Trends in Cognitive Sciences

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REVIEWS

Review

Ecological Validity in Bilingualism Research and the Bilingual Advantage

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Traditional research in bilingualism has consistently found that switching languages is effortful, placing demands on neural systems of cognitive control. This finding runs counter to most bilinguals' intuitive experience. We review a body of recent work showing that, in fact, when bilinguals switch languages voluntarily, both the behavioral cost of switching and the associated recruitment of cognitive control areas are greatly reduced or completely eliminated. This suggests that switching languages is not inherently effortful, but rather, particular communicative demands may make it costly. The new evidence also challenges the basic premise underlying the bilingual advantage hypothesis. We articulate a more nuanced version of it, in which the advantage is limited to bilinguals who frequently switch languages based on external constraints.

Highlights

Results of traditional language switching tasks have suggested that language switching is behaviorally effortful and requires increased involvement of cognitive control areas.

Recent evidence has challenged this conclusion, showing that when bilinguals are allowed to switch languages freely, this cognitive effort and behavioral cost are either greatly reduced or completely eliminated.

These findings show that switching languages is not inherently effortful, but rather particular circumstances and communicative demands may make it costly.

The new evidence also challenges the basic premise of the hypothesis that bilingualism leads to executive control advantages due to frequent use of control mechanisms in language switching. We articulate a more nuanced, experience-dependent, version of this hypothesis, in which the advantage is limited to bilinguals who frequently switch languages based on external constraints.

Language-Switching and Traditional Ways to Model It

Commanding more than one language is the norm for the majority of the world's population [1,2], and multilingualism has been notably increasing in recent years [3]. A remarkable feature of multilingual individuals is their ability to quickly and accurately switch back and forth between their different languages. Thus, multilingual individuals not only command each of their languages independently, but they are additionally able to alternate and coordinate the rules that govern each language. What are the mechanisms that allow bilingual individuals to effectively do this? How are these systems organized to achieve seamless transitions from one language to the other?

Methodologically, these questions are not easy to answer as it is highly nontrivial to find reliable ways to elicit language switches on demand in the laboratory. To accomplish this, researchers have commonly devised rather artificial switching paradigms, in which bilingual individuals are asked to name a picture or a number in one or another language as prompted by an external cue displayed on the screen [4–14]. The relation between the external cue and its associated language has been arbitrary in these designs: a color or a symbol is selected randomly, and participants are asked to learn the association between this cue and the language it represents. Studies using such paradigms have consistently demonstrated longer reaction times and higher error rates for trials in which participants must switch languages than for trials involving no switching [4–6,8–13] (for a review see [15,16]). This has led to the conclusion that language switching is behaviorally effortful [i.e., there are **switch costs** (see Glossary)]. Neurobiological investigations using these paradigms have additionally found that language switching as prompted by a cue elicits engagement of executive control regions, mainly the prefrontal cortex [7–9,17–19], the pre-supplementary motor area/anterior cingulate cortex (pre-SMA/ACC) [7,8,19–24], and the left caudate nucleus [23–27] (see meta-analysis in [18] and reviews in [26–30]). The literature stemming from this paradigm has proven highly consistent, with widely replicated results across the world in multilingual individuals with many different linguistic backgrounds [7–17,20–25]. As a result, this work has formed the main empirical basis for models of bilingual language switching.

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However, the aim to design carefully controlled experiments that eliminate all potential confounds may have led researchers to create laboratory studies that do not represent actual bilingual language use [31–33] (for a specific description of the methodological limitations of these paradigms see [34]). Relatedly, the finding that switching languages is effortful does not typically match the intuitive experience of bilingual individuals. After all, language switching in bilingual communities is a widespread and well documented phenomenon [35–37]. If switching was effortful, why would bilinguals do it so much? Two properties of the artificially cued paradigms are likely the culprits behind this disconnect: (i) the arbitrariness of the relation between the cue and the target language, and (ii) the forced nature of the switch. Both of these likely lead to more effortful switching than what occurs naturally in bilingual communication. New avenues of research have recently begun to address the influence of these design features and to characterize the nature of language switching in more ecologically valid conditions.

