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On the overlap between bilingual language control and domain-general executive control

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ABSTRACT

We explored the overlap between bilingual language control (bLC) and domain-general executive control (EC) by focusing on inhibitory control processes. We tested 62 bilinguals in linguistic and non-linguistic switching tasks for two types of costs, such as the n − 1 shift cost and the n − 2 repetition cost. In order to explore the involvement of inhibitory control in bLC and EC, we assessed the pattern of switch costs in the two tasks and then we correlated them between tasks. Results showed reduced n − 2 repetition costs as compared to n − 1 shift costs in the linguistic task only, suggesting that small amount of inhibition were deployed when switching between languages. Importantly, neither the n − 1 shift costs nor the n − 2 repetition costs were correlated between tasks. These results, supported by additional evidence from the ex-Gaussian analysis, suggest that inhibitory control is differently involved in bLC and in EC.

1. Introduction

The issue of how bilingual speakers manage to restrict lexicalization to one of their languages, while preventing massive interference from their other language, has prompted a great amount of research in the last decades (e.g., Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006; Jackson, Swainson, Cunnington, & Jackson, 2001; Christoffels, Firk, & Schiller, 2007; Misra, Guo, Bobb, & Kroll, 2012; Branzi, Martin, Abutalebi, & Costa, 2014; Branzi, Della Rosa, Canini, Costa, & Abutalebi, 2015; for a review see Baus, Branzi, & Costa, 2015). As a result of this research, there is agreement in assuming that the bilingual language control (bLC) system makes use of various processes of the domain-general executive control (EC) system (e.g., Abutalebi & Green, 2007). However, the precise nature of the overlap between bLC and EC processes is still an open issue. The aim of this article is to provide new evidence regarding the relationship between these two cognitive systems.

Recent research on the overlap between bLC and EC has focussed on different strategies. One of them is to correlate participants' behaviour in comparable tasks that either involves bLC or domain-general EC processes (e.g., Calabria, Hernández, Branzi, & Costa, 2012; Weissberger, Wierenga, Bondi, & Gollan, 2012; Prior & Gollan, 2013; Calabria, Branzi, Marne, Hernández, & Costa, 2015; Cattaneo, Calabria, Marne, Gironell, Abutalebi, & Costa, 2015; Babcock & Vallesi, 2015). The argument made is that to the extent these tasks tap into comparable control processes, there should be a correlation between the effects measured in them. For example, Calabria et al. (2012; 2015) tested bilinguals of different ages in both linguistic and non-linguistic switching tasks. In the linguistic task, participants were required to name some pictures in Catalan and some other pictures in Spanish according to a cue (i.e., Catalan and Spanish flag). In the non-linguistic task, instead, participants were required to classify pictures according to a non-linguistic classification rule (i.e., classify pictures by their color and by their shape). The cost of switching between languages or tasks was calculated by subtracting reaction times (RTs) of "repeat" trials (AA task sequences) from those of "switch trials" (BA task sequences). This cost, the so called "n − 1 shift cost", is considered a measure of the efficiency of bLC and EC functioning (see Kiesel, Steinhauser, Wendt, Falkenstein, Jost, Philipp, & Koch, 2010).

The current evidence indicates there is no correlation between linguistic and non-linguistic n − 1 shift costs (Calabria et al., 2012, 2015; Prior & Gollan, 2013; Cattaneo et al., 2015), hereby suggesting a lack of overlap between bLC and EC, at least for those cognitive mechanisms measured through the n − 1 shift cost (see also Weissberger et al., 2012). In accord with these findings, Tse and Altarriba (2014) tested a group of Cantonese-English bilingual children and revealed a lack of association between measures of language proficiency and ex-Gaussian parameters in a non-linguistic Simon switching task.

