Heuven, 2002; see also Green, 1998; Schwieter & Sunderman, 2008), language control is domain general. If this is the case, then we should have observed a larger language congruency effect for participants with a high non-linguistic congruency effect relative to those with a low non-linguistic congruency effect. This was not the case, as there was no difference in the language congruency effect for bilinguals with a high or low non-linguistic congruency effect.

However, a null effect does not always provide clear evidence against the alternative hypothesis. To provide statistical evidence in favor of the null hypothesis for the interaction, we ran an additional Bayesian null hypothesis analysis. The results showed positive evidence favoring the null hypothesis over the alternative hypothesis ($BF_{01} = 6.451$; Kass & Raftery, 1995). This entails that the null hypothesis was at least six times more likely to explain the data than the alternative hypothesis. So, our data provides evidence that there is no substantial overlap between language control and executive control. Additional evidence along these lines was observed with the correlation analyses, which showed no substantial correlations between the two types of congruency effect.

To further support our claim that comprehension-based language control is not domain general, we reanalyzed our data by examining whether high vs. low non-linguistic congruency would affect another

[3] A convergence issue occurred for the RT analysis. To overcome this issue, we determined the maximal random effects structure permitted by the data (cf. Barr et al., 2013), which led to a model with random intercepts and random by-participant slopes for both main effects.

There was also a convergence issue for the error analysis. The maximal random effects structure permitted by the data consisted of a model with random intercepts and random by-participant slopes for the main effect of group.

[4] When adding the size of the non-linguistic congruency effect as a covariate in the linear mixed effects model, the same pattern of significance occurred as the analysis where the size of the non-linguistic congruency effect was not a covariate.

measure of language control, namely language switching. We examined language switching of the target word[5] in a 2 (switch vs. repetition) x 2 (French vs. English) x 2 (high vs. low non-linguistic congruency) analysis. The results showed significant language-switch costs of 9 ms, $b = 0.056$, SE = 0.024, $t = 2.296$, and larger English switch costs (31 ms) than French switch costs (−13 ms), $b = 0.064$, SE = 0.032, $t = 2.032$.[6] However, both these effects did not interact with group, $ts < 0.403$. This was further supported by Bayesian null hypothesis analyses (for the switch costs x group interaction: $BF_{01} = 3.532$; for the asymmetrical switch costs x group interaction: $BF_{01} = 3.081$). Additionally, a correlation analysis across all 50 French-English bilinguals showed no substantial relation between language-switch costs and the non-linguistic congruency effect, r(50) = −0.091, $p = .531$. These results are in line with findings of Jylkkä et al. (2018) who also found no relation between a non-linguistic congruency effect and comprehension-based language switching.

Consequently, our findings are in line with bilingual language comprehension models that do not assume an overlap of language control with executive control (e.g., Grainger et al., 2010; Grainger & Dijkstra, 1992; see also Declerck et al., 2015). According to these models, language control during bilingual language comprehension is initiated by the language of the stimulus, which automatically activates its corresponding language node (i.e., a mental language membership representation), in turn resulting in inhibition of word representations of the other language. So, these models propose that language control is initiated and occurs during language processing, not by a control process outside of language processing.

These models are further supported by Jylkkä et al. (2018), who observed no connection between the Simon effect, flanker effect, or task-switch costs and language-switch costs. It is also mainly supported by Struys et al. (2019), who observed no correlation between the Simon effect and language-switch costs. However, this study did show a correlation between the cost related to switching to an incongruent trial and language-switch costs. Since switching between congruent and incongruent trials is related to conflict monitoring (e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001), this might point to some similarity in how comprehension-based language control and executive control detect interference and in turn initiate interference resolution (for evidence against this claim, see Eben & Declerck, 2019).

However, some possible limitations of the current study need to be pointed out. It could be that because the task (i.e., is the string of letters a French or English word) and manipulation (i.e., same vs. different language of target and flanker words) are connected in the bilingual flanker task, that part of the language congruency effect is due to response competition. However, this is not necessarily the case. In Declerck et al. (2018), a language congruency effect was observed without the task (i.e., is the string of letters a word or not) and manipulation (i.e., same vs. different language of target and flanker words) being connected, and thus a language congruency effect was observed without response competition.

Another possible limitation is that the language decision task implemented in the bilingual flanker task might not tap into the language control process. Yet, most studies and models assume that the language decision task relies on the activation of the mental representation of each language (e.g., Dijkstra & van Heuven, 2002; Grainger et al., 2010; Von Studnitz & Green, 1997), such as language nodes in the model of Grainger and colleagues. Since these mental language representations are generally assumed to play a key role during language control (cf. Grainger et al., 2010; Green, 1998), it follows that language control can be examined with this task.

Taken together, the current study showed no overlap in congruency effects with a bilingual and non-linguistic flanker task. These results indicate that there might not be a connection between comprehension-based language control and executive control. This is in line with models that do not assume comprehension-based language control to be domain general.

[5] We additionally ran a similar language-switching analysis on the flanker words, but observed no switch costs, $b = 0.013$, SE = 0.021, $t = 0.605$, and no interaction with switch costs, $ts < 0.846$.

[6] While asymmetrical switch costs are typically larger for the more dominant language, a pattern with larger switch costs for the less dominant language has been observed in prior research (Declerck, Stephan, Koch, & Philipp, 2015). Moreover, it is also in line with some models of bilingual language comprehension (e.g., Grainger et al., 2010).

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