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Bilingualism, executive function, and beyond: Questions and insights

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Bilingualism, Executive Function, and Beyond

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Volume 57

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Edited by Irina A. Sekerina, Lauren Spradlin and Virginia Valian

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Edited by

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Bilingualism, executive function, and beyond

Questions and insights

Irina A. Sekerina, Lauren Spradlin and Virginia Valian
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1. Past

The study of bilingualism has charted a dramatically new, important, and exciting course in the 21st century, benefiting from cognitive science's integration of cognitive psychology, especially work on higher-level cognitive processes often called executive function or executive control, theoretical linguistics, and psycholinguistics. Bilingualism had been a well-established field of research within linguistics and education for several decades (De Groot & Kroll, 1997; Homel, Palij, & Aaronson, 1987), but prior to the 1990s, there was little work on cognitive benefits of bilingualism. This book focuses on possible cognitive benefits, but we note that speaking two languages may have a range of cognitive effects, from creativity (for review, see Kharkhurin, 2018) to perspective taking (e.g., Greenberg, Bellana, & Bialystok, 2013; Liberman, Woodward, Keysar, & Kinzler, 2017; but also see Ryskin, Brown-Schmidt, Canseco-Gonzalez, Yiu, & Nguyen, 2014).

Ellen Bialystok introduced the ideas that the experience of being bilingual had advantages for higher cognitive functioning in children (Bialystok, 1999) and in older adults, delaying dementia (Bialystok, Craik, & Freedman, 2007). The first decade of the 21st century served as the initial phase of research concerning the proposed positive impact of bilingualism on children's cognitive development and its protective effect against age-related neurodegenerative diseases. Researchers hypothesized that the processes required to manage multiple languages would lead to superior executive function. *Executive function (EF)* or *executive control* refer to those cognitive processes that integrate, regulate, and control other cognitive processes, processes such as planning, inhibiting, shifting (from one task or rule to another), and updating (stored material with new material). In one model (Miyake & Friedman, 2012), executive function is seen as result of the complex

interaction of a suite of functions representing both unity – a factor common to all higher level cognition, similar to inhibition – and diversity – the more specific factors of shifting and updating, which show little overlap.

Empirical investigation broadened to include more languages, a wider range of experimental tasks, and social and demographic factors. What began as work primarily on speakers of Indo-European languages such as French, German, and English, developed into work with speakers of more typologically diverse languages, as in the case of the genetically unrelated and geographically distant Mandarin and English (Prior & Gollan, 2011; Yow & Li, 2015), the unrelated, but geographically adjacent Swedish and Finnish (Soveri et al., 2011), and the closely related and adjacent Spanish and Catalan (Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009). A wider range of tasks used to measure executive function was implemented from study to study, but always included one or more of five main tasks (e.g., ANT, antisaccade task, flanker, Simon, and Stroop). Finally, additional non-linguistic social and demographic factors, including bilingual speakers' socioeconomic status (SES) and level of education (Calvo & Bialystok, 2014; Morton & Harper, 2007), were added as moderators that significantly affected the bilingualism-executive function relationship.

Not all research has confirmed the initial findings that bilingualism leads to superior executive function (e.g., Costa et al., 2009; Paap & Greenberg, 2013; Paap, Johnson, & Sawi, 2015), prompting interest in meta- and systematic analyses of the large body of literature on the interaction between bilingualism and executive function (Adesope, Lavin, Thompson, & Ungerleider, 2010; Hilchey & Klein, 2011; Lehtonen et al., 2018; Paap, Johnson, & Sawi, 2015). Those analyses have generally found little if any evidence for the bilingual advantage, especially in young adults. The latest and most comprehensive meta-analysis of 152 studies, including unpublished experiments which compared bilingual and monolingual adults' performance in six executive domains, found no benefit of bilingualism on executive function (Lehtonen et al., 2018). Other reviews have noted that positive findings have been published more often than negative findings (De Bruin, Treccani, & Della Sala, 2015), and that some laboratories more likely than others to report positive findings (Donnelly, Brooks, & Homer, 2015).

