

**A Developmental Approach to Bilingual Research:  
The Effects of Multi-language Experience from Early Infancy to Old Age**

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## **Abstract**

### *Aims and Objectives*

In this commentary article we consider the benefits of adopting a neuroconstructivist approach (Filippi & Karmiloff-Smith, 2013) in the study of bilingualism in order to promote empirical and theoretical progress on the fiercely debated issue of whether bilingualism confers genuine cognitive advantages.

### *Significance/Implications*

Although there is a general consensus that exposure to multilingual environments does not impair cognitive development, there are still doubts on the possible beneficial advantages of bilingualism. Critics argue that the evidence for this advantage might have been confounded by unsound or questionable methodological practices. Some investigators have abandoned research in this area, indicating either that there is no bilingual advantage or that it is impossible to capture and therefore rule out alternative explanations for group differences. Rather than dismissing this important theme in the literature, we advocate a more systematic approach in which the effects of multi-linguistic experience are assessed and interpreted across well-defined stages of cognitive development.

### *Conclusions*

We encourage a broad, developmentally informed approach to plotting the trajectory of interactions between multi-language learning and cognitive development, using a convergence of neuroimaging and behavioral methods, across the whole lifespan. We believe that, through studying infants, children, young adults, adults and the elderly within a coherent and systematic developmental framework, a more accurate and valid account of potential cognitive and neural changes associated with multi-language learning will emerge.

## **Introduction**

Throughout history, philosophers, educators, health professionals, linguists and psychologists advocated either disadvantages or advantages of “being bilingual”. Still today, bilingual and multilingual school children in the UK are labeled as EAL (English as an Additional Language) pupils, which arguably implies a vaguely negative connotation or the categorization of multilingual learners as having some sort of ‘special needs’. Anecdotally, there are still cases in which educators discourage multilingual families to raise their children as multilinguals (Festman, Poarch & Dawaele, 2017). Such behavior should be rendered unacceptable, and it is – at least in part - the responsibility of the scientific community to provide research-based counter-arguments against such discouragement.

Researchers in the field have always been divided about the effects that learning multiple languages may have on cognitive development. Early studies in which bilingual and monolingual children were compared with measures of IQ, reported a bilingual cognitive disadvantage (e.g. Saer, 1922, 1923). These results inoculated the general belief that being raised in a multilingual environment was largely detrimental for children’s intellectual development. The association between bilingualism and a sort of mental retardation generated misconceptions and concerns within families and schooling systems for decades in the 20<sup>th</sup> century, until a study conducted by Peal & Lambert (1962) demonstrated the reverse pattern of results: this time it was the bilingual children who significantly outperformed an age-matched group of monolingual peers on similar IQ measures. Why? Early studies were particularly poorly controlled with one of the major confounds being differences in

socio-economic status (SES) across bilingual and monolingual groups (see Hakuta and Diaz, 1985, for a review). More rigorous studies which better controlled for SES indicated that acquiring a second language enriched some crucial aspects of cognition beyond the language system, such as the ability to inhibit irrelevant non-verbal information (e.g., Bialystok & Martin, 2004; Costa, Hernandez & Sebastián-Gallés, 2008). In comparison to monolingual speakers, bilinguals seemed to adapt better to unexpected changes, and their level of executive function (i.e., those higher level cognitive abilities that allow us to operate effectively in complex environments) appeared to benefit from their enhanced linguistic experience. A rather intuitive hypothesis, the *Bilingual Advantage hypothesis* (Bialystok, 1999) explains these data by proposing that the constant use of two or more languages and the intense, effortful demand of switching between languages that goes with it, may strengthen general non-linguistic abilities, such as selective attention (Bialystok, 2017).

