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The effects of bilingualism on conflict monitoring, cognitive control, and garden-path recovery

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ABSTRACT

Bilinguals demonstrate benefits on non-linguistic tasks requiring cognitive control—the regulation of mental activity to resolve information-conflict during processing. This "bilingual advantage" has been attributed to the consistent management of two languages, yet it remains unknown if these benefits extend to sentence processing. In monolinguals, cognitive control helps detect and revise misinterpretations of sentence meaning. Here, we test if the bilingual advantage extends to parsing and interpretation by comparing bilinguals' and monolinguals' syntactic ambiguity resolution before and after practicing N-back, a non-syntactic cognitive-control task. Bilinguals outperformed monolinguals on a high-conflict but not a no-conflict version of N-back and on sentence comprehension, indicating that the advantage extends to language interpretation. Gains on N-back conflict trials also predicted comprehension improvements for ambiguous sentences, suggesting that the bilingual advantage emerges across tasks tapping shared cognitive-control procedures. Because the overall task benefits were observed for conflict *and* non-conflict trials, bilinguals' advantage may reflect increased cognitive flexibility.

1. Introduction

Balanced bilinguals—people who are equally proficient in two languages—seem to experience a host of cognitive advantages over monolinguals. This so-called "bilingual advantage" is evident across the lifespan: young bilingual children outperform monolinguals on executive function tasks requiring inhibition and focused attention (Bialystok, 1999; Bialystok & Martin, 2004; Kovács & Mehler, 2009; Martin-Rhee & Bialystok, 2008); healthy adult bilinguals are faster than monolinguals on cognitive control tasks (Bialystok, 2006; Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009); and older adult bilinguals exhibit less cognitive decline due to aging than monolinguals (Bialystok, Craik, Klein, & Viswanathan, 2004; Schweizer, Ware, Fischer, Craik, & Bialystok, 2012). In the current research, we are interested in whether there exist broad, domain-general effects of bilingualism on different tasks involving cognitive control—the ability to regulate mental activity to resolve information-conflict during processing. Here, we use the term cognitive control instead of inhibitory control (or inhibition) to describe this process, because conflict could be successfully resolved by inhibiting irrelevant information, by promoting relevant information, or both (Botvinick, Braver, Barch, Carter, & Cohen, 2001). Despite some evidence supporting a bilingual advantage in cognitive control (Bialystok, 2010; Bialystok, Craik, Green, & Gollan, 2009; Bialystok et al., 2004; Costa et al., 2009; Martin-Rhee & Bialystok, 2008; but see also Hilchey & Klein, 2011; Paap & Greenberg, 2013), there are still several unanswered questions regarding its nature, specificity, and extent.

In particular, few studies have tested whether the bilingual advantage cascades into language processing. Provided that the source of bilinguals' cognitive advantage is the systematic control of two languages, these benefits should be observed in the linguistic domain—however, much of the work in this area focuses on the effects of bilingualism in *non-linguistic* contexts. It is also unclear

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how robust the bilingual advantage is to changing task demands, especially given reports of a lack of uniformity in cross-task bilingual performance (Paap & Greenberg, 2013; Paap, Johnson, & Sawi, 2014): Does the advantage emerge consistently across tasks tapping shared cognitive control functions? Do monolinguals 'catch up' to bilinguals during cognitive control practice? The present study aims to address these issues by testing whether healthy, young adult bilinguals outperform monolinguals on a reading task involving syntactic ambiguity resolution—a cognitive control task in the linguistic domain—both before and after brief practice with a recognition-memory task that theoretically taps shared conflict-resolution functions.

We begin by reviewing what is known about the effects of bilingualism on cognitive control and the theoretical accounts of these observed effects. We then discuss how such effects might cascade into on-line sentence processing by providing an account of the role of cognitive control within sentence interpretation. Finally, we present our study, which addresses the open questions raised above.

2. What is the effect of bilingualism on cognitive control?

It is striking that the bilingual advantage is observed on *non-linguistic* cognitive control tasks: bilinguals exhibit faster response times (RTs) on (1) the Simon task (Bialystok et al., 2004), in which participants identify a non-spatial attribute of a visual stimulus presented on the same (congruent) or opposite (incongruent) side as the correct response; (2) the Flanker task (Costa et al., 2009), in which participants indicate the direction of an arrow that is flanked by task-irrelevant arrows pointing in the same (congruent) or opposite (incongruent) direction; and (3) the spatial Stroop task (Bialystok, 2006), in which participants indicate the direction of a single arrow that appears on the same (congruent) or opposite (incongruent) side as the correct response. Despite overt dissimilarities, these tasks all involve occasional "conflict trials," where task-irrelevant stimulus features provide misleading information; thus, they all require cognitive control to resolve competition between different sources of information.

