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Non-linguistic effects of language switching training

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ABSTRACT

What is the relationship between bilingual language control (BLC) mechanisms and domain-general executive control (EC) processes? Do these two domains share some of their mechanisms? Here, we take a novel approach to this question, investigating whether short-term language switching training improves non-linguistic task switching performance. Two groups of bilinguals were assigned to two different protocols; one group was trained in language switching (switching-task training group) another group was trained in blocked language picture naming (single-block training group). Both groups performed a non-linguistic and linguistic switching task before (pre-training) and after training (post-training). Non-linguistic and linguistic switch costs decreased to a greater extent for the switching-task training than for the single-block training group from pre- to post-training. In contrast, mixing costs showed similar reductions for both groups. This suggests short-term language switching training can transfer to the non-linguistic domain for certain sub-mechanisms (i.e., switch cost). Thus, there is some overlap of the control mechanisms across domains.

1. Introduction

The extent to which bilingual language control (BLC) and domain-general executive control (EC) processes share some of their mechanisms is a debated issue (Abutalebi & Green, 2007; Declerck, Koch, & Philipp, 2015; Dijkstra & van Heuven, 2002; Grainger, Midgley, & Holcomb, 2010; Green, 1998). This question is relevant when trying to understand whether BLC mechanisms are an instantiation of domain-general EC processes. The experimental evidence used to inform this issue comes from several sources. One of the most common paradigms used in the question regarding cross-talk is the comparison (either behaviorally or through neuroimaging studies) of a bilingual's performance in linguistic and non-linguistic control tasks (Branzi, Calabria, Boscarino, & Costa, 2016; De Baene, Duyck, Brass, & Carreiras, 2015; Timmer, Calabria et al., 2018; Timmer, Grundy, & Bialystok, 2017a). Here, we take a novel approach and explore cross-talk between BLC and EC by assessing whether short-term training in BLC affects performance on tasks that involve EC but do not (or only minimally) involve linguistic processes (Abutalebi et al., 2008; Dijkstra & van Heuven, 2002; Green, 1998).

The evidence regarding cross-talk that comes from correlational studies is based on the idea that if the two domains share cognitive processes then individuals' performances in tasks that involve linguistic and non-linguistic control should correlate to some extent. To put it simply, if BLC is subsumed to EC processes, those individuals that are good at the latter should be good at the former too. This hypothesis has been tested mostly by looking at switching tasks (linguistic switching vs. non-linguistic switching tasks). Given that we also used these tasks in the present study, the following review will be focused on these types of studies. Most of the correlational studies do not reveal a correlation between switching costs across the linguistic- and non-linguistic tasks (Branzi et al., 2016; Calabria, Branzi, Marne, Hernández, & Costa, 2015; Calabria, Hernández, Branzi, & Costa, 2011; Cattaneo et al., 2015; Declerck, Grainger, Koch, & Philipp, 2017; Prior & Gollan, 2013). However, some studies revealed a correlation for the switch cost across domains (Declerck et al., 2017; Timmer, Calabria et al., 2018) or for the mixing cost across domains (Cattaneo et al., 2015; Prior & Gollan, 2013).

Moreover, other studies have looked at whether performance in task switching varied depending on the frequency of language switching in real life. The results of these studies suggest that more frequent language switching in daily life improves non-linguistic task switching performance (Hartanto & Yang, 2016; Pot, Keijzer, & de Bot, 2018; Prior & Gollan, 2011; Soveri, Rodriguez-Fornells, & Laine, 2011; Yang, Hartanto, & Yang, 2016). For example, Hartanto and Yang (2016) showed diminished switch costs in a non-linguistic task for those

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participants who used both languages within the same context (dual-language context) compared to bilinguals who only speak one language in a specific environment (single-language context) (for a similar study but opposite results see Jylkkä et al., 2017). This suggests that the language context a bilingual resides in matters to some extent. Indeed, bilinguals that switch between their languages more frequently seem to engage control mechanisms to a different extent (the adaptive control hypothesis, Green & Abutalebi, 2013). Hence, these observations suggest that training in BLC may affect performance in domain-general EC tasks, a hypothesis tested in our study, however, clear attention needs to be paid to the type of context bilinguals are in.[1]

Along with behavioral data, neural data has also been investigated for the presence of cross-talk between BLC and EC. Imaging results show a greater recruitment of BLC areas when performing a non-linguistic switching task for bilinguals than monolinguals (Garbin et al., 2010; Rodríguez-Pujadas et al., 2013). However, studies that compared brain activity in linguistic versus non-linguistic switching tasks directly in the same bilingual speakers suggest that there is only partial overlap across the domains (De Baene et al., 2015; Weissberger, Gollan, Bondi, Clark, & Wierenga, 2015). Some degree of overlap between both switching tasks has been found over prefrontal/frontal areas (lateral and medial) and the parietal lobule (inferior and superior) (De Baene et al., 2015). However, Weissberger et al. (2015) found that activation for the non-linguistic task was more widespread than for the language task and dependent on type of trials (switch or repeat). Moreover, an electrophysiological (EEG) study demonstrated that for the switch cost the scalp distributions showed overlap between task switching and language switching for the P3/LPC (Latent Positive Component), but not for the N2 (Timmer, Grundy, & Bialystok, 2017a). In sum, the current evidence of a common neural network of the BLC and the EC system does not seem to support a complete overlap.

