The Impact of Bilingualism on Cognition

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Abstract

In spite of early warnings of dire consequences of bilingualism for children's cognitive development, research in the past 50 years has revealed that bilingualism is in fact a positive developmental experience. These benefits were more recently shown to extend across the life span. New research is incorporating neuroimaging to determine the brain bases of these effects and exploring the possibility that the beneficial effects of bilingualism can compensate for degeneration of other cognitive functions that are associated with dementia, thereby postponing symptom onset.

INTRODUCTION

The relation between language and cognition has long captured the interest of theorists and researchers: How do language and thought interact? Is cognition limited by levels of linguistic proficiency? What are the conditions necessary to achieve high levels of language ability? Nowhere is this interaction more dramatic or more consequential than in child development. In the first several years of life, the emergence of both these abilities is well documented and occurs at a breathtaking rate. And yet, in spite of ongoing philosophical debate about such possible interactions, there has always been a common belief that language matters deeply for cognitive development, and that introducing multiple languages into children's lives must have consequence. For almost a century, therefore, the possibility that childhood acquisition of more than one language could significantly affect the developing cognitive system has been considered to be an important issue. What has changed over time is the judgment about the outcome. With only a few exceptions, the majority of early studies on childhood bilingualism reported superior cognitive performance, often defined in terms of IQ scores, for monolingual children, sometimes describing bilingual children as "inferior" or suffering from "mental confusion" (Saer, 1923). Thus, the prevailing consensus was

Emerging Trends in the Social and Behavioral Sciences. Edited by Robert Scott and Stephen Kosslyn.
 ISBN 978-1-118-90077-2.

that bilingualism created an obstacle to children's cognitive development (for reviews see Barac & Bialystok, 2011; Darcy, 1963; Hakuta, 1986). A significant change in this attitude began to emerge after an influential study by Peal and Lambert (1962) in which they demonstrated better performance on both verbal and nonverbal tests for bilingual children than for comparable monolinguals. The possibility that bilingualism might be beneficial to children's development was a radical departure from commonly held views. The investigation of the effect of bilingualism on children's cognitive development is now an active area of research, and the results are more complex and more nuanced than the early research allowed. Research on bilingualism now informs an understanding of the relation between language and cognition in development, the role of experience and training in cognition across the life span, and cognitive change in older age. Thus, to a degree that would have surprised the early researchers, the study of bilingualism provides a powerful model of the effect of experience on the mind and the role of neuroplasticity in the development and modification of brain networks throughout life.

FOUNDATIONAL RESEARCH

The earliest systematic research indicating positive outcomes for bilingual children focused on the development of metalinguistic awareness. The idea was that children who were learning two languages would more rapidly develop the formative insights about language and its structure that are essential for high-level language use and literacy. Consistent with this idea, studies examining children's awareness of phonology (e.g., Ibrahim, Eviatar, & Aharon-Peretz, 2007), syntax (e.g., Galambos & Goldin-Meadow, 1990), words (e.g., Feldman & Shen, 1971), and morphology (e.g., Cheung *et al*., 2010) generally showed more advanced understanding for bilingual children. However, such outcomes were not found in all studies, pointing to a more complex story. Considering just phonological awareness, an essential foundation for alphabetic literacy, subsequent research revealed that the extent to which bilingual children demonstrated precocious development depended on the nature of the writing system (McBride-Chang, Bialystok, Chong, & Li, 2004), the relative complexity of the orthography (Bialystok, Majumder, & Martin, 2003), and the language of schooling (Barac & Bialystok, 2012), to name a few. Crucially, the type of task also mattered: Metalinguistic tasks that simply tapped knowledge of rules were performed equivalently by monolingual and bilingual children but similar tasks that included interfering information that needed to be ignored were performed better by bilingual children. For example, in a grammaticality judgment task in which children were instructed to respond to the grammaticality

of sentences and ignore the meaning, all children were equally accurate in determining that the sentence "Why is the dog bark?" contains a grammatical error so is incorrect, but bilingual children were more successful than monolingual children in responding that the sentence "Why is the cat barking?" is grammatically correct, although it is silly (Bialystok, 1986). Thus, bilingual children were not misled by the salient but irrelevant meaning.

