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CHAPTER 4

Adaptive control and brain plasticity

A multidimensional account of the bilingual experience and its relation to cognition

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A central question in cognitive neuroscience concerns how individuals' cognitive abilities are shaped by learning from experience. This paper presents a critical overview of the discoveries that have emerged from the study of bilingualism, and the implications that they hold for language, cognition, and the brain. In particular, we review the range of cognitive control processes that appear to be influenced by bilingualism and the theoretical frameworks that have been proposed to account for the differences between bilinguals and monolinguals as well as among bilinguals themselves. We discuss current research directions on the consequences of bilingualism, and report emerging findings on the role of bilingual experience in the adaptation of the bilingual language system.

Keywords: bilingualism, cognitive control, parallel activation, inhibition, conflict monitoring

1. Introduction

A central question in cognitive neuroscience concerns how humans' cognitive abilities are shaped by experience. The study of neuroplasticity is a growing area of research with evidence pointing to changes in brain structure and function in response to environmental demands. Structural changes have been reported in the form of increased neuron density or volume in regions responsible for relevant skills such as spatial navigation in taxicab drivers (Maguire et al., 2000) or spatial memory in adults who engage in exercise (Erickson et al., 2010). At the functional level, specific forms of training, such as playing an instrument, have been found to affect the development and efficiency of cognitive functions (Bialystok & Depape, 2009). The acquisition and regular use of more than one language is a particular

stimulating experience, also shown to have systematic and enduring consequences for the mind and brain (Bialystok, 2017).

In recent years, the bilingual brain has become a hallmark of neuroplasticity, providing insight into the conditions and constraints that characterize the underlying processes of language and cognition. How does the bilingual experience lead to enhanced neuroplasticity, and affect cognition more generally? This paper presents a critical overview of the discoveries that have emerged from the study of bilingualism and of the implications that they hold for language, cognition, and the brain. In particular, we review the range of cognitive control processes that appear to be influenced by bilingualism, and the theoretical frameworks that have been proposed to account for the differences between bilinguals and monolinguals as well as among bilinguals themselves. In our discussion, we assess the evidence in favor of and against such differences, and we conclude by discussing current challenges and promising directions in the field.

Although our understanding of the scope of the cognitive consequences of bilingualism is evolving, one prominent proposal is that the mechanisms underlying experienced-induced effects are likely found in the cognitive (or executive) control system: a set of domain-general processes responsible for monitoring and regulating goal-directed behavior (e.g., Miyake, 2012). The link between bilingualism and cognitive control has been attributed to the observation that bilingualism differentially affects distinct cognitive control processes.

The remainder of this paper is structured as follows. First, we review two lines of research on the consequences of bilingualism for language processing. The first exploits the observation that both languages are active even when bilinguals intend to use one language alone (Kroll, Dussias, Bice, & Perrotti, 2015). The second approach examines the adaptation and permeability of the bilingual language system. Results from these two lines of work suggest that the mind and brain are sensitive to the outcomes of the bilingual experience in ways that can have consequences for language, but also for domain-general cognitive processing. In Section 2, we focus our review on studies investigating the relation between language and cognition in younger adults, using both behavioral and neuroscientific methods. Although most of the work reviewed here reports some association between these two factors, bilingual effects are not always consistently observed. This paper attempts to reconcile these discrepant findings by proposing a more in-depth characterization of the bilingual experience and of individual differences. We conclude with a discussion of current research directions on the consequences of bilingualism, and report emerging findings on the role of bilingual experience in bilingual adaptation.

1.1 Bilingual language activation

A key finding in bilingualism research is the evidence that a bilingual's two languages are simultaneously active to some degree when processing words in one language alone (see Kroll, et al., 2015, for a review). For example, many studies have demonstrated that cognates, which are words that have similar orthography and carry the same meaning in two languages ('piano' /pi'ænəʊ/ in English and 'piano' /'pjano/ in Spanish), are processed more quickly than non-cognate words. At the same time, interlingual homographs, which are words that share orthography but not meaning (e.g., 'pie' in English means 'foot' in Spanish) are processed more slowly (Dijkstra, Grainger, & van Heuven, 1999). If bilinguals could keep the two languages functionally separated, then word recognition in one of the bilingual's languages should operate independently of the other language. The fact that it doesn't means that bilinguals also activate the language not in use, and are open to its influence during lexical processing (Kroll & Dussias, 2013).