The requirement to inhibit the non-target language during communication has been proposed as the primary recruitment driver for executive resources. Green (1986, 1998) proposed the Inhibitory Control Model (ICM), claiming that general attentional resources are involved in the voluntary control of language selection and language production (see Hilchey & Klein, 2011 for a comprehensive review, including alternative accounts) – and this model provides some of the theoretical foundations for the bilingual advantage hypothesis later proposed by Bialystok. A sophisticated evolution of the ICM, the Adaptive Control hypothesis (ACH), predicts different effects on cognitive control in relation to how multilinguals use their languages in context (Green & Abutalebi, 2013; Abutalebi & Green, 2016). We return to this issue later.

Like those early studies highlighting cognitive *disadvantages* associated with bilingualism, recent research claiming advantage has also been subject to claims of poor experimental control, particularly with respect to the adequacy of matching across monolingual and multilingual groups. This claim, that like is not being compared with like across candidate confounding covariates such as socio-economic status or cultural factors, is increasingly prominent in the literature (e.g., Antón et al., 2014; Duñabeitia et al., 2014; Gathercole et al., 2014; Paap, Johnson & Sawi, 2015; Paap & Greenberg, 2013; Morton & Harper, 2007). Arguably, the complexity of cognitive, social, educational and cultural factors operating within and across groups, is such that it is impossible to demonstrate that satisfactory matching is achieved. Indeed, some authors consider this (along with questionable replicability and other methodological concerns) to be an intractable issue and, in consequence, have recommended abandoning research on the bilingual advantage hypothesis altogether (as reported in a widely read debate, recently published in *The Atlantic* (Yong, 2016)).

We reject this argument, and instead encourage researchers to adopt a more sophisticated approach than that of identifying broadly applicable *advantages* and *disadvantages* associated with ‘multilingualism’. Today, it is estimated that a large majority of people in the world speak two or more languages (Grosjean, 2010), and that this majority is destined to grow as a consequence of migration flows and globalized employment opportunities. Multi-language learning is an *inevitable* real life global phenomenon, and the impact of this escalating trend on cognition deserves careful and thorough analysis.

In order to work towards a more solid theoretical basis and a methodologically secure empirical approach for resolving the debate on whether (and how) multilanguage acquisition may impact on cognition, we must consider the key issues

that have divided the scientific community. Here, we review these issues and encourage the adoption of a developmental approach which might better capture the impact (if any) of multi-language learning on cognition across the lifespan.

*Are the tests fit for purpose? Focus on the Simon Task*

Ellen Bialystok, the leading advocate of the bilingual advantage hypothesis, has recently acknowledged the methodological weakness of tools typically employed in this area of research (*The Atlantic*; Young 2016). We welcome this recognition, but it necessarily follows that we also acknowledge that it is on the basis of such tests that the bilingual advantage hypothesis has been proposed and subsequently developed. It is beyond the scope of this paper to debate strengths and weaknesses across the range of tests employed in this area, and instead focus in detail on one of the more widely used tools, the *Simon Task* (Simon & Rudell, 1967; Simon, 1990). Much of the early evidence base for the bilingual advantage has been based on performance on this task (e.g., Bialystok et al., 2004, 2005, 2006; Martin-Rhee & Bialystok, 2008). In the standard computerized version, one of two stimuli (a blue or a red square) appears either on the left or the right side of the computer screen, with participants required to respond as quickly and accurately as possible by pressing a left or right button (each of which is associated with one of the two colors). This button/color mapping allows manipulation of trials such that some are congruent (i.e., the correct response is on the same side as the stimulus, left/left or right/right) or incongruent (the correct response is on the opposite side to the stimulus, left/right or right/left). In manipulating congruency, the test bears logical similarity with other well-known tests such as the Stroop test (Stroop, 1935) and antisaccade test (Hallet, 1978), and as in those,

participants typically exhibit faster and more accurate responses in congruent (relative to incongruent) trials, a phenomenon referred to as the *Simon effect* (Craft & Simon, 1970; Simon, 1969; Simon & Berbaum, 1990; Simon & Rudell, 1967).

