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Working memory development in monolingual and bilingual children

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ABSTRACT

Two studies are reported comparing the performance of monolingual and bilingual children on tasks requiring different levels of working memory. In the first study, 56 5-year-olds performed a Simon-type task that manipulated working memory demands by comparing conditions based on two rules and four rules and manipulated conflict resolution demands by comparing conditions that included conflict with those that did not. Bilingual children responded faster than monolinguals on all conditions and bilinguals were more accurate than monolinguals in responding to incongruent trials, confirming an advantage in aspects of executive functioning. In the second study, 125 children 5- or 7-year-olds performed a visuospatial span task that manipulated other executive function components through simultaneous or sequential presentation of items. Bilinguals outperformed monolinguals overall, but again there were larger language group effects in conditions that included more demanding executive function requirements. Together, the studies show an advantage for bilingual children in working memory that is especially evident when the task contains additional executive function demands.

Introduction

It is now recognized that a variety of cognitively demanding experiences modulate brain development and, by extension, modify cognitive functioning (e.g., Green & Bavelier, 2003; Maguire et al., 2000; Polk & Farah, 1998; Salthouse & Mitchell, 1990). The modification to cognitive functioning

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typically follows from intensive practice in a particular process entailed by the experience. For example, video game players have superior spatial resolution of visual processing, presumably because of the practice obtained during gaming (Green & Bavelier, 2003). The exercise of speaking two or more languages on a daily basis is another experience that has been shown to produce changes in cognitive performance (see review in Bialystok, 2009). The mechanism by which bilingualism leads to this experience-induced cognitive change is likely based on the need to monitor attention to the target language in the context of joint activation of the other language. Substantial evidence from a variety of sources has supported the view that both languages are active in mind to some extent during both comprehension and production (Blumenfeld & Marian, 2007; Francis, 1999; Grainger, 1993; Kroll & de Groot, 1997; Marian & Spivey, 2003; Rodriguez-Fornells, Rotte, Heinze, Nosselt, & Munte, 2002; Thierry & Wu, 2007). The procedures for monitoring attention to the target language have been shown to be handled at least in part by the executive control system (see Luk, Green, Abutalebi, & Grady, in press, for a meta-analysis of functional magnetic resonance imaging evidence), and the recruitment of that system for language use improves its efficiency for a broad range of tasks. The process by which the executive control system interacts with language selection and the subsequent effect on specific aspects of that system, however, are not well understood. Such precision is necessary in order to understand the unique structure of bilingual minds and how experience can affect cognitive outcomes.

One area of uncertainty is the identification of the specific executive control function components that are involved in bilingual language processing and, subsequently, are boosted for bilinguals. A widely accepted interpretation of executive control proposed by Miyake and colleagues (2000) consists of three core components roughly corresponding to inhibition, shifting, and working memory. Early studies showing bilingual differences in performance focused primarily on inhibition (see Bialystok, 2001, for a review), tracing the bilingual advantage in executive control to the need to inhibit the irrelevant but jointly activated language (cf. Green, 1998). Subsequent research, however, has challenged that interpretation; bilingual advantages have been found in preverbal infants long before any inhibition could be relevant (Kovács & Mehler, 2009), some types of inhibition have been implicated in these effects and others have not (Colzato et al., 2008), and conditions that involved no inhibition appear to be equally affected (Hilchey & Klein, 2011). Therefore, the precise nature of how executive control is involved in bilingual performance is not clear.

Recently, Miyake and Friedman (2012) took a broader view and proposed that the executive function is characterized by "unity and diversity," that is, a set of correlated but separable abilities. This view captures a trend in recent research that emphasizes a reliance of executive function components on a common underlying mechanism (Best & Miller, 2010; Garon, Bryson, & Smith, 2008; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003). On this view, working memory is automatically affected by any experience that affects the executive function system more broadly. Evidence for bilingual advantages in aspects of two of the three components, inhibition and shifting, is already documented, so from the concept of "unity" it follows that bilinguals should demonstrate enhanced working memory.

Understanding both the status of working memory in the constellation of the executive function and the effect of bilingualism on its development is important because working memory is arguably the most important component of the executive function. Working memory is central to a wide variety of cognitive abilities, especially those that involve dealing with interference, conflict, or distraction (see Kane, Conway, Hambrick, & Engle, 2007, for a review) and predicts essential cognitive and academic outcomes in children. For example, reading comprehension requires holding the previous text in mind so it can be related to the current material, and mental arithmetic requires holding numbers in mind while the operation is applied to update the result. Not surprisingly, therefore, the early acquisition of literacy and numeracy skills (Adams & Gathercole, 1995; Blair & Razza, 2007; De Beni, Palladino, Pazzaglia, & Cornoldi, 1998; Gathercole, Pickering, Knight, & Stegmann, 2004; Savage, Cornish, Manly, & Hollis, 2006) and later language and math achievement (Barrouillet & Lepine, 2005; Blair & Razza, 2007; Bull & Scerif, 2001; Espy et al., 2004; Gathercole et al., 2004; Passolunghi, Vercelloni, & Schadee, 2007; Swanson & Kim, 2007) depend heavily on working memory.

Previous research investigating the effect of bilingualism on executive control has focused largely on the role of inhibition and shifting. Thus, the tasks typically require participants to switch between rules (Bialystok, 1999; Bialystok & Viswanathan, 2009; Costa, Hernández, Costa-Faidella, &