The observation that the bilingual advantage in metalinguistic tasks was confined to conditions in which attentional effort was required to ignore distraction led to the possibility that this effect might be seen beyond the domain of language. It is not surprising that a linguistic experience impacts aspects of linguistic development, but it is more surprising that effects would be found in nonverbal cognitive performance. Using paradigms similar to those showing bilingual advantages in metalinguistic tasks, the early research using nonverbal cognitive tasks revealed better similar performance by monolingual and bilingual children on tasks that were based largely on knowledge but better performance by bilingual children on tasks that included distraction (Bialystok & Majumder, 1998). This distinction between tasks based primary on representational knowledge and attentional control has been maintained in recent research: Monolingual and bilingual children perform equivalently on tests of representation, such as short-term visual memory, but bilingual children outperform monolinguals tasks requiring attentional control, such as the flanker task (Engel de Abreu, Cruz-Santos, Tourinho, Martin, & Bialystok, 2012). Overall, bilingual advantages have been reported in a range of nonverbal cognitive tasks that require attentional control, including tests involving inhibition (Carlson & Meltzoff, 2008), monitoring (Bialystok, 1999), creativity (Adi-Japha, Berberich-Artzi, & Libnawi, 2010), theory of mind (Goetz, 2003), and multi-tasking (Bialystok, 2011). Together these studies converge on the interpretation that executive control is more advanced in bilingual children than in monolinguals.

The next step in establishing this body of research was to determine whether these effects found with children persisted into adulthood. Although it was interesting that bilingual children had more advanced executive control than comparable monolingual children, it is also the case that for the types of tasks used in this research, all children would eventually be able to solve them, so there may not be any added value in mastering them a little earlier. However, evidence for these effects in adulthood would have greater consequence. The first study to investigate this question compared monolinguals and bilinguals between the ages of about 30 and 80 years old performing a Simon task, a standard measure of executive control. The results showed reliable effects of bilingualism at all ages, providing the first evidence that the impact of bilingualism might be more extensive and more profound than previously thought (Bialystok, Craik, Klein, & Viswanathan,

2004). These results were subsequently replicated using different tasks, populations, and methodologies (Bialystok, Craik, & Luk, 2008; Gold, Kim, Johnson, Kryscio, & Smith, 2013; Salvatierra & Rosselli, 2010).

Why would the experience of using two languages have an impact on nonverbal cognitive performance? The answer appears to be based on the discovery that both languages for a bilingual are constantly activated to some degree when the individual is using one of them. This somewhat surprising finding has been supported by enormous amounts of evidence from behavioral, imaging, and patient studies (see Kroll, Dussias, Bogulski, & Valdes-Kroff, 2012, for a recent review). This constant activity from the nontarget language should lead to frequent errors in language selection, yet such errors are extremely rare. Therefore, there must be a mechanism that controls selection of the correct language in the face of interference from the activated but inappropriate alternative. An early suggestion for this mechanism was proposed by Green (1998) in his Inhibitory Control Model. The essential claim was that a domain-general attention system used broadly to focus attention on relevant targets and inhibit incorrect alternatives was applied to the problem of language selection. Research examining the neural bases of these claims confirmed the involvement of such domain-general processes in language selection (Abutalebi *et al*., 2008; Luk, Green, Abutalebi, & Grady, 2012). The interpretation, therefore, is that the constant use of this domain-general control system for language selection enhances that system in bilinguals and is manifest as better performance by bilinguals on a broad range executive control tasks, including nonverbal ones (Bialystok, Craik, Green, & Gollan, 2009).

CUTTING-EDGE RESEARCH

Two recent developments extend this research into new domains. The first is the incorporation of neuroimaging into these investigations and the second is the possibility that bilingualism contributes to cognitive reserve.