Within the framework of dual route models (e.g., Kornblum, Hasbroucq & Osman, 1990), the Simon effect is generated by the parallel activation of two routes from perception to action. The *conditional* route is determined by the task instructions, and is therefore under top-down, volitional control. In contrast, the *unconditional* route is a bottom-up, automatic and comparatively rapid process activated purely by stimulus location (de Jong, Liang, & Lauber, 1994; Eimer, 1995; Kornblum, 1994; Kornblum, Hasbroucq, & Osman, 1990; Ridderinkhof, 2002b; Wiegand & Wascher, 2005). As a result, participants performing the Simon task automatically align their motor response to the location of the relevant stimuli. In incongruent trials, where the correct response is mapped to the opposite side of space from the stimulus location, the response is slowed due to the demand for top-down strategic control (de Jong et al., 1994; Eimer, 1995; Ridderinkhof, 2002b; Wiegand & Wascher, 2005).

An advantage of the Simon task over many other standard experimental methods is that it does not require modification for different age groups (it is neither trivially easy for an adult, nor extremely difficult for a child). Across a series of studies targeting young children, adults and the elderly population, Bialystok and colleagues demonstrated a significant bilingual advantage over monolinguals in response times on *both incongruent and congruent trials* (Bialystok, 1999; Bialystok & Martin, 2004; Bialystok et al., 2004; Carlson & Meltzoff, 2008; Martin-Rhee & Bialystok, 2008). This observation raises the possibility that the observed advantage is broader than a straightforward enhancement in inhibitory control (which, intuitively,

would predict better performance on incongruent trials only). More problematic for claims of a universally applicable bilingual advantage is that an attenuation or absence of a bilingual advantage in cognitive control is sometimes observed within the young adult population (Bialystok, Martin & Viswanathan, 2005; Bialystok, Craik & Ryan, 2006), perhaps due to developmental factors (e.g., when rate of higher level cognitive development is at its peak, differences in executive processing may be more difficult to detect).

Nonetheless, the cumulative evidence base from a large number of studies that employed the Simon task has indicated that the use of two (or more) languages throughout the lifespan confers a general advantage in high level cognitive abilities, such as inhibition/control of task-irrelevant interference, updating of working memory content and cognitive flexibility. Bialystok and colleagues (2004) further proposed the hypothesis that lifelong experience of managing two languages in a single mind might attenuate the decline of cognitive processes as age increases, a theory that seems to be supported by some recent studies (e.g., Alladi, Bak, Duggirala, et al., 2013; Bak & Alladi, 2014). Other measures have also been used, some of them arguably more sensitive than the Simon task (e.g., the attentional network task, ANT; Fan et al., 2002). In almost three decades, the bilingual advantage has been reported in many studies conducted by different groups of researchers across the world. However, in the last ten years, new counter-evidence has shaken this line of research.

*Is the weight of evidence for a bilingual advantage solid and consistent?*

Many studies reporting a bilingual cognitive advantage can justifiably be criticized. In their comprehensive systematic review, for example, Hilchey and Klein



(2011) report that the cumulative evidence for a bilingual advantage in inhibitory control is very limited, but that there may be a broader executive processing advantage. In a more recent meta-analysis, De Bruin, Treccani, & Della Sala (2015) report an average effect size of  $d = .30$ , indicating a small bilingual advantage in cognitive control, but the authors raise caution in the context of possible publication bias towards confirmatory findings. The issue of publication bias is not, of course, restricted to bilingualism research, but it seems clear that a correction towards equal treatment of research findings, irrespective of directionality, is needed.

In 2007, Morton and Harper challenged Bialystok's findings of a bilingual advantage. They conducted a replication study using the same version of the Simon task and a comparable sample (and sample size) of bilingual and monolingual participants in Canada. They found no performance differences across the groups, but instead reported that socio-economic status was the single best predictor – more important than linguistic experience – of Simon task performance.