Switching in Response to Natural Cues

Why do bilinguals switch languages in the real world? Typically, people make language choices on the basis of what they know about the interlocutor. In comprehension, script can also be a strong cue to language, for example, a word written in Hangul is very likely to be a Korean word. Recent work has begun to model these types of more naturalistic cues in the lab, with results showing that more natural language cues elicit faster switching and less prefrontal engagement. For example, one study [38] found that the presentation of faces as language cues facilitated lexical access and naming latencies when there was a match between the race of the face and the expected language (e.g., an Asian face as a cue to Chinese). This finding was replicated and extended in [39], which showed that not only faces but also other natural cues such as script facilitate language access, leading to faster reaction times and lower engagement of prefrontal control regions than when there was not a natural association between the utilized cue and the target language (for a further replication, see [40]). Additional work has shown that this facilitatory effect is not specific to faces of particular races or cultural backgrounds. Rather, familiarity with a speaker is enough to create an association between a language and a face that results in faster naming than when this association is absent [41]. Related recent research on bilingual language processing with different paradigms and tasks has additionally suggested that using naturalistic cues facilitates predictions about upcoming language [42,43] (for a review on the role of visual cues for language selection see [44]).

In all, studies using more naturalistic language cues have revealed that although forced language switching is always somewhat costly, it is less costly if the cue that elicits the switch is more natural. This calls into question whether artificially cued switching paradigms usefully model the process of interest (see also [45,46]) and makes a case for more ecologically valid paradigms when attempting to characterize language control in a biologically plausible way.

Uncued, Voluntary Switching: No Prefrontal Engagement, Facilitated Performance

Although the importance of ecological validity in cue selection is likely uncontroversial, cued paradigms still only represent one conversational scenario in which bilinguals code-switch, namely a so-called dual language context. In this context, the choice of language is determined by external demands, most typically the language competences of interlocutors who do not share a language (for example, you might speak one language to your monolingual spouse and a different language to your monolingual mother, leading you to switch when you are all together). However, there is a whole realm of bilingual language switching that does not fit this mold, the so-called '**dense code-switching**' **context**, which occurs in bilingual communities where all individuals speak both languages and thus can switch languages voluntarily without

Glossary

Bilingual advantage: an advantage in various aspects of executive control including attention, inhibition of nonrelevant information, and conflict resolution, derived from the experience of being a bilingual individual and having to constantly monitor and control two languages.
Bimodal bilingual: a person who can produce and understand two languages, each of which uses a different set of articulators (e.g., a person who can sign American sign language and speak English).
Dense code-switching context: a conversational context in which two languages are used, but all interlocutors in the conversation understand both languages, thus imposing no constraints on language choice.
Dual-language context: a conversational context in which one language is utilized with at least one interlocutor and a different language has to be utilized with at least one other interlocutor.
Mixing cost: the overall difference in naming latencies between a situation in which one uses and mixes two languagesand a situation in which only one language is used.
Switch cost: the slower behavioral responses (and associated neural effects) elicited by switching languages for a given item, as compared to not switching.
Unimodal bilingual: a person who can produce and understand two languages, both of which use the same set of articulators (e.g., a person who can sign American sign language and German sign language, or a person who can speak English and German).

any particular demand for them to do so (e.g., Hispanic communities in the USA where Spanish and English are frequently intermixed; for a description of the control processes hypothesized to be involved in each of these contexts, see [47]).

