The importance of language use when studying the neuroanatomical basis of bilingualism

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Abstract

Studies on the neuroanatomical basis of bilingualism have yielded various but inconsistent differences between bilinguals and monolinguals. In this commentary, we will discuss how differences in background variables between language groups could explain part of this variation. We will furthermore argue that besides language proficiency and age of acquisition, more research needs to be done on the effects of language use and language context. The Adaptive Control Hypothesis (Green & Abutalebi, 2013) could guide the investigation of how language use and context could affect the structure of the brain. Lastly, given the inconsistency in (the direction of) neuroanatomical effects of bilingualism, we discuss how structural differences are difficult to interpret in the absence of behavioural data. A more theory-driven approach is needed to interpret the potential effects of bilingualism on a behavioural as well as neural level.

Keywords: Bilingualism, neuroplasticity, language use, cognition

Bilingualism and its potential effects on cognition have become a well-discussed topic in recent years. Although the question regarding behavioural cognitive advantages can only be addressed through behavioural studies, recent years have seen an increase in studies examining the effects of bilingualism on the structure and functioning of the brain. García-Pentón and colleagues (2015) show that neuroanatomical studies have observed various but inconsistent differences between bilinguals and monolinguals. In this commentary, we will argue that potential background differences between language groups as well as different types of language use could partially explain the lack of consistency. We will furthermore discuss the difficulties regarding the interpretation of structural differences.

Matching language groups on background variables

García-Pentón et al. focus on the different types of bilinguals that have been tested. Yet, in most studies bilinguals are not the only group. The effects contributed to bilingualism depend on the comparison between bilinguals and monolinguals. In this respect, it is of great importance that the two groups do not differ on background variables. In behavioural studies, this is often not the case (see Table 1 for examples of background differences). Similar issues with background differences appear to be present in neuroanatomical studies. For example, some of the studies described by Garcia-Pentón et al. tested bilinguals and monolinguals from similar backgrounds (e.g., in Klein, Mok, Chen, & Watkins, 2014, all participants came from the area of Montreal, Canada). However, in other studies, bilingual and monolingual participants did not grow up in the same country. For instance, Pliatsikas, Johnstone, & Marinis (2014) compared Greek-English bilinguals to English monolinguals. Although both bilingual and monolingual participants were living in the UK at the time of testing, the bilingual participants were immigrants and had only been UK residents for an average of four years. Similarly, bilinguals from Hong Kong have been compared to monolinguals from Italy (Abutalebi, Canini, Della Rosa, Green, & Weekes, 2015).

Effects of cultural background and bilingualism on brain structure may be difficult to disentangle (cf., Fuller-Thompson & Kuh, 2014). Chee, Zheng, Goh, Park, and Sutton (2011) compared large samples of Asian and American younger and older adults and concluded that American adults had higher cortical thickness in frontal, parietal, and medial-temporal areas. However, despite the suggestion that culture and ethnicity underlie these differences, most American participants were monolingual and Singaporean participants bilingual. Thus, it is

difficult to tear apart effects of cultural background, country of origin, immigrant status, and bilingualism. Yet, differences in the extent to which language groups are matched are likely to explain part of the inconsistencies across studies.

Language use and context as a way to measure effects of bilingualism

Despite the commonly generalised use of the term 'bilingualism', bilinguals often differ in many respects, including the age of acquisition and language proficiency. These two aspects of bilingualism appear to be related to higher GM volume and WM connections. However, language proficiency and acquisition are not the only aspects that characterise a bilingual. Language use is equally important yet relatively unstudied. The Adaptive Control Hypothesis (Green & Abutalebi, 2013) offers a theory-based approach to study the effects of language use. In this hypothesis, three language contexts are identified that could affect neuronal mechanisms in different ways. The first context is a single-language context in which one language is used in one context (e.g., home), and the second language in another context (e.g., work). In this setting, bilinguals do not often switch between the two languages. The second context is a dual-language context in which the two languages are used in the same context but with different speakers. In this setting, language switching may take place in a conversation but usually not within a sentence. In the third context, the dense code-switching context, bilinguals frequently switch between their languages even within an utterance. These types of language use place different demands on the speaker. In the dense code-switching context, bilinguals can switch freely between their two languages and thus need less control over their two languages. Green and Abutalebi argue that this context places relatively low demand on control processes such as conflict monitoring, interference suppression, and response inhibition. However, these processes are crucial in the dual-language context in which speakers have to control how and when they switch between languages. The dual-language context is therefore argued to require changes in the network including the basal ganglia and frontal regions linked to conflict monitoring and interference suppression, and parietal regions linked to changes between tasks. The dense code-switching context places fewer demands on language control and inhibition but does require planning and a cooperation between the different language schemes. Green and Abutalebi therefore state that this context predicts changes in the connectivity of the right cerebellar and left inferior frontal regions. The single-language context requires suppression of the

non-target language but no switching and therefore places no additional demands on subcortical structures linked to language switching.

Examining language use when investigating the neuroanatomical basis of bilingualism has multiple advantages. First, it will aid researchers to develop a theoretical framework when describing the effects of bilingualism. Different types of language use and context could have different impacts and this could improve our understanding of the inconsistent effects observed in the current literature. Second, studying the effects of language use is possible in the absence of differences in age of acquisition and proficiency. As noted by García-Pentón et al., effects of age of acquisition do not only correspond to bilingualism but also to learning processes in general and depend on developmental constraints. Third, as described above, a comparison between bilinguals and monolinguals can be problematic when the language groups differ in background variables. Language use and context, however, can be studied at an individual level within bilinguals. Instead of trying to find out whether one group is better than the other, we should aim to unravel the relation between language and cognition as well as the possible impact of different bilingual experiences (see Vaughn, Greene, Nunez, & Hernandez, 2015, for a similar argument).