Cross-language interactions have been observed when bilinguals process in the second language (e.g., Dijkstra, Van Jaarsveld, & Ten Brinke, 1998), but also when they process their first language (e.g., van Hell & Dijkstra, 2002); these interactions have been reported across different language modalities (Morford, Wilkinson, Villwock, Piñar, & Kroll, 2011) and also across languages with different writing scripts (Hoshino & Kroll, 2008; Thierry & Wu, 2007). Although the majority of research revealing parallel activation between the bilinguals' two languages comes from work examining lexical access through the processing of cognates and homographs, there is a growing body of evidence supporting non-selective effects in other linguistic domains, such as phonology (e.g., Jacobs, Fricke, & Kroll, 2016) and syntax (e.g., Hartsuiker, Pickering, & Veltkamp, 2004; Hatzidaki, Branigan, & Pickering, 2011; Runnqvist, Gollan, Costa, & Ferreira, 2013; Sanoudaki & Thierry, 2014).

One observation is that despite the parallel activation of the two languages, bilinguals rarely make errors of using the unintended language (Bobb & Wodniecka, 2013); this raises the question of what processes enable bilinguals to control or regulate that competition. Studies examining the effects of cross-language competition provide empirical evidence in support that bilingual language selection implicates inhibitory processes. For example, Macizo, Bajo, and Martín (2010) asked Spanish-English bilinguals to decide whether pairs of English words were semantically related. Critical word pairs were interlingual homographs (e.g., 'pie-toe', where 'pie' is the Spanish word for 'foot') followed by word pairs that included the English translation of the Spanish homograph (e.g., 'foot-hand'). Participants were slower to respond to word pairs that contained homographs (e.g., 'pie-toe'), but more importantly, they were also slower to respond to word pairs that

contained the translation of the Spanish meaning of the homograph (e.g., ‘foot’ in the example above). This suggests that bilinguals had actively suppressed the Spanish translation during the homograph condition and had not yet overcome this inhibition.

There is also behavioral evidence that individual differences in cognitive control abilities can modulate cross-language competition (e.g., Lev-Ari & Keysar, 2014). For example, in an eye-tracking study of L2 sentence reading, Pivneva, Mercier, and Titone (2014) reported that the relation between inhibitory control skill and language proficiency is much more complex than previously assumed. Their results showed that greater L2 proficiency reduced cross-language activation in terms of cognate facilitation but did not modulate the degree of homograph interference. In contrast, greater inhibitory control reduced cross-language activation in homograph interference but did not modulate the degree of cognate facilitation. Together, the results suggest that the bilingual language system and cognitive control network are subject to adaptive changes that may depend on individual differences in cognitive resources and on certain aspects of the bilingual experience. Importantly, these findings underscore the role that both cognitive control and language experience (here indexed by proficiency) play a role in how bilinguals manage cross-language interactions. Although the extent to which individual variability modulates this relationship is not yet well understood, future research should leverage this evidence to better understand the heterogeneity of previous findings, and to gain new insights on the fundamental dynamics between language and cognition (e.g., Surrain & Luk, 2017).

1.2 Bilingual language adaptation

Becoming bilingual is perhaps one of best illustrations of adaptation of the human mind. The evidence suggests that the continual interplay between the two languages involves a dynamic set of adaptive changes across the lifespan (Bialystok, 2017; de Bot, Lowie, & Verspoor, 2007). In recent years, researchers have exploited the existence of bidirectional influences between languages to examine the degree to which bilingual minds accommodate to experience. Evidence of changes to the native language has been reported from the earliest of stages of L2 learning (Bice & Kroll, 2015) to higher levels of proficiency, and at all levels of language processing from the lexicon (e.g., Ameel, Storms, Malt, & Sloman, 2005), to the phonology (e.g., Chang, 2013), and the grammar (e.g., Hartsuiker, Pickering, & Veltkamp, 2004; Dussias & Sagarra, 2007).