Code-switching being a sentence/discourse level phenomenon [48], it is remarkably hard to study in the laboratory, particularly in production, given the inherent difficulty in accounting for production related artifacts in neural measures and in controlling the utterances participants produce (see Outstanding Questions). However, recent behavioral and neuroimaging research has taken initial steps to try to characterize it at the single word level. In a recent language switching experiment with picture-naming [40], instead of asking Arabic–English bilingual participants to switch languages following an external, artificial cue, participants were first familiarized with one bilingual and two monolingual interlocutors (one English and one Arabic speaker). The experiment itself mimicked a phone conversation with these individuals as they appeared on the screen inside an iPhone-like display. The participants named pictures in a language suitable for communicating with the interlocutors 'on the phone', that is, with the bilinguals they could freely choose which language to use, while with the monolinguals they had to stick to the language spoken by that person. Critically, the stimuli were carefully selected to elicit likely switching with the bilingual interlocutor, that is, some of the items would tend to always be named in English, some always in Arabic, and others in either language depending on the situation, as determined by a prior norming study. The results showed that when participants were voluntarily switching languages, the signatures of effortful language switching – that is, increased anterior cingulate and prefrontal cortex involvement and delayed behavioral latencies – disappeared (Figure 1). This finding can be accounted for by the hypothesis that when free switching is possible, bilinguals often switch languages when this results in facilitated production, that is, if the word(s) come to mind easier in a language other than the one they previously used [49] (also, see [50] for a benefit from being allowed to mix languages as opposed to having to stay in a single language). Intuitively, this is exactly what happens during free switching in a dense code-switching context.

An increasing literature offers further support for the hypothesis that free, voluntary switching is effortless, at least when this switching pertains the insertion of single words from one language into the structure of the other language [35]. Participants in the voluntary switching condition of [49] were instructed to name each picture in whichever language was easier for them, but to then be consistent, and always name that picture in the same language. Presumably, even if the stimuli in this experiment were not chosen to follow a normal distribution of likelihood to be named in each language (cf. [40]), this instruction artificially fulfilled that purpose by making the labels for each object more available in one language than the other as the experiment went on and participants kept repeating the label in the same language. This resulted in participants switching languages for these items and doing so without any additional cost. These results extended previous research by the same group [51] that had also shown cost-free switching when participants named each picture consistently in the same language (reflecting bottom-up availability of the label) as opposed to choosing one language or the other randomly for each picture to ensure they were using both languages equally as frequently, as required by the experimenters (see also [52], their Experiment 1, Figure 2 showing lack of switch costs for voluntary switching in balanced bilinguals). Other experiments where participants also chose freely which language to use replicated reduced behavioral switch costs and distinct engagement of dlPFC (dorsolateral prefrontal cortex) and SMA/ACC during voluntary switching as compared to forced switching [53], (see also [54], although it remains to be corroborated whether activation in the striatal and cerebellar regions, which are also integral to language control, show similar reductions).

