Future Directions in Examining Neurological Adaptation to Bilingual Experiences

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ABSTRACT: In recent years, research examining the neurocognitive effects of bilingualism has undergone a shift in focus towards examining the neurocognitive effects of individual differences within specific aspects of language experience. The DeLuca et al study advances this direction in showing a specificity of neural adaptations to separate aspects of language experience. However, this approach is an early step of several in towards a more comprehensive understanding of the nature of neural adaptation to bilingual language use. This commentary discusses several future directions worth further consideration in research examining bilingualism-induced neuroplasticity.

KEYWORDS: Bilingualism, neuroplasticity, individual differences

Introduction

The DeLuca et al[1] study examined the effects of several experience-based factors (EBFs) on brain structure and functional connectivity. These EBFs were related to (1) duration of second language (L2) use (measured as second language age of acquisition [L2 AoA] and length of L2 Immersion), (2) extent of L2 use in home and social settings, and (3) the combined aspects of duration and extent of L2 use, measured as the duration of active engagement with the L2 both overall and in immersive settings. Independent and distinct effects of each EBFs are reported. Those related to duration of language experience correlated with adaptations towards increased efficiency in language processing and control. EBFs related to extent of engagement with the L2 correlated to adaptations towards increased language control demands. Finally, EBFs related to duration of active L2 use related to adaptations towards increased efficacy in language control processes.

The study contributes to a growing body of evidence which shows that individual differences in bilingual language experience modulate adaptations in brain structure and function towards bilingual language control demands.[2-5] This approach is proposed as a step towards the more accurate modelling and understanding of the relationship between bilingual language experience and neurocognitive adaptation. But what are some of the next steps? Several future directions which warrant further investigation are discussed below. These include (1) assessing how different language experiences modulate one another's effects in terms of neural outcomes, (2) reconsidering the inclusion of monolinguals as the default control group in such studies, and (3) accounting for genetic and neurophysiological predispositions. Better understanding within these domains will further clarify the nature of neurological adaptations to the bilingual experience.

More Language Experiences and Their Interactive Effects

The EBFs included in the DeLuca et al study do not comprise a comprehensive list of relevant factors to consider. Other factors have been found to relate to distinct outcomes in both cognitive task performance and neurophysiological adaptation, including entropy or diversity of language use,[6] first language (L1) vs L2 dominance,[7] and degree and nature of switching between one's languages.[8] To date, these factors have not been widely examined in relation to adaptations in brain structure (but see Zou et al[9]).

Furthermore, studies examining individual language experience have thus far isolated respective EBFs to measure their individual contributions to neurocognitive adaptations and report distinct effects of each type of experience. For example, EBFs related to duration of bilingual language use have been found to correlate with neural adaptations towards increased efficiency of language use including fluctuations in white matter integrity in tracts associated with language control,[1,3,4] and changes in functional connectivity related to increased reliance on reactive control.[2] In contrast, EBFs related to increased intensity or diversity of language use have been found to correlate with adaptations towards increased language control demands.[1,2] However, these language experiences do not occur in isolation. It thus stands to reason that their respective contributions to neural adaptation will be modulated by the effects of other relevant experiences. The DeLuca et al study addressed this to some extent with the inclusion of the variables of duration of active L2 use. However, future research should examine how EBFs *interact* with each other; that is, how they modulate the effects of other EBFs with respect to related neurocognitive outcomes.

As an example of such a modulatory relationship, it is suggested within the Adaptive Control Hypothesis (ACH)[10] that

increased exposure to a given conversational context (single-language, dual language, dense code switching) will reinforce the language control and production networks that are implicated in each context. However, the way in which duration of engagement in each context modulates the required control networks is not fully established. While prolonged engagement with a specific communicative context would reinforce the control and processing networks required to handle the demands with each context, the degree to which specific contributory hubs or regions within the networks are required may increase at first and then decrease again as efficiency increases. Similarly, it is also likely that the intensity of L2 exposure and use might modulate the latency, or potentially the mechanism by which neural adaptations towards efficiency or automation of language control take place. Models which take a more durative perspective to neurocognitive adaptation, such as the Bilingual Anterior to Posterior and Subcortical Shift (BAPSS) framework[11] or Dynamic Restructuring Model (DRM)[12], state that reliance shifts reliance shifts from corticofrontal regions to the subcortical structures and posterior regions, as (bilingual) language control and processing become more automated and efficient. Fluctuations in the latency or mechanism of adaptation can occur within as a function of increased engagement with one or more of the contexts described by the ACH. For example, greater intensity of exposure with a dual language context might shorten the latency in which the shift in reliance to subcortical regions occurs. The relationships between different language experiences, particularly in terms of how they affect neural adaptation, remain open questions to be investigated in future work.