In his seminal work, Green (1998) proposed the inhibitory control (IC) model of bilingual language processing, which theorized that a central inhibitory-control mechanism played an important role in bilingual language use by suppressing items from the lexicon not currently in use. For instance, bilinguals might inhibit words from their native language (L1) when speaking their second language (L2). Under this model, bilingualism could strengthen domain-general inhibitory control via extensive practice (Abutalebi & Green, 2008; Bialystok et al., 2009), and bilinguals could then apply their improved control to non-verbal tasks.

However, the IC model does not fully account for the diverse empirical evidence supporting an effect of bilingualism on cognitive control. If bilinguals are better specifically at inhibiting irrelevant information, then they should outperform monolinguals selectively on conflict trials where such inhibition is required. Yet in many studies, bilinguals outperform monolinguals on both congruent *and* incongruent trials (for review, see Hilchey & Klein, 2011). Indeed, in their meta-analysis of bilingual cognitive control studies, Hilchey and Klein (2011) found limited evidence that bilinguals had smaller interference effects than monolinguals, but showed that across studies, bilinguals appeared to enjoy a general advantage as long as the *task* involved conflict processing. On the basis of such evidence, Costa et al. (2009) proposed that bilinguals have superior "conflict monitoring": the ability to detect information conflict and reactively increase cognitive control recruitment (Botvinick et al., 2001). During conflict monitoring, people continuously evaluate input to determine if it contains conflicting sources of information. If so, then cognitive control is recruited to help resolve the competing evidence by inhibiting routine responses or irrelevant information, and/or by promoting correct responses or goal-relevant information; otherwise, cognitive control need not deploy (Botvinick et al., 2001). Cognitive control is thus a sub-component of conflict monitoring that is downstream from monitoring for and detecting conflict (Kerns et al., 2004). Conflict-monitoring demands are high when the input frequently switches between stimuli with and without conflict; people must therefore flexibly recruit cognitive control on a moment-by-moment basis. In such contexts, monitoring facilitates the detection of conflict and subsequent engagement of cognitive control, but it also helps to detect the *absence* of conflict—monitoring occurs continuously because the individual cannot know a priori if a given stimulus will contain conflict. By contrast, in environments where conflict is always or nearly always present, monitoring demands are low because cognitive control can be applied uniformly (Botvinick et al., 2001; Costa et al., 2009).

Consistent with this account, Costa et al. (2009) found that the magnitude of the bilingual advantage was larger on Flanker task versions with approximately equal proportions of conflict and non-conflict trials than versions with relatively unequal proportions. When congruent and incongruent trials occurred equally often, imposing heavy monitoring demands, bilinguals were significantly faster at both trial types. Yet bilinguals performed no differently from monolinguals when the vast majority of trials (92%) were incongruent (Costa et al., 2009); their advantage disappeared when conflict-monitoring demands were low, despite high cognitive control demands. Moreover, brain-imaging research finds that language switching trials and incongruent Flanker trials co-activate overlapping voxels in the anterior cingulate cortex (ACC), a medial-frontal region thought to be involved in monitoring for conflict and signaling adjustments in control (Abutalebi et al., 2012; see Botvinick et al., 2001). This idea is supported by evidence that conflict-related activity in the ACC is reduced when conflict is expected (Carter et al., 2000) and that the ACC responds to cues indicating the conflict-status of an upcoming trial, regardless of whether that status is congruent or incongruent (Aarts, Roelofs, & van Turennout, 2008). Thus, bilinguals' experience of language switching may engage and strengthen the domain-general conflict monitoring system.

Despite this evidence, inconsistencies across the bilingualism literature question the robustness of an effect of bilingualism on conflict monitoring and cognitive control. One problem is that monolinguals often 'catch up' to bilinguals with a small amount of practice (see e.g., Bialystok et al., 2004; Costa et al., 2009). If one session of practice on the Simon or Flanker task is equivalent to a lifetime of bilingual language experience, then the effect of bilingualism on conflict monitoring and cognitive control seems rather weak—perhaps bilinguals reach a functional limit and are unable to improve further. Yet characteristic cognitive control tasks (e.g., Simon, Flanker) typically yield high performance and bilinguals may already be performing at a task ceiling (e.g., accuracy greater than 97% with reaction times faster than 400 ms across several task blocks; Bialystok et al., 2004); thus it may be impossible to observe continued improvements. The current study examines whether monolinguals and bilinguals benefit differentially from cognitive control practice by administering tasks with initially low performance, allowing for greater practice-related changes, potentially even in bilinguals.

A final issue is that a bilingual advantage is observed in some experiments but not in others, with no apparent pattern to its (non-)occurrence (Hilchey & Klein, 2011; Paap & Greenberg, 2013). Indeed, Paap and Greenberg (2013) assessed the stability of bilingual benefits by administering within-subjects a variety of executive function tasks (Simon, Flanker, Antisaccade, Ravens