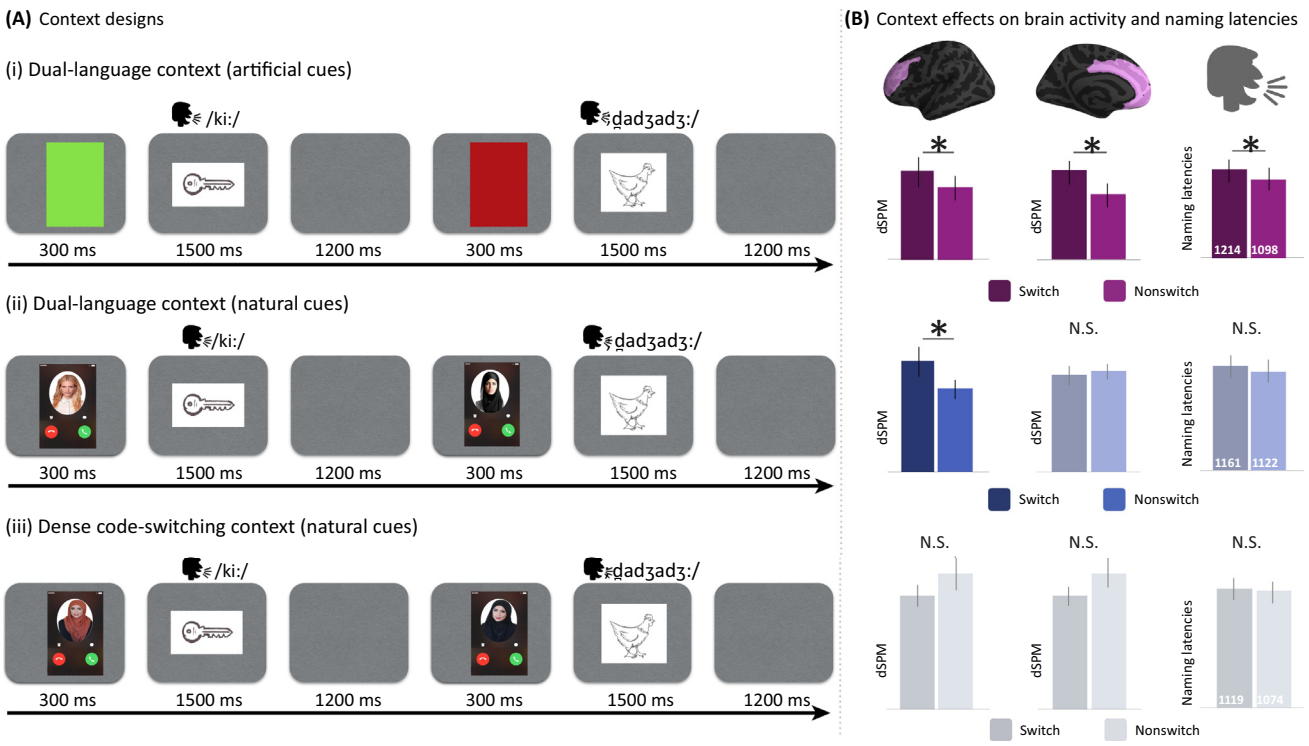

Figure 1. Language Switching Effects through Different Communicative Contexts. Trial design for experimental conditions varying from less natural to more natural contexts (taken from [40]). In all conditions, participants were asked to name the drawing as quickly and as accurately as possible in the language that matched the cue they had just seen. (A) In conditions (i) and (ii), participants had to switch languages based on the available cue. In condition (iii) participants were allowed to choose the language to name the picture freely. (B) Dorsolateral prefrontal cortex (dlPFC; left column), anterior cingulate cortex (ACC; middle column) and reaction time (right column) results for Switch (dark shades) versus Nonswitch (light shades) trials, across the three contexts. Statistical significance is marked with an asterisk (*), nonsignificance is marked with N.S. dSPM stands for dynamic statistical parameter maps, which index noise-normalized brain activity [111].

An exception to these results may be those who found that voluntary switching did not eliminate switch-costs completely [50,51] (see also the unbalanced bilingual group in [52], and the reaction time but not error rate analysis in [55]). Importantly, however, they still found benefits for mixing languages as opposed to sticking to one language, that is, bilinguals were overall quicker when they were allowed to use either language than when forced to use only one of them, showing a benefit for mixing languages (e.g., language mixing benefit, in [55] this benefit is found for the nondominant language). Further, in [50] researchers found that language choice was predicted by behavioral naming times: in this experiment, items that were named more slowly in Basque were named more often in Spanish and vice versa. This again is consistent with the hypothesis that bilinguals voluntarily switch languages based on availability, and that therefore, switching may in many situations be easier than to stay in the same language [40,49].

Similar results pointing to effortless language switching have also been reported in comprehension when using more naturalistic stimuli and paradigms above the single word level. When participants were presented with between-sentence language switches similar to those that frequently occur in natural bilingual conversations, there was no cost associated with switching in reading times (in self-paced silent reading, both for bilingual individuals and for professional translators [56]), or in naming times when participants read a sentence in

