

Commentary

The Bilingual Cognitive Advantage: No Smoke without Fire?

Thomas M. H. Hope

Wellcome Trust Centre for Neuroimaging, University College London, 12 Queen Square, London WC1N 3BG; Email: t.hope@ucl.ac.uk; Tel: +44 (0)20 3448 4362.

Abstract: In a commentary on a review article by Paap and colleagues [1], and a response to that review by Saidi and Ansaldo [2], I examine the key arguments for and against the existence of a ‘bilingual advantage’ in cognitive functions, including the effects of small samples, and of confounding variables in studies on both sides of the debate. While accepting that the behavioural evidence here is inconclusive, I argue that the evidence for wide-ranging, plastic change in the bilingual brain would seem to predict that bilingualism may have similarly wide-ranging effects on behaviour. Finally, I note that bilingual cognitive advantages – if any exist – are inherently longitudinal phenomena, in the sense that they are thought to emerge as a function of the transfer of practice effects from linguistic to non-linguistic cognitive control skills. In that context, the most direct way to characterise those advantages, and the mechanisms that make them possible, may be with longitudinal studies, which also naturally control for many of the factors that may confound the cross-sectional studies which have dominated the field so far.

Keywords: bilingualism; cognitive advantage; practice; transfer; longitudinal

1. Introduction

Research suggests that bilinguals activate both (or all) of the languages they use even when only one is required. Cross-lingual interactions can be observed when bilingual participants perform word/non-word discrimination tasks, with faster responses observed for ‘cognates’, or words which share similar orthographic or phonological form and meaning across both languages (e.g. [3,4]). Cross-lingual interaction has even been reported to accumulate over three languages, with cognates in Dutch, English, and German associated with greater facilitation for fluent speakers of those languages than those in Dutch and German but not English [5]. Despite these cross-lingual interactions, most bilinguals manage multiple languages with comparative ease and skill, which in turn implies that they develop extreme proficiency in the ‘mental juggling’ act [6] that bilingualism seems to require. And unless that practice operates on cognitive control mechanisms that are wholly specific to language – as some have suggested they might be [7] – it seems sensible to allow that

other, non-linguistic (i.e., executive) control functions might be improved as well [8,9].

Many of the early results that seemed to confirm this hypothesis (e.g. [10–14]) have recently been called into question, as outlined in the review article by Paap and colleagues in this special issue [1]. Some responses to those criticisms have also been made in the same special issue, by Saidi and Ansaldo [2]. After briefly discussing this debate, as represented by these two commentaries, I argue that: (a) the apparently wide-ranging effects of bilingualism on the brain would make a wholly specific impact on language the more surprising result; and (b) the cross-sectional studies which dominate research in this area may be less informative than longitudinal studies, which attempt to measure when and to what extent practice effects are transferred across the boundary from linguistic to non-linguistic cognitive domains.

2. Does the Bilingual Advantage Only Appear in Under-Powered Studies?

Paap and colleagues' first, and potentially most damning, criticism of the evidence base for a bilingual advantage is that the strength of that evidence tends to diminish as sample sizes increase. In other words, most studies which report positive results – showing a significant, cognitive advantage for bilinguals over monolinguals – may well be under-powered. Under-powered studies have traditionally been associated with inflated false-negative rates: to say that a study design has a statistical power of 20% is to estimate that the design will only identify 20% of the 'true' effects it is used to measure [15]. In this formal sense, Saidi and Ansaldo are correct when they assert that repeated positive findings in under-powered studies might actually enhance, rather than reduce, confidence in the robustness of the effect. But as Paap and colleagues note, in their reference to a recent review [16], under-powered studies can also inflate false positive rates. And if support for a bilingual advantage really does tend to evaporate as the power of our studies improves – the opposite of the expected trajectory if the advantage is real – the implication is that those positive, under-powered studies may be misleading.

However, the literature on the bilingual advantage does not fit this pattern precisely. For example, though potentially powerful as evidence against a bilingual advantage in inhibitory control, the review by Hilchey and Klein [17] does report a consistent advantage in global reaction times for bilinguals. Paap and colleagues cite studies which find no such advantage [18,19], and their own studies cast doubt on the popular interpretation of the more global effect as an advantage in 'monitoring' [7,20,21], but the empirical difference itself cannot be dismissed as an artefact of under-powered designs. Moreover, bigger is not necessarily better in study design; power can even be improved by reducing samples to ensure that groups are more comparable, or more formally, that uncontrolled variance in the samples is minimised [16]. In other words, smaller studies can be more informative than larger studies, if they are better controlled.