More recently, Paap and colleagues (2013, 2015) in the USA and Duñabeitia and colleagues (2014) in Spain attempted to replicate Bialystok's findings using the Simon task, and found no evidence of better performance in bilingual participants. They also tested larger samples in a series of studies targeting different age groups and, again, reported null results.

These findings appear to have polarized the scientific community, arguably resulting in an impasse between the two 'factions', those claiming a bilingual advantage and those refuting its existence altogether. In his dismissal of this field of research, Duñabeitia has suggested that scientists should "do something more important", while, conversely, Bak, who supports the notion of a bilingual advantage, suggested that Paap shows bias and incomplete understanding of the field. The

debate has recently culminated in some authors rejecting the possibility of working with “the other side”, maintaining that “no good collaboration can result”. Full details of this debate, including these quotations, are presented in *The Atlantic* (Yong 2016).

In truth, authors such as Paap and Duñabeitia do not claim that bilingualism is harmful to cognitive development and, indeed, stress the positive and multi-faceted benefits of acquiring multiple languages. Their argument is simply that there is no global, solid or consistent evidence base which favors the existence of a cognitive advantage conferred via the process of becoming multilingual. For these reasons they also reject the claim that using two or more languages in everyday life can delay the onset of dementia, with this delay quantified by Bialystok, Craik and Freedman (2007) to be in the order of 4 years.

These are perfectly reasonable positions to hold, and rejecting them out of hand runs counter to the expected course of scientific inquiry. While comparison among studies is complicated due to variability in designs, test batteries and participant characteristics, the argument stands that the evidence base for a bilingual advantage, particularly in terms of inhibitory control, is limited. (see Paap et al., 2015, for a more exhaustive discussion). To make real progress in reconciling the entrenched claims, we may need a new framework, broad and detailed enough to capture interactions between cortical and neocortical development, environmental and sociocultural variables. Recent work has also addressed the possible role of genetics in cognitive control within and between different populations, such that the systematic variability in distribution of specific allele frequencies between monolingual and bilingual groups may contribute to observed differences in executive function (Hernandez, Greene, Vaughn, Francis, & Grigorenko, 2015). We therefore suggest that future frameworks must incorporate the ways in which these variables interact differentially

throughout development, such that the impact (if any) of multi-language acquisition on cognition might be predicted for a given individual at a given stage of development.

### **Bilingualism and neuroimaging**

Neuroimaging techniques may help reveal the loci of verbal control mechanisms and identify possible structural differences between the monolingual and the bilingual brain (e.g., Abutalebi and Green, 2008). Language processing involves the typically left lateralized perisylvian language network (Broca's area in the inferior frontal lobe, Wernicke's area in the superior posterior temporal lobe, and the arcuate fasciculus connecting the two) as well as the caudate nucleus, superior frontal gyrus, and superior longitudinal fascicle for speech acts (Friederici & Gierhan, 2013). In addition to this general language network, which is activated during listening and speech tasks, linguistic knowledge may draw on Heschl's gyrus (for phonology) and amodal association areas (for semantic vocabulary). This language network is activated in both bilinguals and monolinguals. However, according to Green's (1998) Inhibitory Control hypothesis, to inhibit activation of non-target lexical representations during language production, bilinguals additionally recruit *domain-general* inhibitory control mechanisms in dorsolateral prefrontal cortex (DLPFC).

Evidence in support of this theory came from a study by Blanco-Elorrieta and Pylkkanen (2016), which demonstrated that whereas switching languages in comprehension recruits language-specific control processes in anterior cingulate cortex (ACC), switching languages in *production* draws upon *domain-general* executive control processes in DLPFC (see also Hernandez, 2009; Hernandez, Dapretto, Mazziotta, & Bookheimer, 2001). In other words, managing two or more

languages during production frequently recruits, and thus strengthens, a domain-general executive control resource. This may explain why bilinguals have been reported to outperform monolinguals in tasks that require executive control. Other research has focused on the importance of fronto-striatal connectivity in the conferring of persistent cognitive advantages associated with multi-language acquisition (e.g., Wattendorf et al., 2014; see Stocco, Yamasaki, Natalenko & Prat, 2014, for a theoretical framework and review).