silence and had to read a single target word aloud [57]. Studies on within-sentence switching have reported convergent findings. For example, when experimenters compared single-language sentences to sentences containing switches between the Spanish progressive auxiliary *estar* (be) and an English present participle, which are commonly found in natural speech corpora, experimenters found no switch-cost in eye-tracking measures (R.E. Guzzardo Tamargo, PhD thesis, The Pennsylvania State University, 2012). This lack of switch costs in comprehension also extends to studies on the auditory comprehension of naturalistic language switches ([40,58] during bilingual mode, cf. [59]). For example, in [40], participants listened to whole natural conversations and showed no costs for the perception of inter or intra sentential switches at any syntactic boundary (sentence, clause, phrase, or single word), which covered the three types of possible code-switches (insertion, alternation, and congruent lexicalization) as described by [35]. In the auditory domain, speakers appear to generate subtle implicit phonetic cues in anticipation of upcoming code-switches [59–63]. These cues then have a predictive value for bilingual listeners who are consequently able to foresee when a switch is coming. In naturalistic paradigms where these phonetic cues are maintained in the stimuli, switching has been found to be effortless. Thus, the costs that are observed in more artificial comprehension paradigms may emerge from the elimination of these subtle cues, making the language switches unpredictable or sudden in a way that does not represent real language switching.

In all then, recent work shows that when bilingual individuals are placed in a dense code-switching environment where they are allowed to switch languages freely, switching is behaviorally effortless and the involvement of language control networks is decreased. This invites a revision of the persistent idea in bilingualism research that language switching is intrinsically effortful. It now seems likely that switch costs in the literature are due to a large extent to specific circumstances common in laboratory experiments, such as artificial external cues. In more ecologically valid conditions, particularly when participants are given freedom to switch, language switching is not inherently effortful and may even be overall beneficial, a finding that clearly conforms to most bilinguals' intuitive experience.

Experience Dependent Bilingual Advantage

The relative costlessness of language switching as discussed here, also has critical consequences for the so-called **bilingual advantage** hypothesis, a source of heated debate in the last decade. According to this hypothesis, bilingual individuals, as a mere consequence of being bilingual develop an improved cognitive control system. Because the neural underpinnings of language control and general domain executive control overlap to some extent [8–10,25,64–67]; cf. [11,68], this enhancement in language control mechanisms is proposed to generalize to nonlinguistic tasks, resulting in an advantage in many tasks requiring selective attention and inhibition (for comprehensive reviews see [69–72]). Specifically, advantages have been found for bilingual individuals over monolingual individuals in tasks that require the inhibition of distracting information (e.g., [73,74]), switching between tasks (e.g., [75–77]), or conflict resolution [78,79], and these effects have been accompanied by decreased activation in executive control regions (for reviews see [71,72,80,81]).

The opponents of this hypothesis have failed to replicate this advantage in young adults [82,83], children [84], and the elderly [85], and have hence suggested that such advantage may be a product of factors other than bilingualism proper (for example, small sample sizes and inconsistencies in the methods [86,87], for a response see [88]; or a result of a publication bias [89], for a response see [90]; for a thorough review of the evidence for and against the bilingual advantage hypothesis please refer to [91]).

If it is the case that language switching in fact is not as effortful as previously described, and does not engage cognitive control as much, then one of the basic premises of the bilingual advantage hypothesis disappears. However, a more nuanced version of the hypothesis could still hold, a possibility that we will elaborate in what follows.

Specifically, a version of the hypothesis that would still conform with our emerging understanding of language switching would be one in which the advantage is restricted to individuals who grow up, or are frequently immersed in contexts in which language switching is common, and further, these switches must be controlled based on outside constraints, which require frequent engagement of top-down control mechanisms. Specifically, we predict that this advantage will be most salient in individuals who frequently find themselves in dual-language contexts, where they constantly have to engage in goal reconfiguration and apply top-down control to fulfill the requirements imposed by different interlocutors. Contexts allowing free and rampant language switching may not offer similar exercise of targeted top-down control, and hence, would not necessarily translate in the same advantage.