A narrative review suggested that bilingualism was just one type of challenging life experience that, along with education, musical training, and active video game playing, could contribute to enhanced executive function (Valian, 2015). Difficulties in seeing a benefit from bilingualism may be due to the presence of concurrent activities that yield cognitive benefits. Valian notes that all the experiences that have been studied have inconsistent benefits, so by parity of reasoning one would either have to say that no activities yield benefits or that they all do, to different degrees in different combinations. Valian also notes that when cognitive

differences between monolinguals and bilinguals *are* found, they are generally in favor of bilinguals.

2. Present

As research has progressed, it has become clear that we need to pay more attention to the variability inherent in bilingualism, in executive function, and in the tasks used to measure executive function. Not all bilinguals are alike, and the type of bilingual experience an individual has may be relevant to tasks where someone does or does not show a benefit of being “bilingual”. Bilinguals vary not just in how balanced their languages are, but in how and when their languages are acquired and used. Some bilinguals, for example, grow up in a bilingual community, some attain another language through choice, and yet others share one language with those at home and another language with those in their wider cultures. Some bilinguals use both their languages every day, and thus switch frequently between their languages, while others use one of their languages less frequently. Since the conditions of bilingualism onset vary enormously, and since the experience of being bilingual varies enormously, it is difficult to determine just which types of bilinguals might show cognitive benefits. Better delineation of which bilinguals show which benefits will help us understand the mechanisms underlying performance.

A bilingual’s languages vary in their morphological and syntactic properties. The linguistic relatedness between a bilingual’s languages vary – Spanish and Catalan are similar in structure; Spanish and Mandarin are not. The relatedness of a bilingual’s languages might or might not have cognitive consequences. Bilingualism may be accompanied by biliteracy or biculturalism – or not. Bilinguals may be immigrants – or not. Depending on the community, bilinguals may be of lower socioeconomic status than monolinguals, of higher socioeconomic status, or of equivalent status. Thus, some of the inconsistencies in whether one finds a cognitive benefit of bilingualism may be due to which bilinguals are being observed. By carefully comparing groups that do and do not show a bilingual advantage, it should be possible to determine which bilingual backgrounds are either necessary, sufficient, or necessary and sufficient. That in turn should make it possible to investigate the underlying mechanisms behind advantages on executive function tasks.

It has also become clear that not all tasks measuring higher cognitive functioning are alike. Different tasks not only measure different aspects of executive functions but inevitably involve other aspects of cognition – such as visual perception – as well (Wimmer & Marx, 2014). Such task impurity makes it difficult to know how to interpret varying results when a suite of tasks is administered. An

experiment may contain a battery of different executive function tasks. Since it is often unclear which aspects of executive function each task measures, it is difficult to make predictions about which tasks might yield superior performance on the part of bilinguals.

Executive function tasks also vary in how difficult they are. Some tasks, like the Simon task, are “easy”. In the Simon task, for example, a participant responds with the right hand to a rectangle of one color and with the left hand to a rectangle of another color. When the rectangle on the computer screen is isomorphic with the hand that is associated with that rectangle (congruent trials), responses are faster than when the rectangle is on the screen opposite to the hand doing the responding (incongruent trials). For adults, the difference in reaction time between the incongruent and congruent trials, known as the Simon effect, or the conflict effect, is relatively small, on the order of 25 ms (Bialystok et al., 2005). The conflict between the side of the computer screen on which the stimulus appears and the side of the body that produces a response requires minimal monitoring. Young adults, whether their language status is mono- or bilingual, find the task very easy after a few trials. Thus, the common failure to find any difference between mono- and bilingual young adults on this task may be due to the general ceiling effect: it is so easy that all young adults can do well. The idea of a ceiling effect applies less well to tasks like the flanker task, which yield larger conflict differences (on the order of 80 ms), and where it would seem possible to show group differences.

Any given task involving executive functions typically allows for a suite of different measures. The Simon task, for example, provides accuracy and reaction time data for performance on congruent trials and for performance on incongruent trials. One can measure accuracy and speed for both types of trials, or measure the *difference* in accuracy or reaction time (or both) between congruent and incongruent trials. Computation of a large number of dependent measures can create statistical issues, as they increase the likelihood that at least one comparison will be significant. Some, but not all, studies adjust the *p* value accordingly.