However, as D'Souza and D'Souza (2016) pointed out, the participants in Blanco-Elorrieta and Pyllkanen's (2016) study were adults and thus well-rehearsed at both comprehending and producing two or more languages. A better test would have probed for a bilingual advantage in participants who could comprehend but not produce language, i.e., preverbal infants between 6 and 12 months of age (D'Souza & D'Souza, 2016). If preverbal infants show a bilingual advantage, then Green's (1998) inhibitory control theory requires revision. As it so happens, 6- and 7-month-old infants exposed to a bilingual environment have been probed for a bilingual advantage and, contrary to Green (1998), demonstrate better executive control than their monolingual peers (e.g., Kóvacs & Mehler, 2009).

Kovelman, Baker, & Petitto (2008) found, in an fMRI study, that DLPFC and inferior frontal cortex (IFC) were more strongly activated in bilingual adults than monolingual adults when undertaking a syntactic sentence judgement task (see also Jasinska & Petitto, 2014, for evidence of increased activity in rostralateral prefrontal cortex[RLPFC]). Structural differences between bilingual and monolingual adults have also been identified in other areas of the frontoparietal network (e.g., increased grey matter density in the inferior parietal cortex (IPC), related to age of acquisition and proficiency; Mechelli et al., 2004; see also Della Rosa, Videsott, Borsa, Canini et

al., 2013, and Grady, Luk, Craik, & Bialystok, 2015), as well as basal ganglia (e.g., increased grey matter volume and density in left caudate nucleus; Zou, Ding, Abutalebi, Shu & Peng, 2012; see Li, Legault, & Litcofsky, 2014, for review) and the posterior paravermis of the right cerebellum (Filippi et al., 2011).

Although a developmental study is critical for interpreting these neuroimaging data, we can speculate that differences in the frontoparietal network (e.g., DLPFC, IFC, RLPFC, IPC) account for enhanced attentional and cognitive control in bilinguals, while functional/structural differences in caudate nucleus and cerebellum, both of which are connected to prefrontal cortex, confer benefits in switching ability and interference control. However, a developmental study would be needed to elucidate how these networks emerge over developmental time. For example, the dorsal anterior cingulate cortex (dACC) is part of the frontoparietal network in children but gradually detaches and becomes embedded in the cingulo-opercular network in adults, so it may be domain-general in children but domain-specific in adults (D'Souza & D'Souza, 2016; Fair, Dosenbach, Church et al., 2007). Thus, the neural networks underpinning executive functions evolve over the lifespan, once more highlighting the importance of adopting a developmental approach in order to identify structural and functional characteristics underpinning differences between bilingual and monolingual cognition which operate at a given time.

### **A developmental approach to bilingual research**

Models of bilingual language processing in the bilingual brain such as the one proposed by Green and Abutalebi (2008, 2013) provide useful frameworks for understanding neurocognitive adaptation to the demands of bilingual communication but they are not developmental accounts: they describe how processing may occur in

the *adult* brain. A critical but unresolved issue, therefore, is how multilinguistic experience impacts on crucial cognitive processes *across the lifespan*, from infancy to old age. Related issues include i. the point in time at which divergence in executive function in monolinguals and bilinguals begins; ii. how these differences evolve in young adulthood; iii. the factors determining whether, and the extent to which, bilingualism protects the brain from age-related cognitive deterioration.

