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AUTHOR'S RESPONSE

Bilingualism and cognition: A focus on mechanisms*

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The goal of my keynote article, "Bilingualism and Cognition" (Valian, 2014), was to resolve the inconsistencies in effects of bilingualism on executive functions, whether the individuals were children, young adults, or old people. To summarize (and sharpen) my argument:

1. Especially in children and young adults, benefits of bilingualism for executive functions are not reliable. In old people, there are benefits for executive functions but contradictory results on delay of cognitive impairment, depending on whether studies are retrospective or prospective.
2. All experiences that have benefits for executive functions and aging – and there are many – yield inconsistent effects. Bilingualism is not alone.
3. Three reasons for inconsistencies in bilingualism and other experiences are:
   a. Executive function and cognitive reserve are broad cover terms for a variety of mechanisms, most of which are ill-understood. Because we mean different things by 'executive function' from one experiment to the next, we can both think we don't have an effect when we do and think we have an effect when we don't.
   b. Tasks are impure: apparently similar tasks measure different aspects of executive function and measure other aspects of cognition as well. Because we lack a good analysis of tasks, we too often do not know what we are measuring. I encourage readers to examine the demos in the supplementary materials of the keynote article to see for themselves what the tasks are like.
   c. Individuals engage in many different activities that may be on a par with bilingualism in their benefits.
4. Different types of bilingual experience are unlikely to explain the variability of findings, given the inconsistencies in extant data on varieties of bilingualism.
5. There is a benefit of bilingualism, but bilingualism competes with other sources of benefits. Especially for children and young adults, whose daily lives are full of cognitively enriching and challenging experiences, we should expect variability in effects of being bilingual.
6. The way forward is to focus on underlying mechanisms.

There was broad agreement on some parts of my argument, such as that executive function is not monolithic, nor are the tests purporting to measure different aspects of it. Similarly, many commentators agree that methods could be improved, although they have different suggestions for how those improvements should take place. The most important commonality across the commentaries and my keynote is the focus on understanding the mechanisms underlying effects of bilingualism on cognition. Several commentators explicitly or implicitly call for more interdisciplinary work. I heartily agree.

My reply is directed to those aspects of the commentaries that directly addressed or criticized my argument.

Executive function and the tasks that measure it

In the keynote, I adopted a particular model of executive function (Miyake & Friedman, 2012) without any argument or review of other models. As Costa, Hernández and Calabria (2014) and Kroll (2014) point out, there are other models. My choice was not completely arbitrary: I think that Miyake and Friedman have provided the most structured analysis. But I agree that there is much more to be said about executive function. I echo Costa et al.'s suggestion that the field will benefit by having more input from cognitive psychologists who work on executive function. I do so while also agreeing with Mishra (2014) that cognitive psychology does not currently offer us everything we need. An explicit discussion of different conceptions of executive function and its components, and the implications of different conceptions for work in bilingualism, is, to my mind, overdue. In the meantime, I suggest that we stop using the term 'executive function' (even though I do so throughout this reply, where possible in the plural) and instead be more precise about which

* I thank the commentators! They have provided a rich set of suggestions about how to think about the current data and where to go next. I wish I could do justice to the full range of ideas that they have proposed, but time and space constraints prevent that. This work was supported in part by a grant from the National Science Foundation (BCS-0236700).

aspect(s) of executive function we think we are measuring, a suggestion in line with Mishra's (2014) viewpoint.

Marton (2014) emphasizes the need for theoretical models that integrate bilinguals' cognitive and linguistic processes. I agree. She recommends eschewing global tests of executive function such as the Stroop, noting that it has variously been claimed to measure interference, speed of processing, automatic response inhibition, and ability to maintain goals and resolve conflicts (in turn dependent on working memory capacity). Instead, she recommends using tests of specific aspects of executive function. I agree, but I am less sanguine than Marton that we can find a test – aside, possibly, from delay of gratification – that measures only a single aspect of executive function.