The same basic task can also be made harder or easier. The flanker task, for example, requires participants to identify the direction of a central arrow which may be flanked by arrows aligned in the same direction or the opposite direction by pressing a key on the right side of the keyboard if the arrow is pointing right and a key on the left side if they arrow is pointing left. That task can be interspersed with a go/no-go task in which participants respond if the arrow is surrounded by diamonds but do not if it is surrounded by Xs. The “normal” flanker task is harder in trial blocks where it is combined with the go/no-go task than when it is the only task. Thus, one can compute the difference between congruent and incongruent flanker trials in different blocks. There, too, the statistical problem of multiple comparisons exists.

Another statistical issue involves comparisons across tasks. The Simon and flanker tasks appear very similar at one level – they both involve a conflict related to spatial direction (side of the screen for the Simon and direction of an arrow for the flanker). The Simon conflict is spatio-motor: the rectangle requiring a right key press may be either on the right or left side of the screen. The flanker conflict is perceptual: the arrow that should be guiding the response is either in the same direction or the opposite direction as the flanking arrows. One might expect performance on the two tasks to correlate, but it does not. Not all “conflict” tasks are the same.

Finally, it has become clear that the differing language experiences of mono- and bilinguals may be seen in different patterns of brain activity, even when differences are not observed in behavior (Xu, Baldauf, Chang, Desimone, & Tan, 2017). Brains may accomplish the same task in different ways, depending on their experiences, but produce the same behavioral output.

To sum up, the inconsistencies in whether responses in executive function tests show an advantage for bilinguals compared to monolinguals may be explained by many different factors, including, of course, the possibility that there is no difference between monolinguals and bilinguals at all.

3. This volume

The papers in this volume continue the quest to investigate the moderating factors and understand the mechanisms underlying effects (or lack thereof) of bilingualism on cognition in children, adults, and the elderly. They grew out of a 2015 workshop organized by two of us (Irina Sekerina and Virginia Valian) at the Graduate Center of the City University of New York, funded by NSF’s Developmental and Learning Sciences and Linguistics Programs (grant #1451631).

The workshop’s goal was to bring together researchers whose fields did not always overlap and who could learn from each other’s insights. In attendance were linguists working on bilingualism, cognitive psychologists interested in executive function and working memory, and medical researchers studying executive function in the laboratory and in the field. Until our workshop, the conditions and factors instrumental to connecting bilingualism and executive function were primarily explored from within bilingualism, with less direct input from cognitive psychologists, linguists, and researchers on aging. Thus, our goal was to bring together experts from different disciplines – who rarely had the opportunity to interact at the same scientific venues – and facilitate interdisciplinary conversation that could bridge the gaps between the fields.

Eleven papers from that workshop were published in 2016 in a special issue of *Linguistic Approaches to Bilingualism* 6(5) are reprinted here (Bak; Bialystok;

Clahsen & Verissimo; Friedman; Gathercole et al.; Hofweber, Marinis, & Treffers-Daller (1); Klein; Marton; Sorace; Valian; Watson, Manly, & Zahodne). Nine posters from the workshop were written up and are published here for the first time (*Beatty-Martinez & Dussias; Hofweber, Marinis, & Treffers-Daller (2); Kim, Marton, & Obler; Marton & Yerimbetova; Nadig & Gonzalez-Barrero; Poarch & van Hell; Whitford & Luk; Wolleb, Sorace, & Westergaard; Zirstein, Bice, & Kroll*). These 20 chapters are grouped in four parts: Part I *Beyond Simple Relations*, Part II *Language Processing*, Part III *Cognition and Bilingualism*, and Part IV *Development, Aging, and Impairment*.

