

On the consequences of bilingualism: We need language and the brain to understand cognition

JUDITH F. KROLL
Pennsylvania State University
jfk7@psu.edu

In the last two decades there has been an explosion of research on bilingualism and its consequences for the mind and the brain (e.g., Kroll & Bialystok, 2013). One reason is that the use of two or more languages reveals interactions across cognitive and neural systems that are often obscured in monolingual speakers of a single language (e.g., Kroll, Dussias, Bogulski & Valdes Kroff, 2012). From this perspective, the interest in bilingualism is about developing a platform to ask questions about the ways that cognitive and neural networks are engaged during language use, in different learning environments, and across the lifespan. Another reason is that an emerging body of research on the consequences of bilingualism suggests that language experience changes cognition and the brain (e.g., Abutalebi, Della Rosa, Green, Hernandez, Scifo, Keim, Cappa & Costa, 2012; Bialystok, Craik, Green, & Gollan, 2009). Some of these changes have been claimed to produce cognitive advantages (see Bialystok et al., for a review of bilingual advantages and disadvantages).

In this keynote article, Valian (2014) provides a close analysis of one source of evidence that has been discussed and debated in this context. She focuses on studies across the life span that compare bilingual and monolingual performance on behavioral measures of executive function. The initial interpretation of the evidence for bilingual advantages in executive function was that the continual requirement to juggle the activation of the two languages conferred expertise that generalized beyond language to cognition more generally. But in Valian's review and comparison of executive function tasks across bilinguals of all ages, she argues that the evidence is inconsistent. Bilinguals sometimes outperform monolinguals and sometimes they don't. She concludes that bilingualism contributes to cognitive functioning no differently from any other life experience.

There are many positive things to say about Valian's review and analysis. For those unfamiliar with the research on executive function, there is a useful review and appendix of tasks (although the work of Braver, 2012, on reactive and proactive components of executive function is noticeably absent). There is also an informative review of some of the recent work on other types of expertise

that have been hypothesized to confer related cognitive advantages.

The suggestion in this paper is that having a more detailed understanding of the components of executive function and their role in particular behavioral tasks will once and for all answer the question, of whether, and under what circumstances, there are cognitive benefits associated with multiple language use. In this brief commentary, I argue that this is a misguided approach. The evidence in the domain that is reviewed is indeed inconsistent. But the analysis itself is focused too narrowly. Without attention to how language itself is used and how the brain networks that support both language and cognition are affected by language use, we have an incomplete and potentially misleading picture of the problem. Valian (2014) notes that evidence has been reported for differences in bilingual and monolingual brains and suggests that there is analogous inconsistency in both the behavioral and neural data. But this misses the point that a much more complex analysis is required. That analysis will identify the cognitive and neural processes that are engaged by language use. A focus on inconsistency suggests that there is nothing particularly special about the mapping between bilingual language experience and its consequences. To the contrary, the recent evidence suggests that to investigate this relationship one needs a more sophisticated analysis that goes beyond the question of whether bilinguals differ from monolinguals on specific components of executive function to ask how bilingualism affects language processing and the cognitive and neural systems that support it.

A number of recent papers have attempted to provide a preliminary framework for investigating these issues (e.g., Baum & Titone, 2014; Green & Abutalebi, 2013). Most notably, Green and Abutalebi argue for what they call the *adaptive control hypothesis*, the idea that neural networks will be tuned according to the demands of language processing and language experience. Two bilinguals who are equally proficient may have acquired and may use the two languages in very different ways (and see Luk & Bialystok, 2013). Some bilinguals code switch and others do not. Some bilinguals live in their native language environment and others in a second

language environment. Some bilinguals use one spoken language and another signed language. The differences in these bilingual circumstances have been shown to affect the resulting cognitive consequences and provide a basis for generating specific hypotheses about their source (e.g., Emmorey, Luk, Pyers & Bialystok, 2008). Likewise, monolinguals will differ in all the sorts of life experiences described in Valian's (2014) analysis and there is frequently little attention paid to the variation in monolingual language experience that presumably contributes to some of the inconsistencies observed in the comparisons between bilinguals and monolinguals (e.g., Pakulak & Neville, 2010).

I list below an additional, but partial, set of observations to illustrate the type of evidence that needs to be addressed to begin to allow the full and complex analysis that is required.

Coordination across the components of executive function

Valian (2014) mentions the Costa, Hernández, Costa-Faidella & Sebastian-Galles (2009) study on the effects of monitoring difficulty but other recent studies (e.g., Morales, Gómez-Ariza & Bajo, 2013) suggest that the consequences of bilingualism can be seen most clearly not in individual components of executive function but in the way that they are coordinated. Using a framework adopted from Braver (2012), Morales et al. found that a bilingual advantage in conditions that demanded an adjustment of proactive and reactive components of processing, but not an overall advantage. This result suggests a different approach to componential analysis (and see Kroll & Bialystok, 2013).

Aspects of language processing

Bilinguals do many different things with language (e.g., Kroll, Bobb & Hoshino, 2014). Understanding how different aspects of language processing will engage cognitive and neural processes will be crucial. Valian (2014) uses an observed dissociation between language switching and more general task switching to argue for a degree of modularity. But the recent evidence on catching the consequences of bilingual language processing on the fly suggests a much more dynamic and interactive picture (e.g., Blumenfeld & Marian, 2011; Pivneva, Mercier & Titone, 2014; Wu & Thierry, 2013), with consequences to executive function as language is processed. There is a great deal that remains to be understood about the long term consequences of these effects, but the fact that these changes occur suggests that these are not modular systems. Likewise, we see effects of the second language on the native language that demonstrate a level of plasticity across the bilingual's two languages that hold

implications for the unique consequences of bilingualism (for a review see Kroll, Dussias, Bice & Perrotti, in press).