Combining neuroanatomical and behavioural studies

Neuroanatomical studies are a valuable method to investigate the biological mechanisms that underlie language and cognition (Vaughn et al., 2015; van Heuven & Coderre, 2015). One key advantage of neuroanatomical comparisons is the lack of task impurity. Whereas behavioural and functional MRI studies require a task to examine effects of bilingualism, this is not needed in structural studies. The diverse use of tasks across behavioural studies hinders a generalisation of the observed effects. Even when executive control tasks are argued to tap into similar mechanisms, they do not only measure executive functions but are also affected by task-specific and non-executive components such as the type of stimulus materials (see de Bruin, Bak, & Della Sala, 2015). This task impurity may lead to contrasting outcomes that are not necessarily related to bilingualism.

Neuroanatomical studies can inform us about the locations in the brain that could be associated with bilingualism. Identifying structural differences between bilinguals and monolinguals in the brain may be an interesting question on its own. Still, the main question remains whether they can also provide convergent evidence towards models of bilingualism

and cognition. Neuroanatomical studies can elucidate differences in brain structure that may be related to language experience. Even in in the absence of behavioural effects, this can suggest that language groups process cognitive tasks differently (Kousaie & Taler, 2015).

Yet the interpretation of neuroanatomical differences in the absence of behavioural data is complicated, especially considering the inconsistent results. Even when bilingual-monolingual differences are observed in similar areas, their direction can vary across studies. Whereas Gold, Johnson, and Powell (2013) found decreased FA values in the corpus callosum (CC) for bilinguals, Luk, Bialystok, Craik, and Grady (2011) found increased FA values in the CC for bilinguals compared to monolinguals. In both studies, bilinguals and monolinguals showed no differences on neuropsychological tests including executive control tasks (Treccani & Mulatti, 2015). Despite the absence of behavioural differences and despite the opposing directions in neuroanatomical data, both studies interpret these findings as showing the brain mechanisms underlying cognitive benefits for bilinguals. The interpretation of these data is thus ambiguous (also referred to as 'valence ambiguity', Paap, Johnson, & Sawi, 2015) when some researchers interpret increased neural values as positive and others judge them to be negative.

Additionally, there is no direct mapping between the location of a brain area and cognitive processes. Finding a difference in a certain brain area therefore does not necessarily provide information about the cognitive process involved (Duñabeitia & Carreiras, 2015). Language and cognitive control have been associated with a wide range of brain areas (cf., Abutalebi & Green, 2007) that include much of the frontal, parietal, and subcortical areas of the brain. Finding a difference in one of these areas can therefore not easily be assigned to a specific cognitive process. Furthermore, similar brain areas may be involved in language control and non-verbal cognitive control (e.g., Abutalebi & Green, 2007; de Bruin, Roelofs, Dijkstra, & FitzPatrick, 2014; De Baene, Duyck, Brass, & Carreiras, 2015). Thus when bilingual-monolingual differences are observed in these frontal, parietal, and subcortical regions, we do not know whether these relate to cognitive control, language control, or both.

It is in this respect that behavioural results could help to interpret the effects observed in neuroimaging studies. We therefore agree with the point raised by García-Pentón and colleagues. Neuroimaging data alone are not going to solve the debate on the behavioural bilingual advantage. However, bilingual effects at the behavioural level are

inconsistent too. Although many studies have provided evidence for a behavioural bilingual advantage (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004), recent studies have argued that these effects may only appear in restricted circumstances or not at all (see Paap et al., 2015, for an overview). At the moment, evidence for a behavioural bilingual effect is at best inconsistent and the circumstances that may modify an effect are unclear. If we want to interpret the meaning of structural and functional differences, we also need to identify if and how bilingualism affects cognition at a behavioural level. Yet, alignment between behavioural and neuroimaging studies is often lacking (e.g., Luk, Anderson, Craik, Grady, & Bialystok, 2010; Ansaldo, Ghazi-Saidi, & Adrover-Roig, 2015). Rather than focussing on between-group comparisons, behavioural-imaging correlations may be able to shed more light on the meaning of structural differences (Gold, 2015). For instance, younger age of acquisition has been associated with higher grey matter density in the inferior parietal cortex (Mechelli et al., 2004).

Combined, behavioural, functional and structural imaging data may elucidate whether and how bilingualism affects cognition and the structure of the brain. Regardless of the technique used, however, it is crucial to develop a more theory-driven approach. The past years have seen many changes in the theoretical predictions regarding effects of bilingualism, varying from initial claims of inhibitory advantages specifically (e.g., Bialystok et al., 2004) to more global advantages on conflict tasks (e.g., Hilchey & Klein, 2011) or conflict monitoring (e.g., Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009). More recently, bilinguals have simply been argued to show greater 'mental flexibility' than monolinguals (e.g., Kroll & Bialystok, 2013). This term is unspecific enough to attribute any effect of bilingualism to increased mental flexibility. The current approach appears to be to identify tasks or brain areas that show an effect of bilingualism without a clear underlying theoretical prediction (cf., Hartsuiker, 2015). The inconsistencies found in neuroanatomical as well as behavioural data show that a theoretical framework is greatly needed. The characteristics of bilingualism, rather than a between-group comparison, should be central in this approach. Especially language use, a relatively unstudied feature, deserves more attention. Comparing results across different approaches should lead to a better and more detailed understanding of the cognitive processes involved in bilingual language processing as well as the potential impact of bilingual language processing on cognitive processes.

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