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If experience is not enough: Understanding multilingualism through early neurobiological variability

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In their neuroemergentism framework, Hernandez et al. (2018), propose a new perspective for understanding human cognition; in accordance with the classic emergentist framework (e.g., Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979), the proposed perspective is based upon the assumption that the combination of smaller parts can bring us to a greater whole. However, the novelty of the proposed neuroemergentist approach is that the authors suggest to take into consideration individual differences as well as individual genetic backgrounds in order to understand neurocognitive functioning of individuals. In detail, within the neuroemergentism framework, Hernandez et al. (2018) call for the study of individual differences as a promising avenue for the advancement of our understanding of language acquisition in general and among others also multilingualism. In their view, such differences may have a key role in explaining how individuals learn a second language and how they use cognitive control in linguistic and non-linguistic performances. We are sympathetic with this view and we also believe that looking at individual differences may, indeed, allow us to make a big step forward in both understanding the multilingual brain and helping to reconcile current contrasting evidence on the relation between cognitive control and multilingualism.

Hernandez et al. (2018) discuss a multitude of fields where their proposed neuroemergentist theory may provide an explanatory framework seeking to bind the brain to cognition and *vice versa*. Because of our research background, in our commentary to their keynote article we will mostly focus on its implications in the field of multilingualism. Moreover, as aforementioned, we take their excellent point on individual differences in order to illustrate and discuss on some recent results from our and other labs to show how behavioral experience may affect cognitive performance in different ways depending on inter-individual pre-natal brain variability, in line with the conjectures made by Hernandez et al. (2018). In particular, we will consider variation in brain anatomy as a proxy of individual differences and, more shortly, genetic background to highlight and discuss the impact of inter-individual variability on cognitive performance; we will conclude by arguing that individual neurobiological differences should be taken into account whenever investigating the putative cognitive differences between monolinguals and bilinguals, which itself is a topic of a lively debate.

Recently, Cachia et al. (2017) investigated the relation between bilingual experience on conflict monitoring – i.e., the ability to manage conflicting information – and individual cortical sulcation – which is a qualitatively anatomical feature that is not affected by brain maturation, cognitive training, or life-long experience-related factors (e.g., Sun et al., 2012). With regard to the latter, Cachia et al. (2017) focused on the anterior cingulate cortex (ACC) sulcation, which is determined in utero and occurs between 10 and 15 weeks of fetal life (Chi, Dooling, & Gilles, 1977; Feess-Higgins & Larroche, 1987). The ACC is a core region of the neural network for both verbal and non-verbal conflict monitoring (e.g., Abutalebi et al., 2012; Hernandez, 2009) and its sulcal patterning has been recently correlated with cognitive control efficiency in monolinguals. Borst et al. (2014) investigated the relation between ACC sulcal patterns and inhibitory control as measured by a Stroop task in children; they found a better inhibitory control efficiency in those children with asymmetrical ACC sulcal pattern – i.e., when sulcation differed across hemispheres, with only one hemisphere showing a sulcus parallel to the ACC – than in those with a symmetrical sulcal pattern. The same pattern of results was also reported with adult participants (Huster et al., 2009).

Thus, ACC sulcation, because of its inter-individual variability, may become a tool to look at how early (i.e., pre-birth) brain

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development modulates bilingual experience on conflict monitoring. By testing monolinguals and bilinguals on a cognitive control task (i.e., the Flanker Task) and investigating the ACC sulcal features of their participants, Cachia et al. (2017) found that the differences of brain morphology affected cognitive control efficiency of bilinguals (and monolinguals): those participants with an ACC symmetrical pattern – i.e., both hemispheres showing a similar ACC sulcation – performed better (i.e., smaller conflict effect on RTs) than those with leftward ACC asymmetry – i.e., only the left hemisphere showing a sulcus parallel to the ACC. These results provide first evidence that pre-birth determined inter-individual differences in the brain structure (e.g., ACC sulcation) may modulate how behavioral experiences (e.g., bilingualism) affect humans.

Note that the relation between inter-individual variability in ACC sulcation and the ability to deal with conflicting information has been also reported outside the literature on bilingualism and with participants of different ages (e.g., Buda, Fornito, Bergström, & Simons, 2011; Cachia et al., 2014).

The findings reviewed above suggest that the investigation of the interplay between individual cortical sulcation, life-long environmental experience, and behavioral difference is a promising field of research to increase our understanding of complex cognitive activities as, (second) language learning or conflict resolution. In this scenario, ACC sulcation is particularly interesting because it is determined pre-birth and, hence, not affected by brain maturation and cognitive training. For this reason it may be considered a good index to isolate the impact of neurobiological inter-individual variability on cognitive functioning. The investigation of cortical sulcation in different populations may thus provide us an excellent example for studying inter-individual differences adding complementary evidence to that offered by the study of genetic backgrounds. As to the latter, recently, the literature on bilingualism has been paying increasing attention to genetics, and has started to investigate the relationship between genetic background, language proficiency and language control. Take as an example the study by Vaughn et al. (2016) who showed that neural activity in the inferior frontal gyrus during picture naming in L2 (second language) and neural activity in the ACC during a conflict monitoring task could be predicted by DRD2 genotype, i.e., a gene encoding the D2 subtype of the dopamine receptor. Based on these findings, the authors concluded that variation of the DRD2 gene (and thus in dopamine availability) could play an important role for language use and cognitive control in bilinguals (for further evidence on the relation between bilingualism and genetic background, see Vaughn & Hernandez, 2018).

To pull the strings, in line with the neuroemergentist approach proposed by Hernandez et al. (2018), we strongly believe that recent work looking at the interplay between bilingualism and cortical sulcation, on the one hand, and bilingualism and genetic background, on the other hand, will give us a better understanding of the multilingual brain and pave the way to look at current debates in a novel way. One field where this approach may be particularly fruitful is the current heated debate on the so called bilingual executive advantage, i.e., the putative better performance of bilinguals over monolinguals in tasks involving executive functions (e.g., Abutalebi et al., 2012; Bialystok, Craik, & Luk, 2012; Costa, Hernández, & Sebastián-Gallés, 2008). This general view has been recently challenged by opposite results (see, for instances for null results, Antón et al., 2014; Paap, Johnson, & Sawi, 2015) leading, as aforementioned, to a heated debate in the field. One possible solution to reconcile the current contrasting findings might come from taking into account the inter-individual differences determined by neuroanatomical (e.g., ACC sulcation) and genetic backgrounds (e.g., DRD2 polymorphism), which are emerging as an important source of variation of individuals' executive abilities. We believe that these factors might show that putative cognitive differences between monolinguals and bilinguals do not arise only because of different linguistic experiences, but also from the interaction of such experiences with early neurobiological factors. Our suggestions are in line with the view of Hernandez et al. (2018) expressed in the keynote article on the Neuroemergentist framework, and we are highly confident that future studies will successfully employ such approaches to investigate the brain and cognition relationship.

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