Kroll (2014) suggests that meta-executive function might be more influenced by bilingualism than are the individual components, a possibility worth further investigation. Kroll also suggests that rather than looking narrowly at the relation between bilingualism and executive function, we should focus on how mono- and bilinguals process language. Titone, Pivneva, Sheikh, Webb and Whitford (2014) review work from their laboratory giving an example of how that could take place. Their work demonstrates that different executive function tasks are linked to different aspects of word processing in bilinguals. They thus suggest examining how bilinguals' language processing is related both to bilingual experiences and to executive function. Mishra (2014) also presents work showing that response modality matters and recommends paying more attention to processing and the contexts in which processes takes place. I agree.

Individual differences

If, as I claim, one source of variability is the number of different cognitive challenging activities that individuals may engage in, more attention to individual differences would be required (Costa et al., 2014). As with understanding executive function and the tasks that measure it, understanding individual differences would be aided by more input from researchers who specialize in that area. I agree.

Bilingualism

Many commentators suggest that I am too quick to dismiss variations in bilingualism as a factor in the inconsistency of results. The reason for my skepticism is the variability in the results to date: sometimes late second-language learners show benefits, sometimes "balanced" bilinguals don't; sometimes proficiency matters, sometimes it doesn't (as Paap, 2014 also notes). Although I have not detected generalizations that hold across experiments, I agree with Kaushanskaya and Prior (2014), Kroll (2014), Luk (2014), Mishra (2014), and Zahodne and Manly (2014) that a more systematic exploration of varieties of bilingualism will improve experimentation.

Luk (2014) refers to a multi-dimensional spectrum that involves, at a minimum, how speakers' languages were acquired, how extensively they are used at present, their proficiency in each language, the social contexts in which they use each language, and so on.[1] Titone et al., (2014) and Mishra (2014) mention that effects of bilingualism may also vary depending on geography. Mishra suggests including comparisons between proficient and less proficient bilinguals, or frequent vs less frequent language switchers, in contexts, such as India, where monolinguals do not exist. My caveat is that with so many possible categorization schemes, the choice of scheme(s) has to go hand-in-hand with hypotheses about the mechanisms underlying superior task performance. Different tasks and different functions may benefit from different experiences.

In comparing bilingualism with other benefits to executive functions, Mishra (2014) considers the differences in what aspects of cognition are involved. Language, she suggests, is intentional and creative in a way that exercise and video game playing are not; language (at least one's first language) is acquired extremely early. I would add that language has many more applications than other activities do and that speaking and listening are richer than most other activities, because language is beautifully tied to thought. Language has a formal structure that people acquire effortlessly. Language is special. All of those facts hold for any speaker, mono- or bilingual. I think the question is whether having multiple languages provides cognitive advantages over and above those provided by having one, a question that Paap (2014) answers with no. Although my answer is a qualified yes, it is not based on any of the properties that make language special. The fact that language acquisition is effortless, while managing more than one language is effortful, suggests to me that it is something about the effort involved that gives bilingualism its advantages over monolingualism.

The brain

Several commentators refer to neural differences that might elucidate (or cloud) the connection between executive function and bilingualism (Kroll, 2014; Luk, 2014; Paap, 2014; Titone et al., 2014; Zahodne & Manly,

[1] Luk (2014) refers to a study by Macnamara and Conway (2014) that I did not cite because there was no control group, only a comparison of before- and after-training in interpreting ASL. Two years of any intense college experience might have an equivalent effect on monolingual students.

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2014). Kroll, for example, recommends a fine-grained neural and cognitive analysis of on-going processing. Whether such analyses will reveal the mechanism of cognitive benefits remains an open question. At present, the findings are inconsistent and there is no clear correspondence between cognitive and neural mechanisms.