Neuroconstructivism is a theoretical framework that seeks to understand the multi-dimensional dynamics of development by integrating research from various levels of analysis (e.g., genes, brain, cognition, behavior, social context; Mareschal, Johnson, Sirois, Spratling et al., 2007). New cognitive abilities are claimed to arise from context-dependent interactions that occur both within the child (e.g., between neural systems) and between the child and the environment (e.g., when the child selects a new object to explore). Moreover, because contexts change over time, proponents of neuroconstructivism seek to understand cognitive development by tracing higher-level cognitive functions back to their low-level roots in early childhood (Karmiloff-Smith, 1998). This is an important research strategy because changes in neural structures early in development are likely to constrain the emergence of later developing neural structures. For instance, if a group of neurons are recruited to process a child's first language, and the response properties of the neurons become increasingly selective to processing stimuli from that first language (a developmental process called 'specialization'; Johnson, 2011), then the ability of that coalition of neurons to process a second language will decrease over developmental time. This is due to 'neural commitment' (Kuhl et al., 2006). As an analogy, consider how, if we tune a radio to receive a particular signal, then this reduces its chances of picking up any other signal. Likewise, if a population of

neurons becomes specialised for responding to a particular set of stimuli early in development (e.g., spoken English), then this will alter their ability to respond to a different set of stimuli later in development (e.g., spoken Italian).

Thus, if we are to accept these theoretical claims, it is imperative to investigate multiple cognitive and non-cognitive domains so that we can work towards a comprehensive understanding of the complexities of language development - which is both constrained and underpinned by interdependencies among dynamically evolving internal (e.g., attention, memory) and external (e.g., social interaction) factors (see D'Souza, D'Souza, & Karmiloff-Smith, 2017, for further discussion).

What happens early in development may affect what can occur later in development (see D'Souza & Karmiloff-Smith, 2016), and for this reason, any broad theoretical consideration of the bilingual advantage will most likely be inadequate unless it incorporates a developmental perspective. The neuroconstructivist approach is critical for progress in bilingualism research because current models are based on the adult brain and the theoretical frameworks do not incorporate early development. To develop a more nuanced understanding of the bilingual advantage, researchers must investigate across domains and developmental time. As an example, we might consider the inhibitory control hypothesis (ICH). According to this model, the bilingual advantage arises because managing two languages during language production draws upon, and thus strengthens, inhibitory control mechanisms. Some studies comparing monolinguals and bilinguals on measures of inhibitory control (i.e., static snapshots of differences between two groups of participants) provide support for the ICH. The neuroconstructivist approach, however, places development at the heart of explanatory accounts. As neuroconstructivists, we take the position that bilinguals and monolinguals may exhibit differentially constrained developmental

trajectories. That is, one set of developmental constraints may operate in bilinguals, while a different set may operate in monolinguals. These developmental constraints may lead to an inhibitory control advantage in bilinguals at one time point (e.g., in adults who must manage two languages during language production) but not at another time point (e.g., preverbal infants; D'Souza & D'Souza, 2016). It is possible that different constraints operate across the lifespan. Indeed, Donnelly, Brooks & Homer (2015) found that whereas bilingual adults show an inhibitory control advantage, bilingual children instead show a more general executive control advantage. It is therefore, in our view, essential to take a neuroconstructivist approach and test different domains across the lifespan.

#### *Raising children in a multilingual environment*

As outlined above, current theories of the bilingual advantage fail to adequately take account of developmental processes. From a neuroconstructivist viewpoint, we argue that development is key to understanding cognition and the bilingual advantage is likely to be underpinned by different mechanisms at different ages. Unlike adult language learners, who have already acquired their native language, we argue that infants who are exposed to more varied, less predictable language input (i.e., persistently hearing two or more languages) and receive less input from each individual language (than is the case in monolingual households), need to process information more efficiently than infants raised in monolingual homes. One possible route to achieving this is to develop an enhanced sensitivity to novelty, such that attention can more easily be switched from familiar to unfamiliar stimuli (D'Souza & D'Souza, 2016). If this hypothesis is correct, then we would expect bilingual infants to show reduced familiarity preference (which is something that helps infants to build



more detailed models) and more novelty preference than monolingual controls. We would also expect them to recall fewer source details than their monolingual peers (because attention is more dispersed among competing sources). If these predictions are borne out, they might help explain why preverbal bilingual infants typically show an advantage, and why the advantage differs between young bilingual children and bilingual adults – with the former showing more of a processing advantage and the latter showing more of an inhibitory control advantage. They might also enable us to account for evidence that bilinguals exhibit reduced metacognitive abilities in comparison to monolinguals (Folke et al., 2016). Current models are simply unable to explain these phenomena.