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However, other behavioural studies have provided evidence of a link between bilingual language processing and EC (e.g., Festman, Rodriguez-Fornells, & Münte, 2010; Festman, 2012; Prior & Gollan, 2011; Soveri, Rodriguez-Fornells, & Laine, 2011; Hartanto & Yang, 2016). For instance, Soveri et al. (2011) revealed that the frequency rate with which bilinguals switched between languages on a daily basis predicted the magnitude of mixing costs in error rates in a set-shifting task. In addition to this, Goral, Campanelli, and Spiro (2015) recently revealed that language use and language proficiency affect the performance in the Simon task in older bilinguals. Besides, it has been also demonstrated a relationship between intrusion errors in a single-language conversational context and cognitive measures of executive functioning (Festman, 2012; Gollan, Sandoval, & Salmon, 2011) and between measures of language control and the control of nonverbal interference (e.g., Prior & Gollan, 2011; Linck, Schwieter, & Sunderman, 2012; de Bruin, Roelofs, Dijkstra, & FitzPatrick, 2014). For instance, Prior and Gollan (2011) showed that Mandarin–English bilinguals with higher fluency scores in Mandarin incurred smaller switch costs in a non-linguistic switching task. Note, however, that this result was not replicated in another group of bilinguals (Spanish-English bilinguals) tested in the same study.

Another indication of a link between bilingual language use and EC processing can be found in those studies that compared monolinguals and bilinguals performing EC tasks (e.g., Bialystok & Martin, 2004; Bialystok & Viswanathan, 2009; Prior & MacWhinney, 2010; Tao, Marzecova, Taft, Asanowicz, & Wodniecka, 2011; Costa, Hernández, & Sebastián-Gallés, 2008; Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009; Wiseheart, Viswanathan, & Bialystok, 2016). In fact, some of these studies revealed that the continuous use of two languages affect the cognitive processes related to domain-general EC, such as those put at play during non-linguistic switching tasks (e.g., Prior & MacWhinney, 2010; Prior & Gollan, 2011; Prior, 2012; Wiseheart et al., 2016), thereby suggesting a certain functional overlap between those processes involved in linguistic and non-linguistic domains of cognitive control. Despite these findings have motivated recent research to focus on the extent of this overlap (e.g., Calabria et al., 2012, 2015; Weissberger et al., 2012; Cattaneo et al., 2015; Coderre, Smith, van Heuven, & Horwitz, 2015; Weissberger, Gollan, Bondi, Clark, & Wierenga, 2015; De Baene, Duyck, Brass, & Carreiras, 2015), other recent findings have strongly undermined the basic assumption of the existence of an overlap between bLC and EC (e.g., Paap & Greenberg, 2013; Hernández, Martin, Barceló, & Costa, 2013; Paap & Sawi, 2014; Duñabeitia et al., 2014; Kousaie, Sheppard, Lemieux, Monetta, & Taler, 2014; Antón et al., 2014; von Bastian, Souza, & Gade, 2015).

Hence, at present, the available evidence is contradictory regarding the existence of a substantial overlap between bLC and EC processes, particularly as to when such overlap is measured by correlating switch costs between tasks (e.g., Calabria et al., 2012, 2015; Prior & Gollan, 2013).

Informative as this lack of correlation might be, indeed, it might not tackle specifically those control processes that are supposed to be influenced by bilingualism, such as inhibitory control processes (e.g., Green, 1998). In fact, despite the n − 1 shift cost measures inhibitory control processes, it reflects also the efficiency of other EC mechanisms involved in switching between tasks (e.g., task-set activation mechanisms; see Kiesel et al., 2010). Hence, the lack of correlation between linguistic and non-linguistic tasks might be due to the variability added by these other processes measured through the n − 1 shift cost.