One illustration comes from the study of syntactic ambiguity resolution in bilingual speakers. In an eye-tracking study, Dussias and Sagarra (2007) asked whether living in the L2 environment could influence how bilinguals interpret

ambiguous sentences in their L1. Spanish monolinguals and Spanish-English bilinguals with either limited or extensive exposure in the L2 environment read syntactically-ambiguous sentences containing a relative clause that appeared after a noun phrase with two potential attachment sites (e.g., *El policía arrestó a la hermana de la criada que estaba enferma* ‘The policeman arrested the sister of the servant_{FEM} who had been ill_{FEM}’). They found that while monolinguals and bilinguals with limited L2 exposure attached the relative clause to the first noun (the feature typical of Spanish), the bilinguals with extensive L2 exposure attached the relative clause to the second noun. These results suggest that exposure to the English interpretation had modified bilinguals’ sentence parsing preferences in the native language. The extent of the consequences that stem from bidirectional influences is unclear. What is apparent is that a bilingual’s two languages do not functionally behave like either native language of monolinguals (Grosjean, 1989) and might, therefore, result in consequences that extend to domain-general cognition.

Adaptive changes involved in learning an L2 have been shown to lead to the structural (Li, Legault, & Litcofsky, 2014; Mechelli et al., 2004) and functional (Luk, Green, Abutalebi, & Grady, 2012; Perani & Abutalebi, 2005; Zou et al., 2012) reorganization of the brain’s networks. There is an increasing body of evidence from neuroimaging studies showing that the brain plasticity associated with lifelong bilingualism is not necessarily specifically linguistic; rather, it appears to involve domain-general cognitive control processes (e.g., De Baene, Duyck, Brass, & Carreiras, 2015; Hervais-Adelman, Moser-Mercer, & Golestani, 2011).

2. The cognitive underpinnings of the consequences of bilingualism

Approaches to understanding the consequences of bilingualism have traditionally focused on isolated processes as indexed by performance on linguistic and nonlinguistic tasks. There is considerable evidence suggesting that bilinguals differ from monolinguals in their performance on cognitive control and linguistic tasks (for reviews, see Bialystok, 2009; Bialystok & Craik, 2010; Bialystok, Craik, Green, & Gollan, 2009). One claim that has been examined is that, whereas bilinguals typically outperform monolinguals in tasks involving cognitive control, their performance is hindered in tasks that rely on linguistic domains due to bilinguals’ constant need to control and manage their languages (Kroll & Gollan, 2014). Notwithstanding, differences are not always consistently observed across studies, and the evidence for the precise processes supporting these differences in cognitive control is equivocal and a matter of ongoing research (Bobb, Wodniecka, & Kroll, 2013). Below we discuss two theoretical explanations that have been proposed to account for the effects of bilingualism on cognition.

2.1 Inhibition-based approaches

According to the Inhibitory Control (IC) model (Green, 1998), a theoretical approach that is based on Norman and Shallice's (1986) model of cognitive control, language selection requires an inhibitory control mechanism that regulates parallel activation by suppressing the representation of the language not in use. While the IC model does not explicitly predict an advantage of bilinguals over monolinguals in their ability to resolve conflict in nonlinguistic tasks, research supporting the claims of this model suggested that the underlying cause for bilingual effects resides in the ability of bilinguals to regulate cross-language interference (Abutalebi & Green, 2007; Bialystok, 2001; Bialystok, Craik, Klein, & Viswanathan, 2004).

Perhaps the most compelling evidence for this proposal comes from a study by Emmorey, Luk, Pyers, and Bialystok (2008) on bimodal bilingualism. Emmorey et al. asked whether bimodal bilinguals (i.e., speech-sign bilinguals) would show the same differences as unimodal bilinguals (i.e., speech-speech bilinguals) when compared to monolingual speakers. They compared the performance of monolinguals, bimodal, and unimodal bilinguals on flanker performance. In this task, participants must make a response based on the direction of a target arrow that is flanked by arrows pointing in the same (congruent) direction or the opposite (incongruent) direction. Emmorey et al. observed that while unimodal bilinguals outperformed the other two groups on incongruent trials, monolinguals and bimodal bilinguals performed similarly. These results were taken to suggest that the benefits for unimodal bilinguals can be attributed to the expertise gained as a consequence of a life spent regulating cross-language competition.