Relating behavioral and neural evidence

Valian (2014) sets aside the neuroscience evidence but a complete understanding of the cognitive consequences of bilingualism will require that we have a better account of the mappings between cognition and brain function. These are not one-to-one mappings and the full complexity of how brain networks reflect the mechanisms of cognitive and language control will be critical in determining what changes occur as a result of bilingualism and how they are manifest. A number of recent fMRI studies demonstrate greater efficiency in brain activation for bilinguals relative to monolinguals (e.g., Abutalebi et al., 2012; Gold et al., 2013) but again, these are not simple effects – there are a range of patterns observed for younger and older bilinguals, in different task environments, and sometimes there are effects observed in patterns of brain activation that are not apparent in behavior. Electrophysiological investigations of second language learning have shown that the brain often outpaces behavior in revealing the presence of new learning (e.g., McLaughlin, Osterhout & Kim, 2004). This is not a matter of deciding whether the behavioral and neural patterns of performance converge but rather to have a more nuanced analysis of what they tell us about processing at particular points in time and under conditions that vary in the cognitive demands that are imposed.

Valian's (2014) analysis should stimulate discussion on all of these issues. There is an important point here that bilinguals are also ordinary humans who engage the full range of life experiences, whether or not those experiences include video game playing, musical training, or driving taxi cabs through a dense maze of city streets. Understanding the consequences of bilingualism in this context is complex but not impenetrable.

References

- Abutalebi, J., Della Rosa, P. A., Green, D. W., Hernandez, M., Scifo, P., Keim, R., Cappa, S. F., & Costa, A. (2012). Bilingualism tunes the anterior cingulate cortex for conflict monitoring. *Cerebral Cortex*, *22*, 2076–2086.
- Baum, S., & Titone, D. (2014). Moving towards a neuroplasticity view of bilingualism, executive control, and aging. *Applied Psycholinguistics*.
- Bialystok, E., Craik, F. I. M., Green, D. W., & Gollan, T. H. (2009). Bilingual minds. *Psychological Science in the Public Interest*, *10*, 89–129.
- Blumenfeld, H. K., & Marian, V. (2011). Bilingualism influences inhibitory control in auditory comprehension. *Cognition*, *118*, 245–257.

- Braver, T. S. (2012). The variable nature of cognitive control: a dual mechanisms framework. *Trends in Cognitive Sciences*, *16*, 106–113.
- Costa, A., Hernández, M., Costa-Faidella, J., & Sebastián-Gallés, N. (2009). On the bilingual advantage in conflict processing: Now you see it, now you don't. *Cognition*, *113*, 135–149.
- Emmorey, K., Luk, G., Pyers, J. E., & Bialystok, E. (2008). The source of enhanced cognitive control in bilinguals. *Psychological Science*, *19*, 1201–1206.
- Gold, B. T., Kim, C., Johnson, N. F., Kriscio, R. J., & Smith, C. D. (2013). Lifelong bilingualism maintains neural efficiency for cognitive control in aging. *Journal of Neuroscience*, *33*, 387–396.
- Green, D. W., & Abutalebi, J. (2013). Language control in bilinguals: The adaptive control hypothesis. *Journal of Cognitive Psychology*, *25*, 515–530.
- Kroll, J. F., & Bialystok, E. (2013). Understanding the consequences of bilingualism for language processing and cognition. *Journal of Cognitive Psychology*, *25*, 497–514.
- Kroll, J. F., Bobb, S. C., & Hoshino, N. (2014). Two languages in mind: Bilingualism as a tool to investigate language, cognition, and the brain. *Current Directions in Psychological Science*, *23*, 159–163.
- Kroll, J. F., Dussias, P. E., Bice, K., & Perrotti, L. (in press). Bilingualism, mind, and brain. In M. Liberman & B. H. Partee (Eds.), *Annual Review of Linguistics*.
- Kroll, J. F., Dussias, P. E., Bogulski, C. A., & Valdes-Kroff, J. (2012). Juggling two languages in one mind: What bilinguals tell us about language processing and its consequences for cognition. In B. Ross (Ed.), *The Psychology of Learning and Motivation, Volume 56* (pp. 229–262). San Diego: Academic Press.
- Luk, G., & Bialystok, E. (2013). Bilingualism is not a categorical variable: Interaction between language proficiency and usage. *Journal of Cognitive Psychology*, *25*, 605–621.
- McLaughlin, J., Osterhout, L., & Kim, A. (2004). Neural correlates of second-language word learning: Minimal instruction produces rapid change. *Nature Neuroscience*, *7*, 703–704.
- Morales, J., Gómez-Ariza, C. J., & Bajo, M. T. (2013). Dual mechanisms of cognitive control in bilinguals and monolinguals. *Journal of Cognitive Psychology*, *25*(5), 531–546.
- Pakulak, E., & Neville, H. J. (2010). Proficiency differences in syntactic processing of monolingual native speakers indexed by event-related potentials. *Journal of Cognitive Neuroscience*, *22*, 2728–2744.
- Pivneva, I., Mercier, J., & Titone, D. (2014). Executive control modulates cross-language lexical activation during L2 reading: Evidence from eye movements. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *40*, 787–796.
- Valian, V. (2014). Bilingualism and cognition. *Bilingualism: Language and Cognition*. doi:10.1017/S1366728914000522.
- Wu, Y. J., & Thierry, G. (2013). Fast modulation of executive function by language context in bilinguals. *The Journal of Neuroscience*, *33*, 13533–13537.