Part I, *Beyond Simple Relations*, contains five chapters by *Bialystok, Zirnstein et al., Beatty-Martinez and Dussias, Whitford and Luk*, and *Bak* that provide a theoretical synthesis. In addressing the inconsistencies in findings of a bilingual advantage (see Section 2 *Present*), they suggest – sometimes explicitly and sometimes implicitly – that we need to take those inconsistencies into consideration to arrive at a more nuanced understanding of the specific contexts and the specific properties of mono- and bilinguals and to understand the relation between bilingualism and cognition.

Ellen Bialystok, the author of the bilingual advantage hypothesis, opens up the volume with a chapter on the null results reported in the literature for young adults and explains them by the types of bilingual experiences that lead to cognitive benefits and statistical analyses that should be appropriate. In a similar vein, Megan Zirnstein and colleagues argue that the positive cognitive consequences of bilingualism critically depend on variation in language experience in adult language learning, processing, production, and code-switching. Moreover, the complex nature of this relationship sometimes is not revealed in behavior but only in brain activity that shows neural differences between mono- and bilinguals. Anne Beatty-Martinez and Paola Dussias provide a comprehensive overview of the cognitive implications of the fact that a bilingual's languages are simultaneously active and discuss adaptation and the permeability of the bilingual language system. They suggest a multivariate view of which factors mediate the recruitment of language and cognitive processes in bilinguals.

Veronica Whitford and Gigi Luk specifically address the question of why between-group comparisons of monolingual and bilingual participants' performance on executive function tasks are insufficient. They argue that bilinguals' interaction with their environments differ in their two languages, reflecting the importance of specifying the criteria for separating participants into different groups and carefully considering the types of statistical analyses that are appropriate. Closing Part I is Thomas Bak's discussion of the importance of linking variability in results to specific circumstances, such as culture. He suggests that different findings in experimental studies that have tested bilingualism and executive function

should be regarded in a positive light, as a reflection of the larger contexts in which bilingual people live.

In Part II, *Language Processing*, authors in six chapters address more specific aspects of language processing in monolinguals and bilinguals, ranging from the mechanisms of on-line language processing to sensitivity to different domains within grammar to the relation between code-switching and executive function. Jungna Kim and colleagues provide an overview of the mechanisms underlying interference control in auditory processing as well as the factors that influence the difficulty of listening in a second language, concentrating on listeners' use of contextual knowledge and their proficiency in their second language. They also consider how interference control mechanisms and listener variables may interact with respect to the existence of a bilingual advantage in auditory processing.

Speaker-hearers do not simply use *language*, considered as an undifferentiated whole, but integrate all the different parts of language, from phonetics to prosody to morphology to syntax to semantics. A methodological implication is that it is necessary to attend to different domains within language, and not speak generally of *language*, when assessing differences between mono- and bilinguals. For example, all native speakers make use of morphological regularities, and distinguish between inflectional morphology (such as the past tense *-ed* in English) and derivational morphology (such as the *-ment* that turns the verb *derange* into the noun *derangement*). Harald Clahsen and João Veríssimo investigate the influence of masked priming on processing of inflectional and derivational morphology and show that age of acquisition of a second language differentially affects bilingual speakers' sensitivity to morphological structure. Antonella Sorace explores the effect of bilingualism at the sentential level and shows that monolingual and bilingual use of pronouns is neither exactly the same nor totally different. Both studies suggest the need for a more in-depth look at the components of language, and the cognitive processes necessary to integrate them and use them appropriately in context.

Psycholinguistic methods, such as priming, first developed to investigate native-language processing, can be used to investigate the effect of cognitive mechanisms, such as inhibition, on cross-language priming. Anna Wolleb and colleagues argue that cross-language priming is a useful tool for determining whether bilingual language control processes and executive control processes overlap. They compare between- and within-language priming in balanced-bilingual children and find a correlation between language control and executive control in cross-language priming. They conclude that, while the exact nature of bilingual language control and its relationship to domain-general executive control remains unclear, bilingual language control is involved in language processing and is taxed more heavily in bilingual contexts.

In two chapters, Julia Hofweber and colleagues use code-switching – the switch within a communication from one language to another – to explore the relation between a bilingual’s languages and executive function. They compare two different ways of measuring code-switching, investigate the relationship between code-switching and performance on an executive function task, and compare speakers with different degrees of mastery of their second language. They find that morphosyntactic control processes activated during dense code-switching involve some form of inhibitory control, depending on whether monitoring of co-activated languages is high or low.