Support for an inhibitory account is also found in neuroimaging studies examining the neural substrates of language switching, which have shown increased intensity of activation when bilinguals are asked to switch between naming in the L1 and the L2, relative to naming in one language only. During language switching, the brain regions involved (e.g., the prefrontal cortex and the left caudate) correspond to areas associated with managing competing interference and inhibition of inappropriate responses (Abutalebi et al., 2008; Hernandez, Dapretto, Mazziotta, & Bookheimer, 2001). There is also evidence showing differences between monolinguals and bilinguals in the functional overlap of language processing and cognitive control processes. To determine the degree of functional overlap of brain regions involved in language and cognitive control, Coderre, Smith, van Heuven, and Horwitz (2016) asked bilinguals and monolinguals to perform the flanker task and a semantic categorization task that required the categorization of nouns as either living (e.g., *dog*) or nonliving (e.g., *table*). Conjunction analysis showed functional overlap in the left inferior frontal gyrus, a brain region often involved during interference suppression and response inhibition in bilinguals, whereas no overlap occurred in monolinguals.

While there is evidence that bilinguals demonstrate reduced interference effects on conflict trials (e.g., Blumenfeld & Marian, 2011; Poarch & van Hell, 2012), other findings are incompatible with the notion that inhibition is the only mechanism underlying bilingual language competition (e.g., Morales, Yudes, Gómez-Ariza, & Bajo, 2015), and consequently, with bilingual advantages in domains of cognitive control (Hilchey & Klein, 2011). Bilingual advantages are often not restricted to contexts involving the suppression of competing responses but have been found in the contexts for which no inhibition is required (Marzecová et al., 2013). To illustrate, one problem with an account based solely on inhibitory control is the recurrent finding of a bilingual advantage in congruent trials (for which there is not conflict) in addition to the advantage in incongruent trials (Martin-Rhee & Bialystok, 2008). Furthermore, advantages have been reported in other control processes sometimes in the absence of an inhibitory control advantage (Bogulski, Rakoczy, Goodman, & Bialystok, 2015).

2.2 Conflict monitoring approaches

Past research has suggested that mechanisms related to monitoring and goal maintenance might alternatively underlie the bilingual advantage in cognitive control (Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009). From this perspective, bilingual language selection involves the continuous monitoring of contextual cues to support the goal of speaking in one language rather than another. Because the development and maintenance of task goals are supported through proactive control processes, it is assumed that bilinguals are able to reduce cross-language interference before it occurs. Recent evidence suggests that language switching training, a paradigm that requires monitoring and maintaining a cue to successfully select the target language, can lead to a preference of a proactive control mode (Zhang, Kang, Wu, Ma, & Guo, 2015).

Based on bilinguals' experience developing and maintaining goal representations, it is hypothesized that bilinguals are better able to exploit cues in their environment more efficiently than monolinguals, which may indirectly lead to greater efficiency of monitoring processing and in selecting goal-relevant information. Costa, Hernández, and Sebastián-Gallés (2008) used the Attentional Network Task (ANT), a cued variant of the flanker task which assesses alerting, orienting, and attention (Fan, McCandliss, Sommer, Raz, & Posner, 2002), to decompose potential consequences of bilingualism in different components of attentional control. The comparison of monolinguals and bilinguals revealed that bilinguals were not only more efficient at resolving conflicting information, but they were overall faster and experienced reduced switching costs due to the presence of an alerting cue. In a subsequent study that manipulated the monitoring demands of

the flanker task, Costa et al. (2009) reported a bilingual advantage only when the task conditions required a high degree of monitoring resources. They interpreted these findings to suggest that bilinguals were better able to adjust to conflict-nonconflict situations than monolinguals, supporting the view that bilingualism taps into strategies involving monitoring and goal maintenance.

Recent neuroimaging studies comparing monolinguals and bilinguals have found qualitative differences of neural networks involved in conflict monitoring. In a study by Abutalebi et al. (2011) investigating adaptive changes in conflict resolution, monolinguals and bilinguals were administered the flanker task. Relative to monolinguals, bilinguals showed less activation in the anterior cingulate cortex (ACC), a region central in detecting and monitoring conflicts in information processing (Abutalebi & Green, 2016; Botvinick, Cohen, & Carter, 2004; Kerns et al., 2004). This pattern of brain activation was consistent with the behavioral data showing a reduced magnitude of the conflict effect in bilinguals compared to monolinguals. Lastly, there was an association between the functional and behavioral size of the conflict effect in the flanker task and gray matter volume in the ACC in bilingual participants only, indicating a more efficient use of this structure and suggesting that bilinguals may adapt better to conflict situations.

