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What bilinguals do with language that changes their minds and their brains

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In the last two decades, there has been an upsurge of research on bilingualism recognizing that bilinguals may be more representative language users than their monolingual peers (e.g., Kroll, Dussias, Bogulski, & Valdes Kroff, 2012). The excitement about bilinguals is related not only to their neglected status in the past literature but also to a set of twin discoveries that have catapulted research on bilingualism into central view in psycholinguistics, cognitive and developmental neuroscience, and gerontology. One of these discoveries is that both languages are active when bilinguals read, listen to speech, and plan speech in either of their two languages (for a review, see Kroll et al., 2012). The other discovery is that bilingualism appears to confer a set of consequences to domain general cognition and to the neural structures that support it (e.g., Bialystok, Craik, Green, & Gollan, 2009). Those consequences are observed across the lifespan and are particularly evident when cognitive resources are challenged because of the normal or pathological trajectory of aging (e.g., Gold, Kim, Johnson, Kriscio, & Smith, 2013). The focus of the new research is on how these two discoveries might be related. The parallel activity of the two languages and the interactions across them require that the bilingual develops skill in language selection to enable fluent performance. The hypothesis that has guided the recent flurry of research is that bilingual minds and brains change as a consequence of having to regulate the two languages. In their Keynote Article, Baum and Titone provide a comprehensive and current summary of the existing evidence on this hypothesis.

Baum and Titone frame the discussion about the consequences of bilingualism as an instance of adult neuroplasticity. Others have made similar arguments (e.g., Green & Abutalebi, 2013; Kroll & Bialystok, 2013), and the spirit across all of these recent papers converges closely in proposing that the story about bilingualism is not simple. Bilingualism takes many different forms depending on the circumstances of language learning and language use, and the ways in which those circumstances impose cognitive demands will shape (and reshape) the neural networks that enable cognitive control over the span of a bilingual's life. As a first step, there are methodological issues to be considered, and many of the conclusions of the Baum and Titone review lead to recommendations that are fundamentally methodological steps toward good practices in bilingualism research. One is to more carefully identify the properties of bilinguals and the context in which they use each language. As others have argued, bilingualism is not a categorical variable (e.g., Luk & Bialystok, 2013), and much of the variability in previous studies is likely due to noisy sampling across groups of bilinguals whose life and language experience cannot be easily aggregated. What seems important in this advice is that it will be as important to identify aspects of bilingual experience that have consequences for language processing and cognition and aspects that do not. For example, there are instances in which bilinguals with structurally dissimilar languages produce results virtually identical to those with structurally similar languages (e.g., Morford, Wilkinson, Villwock, Piñar, & Kroll, 2011).

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Evidence of that sort should not be interpreted to mean that structural differences across bilingual language pairings are not important but rather that we need a much more detailed account of the significance of cross-language differences for each aspect of language processing and for the resulting cognitive and neural consequences. Likewise, in recent discussion of the variability in bilingual experience there has been a focus on the meaning of code-switching experience (e.g., Green & Abutalebi, 2013). Some bilinguals code switch and others do not. However, even those who do code switch do not always mix language in all contexts in the same way or with the same frequency of switching. All of these bilinguals may be equally proficient in the two languages, but the distinct ways in which they use the languages may be highly significant for how they have tuned the brain networks that control switching behavior. Further, the consequences of these behavioral and neural differences may extend beyond language to other cognitive experience.

A second caution that Baum and Titone offer is to remember that most of the evidence bearing on the relationship between bilingualism, cognition, and the brain takes the form of correlations. Bilinguals often, but not always, outperform matched monolinguals on tasks involving executive function. The hypothesis that resolving conflict between the two potentially competing languages gives rise to domain-general expertise in conflict resolution is just that: a hypothesis. Baum and Titone note that, in the absence of identifying a causal mechanism, it is difficult to determine whether the observed correlations between bilingualism, cognition, and neural structure and function are the effects of self-selection or the consequences of bilingual experience. Although it is tempting to infer causality, there are relatively few studies that directly tie the consequences of language processing to cognitive and neural outcomes. The few studies that address this relationship have focused quite reasonably on relatively time-limited phenomena to begin to map out the immediate consequences of language processing for cognition more generally (e.g., Blumenfeld & Marian, 2011; Wu & Thierry, 2013).

The third caution that Baum and Titone offer is to suggest that we frame the discussion in terms of issues of neuroplasticity rather than the simple presence or absence of bilingual advantages. Avoiding the lure of reducing debates to their simplest terms has clear merit, and asking how bilingual experience affects cognition is a broader question than asking only under what circumstances benefits can be observed.

There is little to argue with in the conclusions that Baum and Titone draw in their review. We clearly need an intellectually richer approach to begin to understand how bilingual language experience over the life span affects, and is affected by, the networks that characterize cognitive control. Perhaps what is most compelling in considering the evidence reviewed is its breadth. None of the positive or negative observed effects would be known if we had not asked about the consequences of bilingualism. In that sense, we are encouraged to go forth with a new agenda for investigating the neuroplasticity of language and cognitive experience.