The four chapters in Part III, *Cognition and Bilingualism*, specifically address executive function. Naomi Friedman, an author of the multicomponent model of executive function, describes the latest version of this model. It includes a common executive function component and separate updating and shifting-specific functions. Friedman argues that even the best-designed tasks cannot measure a single component of executive function to the exclusion of others because executive functions are difficult to isolate. Gregory Poarch and Janet van Hell address the convergent validity across two different executive function tasks, namely, the Simon and the Attention Network Task (~~similar to the flanker task~~), in their experiments with bilingual children. Their re-analysis of ~~the~~ earlier results showed no correlation between the two tasks. Similar findings from other laboratories (Paap & Greenberg, 2013) suggest the importance of analyzing exactly what cognitive processes different tasks measure.

The remaining two chapters, by Virginia Valian and Raymond Klein, express critical views of the bilingual advantage in executive function. Valian advocates for the position that bilingualism does confer a cognitive benefit, but that such a benefit coexists with and complements other life-enriching experiences such as education, musical training, and video game playing. She argues that the lack of fine-grained task analyses and the absence of a formal theory of the cognitive mechanisms underlying multilingualism muddies the waters when it comes to developing and testing hypotheses. Klein offers a personal story of his interest in the effect of bilingualism on executive function. He describes how the current evidence that weakened this connection has transformed him from an advocate of the bilingual advantage hypothesis to a skeptic about positive effects of bilingualism on executive function.

Part IV, *Development, Aging, and Impairment*, specifically addresses the relation between bilingualism and executive function in special populations. Three chapters (*Marton; Gathercole et al.; Marton & Yerimbetova*) are dedicated to typically developing bilingual children, and one chapter (*Nadig & Gonzalez-Barrero*), to children with autism spectrum disorder (ASD). The final chapter in the volume (*Watson, Manly, & Zahodne*) is about the effect of bilingualism in the elderly.

Klara Marton summarizes what is known about the bilingual advantage in children; for children the benefits of bilingualism on executive function are somewhat less controversial than for young adults. She analyzes factors such as age, language proficiency, culture, socioeconomic status, and variation in the specific executive functions and tasks. She demonstrates that these factors interact to produce varying outcomes on tests of executive functions in children. In the following chapter, Klara Marton and Zhamilya Yerimbetova focus on reaction time tasks measuring specific cognitive control components. They examine the individual and combined interactions between processing speed, cognitive control, age, and bilingualism vis-à-vis individual differences and task-specific features to determine whether shorter reaction times reflect bilinguals' superior global processing or more efficient cognitive control.

Virginia Mueller Gathercole and colleagues investigate the complex interaction among age, socioeconomic status, and bilingualism. Using a large data set containing five age groups (ages 4 to 70+) of monolingual and bilingual speakers from a homogenous Welsh community allowed the authors to eliminate such confounding variables as cultural and geographic variability. Performance on cognitive tasks was affected by age for young children and the oldest adults (70+), whereas general language ability affected the other three groups. Once age and general language ability were accounted for, there was minimal impact of bilingualism on executive function. Finally, Caitlin Watson and colleagues review the studies on bilingualism as a predictive factor in cognitive aging. They use a prospective design with a community sample to determine whether elderly bilinguals show better executive functioning than monolinguals and whether they are slower to become demented. There is some evidence for the former but none for the latter. They recommend using a prospective, longitudinal, community-based design that measures both cognitive level and rate of cognitive decline to improve future research at the intersection of bilingualism, cognitive decline, and aging.