Relevant empirical evidence comes from recent studies showing a direct relation between individuals' language switching background and their performance during task switching [92–98]. A recent study [92] compared the performance of monolinguals, bilinguals who switch languages often, and bilinguals who do not switch often in a task-switching paradigm. In this task participants were presented with red or blue triangles, or circles, and they had to switch between sorting them based on the color or the shape, following a visual cue. The experimenters found a decrease in switch-costs for bilinguals who frequently switch languages as compared to monolinguals, while bilinguals who do not switch languages often did not differ from monolinguals. Further evidence has shown that bilinguals who are frequently in a **dual-language context** (i.e., switching languages based on the interlocutor they are interacting with) show reduced switch costs as compared to bilinguals with a comparable language background but who do not switch frequently [93]. This experiment also showed that while experience in dual-language contexts decreased the magnitude of the switch cost, experience in dense code-switching did not. Similar results were found in a conflict resolution task in children [94], where children whose parents spoke different languages (i.e., grew up in a dual-language context) outperformed monolinguals of two bilingual parents.

Lastly, a higher rate of everyday language switches has been found to attenuate the costs associated with mixing in a set shifting task [95] (but see also [96,97]), and training bilinguals in externally cued switching has resulted in reduced behavioral switch costs and ACC and dlPFC activity [98]. In all then, a growing body of recent evidence has shown a direct relation between the amount of switching that bilingual individuals experience, and the degree to which they show **mixing costs** and switch-costs during language and task switching.

Our proposal that the bilingual advantage emerges from the way in which languages need to be controlled, as opposed to from being a bilingual in general, also reconciles the evidence from **bimodal bilinguals**, that is, individuals who sign one language and speak another (in contrast to **unimodal bilinguals**, whose two languages employ the same articulators; e.g., two spoken or two signed languages). These individuals do not show evidence of an executive control advantage neuroanatomically [66] or behaviorally [99]. The authors of the latter study found an advantage for unimodal bilinguals over monolingual individuals in a set of flanker tasks, but crucially found that bimodal bilinguals did not perform better than monolinguals. The authors proposed that the reason behind this difference is that unimodal bilinguals need to constantly practice more difficult selection and control processes when switching from one language to

the other; however, bimodal bilingual individuals do not face the same selection constraints and processing demands, arguably because they rarely switch between two languages (instead, they prefer to produce both, and sign and speak at the same time [100,101]). Hence, like bilingual individuals in dense code-switching communities, bimodal bilinguals do not need to control language selection as strictly, given that interference from the nontarget language does not disrupt communication. Thus, they can engage in the type of language switching they usually engage in (switch from one language to both [99–101]) without forcefully having to inhibit the predominant response, recently suggested to be the cause for effortful language switching [102]. However, the cognitive control advantage emerges for bimodal bilinguals if they often simultaneously translate, a context where language control is required [103]; and further, this advantage increases proportionally with experience in this context.

In summary, an increasing literature and set of considerations converge on the idea that the existence, or nonexistence, of the bilingual advantage largely depends on the specific context the bilingual individual lives in, and the switching demands this environment poses on them (see also [46,67,76,97]). Although based on the available evidence, we suggest that dual-language contexts are the environments recruiting the specific control requirements most conducive to subsequent bilingual advantages, we acknowledge that the current data may not yet reveal the full picture. Consequently, it is possible that new evidence in this regard could eventually invite a reformulation and clearer definition of the contextual boundaries that lead to cognitive advantages.

Concluding Remarks and Future Directions

Although significant progress has been made in trying to unveil the cognitive architecture and neural bases of bilingualism, we are still far from a mechanistic, neurobiological understanding of this phenomenon, particularly in environments that more accurately mirror organic language switching. The life experiences of bilingual individuals are remarkably heterogeneous across individuals, given the many combinations of possible languages, social backgrounds, and migratory statuses, and within individuals across a lifespan. How to meaningfully capture and represent this variance in an experimental setting is not trivial [45,85,104,105] (see Outstanding Questions), and quite plausibly, inconsistency in the bilingual advantage literature may largely be due to insufficient representation of this diversity. Further, reliance on self-reports of bilingual proficiency, which have proven to be highly variable and unreliable [106], have additionally confounded which individuals are considered bilinguals, and thus, possibly crucially, influenced who enters the exploration of bilingual advantages. However, from a thorough review of the literature, a few relatively clear facts emerge.