3. Confounds and Uncontrolled Variance

However, quite what constitutes a properly controlled study in this area is yet to be agreed. Studies supporting the existence of a bilingual advantage have, for example, been criticised as confounded by socio-economic [22] or immigrant status [1,18,19,23]. And studies that fail to detect an advantage have been criticised when they rely on samples of young adults, who may be at ceiling in terms of their cognitive abilities, thus masking or minimising group differences [2]. A bilingual

advantage was observed in one recent study which compared large groups of monolingual and bilingual children, which controlled for immigrant and socio-economic status [24], and in another well controlled study that included both middle-aged and older adults, with a focus on working memory [25]. But null results have also been reported in studies involving both children [18,19] and the elderly [23], which were similarly well controlled. So the evidence here is still inconsistent.

One potentially promising way to cut through this inconsistency flows from the increasingly detailed way in which language skills, use and exposure are measured in this work. Since bilingual advantages (if there are any) are essentially practice effects, it seems likely that their nature and extent will be mediated by the detailed differences in that practice between the groups in any given study. Following this logic, bilingual advantages may be masked in studies with heterogeneous groups of bilinguals (e.g. [7,20,21]), or whose language skills are only measured by subjective means such as questionnaires (e.g. [19]), which may be an inaccurate measure of objective skill [26]. They may even be masked if the monolingual group in a study has some exposure to bilingual language (e.g. [18,19]). In emphasising these confounds, we do run the risk of reducing monolingualism and bilingualism to rare, theoretical constructs, rather than the common and quite dramatic differences between people that they really are. Nevertheless, by quantifying skill, exposure and use in reasonable detail, we may hope to explain why some studies detect behavioural bilingual advantages, and others do not.

4. How Relevant are the Neural Markers of the Bilingual Advantage?

Reaction times and accuracy rates are often interpreted as two different measures of the same fundamental process, with faster reaction times associated with more accurate responses and vice versa (e.g. [27]). In this sense, reaction times can operate as a higher resolution alternative to accuracy rates, in the search for factors which mediate behavioural responses. The study by Luk and colleagues [28], for example, can be understood as extending that progression still further by searching for group differences at the level of neural processing, or ‘neural markers’, even where none are found at the level of behaviour: i.e., construing those neural markers as more sensitive measures of the same process that drives behavioural response. This is consistent with Saidi and Ansaldo’s characterisation of behaviour as the ‘tip of the iceberg’ (page 55, final paragraph), and to some extent it mitigates the concerns raised by Paap and colleagues ([1], section 5) about the misalignment between neural markers and behaviour. Close alignment with behaviour may improve the interpretability of neural markers, but imperfect alignment does not necessarily imply that no relationship with behaviour exists.

Nevertheless, the interpretation of neural markers is always ‘risky’ even when they are closely aligned with behaviour. Most experimental tasks will impose a variety of distinct but strongly correlated demands on participants, such as remembering their instructions, attending to the stimuli, and so on; even when neural markers are strongly correlated with responses, there is no guarantee of a causal link (e.g. [29]). This ambiguity may be particularly pertinent to the debate surrounding the interpretation of activity in the anterior cingulate gyrus (ACC). This region appears to be active in tasks involving both linguistic and non-linguistic cognitive control [30], but is also implicated in a plethora of other functions, from reward and pain processing, to decision-making and emotion [31]. Evidence of a more causal quality – based on studies of patients with focal brain lesions – may yet clarify the role of the ACC, and many of these studies do conclude that the ACC is relevant

specifically to cognitive control [32,33]. But one study reported four stroke patients with no apparent detriment to their cognitive control skills despite damage to the ACC (as assessed using Go/No Go and Stroop tasks) [34], so even at this more causal level, the evidence is still ambiguous.

Paap and colleagues make a convincing case that, given this ambiguity, neither the presence nor the direction of any apparent group differences in the activity of the ACC can confirm that any particular bilingual advantage exists ([1], sections 6–7). This is not necessarily a controversial argument: the claim that bilinguals enjoy some behavioural advantage was always going to have to be proved or disproved by behavioural evidence. Instead, studies which focus on the measurement of neural markers of bilingualism may be best interpreted not as weapons in this existential debate, but rather as attempts to characterise the wider impact of bilingualism on the brain.