One of the aims of this study is to assess this issue by measuring a cognitive cost that is supposed to tackle specifically inhibitory control processes and that thus may reveal a correlation between the two tasks. This cost is the "n − 2 repetition cost" (e.g., Mayr & Keele, 2000; Philipp, Gade, & Koch, 2007; see also Koch, Gade, Schuch, & Philipp, 2010) and it refers to the slower RTs observed when participants have to switch into a recently performed task (in an n − 2 trial) as compared to when they have to switch into a not-recently performed task. To give an example, let's consider a switching experiment in which participants have to switch between three different tasks (e.g., sort pictures by color, size and shape). This task affords the calculation of the cost of switching into a recently performed task (ABA–classify by color, classify by size, classify by color), and that of switching into a not recently performed task (CBA- classify by shape, classify by size, classify by color). As it happens, RTs from the former type of trials are slower than those of the later, the so-called n − 2 repetition cost (e.g., Mayr & Keele, 2000; Philipp et al., 2007). As hinted above, the magnitude of this cost is argued to be a signature of the amount of inhibition applied to the repeated task. In other words, the inhibition applied to task A when performing task B would determine an increase of RTs when performing again task A, because of the need to overcome previous inhibition (e.g., Arbuthnott & Frank, 2000; Mayr & Keele, 2000).

The overlap between bLC and EC has not yet been assessed by measuring this index of inhibitory control (but see Babcock & Vallesi, 2015 for some evidence with simultaneous interpreters). Hence, with this study we aim to fill this gap, by exploring not only between-tasks correlations of the n − 1 shift cost (Calabria et al., 2012, 2015), but also those of the n − 2 repetition cost. Importantly, providing an answer to this question is a timely issue given the current debate on the existence of bilingualism advantages in inhibitory control (e.g., Paap, Johnson, & Sawi, 2015). In that, the finding of an association between linguistic and non-linguistic n − 2 repetition costs would contrast with the recent views that suggest that the bilingual advantage in inhibitory control is not a reliable phenomenon (Paap & Greenberg, 2013; Paap et al., 2015).

Under the assumption that the n − 2 repetition cost is a reliable index of inhibitory control,[1] we hypothesize that participants' variability in their inhibitory abilities should be revealed by differences in the magnitude of the n − 2 repetition cost. If bLC makes use of the same inhibitory processing as the domain-general EC system, then participants' variability in their inhibitory abilities should be similarly present in linguistic and in non-linguistic tasks. In other words, the n − 2 repetition cost should correlate between bLC and EC tasks.

In this study, we use an experimental design that affords exploring both the n − 1 shift cost and the n − 2 repetition cost simultaneously. We do so, because the assessment of the patterns of switch costs (i.e., n − 1 shift costs and n − 2 repetition costs) may be informative in respect of the involvement of inhibitory control in the two tasks. Let us explain in more detail the pattern of switch costs we are referring to.

As previously hinted, both the n − 1 shift cost and the n − 2 repetition cost are cognitive indexes that capture inhibitory control in the task. However, our hypothesis is that in doing so they may show opposing effects. That is, based on the assumption that inhibition measured as n − 2 repetition costs contribute to n − 1 shift costs (Mayr & Keele, 2000), the stronger the inhibition applied on the n − 1 task, the smaller the n − 1 shift cost and the larger the n − 2 repetition cost should be.

Therefore, if different amount of inhibitory control are deployed when switching between non-linguistic and linguistic tasks, we may observe different patterns of switch costs in the two tasks. This prediction has not been tested so far. With the present study we aim to shed light on this issue by measuring the two costs simultaneously in linguistic and non-linguistic switching tasks.

[1] The *n*-2 repetition cost is considered a robust and reliable index of inhibitory control. In fact, to our knowledge, besides very few exceptions (e.g., Guo, Ma, & Liu, 2013), all the studies that measured this index reported significant n-2 repetition costs (see, e.g., Arbuthnott & Frank, 2000; Lien & Ruthruff, 2008; Mayr & Keele, 2000; Philipp, Jolicoeur, Falkenstein, & Koch, 2007; Schuch & Koch, 2003; Moritz, Hübner, & Kluwe, 2004; Whitmer & Banich, 2007; Declerck, Thoma, Koch, & Philipp, 2015; Grange & Juvina, 2015; Babcock & Vallesi, 2015; Scheil, 2016; Regev & Meiran, 2016). Importantly, to date the evidence indicating that the n-2 repetition cost reflects inhibitory control is robust against non-inhibitory explanations (see Koch et al., 2010; Mayr, 2007).