First, despite color-cued paradigms having been a useful first step in characterizing language switching, recent results suggest that more naturalistic paradigms are needed for characterizing the cognitive processes underlying language switching in a dual language context (i.e., when following external cues). Further, not only language-switching tasks, but general domain tasks should also be accurate in capturing switching ability, as recent analyses have shown that both the choice of tasks and even minor (yet nontrivial) manipulations of these tasks have played critical roles on the detection of bilingual advantages [46].

Second, given the accumulating evidence that switching costs are modulated by bilinguals' experience with code mixing [33,34,45,92–98], classification of bilinguals into groups in research studies should take into account not only age of acquisition and language use, but crucially, also general rate of language switching and the specific contexts in which language switching occurs. In light of this, a need emerges for the development of a

Outstanding Questions

What is the unit of switching, that is, do bilinguals turn off and on whole lexicons and languages, or do they switch on and off individual lexical items? Relatedly, do bilinguals turn on and off all language levels (phonology, morphology, syntax and semantics), or do they only alter the levels that are relevant for the upcoming switch?

Are language switches determined by the relative frequency of the individual words and phrases that bilingual individuals are planning to produce? If this is so, is there anything inherent to the nature of language switching, when not constrained by external factors, that is qualitatively distinct from frequency driven lexical selection?

If language switching is not inherently effortful, what specific subcomputation involved in this process makes cued or externally constrained language switching costly?

In light of corpus-based and experimental evidence suggesting that well in advance of the actual switch, the phonetic details of speech are predictive of an upcoming switch, can we determine what the nature and full time-course of switch related language planning is?

What paradigms would allow us to overcome methodological challenges such as: (i) production related artifacts in neural measures, and (ii) the difficulty of controlling the utterances participants produce, to get closer to a reliable investigation of spontaneous and sentence or discourse level language switching?

Given the accumulating evidence that individual differences in many aspects of one's language background lead to distinct results in language switching behavior, how can we create objective quantifications of bilingual proficiency and tackle the vast heterogeneity across and within bilingual populations to produce systematic research?

standardized quantitative method for the evaluation of one's language switching experience. Additionally, given the vast imbalance in the amount of research that has been devoted to externally cued language switching, as compared to naturally cued and voluntary switching, greater efforts need to be made to illuminate the latter types of language switching, crucial for obtaining a complete picture of the cognitive mechanisms enabling language switching more generally. In this regard, it is of particular relevance that we both unveil the potential executive demands that may be distributed over time in advance of a code-switch, which could account for speech rate decrease prior to such switches [107], and that we reveal how items from both languages may compete to bind to functional roles in the utterance plan [108].

Third, two bodies of research have emerged with seemingly opposing results in terms of whether there is a bilingual advantage in cognitive control. After a decade of well-controlled research, both sets of evidence are robust enough to deserve careful consideration. Possibly the dissonance between these results does not lie in the ultimate claim of whether or not a general bilingual advantage exists, but rather on the more subtle and specific characterization of what the source and prerequisites for this advantage may be. Given the reviewed literature, we have proposed that only bilinguals well-versed in externally constrained language switching, that is, bilinguals who grew up or find themselves frequently in dual-language contexts, may show this advantage. Whether this hypothesis is correct only empirical research will unveil, but what seems undeniable at this point, is that the nature of the debate, and the need to categorically prove the existence or absence of the advantage in all bilinguals, may be hindering progress towards a more nuanced yet richer answer. It took over 30 years to turn the idea that bilingualism causes retardation [109] into the possibility that there may be some cognitive benefits associated with it [110]; now our task is to understand the specific sources of this advantage, which undeniably is observed in some bilinguals.

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