Whatever their behavioural significance, bilingualism is associated with many structural effects on the brain. Research suggests that bilinguals enjoy increased or preserved grey matter volume, relative to age matched controls, in many regions associated with executive functions, including in the ACC [35], the inferior parietal cortex [36], the hippocampus [37], and the prefrontal cortex [38]. Enhanced or preserved white matter connectivity has also been observed in bilinguals in the frontal lobe, and shown to be significantly associated with behavioural performance in the Stroop task [39]. Indeed, though they object to the precise interpretation of the effects, Paap and colleagues do not suggest that the differences observed in bilinguals' profiles of ACC functional activity [35], or the N400 component of the ERP response [40], are themselves artefactual. And if those differences are replicated and replicable, the very generality of these neural markers suggests that bilingualism has at least some effects on general cognition, whether positive, negative, or ambiguous. This argues against the 'strong modularity' [7] that would seem to be implied if bilingualism really exerts no effects at all on the wider cognitive system.

5. The Bilingual Advantage as a Practice Effect

The fundamental hypothesis here is that bilingualism requires people to practice some skill(s) and that this practice also improves some similar or connected non-linguistic skill(s): in other words, that bilingual cognitive advantages (if any exist) are practice effects, generalised across stimulus category domains [9]. This is the expected result if linguistic and non-linguistic cognitive control skills are really one and the same. However, while 'strong modularity' seems unlikely, for the reasons mentioned in the last section, the evidence suggests that linguistic and non-linguistic control cannot be considered one and the same, because qualitative differences have been observed between patterns of switch costs in linguistic and non-linguistic tasks [41]. These results suggest that, if bilingual advantages really do emerge as a result of practice, they must also be transferred across the boundary between at least partially distinct systems responsible for linguistic and non-linguistic cognitive control.

This kind of generalisation is the exception rather than the rule in 'low-level' perceptual learning, where training effects are often specific to stimulus parameters such as contrast, spatial frequency, orientation, and even the presentation position relative to fixation [42]. Nearer the other end of the cognitive hierarchy, rehabilitation efforts for stroke survivors with language deficits have also struggled to demonstrate reliable generalisation from trained to untrained items [43]. But transfer has been observed in tasks involving cognitive control. For example when Welch and Seitz [44] trained participants on one of two versions of the Simon task, in which the relevant

stimulus property was either colour (red or green), or shape (triangle or square), they found that participants trained on either task tended to be better, without training, on the other.

Very few studies have directly addressed the kind of transfer implied when bilingual advantages are construed as practice effects. In one such study, experienced bilinguals were shown to experience significant improvements in cognitive control and working memory after undergoing intensive training to become simultaneous interpreters [45]. This is an example of exactly the kind of transfer that bilingual cognitive advantages would seem to require, though the training employed in this study is arguably somewhat removed from the normal experience of second language learning. In another study, bilingual speakers who practiced task switching with non-linguistic stimuli were shown to enjoy an advantage when using their non-dominant language in a linguistic switching task [46]. This is a good example of the transfer of practice effects, but transfer was only observed in the ‘wrong’ direction here, from non-linguistic practice to linguistic effect (where the bilingual advantage implies transfer in the other direction). So while both of these studies suggest that practice effects can be transferred across the boundary between linguistic and non-linguistic domains, neither directly supports the existence of a more general, bilingual advantage in cognitive control.

6. Conclusions

Given the apparently wide-ranging effects of bilingualism at the level of brain structure and function, it would be surprising if the behavioural effects of bilingualism really are completely contained within the language system itself. If bilingual advantages (or differences) in executive functions emerge as a function of transfer given practice managing multiple languages [8,9], then: (a) the nature and extent of that transfer will depend on the details of the practice itself (which supports the claim that studies of the bilingual advantage should record those details in as objective a manner as possible); and (b) the neural mechanisms responsible for those differences – the subject of this special issue – may best be understood as the mechanisms responsible for that transfer, rather than those responsible for cognitive control in the linguistic and non-linguistic domains.

These transfer mechanisms are not well understood in any domain, but the best way to study them may be with longitudinal study designs, like those described in the last section [45,46], both because these designs should be sensitive to what is an inherently longitudinal process (i.e., of transferring practice effects), and because within-subject studies can naturally control for many of the potential confounds that have occupied the field in recent years. The purest test of the bilingual advantage might be a longitudinal assessment, over years, as participants actually master a second language. But shorter experiments might be used to characterise what may be the most critical component of the process, namely the transfer of practice effects on cognitive control skills across different cognitive domains.

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Conflict of Interest

The author declares no conflict of interest.

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