A wide range of imaging techniques have been introduced to studies of bilingualism, including structural analyses of brain volume (Mechelli *et al*., 2004), functional investigations of network connectivity (Abutalebi *et al*., 2012; Luk, Anderson, Craik, Grady, & Bialystok, 2010; Grady, Luk, Craik, & Bialystok, 2015), and electrophysiological recordings of brain activity (Rodriguez-Fornells, Rotte, Heinze, Nosselt, & Munte, 2002; Wu & Thierry, 2010). These approaches expand on existing research by identifying precise aspects of brain function, which are modified by bilingualism. Together, these studies document the structural and functional brain changes that follow from extended bilingual experience and the cognitive consequences associated with them. In this way, bilingualism has been shown to be a

model for evidence of lifelong neuroplasticity, the notion that experience can lead to persistent change in behavior that is mediated by the reorganization of synaptic connections in specific neural circuits (Kolb *et al*., 2012). For example, in the study by Luk *et al*. (2010), monolingual and bilingual participants performing a flanker task produced similar behavioral results in terms of reaction time to the various conditions, but bilinguals used different neural circuits than monolinguals when responding to incongruent trials. Moreover, both Abutalebi *et al*. (2012) and Gold *et al*. (2013) showed that bilinguals could achieve equivalent levels of performance as monolinguals with less activation of the anterior cingulate cortex, a crucial part of the executive control network, indicating more efficient performance. The question of the extent to which neuroplasticity is available throughout life, the types of experiences that enable brain reorganization and change, and the possibility for exploiting such experiences to provide intervention and training for cognitive functions that are weak or compromised through disease or disability are exciting new directions for this research.

The second new development comes from recent studies that have reported that bilingualism is associated with a significant delay in the onset of symptoms of Alzheimer's disease (Alladi *et al*., 2013; Craik, Bialystok, & Freedman, 2010). The increasing prevalence of dementia (Plassman *et al*., 2007) in conjunction with promising but limited progress in the search for pharmacological interventions (Zhu *et al*., 2013) points to the need for alternative approaches to disease management. Although bilingualism could not in itself be used as an intervention in the sense that it is implausible to consider that one could postpone societal Alzheimer's disease by teaching foreign languages, it can nonetheless be used as a model for considering how lifestyle factors in general contribute to cognitive reserve and be harnessed to maintain cognitive health into older age.

KEY ISSUES FOR FUTURE RESEARCH

Three issues are a high priority for future research. The first is to define bilingualism in such a way that the essential aspects of bilingual experience that are responsible for these cognitive changes can be identified. The second is to examine various bilingual contexts to extrapolate the key features that differentiate them and determine which contexts are most likely to support cognitive change. The third is to consider the processing demands of different cognitive tasks and refine our notions of the specific effect that bilingualism can be expected to exert on cognition. The effects of bilingualism on cognition are subtle and not found in all circumstances, so understanding how this aspect of neuroplasticity functions requires introducing more precision into all analyses. The exploration of these issues will

require multi-method approaches, including both behavioral and imaging studies, co-operation among researchers operating in different contexts with different languages, and interdisciplinary collaboration to provide sophisticated analyses from linguistics, psycholinguistics, sociolinguistics, cognition, and neuroscience, to name a few.

The essential difficulty with this type of research is that none of the central concepts takes a simple definition. The most essential question—Who is bilingual?—depends on establishing criteria for age of acquisition and circumstances under which a second language was acquired, both absolute and relative levels of proficiency in the two languages, extent to which each of the languages is used, contexts in which each language is used, and so on. It is rare to find people who are purely monolingual in that they have never taken a language course, traveled abroad, or spent time with speakers of another language, or truly bilingual in that they are equally fluent in two languages that they use regularly. The fiction of a categorical distinction between these groups is necessary to make progress on the overall questions, but it is also clear that differences in bilingual experience lead to different outcomes (Luk & Bialystok, 2013). Understanding the details of how learning and using two languages leads to modifications in cognitive ability and organization of cognitive networks will require generating more detailed analyses of relevant individual differences factors that distinguish among bilingual experiences.

