

Doubling down on multifactorial approaches to the study of bilingualism & executive control

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The study of bilingualism has generated great interest about a core issue: does the experience of using two or more languages lead to enduring changes in the bilingual brain. This issue is often framed as a search for bilingual advantages in cognition, most notably behavioral performance on executive control tasks. Valian's timely keynote (2014) adopts this framing.

Valian's conclusion offered at the outset is that there "is a benefit of bilingualism for executive function, but that benefit competes with other benefits that both mono- and bilinguals have to varying degrees." The keynote then describes several sources of enrichment that potentially vary among bilingual and monolingual individuals (e.g., musical ability, exercise), which could cloud interpretation of group effects.

We would add that there are even more fundamental sources of complexity with respect to language itself that make it crucial for bilingualism researchers to adopt a multifactorial, individual-differences approach in lieu of coarse group comparisons (see Baum & Titone, 2014; commentaries and response, Titone & Baum, 2014; see also, Kroll & Bialystok, 2013). For example, bilinguals certainly differ in second language (L2) proficiency (addressed by Valian, 2014), but they also differ in how specific patterns of bilingual experience mesh with the normative communicative environment bilinguals inhabit. Many studies cited in the review are discussed without respect to geography: bilingual vs. monolingual comparisons for cities in the United States could be very different from that for cities in Canada or elsewhere because of geographic differences in the prevalence of early vs. late bilingualism across age groups, relative language dominance, social status or linguistic differences of the languages in question, whether language mixing is normative, and the list could go on (see Green, 2011). The field has only begun to scratch the surface of these issues empirically (our group included).

Thus, like Valian, we fear that the field has become too single-mindedly focused on simple bilingual vs. monolingual comparisons in a way that unfortunately

reduces a highly complex problem space to a binary yes or no question (but see Baum & Titone, 2014; Kroll & Bialystok, 2013). Consequently, like others, our laboratory has pursued the question of how differences among bilinguals in language background and executive control relate to the very aspects of language processing thought to drive bilingual advantages across listening, reading and production. Pivneva, Mercier & Titone (2014) found that individual differences in executive control measured by different tasks (while statistically controlling for L2 ability) were linked to different aspects of bilingual spoken word processing using eye movements and the visual world task. The data suggested that "cognitive" measures of executive control (e.g., Stroop or Simon task) had more to do with the covert process of inhibiting within- and cross-language competitors, whereas "oculomotor" measures of executive control had more to do with the overt process of preventing an eye movement to competitor pictures. In an eye movement study of reading, Pivneva et al. (2014) found that individual differences in executive control (e.g., Stroop, Simon tasks) but not L2 ability related to bilinguals' ability to inhibit cross-language activation triggered by interlingual homographs (e.g., *pain*, which is a physical sensation in English but means bread in French), whereas the reverse was true for cognates. Finally, our work on bilingual production using eye movements (Pivneva & Titone, under review) suggests that individual differences in executive control link to whole-language inhibition rather than to the inhibition of candidate word labels when bilinguals name pictures in a sentential context (see also Pivneva, Palmer & Titone, 2012). Thus, there may be specific aspects of bilingual language processing that are more or less demanding (or perhaps more unique to bilinguals) than others, which recruit specific kinds of executive control resources accordingly. Presumably, the more that different bilingual people are repeatedly challenged by such experiences, the greater the likelihood that they will experience enduring changes in the function and structure of neurocognition.

Valian's keynote also discusses how little we know about what executive control tasks actually measure, and what component operations are included in the broad concept of executive control. We agree. Of note, we have experienced many of these challenges, such as the choice of what executive control tasks to use, how to implement those tasks in sufficiently standard ways, that they rarely correlate except in superficially uninteresting ways, and how to statistically identify linkages between executive control and language performance. Our approach is most certainly evolving, however, we hope that honoring how bilinguals differ by thinking multifactorially from the outset (i.e., outside the ANOVA box) and assessing executive control in varied ways will allow us to move beyond simple group comparisons in addressing what are undoubtedly highly continuous and multifactorial phenomena.

Finally, we are under no illusion that behavioral data alone will solve the problem. For example, it is possible that a particular group comparison may yield no behavioral difference but, if one were to interrogate what was happening neurally across groups, one may observe that the same behavioral outcome is differentially implemented at a neural level (or the same neural implementation may lead to different behavioral outcomes). Of note, the bilingual "effect" may occur in unexpected but potentially meaningful ways when one takes sociocultural demands of language into account. For example, a recent cortical thickness study by Klein, Mok, Chen and Watkins (2014) showed that late L2 learners in Montreal (who presumably work hard to balance strong L1 and weak L2 knowledge in this highly bilingual city) had thicker left inferior frontal cortices (often associated with executive control) than balanced bilinguals (for whom accessing knowledge of multiple languages is fundamental and highly practiced) or monolinguals (who may not attempt to engage the city's bilingual nature). Clearly, the interpretation we are imposing on Klein et al.'s data is speculative, but suffice it to say that we need to carefully consider all sources of information when thinking about who may be "advantaged" in what context. As well, we ought to make greater use of experimental or

prospective approaches, also argued by Valian, to better characterize what capacities people start with and how bilingual experience creates neurocognitive change over time given different starting points (see Baum & Titone, 2014, for similar discussions).

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