4. Future: Where is the field going?

Future research in cognition, we suggest, will increasingly attend to the question of the modularity of higher cognitive functions, investigating the extent to which cognitive processes invoked in one domain, like bilingualism, transfer to a more general domain, like nonverbal executive functions. Similar questions exist in other areas of cognition. For example, there has been controversy over whether training working memory transfers to other domains, including those that are thought to require working memory, such as tasks that measure fluid intelligence (Foster et al., 2017; Shipstead, Redick, & Engle, 2012). In another example, there is similar

controversy surrounding whether active video game playing has benefits for higher cognitive functions (Sala, Tatlidil, & Gobet, 2018). Although the issue is not settled, a case can be made that transfer only occurs between tasks that are very similar to each other and that far transfer does not take place (Sala et al., 2018). Several suggestive reports in bilingualism find a dissociation between ability to switch between languages and ability to switch on a cognitive task (e.g., Calabria, Hernández, Branzi & Costa, 2012; Calabria, Branzi, Marne, Hernández & Costa, 2015; Weissberger, Wierenga, Bondi & Gollan, 2012).

If it turns out that the cognitive processes involved in managing bilingualism are largely restricted to bilingualism itself, we will learn something important and exciting about domain specificity and domain generality. Although few hypotheses have made as much intuitive sense as the analogy between switching languages and switching general rules or inhibiting the possible interference from another language and inhibiting a prepotent response, we may discover that cognitive domains are more sequestered and separated than we thought and that the mind is massively modular (for review, see Samuels, 2012).

Future research on the relation between bilingualism and cognition will also increasingly attend to replicability (Simmons, Nelson, & Simonsohn, 2011) and experimenter degrees of freedom. Research on bilingualism and cognition is a good example of multiple experimenter degrees of freedom. Our earlier discussion of the many different types of bilinguals, the many different age groups, the many different tests of executive function, and the many different measures within each test, demonstrates the difficulty researchers find themselves presented with. It is obviously important to know just which bilinguals under just which conditions will show cognitive benefits on just which tests, but each variable provides many experimenter degrees of freedom. Full reporting (Wicherts et al., 2016), exact replications (Simons, 2014) conceptual replications (Marsden, Morgan-Short, Thompson, & Abugaber, 2018; Stroebe & Strack, 2014), advance specification of moderator variables (Harris, Pashler, & Mickes, 2014), large samples (Button et al., 2013), and use of *p*-curves (Simonsohn, Nelson, & Simmons, 2014) will help. Adherence to such principles may reduce number of publications, because more time will be needed to ensure, for example, large samples. Maybe that is a good thing (Nelson, Simmons, & Simonsohn, 2012).

Another suggestion is to conduct “multiverse” analyses (Steege, Tuerlinckx, Gelman, & Vanpaemel, 2016) to handle the problem of many arbitrary choices. In bilingualism, for example, those choices include measurements of bilingualism (e.g., self-report, picture-naming task, grammar tests, and so on), division of participants into different groups based on those measures, and choice of analyses to conduct. In a multiverse analysis one does every combination – which may be hundreds or thousands – and tabulates the results. That allows

researchers to see how strong a phenomenon is and which analytic decisions had major consequences.

Despite the difficulty of conducting multiverse analyses, the study of bilingualism and cognition will increasingly include them because of the host of arbitrary decisions researchers make. A study of bidialectalism that conducts a multiverse analysis will, we predict, be the first of many (Poarch, Vanhove, & Berthele, 2018). Poarch and colleagues compared bidialectals' performance on the Simon and flanker tasks, predicting that the more balanced participants were between Swabian and German, the smaller a conflict effect they would experience on both tasks. Participants ($n = 35$) were given a score according to how dominant they were in Swabian compared to German. The authors' initial hypothesis was disconfirmed; stronger use of Swabian predicted smaller conflict effects, a result that could become the basis for later studies. Poarch and colleagues ran 2560 analyses, varying the values of the arbitrary decisions they had made. They concluded that their null results (relative to their original prediction) were not due to the various arbitrary decisions that they made.

Finally, as anyone with experience with more than one language knows, one's world is enriched in innumerable ways by speaking more than one language. Whether it is something as small as the ability to make cross-linguistic puns or as big as direct access to literature or film in another tongue, bilingualism confers many benefits. Future research will no doubt explore those benefits.

Our predictions for the future, in sum, are that researchers will delineate which types of linguistic experiences show far transfer in cognition, will undertake more work to determine the breadth and stability of their results, and will expand their inquiries.

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