Just as individual differences matter, so too do the contexts in which individuals function. An important factor in how bilinguals use their two languages is the type and extent of support that one or both languages receive from the community. In communities where bilingualism is considered to be widespread and most individuals will be competent in both languages, control of language selection is less important because intrusions will not disrupt conversation. In contrast, communities that are largely monolingual or entertain negative attitudes toward bilingualism will demand greater degrees of language control for bilinguals in order to function effectively. These distinctions and their possible implications for both behavioral and brain consequences of bilingualism have been described by Green and Abutalebi (2013). Similarly, there may be differential effects from other factors that are external to the individual such as similarity between the two languages or the relation between the writing systems in the two languages that could conceivably mediate the effects of bilingualism on cognition. These issues need to be examined in detail.

The third factor that is currently underspecified in research on the cognitive effects of bilingualism is the nature of the tasks or processes for which these effects may be expected to occur. It is important to delineate the range of performances for which bilingual effects are found in conjunction with those for which bilingualism does not matter. Various proposals for the

types of task performance that are affected by bilingualism have led to different conceptions of the mechanism that might be responsible (e.g., Hilchey & Klein, 2011). Even within specific processes, such as inhibition, differences in the type of inhibition involved seem to determine whether bilinguals will demonstrate performance advantages (Carlson & Meltzoff, 2008; Martin-Rhee & Bialystok, 2008), and small differences in difficulty in a single task conspire to determine whether bilinguals will outperform their monolingual peers (Bialystok, 2006). There is much we do not know about the situations in which bilingual performance can be expected to demonstrate these processing advantages in executive control, but further progress in understanding these effects requires an explicit account of those situations.

There has always been a commonsense belief that language matters for cognition, and that it matters especially for children's cognitive development. Two insights from research in the past 50 years have confirmed and refined that belief. First, the very fact that these interactions between language and cognition occur attests to a model of mind that is holistic and deeply interactive, ruling out earlier ideas centered on modular abilities and isolated skill development. Second, the intuitions that language experience could be important for children's cognitive development has been shown to be a lifelong phenomenon in which the effects of bilingualism impact cognitive processes across the life span, and acquiring another language at any age has the potential to modify cognitive systems. This story is about bilingualism, but it is equally a story about neuroplasticity in which the experiences in which we engage have the potential to induce cognitive change throughout life.

This research reported in this essay was funded by grant A2559 from National Sciences and Engineering Research Council of Canada (NSERC) and grant R01HD052523 from the National Institutes of Health (NIH).

Definition of Terms

Neuroplasticity. This is the view that the brain maintains the ability to continually rewire throughout life, particularly in response to experience or training. It is contrary to earlier ideas that brain networks were fixed in adulthood. The possibility of neuroplasticity has important implications for therapy, such as recovery from stroke, where targeted training can create new circuitry and restore some use of muscles that had been disabled by the stroke.

Simon Task. This is an experimental paradigm in which participants are given a simple rule, "if you see a red square press the key on the right; if you see a blue square press the key on the left" and are asked to respond

as rapidly as possible to red and blue squares that are presented on the computer by pressing the appropriate key. The squares are presented on either side of the display rather than in the center, so the response key can either be on the same side as the stimulus (congruent trial) or on the opposite side (incongruent trial). Because we automatically respond to position information, the incongruent trials require inhibiting that natural response to press the key required by the rule. The additional time necessary to make these responses is the Simon effect and is a measure of executive control.

Flanker Task. This is an experimental paradigm in which participants see a row of stimuli, such as five arrows, and are asked to press a key as quickly as possible to indicate what direction the central arrow is facing. The other four arrows can either be facing in the same direction (congruent trial) or the opposite direction (incongruent trial). The additional time needed to overcome the pull created by the flanking arrows for the incongruent trials is the flanker effect and is a measure of executive control.

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