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Bilingualism influences inhibitory control in auditory comprehension

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ABSTRACT

Bilinguals have been shown to outperform monolinguals at suppressing task-irrelevant information. The present study aimed to identify how processing linguistic ambiguity during auditory comprehension may be associated with inhibitory control. Monolinguals and bilinguals listened to words in their native language (English) and identified them among four pictures while their eye-movements were tracked. Each target picture (e.g., *hamper*) appeared together with a similar-sounding within-language competitor picture (e.g., *hammer*) and two neutral pictures. Following each eye-tracking trial, priming probe trials indexed residual activation of target words, and residual inhibition of competitor words. Eye-tracking showed similar within-language competition across groups; priming showed stronger competitor inhibition in monolinguals than in bilinguals, suggesting differences in how inhibitory control was used to resolve within-language competition. Notably, correlation analyses revealed that inhibition performance on a nonlinguistic Stroop task was related to linguistic competition resolution in bilinguals but not in monolinguals. Together, monolingual-bilingual comparisons suggest that cognitive control mechanisms can be shaped by linguistic experience.

1. Introduction

Detection and resolution of ambiguity is a core element of language processing. For example, during monolingual language comprehension, competition between linguistic alternatives arises in the presence of multiple similar-sounding words (e.g., Bradlow & Pisoni, 1999; Desroches, Newman, & Joanisse, 2008; Luce & Pisoni, 1998; Marslen-Wilson, 1987; McClelland & Elman, 1986) and multiple related word meanings (e.g., Degani & Tokowicz, 2010; Gernsbacher, 1990; Gernsbacher & Faust, 1991; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Swinney, 1979). Resolution of linguistic competition may require cognitive control to focus on relevant information in the face of competing alternatives. In general, a link between linguistic performance and cognitive control abilities has been established across a range of language processing contexts. Cognitive control has been tied to language performance both in children, where the cognitive system is developing (Nakamichi, 2007; Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002) and in older adults, where it is in decline (Kemper & Sumner, 2001; Kwong See & Ryan, 1995; Taylor, O'Hara, Mumenthaler, Rosen & Yesavage, 2005). In addition, when language processing demands are high, more executive control is engaged (Kerns, 2007; Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997; Thompson-Schill, D'Esposito, & Kan, 1999), and better cognitive control is associated with better linguistic performance (Christoffels, De Groot, & Kroll, 2006; Hernandez & Meschyan, 2006).

One way to examine the link between linguistic experience and domain-general cognitive function is to compare groups whose different experiences in the linguistic domain may have influenced their performance in other cognitive realms. The present research focuses on how

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linguistic experience may change cognitive function in bilinguals compared to monolinguals. The study has two objectives: (1) to investigate whether an inhibition mechanism is involved in auditory word comprehension in monolinguals and bilinguals, and (2) to examine the nature of such an inhibition mechanism. It was hypothesized that, if extended immersion in bilingual (high-ambiguity) language comprehension situations[1] honed inhibition mechanisms that resolve competition during auditory comprehension, then bilinguals would exert cognitive control more efficiently than monolinguals. Further, if domain-general cognitive control processes were differentially involved in monolingual and bilingual language comprehension, then the relationship between word recognition and a nonlinguistic inhibitory task would differ across the two groups. More specifically, if bilingual experience resulted in recruitment and modulation of domain-general cognitive control processes, then bilinguals would show stronger relationships between inhibition during word recognition and inhibition on the nonlinguistic task, as compared to monolinguals.

Bilingual language processing involves simultaneous activation of two languages (e.g., Blumenfeld & Marian, 2007; Marian & Spivey, 2003a, 2003b) and requires an ability to efficiently control these languages (e.g., Dijkstra & van Heuven, 1998; Green, 1998) and switch from one language to the other in a context-appropriate manner (e.g., Costa & Santesteban, 2004; Rodriguez-Fornells, Balaguer, & Munte, 2006). During auditory comprehension, similar-sounding words become active across bilinguals' two languages, so that when bilinguals hear a word in one language while presented with pictures, they also look at pictures of between-language competitors that overlap phonologically across languages (e.g., when hearing *marker* in English, Russian-English bilinguals make eye-movements to a stamp, the Russian word for which is *marka*, Marian & Spivey, 2003a, 2003b). This finding has been replicated across different groups of bilinguals and language pairs (Blumenfeld & Marian, 2007; Canseco-Gonzales, Brick, Fischer, & Wagner, 2005; Cutler, Weber, & Otake, 2006; Ju & Luce, 2004; Shook & Marian, under review; Weber & Cutler, 2004; Weber & Paris, 2004), suggesting that bilinguals' experience with parallel language activation and cross-linguistic competition is universal and occurs in addition to the within-language co-activation and competition experienced by monolinguals (e.g., Luce & Pisoni, 1998; Marslen-Wilson, 1987; McClelland & Elman, 1986).