Reconsidering the Role of Monolinguals

While monolingual participants have historically been included in research as a control group, they as well will differ in terms of exposure to and use of additional languages. Few people are truly 'monolingual' in the sense of no exposure to other languages and dialects, and therefore 'true' monolinguals may be better regarded as an extreme on a spectrum of experiences that comprise bilingualism.[13,14] Indeed, recent work by Bice and Kroll[15] has shown that, in functional monolinguals, passive exposure to additional languages in one's daily environment seems to affect neural processes related to language learning. This study specifically showed increased sensitivity to phonological contrasts in a novel language, as measured by event-related potentials (ERPs), for monolingual English-speaking monolingual participants who were routinely, passively exposed to Spanish over English-speaking monolinguals who were not routinely exposed to other languages. This indicates that neurocognitive adaptations to L2 exposure occur in advance of any functional L2 competence and thus warrants further investigation with other modalities of brain structure and function.

Future work might thus include monolingual participants as a baseline on the spectrum of language experiences. That is, these participants will ideally be examined in a similar manner to bilinguals – as a heterogeneous cohort, in terms of their language background and/or current use, to better understand the extremes of the bilingual language experience spectrum.

Endogenous Variables: Genetics and Neural Morphology

In addition to considering language experience, future work may also need to account for more endogenous variables, such as predispositions of genetic phenotypes and neural morphology. With respect to genetics, a handful of studies have found a modulating effect of genetic phenotype on neural or linguistic/cognitive outcomes of L2 use. A study by Mamiya and colleagues[16] found that participants with Met/Val and Val/Val polymorphisms of the catechol-O-methyltransferase (COMT) gene exhibited higher white matter integrity during L2 immersion, whereas those with Met/Met genotype did not exhibit this relationship. Furthermore, accounting the COMT genotype in modelling the relationship between white matter integrity and performance on English (L2) proficiency tests substantially increased the total variance explained within the cohort. Similarly, a study by Vaughn and Hernandez[17] examined both L2 AoA and the ANKK1/TaqIa and Val158Met polymorphisms and their effects on language proficiency in bilingual adults. In earlier AoA, expressions of the genetic variant associated with higher levels of subcortical dopamine (Val/Val and Met/Met polymorphisms) related to higher proficiency. For later AoA, individuals with the genetic variant associated with cortical dopamine levels that are balanced between stability and flexibility (Val/Met) were found to relate to higher language proficiency.

Another predisposition to consider is that of brain morphology, which may modulate the nature or extent of plasticity in relation to bilingual language use. An example of this is the study by Cachia and colleagues[18] who report that differences in sulcation patterns in the anterior cingulate cortex (ACC) modulated performance on a flanker task in both bilingual and monolingual participants. Specifically, monolinguals with leftward asymmetry in sulcation patterns and bilinguals with symmetrical sulcation within the ACC had decreased interference suppression costs (as measured by reaction time differences) on a Flanker task. Similarly, predispositions in regional grey matter volume and white matter integrity have been found to predict aptitude in acquiring a new language[19,20] and individual differences in aspects of executive function.[21] For example, the study by Golestani and colleagues[19] found higher concentrations of regional grey and white matter in Heschl's gyrus to correlate with faster successful acquisition of novel phonetic contrasts. The results from these studies suggest that a modulatory role of both predispositions in genetics and brain structure patterns, in relation to neural outcomes of bilingualism, is an empirical question worth pursuing in future research.

Conclusions

The examination of individual difference measures of language experience and related neurological adaptations seems the ideal way to progress the field in terms of our understanding of

neurocognitive adaptations to the bilingual experience. This said, the goal of all such work is to move us towards a more wholistic understanding of how the brain accommodates the neurocognitive demands associated with bilingual experience. Taking a nuanced approach of examining individual differences in language experience is a necessary step in delineating the complexities of the bilingual experience and its associated neurocognitive demands. However, this approach can also be complemented with the inclusion of the above-discussed directions in future research. Better understanding within these domains will allow for more accurate mapping of the neural adaptations to bilingualism.

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