#### *The effects of multilanguage acquisition across the lifespan*

As discussed, the majority of studies examining cognitive changes associated with bilingualism have been conducted using visual paradigms such as the Simon Task (Bialystok et al., 2004) or the Attention Network Task (ANT) (Costa, et al., 2008). This is rather surprising given that, historically, research on attentional processes and control of interference focused primarily on auditory paradigms (Driver, 2001). Considering that we are routinely surrounded by verbal and non-verbal environmental noise that impacts on concentration and learning (Forster & Lavie, 2008), it is important to investigate whether the bilingual advantage in controlling interference extends to auditory attention.

One of the first studies comparing language comprehension in the presence of verbal noise in highly proficient bilingual and English monolingual adults indicated that bilinguals are disproportionately better at comprehending complex sentences in the presence of auditory linguistic interference (Filippi, Leech, Thomas, Green & Dick, 2012). More recently, these lines of investigation have been extended to

children in order to determine whether this advantage is present early in childhood and, if so, when it emerges (Filippi, Morris, Richardson, Bright, Thomas, Karmiloff-Smith, & Marian, 2015). The authors found that advantages in interference control associated with bilingualism start to emerge at the age of 7 and the size of this advantage increases at least until age 10 (Filippi et al., 2015). Given that the advantage in controlling auditory verbal interference is already observed early in life, we may predict that the areas of the brain involved in auditory processing and control of linguistic interference develop differently in monolingual and bilingual speakers.

As we have seen, recent neuroimaging studies implicate the left caudate and posterior paravermis of the right cerebellum in the control of interference during speech comprehension (Crinion et al., 2006; Filippi et al., 2011), and these areas may be relatively preserved from the effect of ageing in bilingual speakers (Filippi & Karmiloff-Smith, 2013). However, this line of research is currently limited to control of interferences in adulthood. Therefore, a convergence of neuroimaging and behavioral investigations should aim to build a developmental trajectory of control processes and focus on whether there are differences in specific brain regions due to early bilingual experience.

## **Conclusions**

The study of bilingualism has been beset with controversy, generated not only by claims of questionable methodological rigor and control, but also for political and educational reasons. The fact is that high quality investigations of the impact that multilingualism may (or may not) confer on cognitive development are extremely difficult to achieve, given the multitude of alternative explanatory variables that must

be controlled across participant groups, and the dynamically interacting influences that are likely to vary across stages of development from infancy to the end of life.

Further carefully controlled developmental work is clearly needed in order to clarify the mechanisms responsible for observations of a bilingual advantage, and the possibility that different mechanisms operate at different stages of development should not be discounted. Rather than relying on systematic review and meta-analytic approaches with all the attendant problems associated with variable designs, sample sizes, statistical power and questionable control of alternative explanatory variables, we consider it imperative that a large-scale unified program of research is undertaken in which multilingual and monolingual cognition is assessed from infancy through to old age with a coherent and consistent set of assessment tools. This will ensure that – to the maximum extent possible – like is compared with like.

In this article we have encouraged the adoption of a developmental approach that may ultimately resolve intractable positions currently espoused in the literature and lead to a broad and comprehensive understanding of multilanguage processing starting from early life to older age. Future bilingualism research should also incorporate genetics, sociocultural and environmental factors, and extend theoretical frameworks to include atypical development (e.g., autism, ADHD and Down Syndrome). It is our strong belief, that by working towards a comprehensive and genuinely developmental model of the multilingual brain, we will reinvigorate research in this area and drive theoretical progress well beyond the highly simplistic issue of whether the bilingual cognitive advantage is real or spurious.

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