Here we take a novel approach and assess whether training in a task that involves BLC has an impact on participants' performance on an EC task that does not involve language control. To assess this issue, we compare participants' performances on an EC task before and after they conduct a language training task. There were two different training groups: one group performed a language switching training that required BLC (switching-task training group), while the other group performed a language task without the need for BLC (single-block training group). We hypothesize that if BLC and EC share some processes then training in the former domain should lead to some benefits in the latter domain. In fact, the two training protocols could be argued to parallel, to some degree, the two different language contexts described in the adaptive control hypothesis (Green & Abutalebi, 2013). Language switching training (switching-task training group) resembles the dual-language context in which switching between languages occurs, while the blocked language protocol (single-block training group) resembles the single-language context in which each language is used in a different environment. That is, we investigate if EC is differentially modulated depending on the type of short-term language context/training.

The transfer approach used in the present study has already been applied to study the sub-components of EC. For example, non-linguistic task switching training revealed not only improvement on the same task (Buchler, Hoyer, & Cerella, 2008; Karbach & Kray, 2009; Kramer, Hahn, & Gopher, 1999; Kray, Eber, & Karbach, 2008; Minear & Shah, 2008; Zinke, Einert, Pfennig, & Kliegel, 2012), but also improved performance in other tasks and domains of EC (Karbach & Kray, 2009; Kray, Karbach, Haenig, & Freitag, 2012; Zinke et al., 2012). In the context of bilingualism, there is evidence that language switching performance improves with training in the same task (Kang et al., 2017; Kang, Ma, & Guo, 2018; Wu, Kang, Ma, Gao, & Guo, 2018). They found that the language switch cost decreased from pre- to post-test after 8 days of training on language switching, but only when the stimuli at post-test were the same as at pre-test. Moreover, the brain data reveals more efficient processing on the N2 component (Kang et al., 2018) or over the ACC, the neural generator of the N2 (Kang et al., 2017). However, as of yet there is no evidence that language switching training transfers to the EC domain (Prior & Gollan, 2013). In Prior and Gollan's (2013) study one group performed a language task, that included both pure blocks, with only one language, and mixed blocks, with two languages. After a week they performed a non-linguistic task, which did not show improved EC performance. These results led the authors to conclude that the link between the two domains of control is elusive.

In the present study, we investigated the difference between the effect of language switching and blocked language naming on a non-linguistic task with a between group design and we pay attention to two indexes of control, namely switch and mixing costs. These indexes, present in both linguistic and non-linguistic switching tasks (for reviews see Bobb & Wodniecka, 2013; Meiran, 2010), are assumed to capture two different types of control, reactive and proactive respectively (Braver, Reynolds, & Donaldson, 2003). The switch cost is calculated by subtracting performance in repeat trials from switch trials. The mixing cost is calculated by comparing performance in repeat trials within the switching task to trials in blocks that involve just one task (or language); the so called 'pure blocks'. Within the task switching literature switch costs are understood to reveal both the cost associated with retrieving the rules associated with a signaling cue from memory and the need to reconfigure the appropriate stimulus-response mappings for the task at hand (Hernández, Martin, Barceló, & Costa, 2013; Jost, Mayr, & Rosler, 2008; Meiran, 2010; Prior & Macwhinney, 2010). There are similar explanations of switch costs observed in language tasks (Costa, Miozzo, & Caramazza, 1999; Green, 1998; La Heij, 2005; Roelofs, 1998; Timmer, Christoffels et al., 2018). The switch cost has also been understood to index a transient type of control that resolves interference when it is detected in a trial by trial fashion. In contrast, mixing cost has been suggested to involve a more sustained type of control that maintains a task goal active, promotes cognitive flexibility, and facilitates the processing of possible upcoming conflict (Braver et al., 2003). Similarly, proactive control has been related to the ability of maintaining the two languages active (Cattaneo et al., 2015; Ma, Li, & Guo, 2016).

In our study we asked two groups of participants to perform a non-linguistic switching task in two sessions (pre-training and post-training, about a week apart). Between these sessions two training sessions were included. The first training session immediately followed the pre-training task and the second training session immediately preceded the post-training task, that was performed a week after the pre-training and first training session. One group of participants performed a linguistic switching task involving two languages (switching-task training group), and hence engaging BLC as in dual-language contexts (Green & Abutalebi, 2013). The other group of participants (single-block training group) performed a blocked naming task in just one language, and hence they did not switch between languages simulating a single language context. Arguably, this language blocked naming task, recruits BLC processes to a much lesser extent than the language switching task.

By comparing participants' performance for the switching-task training group in the pre- and post-training sessions, we can assess the potential effect of BLC training on the reactive (i.e., switch cost) and proactive (i.e., mixing cost) domain-general EC processes. Specifically, we expected a greater decrease of the switch cost from pre- to post-training for the switching-task training compared to the single-block training group. The switching-task training group trained specifically on reactive language control mechanisms of BLC during language switching, while the single-block training group did not train on these

[1] A different but related topic are studies that show that intensive second language learning has a positive impact on domain-general attentional control (Bak, Long, Vega-Mendoza, & Sorace, 2016) and cognitive decline (Antoniou, Gunasekera, & Wong, 2013) as language learning engages an extensive network of the brain and is cognitively stimulating.