Poeppel (2012) refers to the *maps problem* and the *mapping problem*. The *maps problem* between brain and behavior is that spatial and temporal localizations in the brain provide correlations but not explanations of behavior. In the case of bilingualism, those correlations are still inconsistent, which may mean we are not conceptualizing the relation properly. But even if, contrary to current fact, it were possible to perfectly localize function and identify processing streams, that achievement would not constitute an explanation of the mechanism: it would still be a correlation. The *mapping problem* is the absence of linking hypotheses to connect bilingual language processing with neural processing. The vocabulary of the two domains is different. The vocabulary of bilingual language processing includes terms like "word retrieval" and "code-switching"; the vocabulary of the brain includes terms like "increased firing" and "network patterns". Those are incommensurate and require a theory that will link them (Poeppel, 2012). Thus, although studies of the brain contribute to our understanding of bilingualism, they are not a privileged form of contribution.

Existence of bilingualism benefit

My keynote concludes that there is a cognitive benefit, but that it can be swamped by other experiences. With respect to executive functions, two commentators are less convinced. Klein (2014) shows that the studies using the Simon or flanker tasks from 2005 to 2014 do not find that bilinguals show less of a cost on incongruent compared to congruent trials. Differences between mono- and bilingual participants hover around 0. Although the preponderance of studies show that bilinguals are faster on congruent trials than monolinguals are, more recent studies show less of an advantage. Klein concludes that there is no way of determining whether there is an effect. Paap (2014) is more skeptical and claims that bilingual advantages tend to be absent in large samples. "Large" is a somewhat relative term, since some studies with hundreds of participants include several different age groups or several different types of bilinguals, making the sample size per group relatively small.

In my conclusion that bilingualism has a benefit I am motivated in large part by parity of reasoning. If we throw out bilingualism, we have to throw out a lot of other cognitively challenging activities, too: they all have inconsistent effects, even education. I find the possibility that there are no experiences that lead to better executive function to be implausible. Thus, my preference is to determine more clearly under what conditions bilingualism – *and* other experiences – show an effect on executive function.

With respect to dementia, two other commentators are skeptical. Zahodne and Manly (2014) and Mishra (2014) find the failure of prospective studies to show a delay in dementia among bilinguals to be definitive. I am not quite as quick to dismiss the retrospective studies as they are, although such studies have what I call, in the keynote, the complement class problem – we do not know the characteristics of the people who do not go to memory clinics. I think we need to know specifically why very different retrospective studies in different settings nevertheless tend to find a benefit, sometimes of two and sometimes of more than two languages. Zahodne and Manly also claim that bilinguals in cities or countries where bilingualism is the norm do not show benefits with respect to aging compared to bilinguals in primarily monolingual settings, but that is based on limited data and may itself be confounded with other factors. Zahodne and Manly point out that benefits for executive functions need not entail sparing of dementia. Although I mention that in my keynote article, I think the evidence base is rather limited.

Size of the bilingualism benefit

Some commentators suggest that the benefits may be too small to be worth investigating (Costa et al., 2014; Klein, 2014; Paap, 2014). I think there is no way of knowing at present what the size of bilingualism benefits is. Two strong effects could cancel each other out. A weak effect, without competition, could seem strong. Paap thinks it is unlikely that monolinguals would so frequently have compensatory experiences that would cancel out benefits of bilingualism, but I am not assuming a linear relationship. It could be a step function: individuals need a certain amount of cognitive challenge and, after that amount, more has little or no effect. In most experiments, both mono- and bilingual children and young adults could have a superfluity of cognitively challenging experiences that would promote executive functions. Benefits of bilingualism among old people, should they continue to be found, would make sense on my analysis. In aging, there are fewer cognitive challenges (at least, fewer that lead to cognitive improvement); having two languages, assuming that both are used, would remain a beneficial challenge.

For the sake of argument, however, let's accept the possibility that the benefits are small. I think that does not affect the importance of studying them. The underlying mechanism would still be worth investigating and understanding.

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Conclusion

There remains much to be understood about the effects of bilingualism on executive functions, including: the notions of executive functions and cognitive reserve, what tasks measure, how different types of linguistic experience affect cognition, and the connection between bilingualism and other challenging cognitive experiences. The exact next steps need open discussion. For a start, my commentators and I agree that more interdisciplinary work will accelerate progress.

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