As a consequence of bilinguals' parallel language activation, bilinguals may face consistently higher degrees of linguistic competition compared to monolinguals and, as a result, their performance on executive control tasks may be altered (e.g., Bialystok, 2005, chap. 20; Kroll, 2008), with bilinguals showing cognitive advantages over monolinguals (e.g., Bialystok, 2005, chap. 20; Colzato, Bajo, van den Wildenberg, & Paolieri, 2008; Cook, 1997; Costa, Hernandez, & Sebastian-Galles, 2008; Prior & MacWhinney, 2010). For example, Bialystok and Codd (1997) compared monolingual and bilingual children on two selective-attention tasks where participants had to ignore irrelevant and conflicting information (e.g., to identify a tower containing *more* blocks, participants had to ignore a *higher* tower that actually contained *fewer* blocks), compared to tasks that contained no conflicting information. They found that bilingual children performed better than monolingual children on the task containing irrelevant conflicting information, but performed the same as the monolingual children on the task containing no conflicting information (for similar findings comparing bilingual and monolingual children, see Bialystok, 1999, 2010; Bialystok & Martin, 2004; Bialystok & Viswanathan, 2009). Similar bilingual advantages in inhibitory control, conflict monitoring, and task switching have been found across the lifespan (Bialystok, 2006, 2010; Bialystok, Craik, Klein, & Viswanathan, 2004; Colzato et al., 2008; Costa, Hernandez, Costa, & Sebastian-Galles, 2009; Costa et al., 2008; Kovacs & Mehler, 2009; Prior & MacWhinney, 2010).

The demands of bilingual language processing are the likely source of cognitive advantages in bilinguals (e.g., Bialystok, 2005, chap. 20; Kroll, 2008). Language processes that require greater cognitive demands in bilinguals include language switching (Prior & MacWhinney, 2010) and continued suppression of a second language during production (Linck, Hoshino, & Kroll, 2008; Linck, Kroll, & Sunderman, 2009). While parallel language activation during comprehension has been cited as a potential source of bilingual cognitive advantages (e.g., Kroll, 2008), a direct link between comprehension processes and cognitive control in bilinguals has not yet been established. Findings that identify a link between linguistic and nonlinguistic control processes would provide empirical support for the hypothesis that linguistic competition is at the root of bilingual cognitive advantages previously identified in the literature (e.g., Bialystok, 2005, chap. 20; Costa et al., 2008).

The aim of the present study was to identify a link between monolinguals' and bilinguals' ambiguity resolution during auditory comprehension and their performance on a nonlinguistic task of cognitive control. Monolingual and bilingual listeners completed a combined Eye-Tracking/Negative Priming task (Blumenfeld, 2008) that indexed both activation of multiple word candidates during auditory comprehension and subsequent suppression of irrelevant competing words (see Fig. 1). Participants heard object names, and were asked to identify these target objects from a set of items in a visual display while their eye-movements were tracked (e.g., Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). During target identification, participants' eye-movements to target and competitor pictures reflected parallel activation of both items. In order to examine whether inhibitory control processes were differentially involved in monolingual and bilingual language comprehension, monolinguals' and bilinguals' ability to resolve competition was compared during auditory word comprehension in their native language (English).

To index inhibition of similar-sounding competitor words that became co-activated during comprehension, we added a negative priming component to follow each eye-tracking trial. Negative priming is a unique way to

[1] I.e., listening contexts where bilinguals simultaneously activate their two languages either overtly (because both languages are explicitly used) or covertly (because auditory input occasionally sounds similar to words in the other language).