How should we formulate the new research agenda on bilingualism? From the perspective of neuroplasticity it is perhaps surprising that what is missing from this review is a focus on the period of life in earliest childhood when the

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brain is most plastic. Research on infants exposed to two languages from birth suggests that multiple language input changes the patterns of speech acquisition during the earliest months of life (e.g., Bosch & Sebastián-Gallés, 2003), that bilingual exposure also confers some benefits to attention (e.g., Kovács & Mehler, 2009), and that those benefits may be evident long before the ability to produce speech develops. The studies that have examined crib bilinguals suggest that they are exquisitely sensitive to the cues that are present in speech and in the environment that uniquely signal the presence of one of their two languages (e.g., Sebastián-Gallés, Albareda-Castellot, Weikum, & Werker, 2012). Mapping out the developmental neuroscience of how this ability comes online and how it changes over the life span may provide important information about the constraints and plasticity that shape the bilingual effects that we see in later adulthood and old age. That bilingual advantages have been demonstrated in infancy suggests that there must be multiple contributing factors to these bilingual consequences and that their development is likely to be complex and protracted.

There are other notable aspects of bilingual experience that are absent from the Baum and Titone review that may be critical in developing the neuroplasticity approach that they advocate. A feature of bilingual experience that has received only a bit of attention in the recent literature is new learning. Bilinguals are better word learners than monolinguals (e.g., Kaushanskaya & Marian, 2009), and that skill appears to be somewhat independent of executive function ability per se. The existing literature does not enable us to determine whether a learning advantage occurs only for early bilinguals, who acquired both languages in childhood and for whom there may be residual openness to new learning (e.g., Petitto et al., 2012), or also for late bilinguals who have acquired proficiency in a second language. Given the great plasticity associated with early childhood, looking to the learning processes that are key in early development would appear to provide a promising basis on which to explore the neurocognitive consequences of bilingualism.

In searching for analytic approaches that might enable us to begin to identify the course and consequence of neuroplasticity effects related to bilingualism, it may be helpful to reconsider the evidence for constraints in second language learning. Historically, the claim about late second language learning was that some aspects of the second language are simply not acquired at a native-like level (e.g., Johnson & Newport, 1989; Piske, MacKay, & Flege, 2001). Late learners are likely to miss subtle nuances of the second language syntax and to speak the second language with a marked accent. However, recent neurocognitive evidence has demonstrated that under some conditions it is possible to override these apparent constraints (e.g., Steinhauer, White, & Drury, 2009), demonstrating that adult learners are able to acquire subtle aspects of the second language and to reveal nativelike processing. That conclusion would seem to be congenial with the neuroplasticity approach proposed by Baum and Titone, but it may also provide clues in the search for the ways that different bilingual experiences may shape language and cognitive processes and their neural underpinnings. We need to ask where there is plasticity, but we also need to identify where and for whom there are constraints. The literature on late second language learning would seem to provide a rich source of hypotheses for linking bilingualism and its consequences.

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The Baum and Titone Keynote Article provides a comprehensive summary of the scholarship on the cognitive and neural consequences of bilingualism, establishing a base on which a new phase of bilingualism research can be built. We agree that reframing the debate in terms of neuroplasticity more generally is an important step toward developing a more detailed analytic approach that will ultimately allow true progress to be made. We look forward to this next phase of research on bilingualism with great optimism about what it will hold, not only for bilinguals but also for language and cognitive science and neuroscience more generally.

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Judith F. Kroll
Melinda Fricke
Pennsylvania State University

How much bilingual experience is needed to affect executive control?

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A wealth of research on experience-related plasticity has shown that specific experiences, such as musical training (Herholz & Zatorre, 2012) or juggling (Draganski et al., 2004), can modify brain function and structure and induce long-term changes in cognitive behavior throughout the life span. In their comprehensive Keynote Article, Baum and Titone focus on the neural and cognitive implications of lifelong experience with multiple languages. They discuss empirical studies on bilingualism, executive control, and aging to enhance our understanding of the frequently observed executive control advantages in bilinguals and how lifelong bilingualism may contribute to the development of cognitive reserve and buffer age-related declines in executive control functions. In reframing these issues in terms of neuroplasticity, Baum and Titone propose to "embrace the inherent individual variability among bilinguals in all its glory" and identify key issues related to individual variability to pave the way to new avenues of research. We fully concur with Baum and Titone's general recommendation to embrace variability among bilinguals to advance our understanding of bilingualism, aging, and neuroplasticity, but we would like to particularly highlight the importance of the earlier stages of second language (L2) learning and the emergence of executive control advantages, a topic we believe has been understudied in this domain. How much bilingual experience is needed to affect executive control?

As Baum and Titone's review shows, bilingual children and younger and older adults often perform better on a wide range of executive control tasks than their monolingual peers, although some studies did not observe such cognitive advantages. The presumed source for this executive control advantage is the bilinguals' lifelong experience using executive control functions to manage two language systems that, as research has abundantly shown, are both active even when only one language is used. The body of evidence demonstrating

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