However, evidence supporting a bilingual advantage in monitoring processes has not been consistently observed. Prior (2012) tested bilinguals' inhibitory control and monitoring abilities in a task-switching paradigm. While bilinguals exhibited stronger inhibitory control relative to monolinguals, there was no advantage in monitoring abilities between the two groups. One reason for the inconsistent findings across studies may be related to the specific task demands of the different paradigms used and/or to differences in bilingual sample characteristics (see Surrain & Luk, 2017, for a detailed discussion).

In this regard, a study by Tao et al. (2011) suggests that the inclusion of characteristics pertaining to language experience may reveal a much more complex view of bilingual consequences. In the study, monolinguals and early and late Chinese-English bilinguals performed a variant of the ANT task to examine the impact of age of L2 acquisition and language proficiency on the modulation of cognitive control processes. Between-group comparisons revealed a differential impact of early and late bilingualism on cognitive control. Both bilingual groups outperformed monolinguals in the task, but while late bilinguals seemed to show enhanced conflict resolution, early bilinguals showed the greatest advantage in monitoring processes. This suggests that individual characteristics of language experience can differentially affect components of cognitive control.

The search for the underlying component process of cognitive control to account for between-group differences in nonlinguistic cognitive control confirms the limitations of the past research. Accounts based exclusively on inhibition

or monitoring cannot explain performance in tasks that tap into other aspects of cognitive control (Bialystok, 2010; Prior & MacWhinney, 2010). We also note that studies investigating the potential consequences of bilingualism on brain and behavior has not always yielded converging evidence (see discussion in Bialystok, 2017, this volume). Most relevant to our discussion is that inconsistent findings in the literature have spawned a debate questioning the existence of the bilingual effects, particularly with regard to the bilingual advantage in cognitive control (Paap & Greenberg, 2013; Valian, 2015). The reasons underlying this debate are twofold: first, single-process accounts can only explain some bilingual differences but not others (e.g., differences in inhibition but not in working memory or task switching); and second, the presence or absence of differences are not consistently observed across studies. Another factor that may also result in cognitive effects of bilingualism is the complexity of characterizing variability in language experience. The current literature lacks consistency in this regard, as exemplified by the recent and systematic review by Surrain and Luk (2017) of the labels and descriptions that have been used to describe bilingual and monolingual participants. Their review, based on 186 studies, found that less than half the studies included objective measures of linguistic proficiency, and that only 30% of studies reported information about the sociolinguistic context in the description of the sample. We elaborate on how bilingual language experience may modulate language processing and cognitive control in the following section.

3. Towards an ecological approach to bilingualism

Current research trends suggest a paradigm shift that breaks away from between-group comparisons in simple cognitive control tasks to advance our understanding of the consequences of bilingualism (Baum & Titone, 2014; Bialystok, 2017; Bialystok, Kroll, Green, MacWhinney, & Craik, 2015; Green & Abutalebi, 2013; Surrain & Luk, 2017). An issue that stems from viewing the bilingual advantage as a monolithic construct is that one-to-one correspondences between individual control processes and bilingualism necessarily imply effects that are specific and isolated. Notwithstanding, the evidence suggests that bilinguals may differ from monolinguals on a range of control processes. These findings are also congruent with recent conceptions of the cognitive control system, which propose that individual cognitive components are correlated, sharing a common core yet separated with unique features (Miyake & Friedman, 2012). Although the fractionation and interdependence of the cognitive control network remains a matter of ongoing debate, recent proposals have suggested that bilingual consequences are best explained by a combination of different mechanisms.

An increasing number of studies have adopted an integrative approach to examine the coordination and interaction of control processes in bilinguals. For example, Morales et al. (2015) examined the dynamic interplay between monitoring/proactive and inhibitory/reactive control modes in monolinguals and bilinguals. Participants were administered the AX Continuous Performance Task, in which the continuous adjustment between the two components of control is required. In this experimental paradigm, participants were asked to respond to target and nontarget probes based on a cue stimulus presented at the beginning of each sequence. Demands for employing contextual information are increased by introducing three distractor letters between every cue and probe. Morales et al. predicted a modulation of both control processes in bilinguals, given their extensive experience with increased demands associated with monitoring and inhibitory processes. While the overall performance did not differ between the two groups, bilinguals outperformed monolinguals on conditions requiring a reactive readjustment of a proactive control mode, suggesting that the study of the cognitive consequences of bilingualism cannot be reduced to single componential analyses but rather should consider a range of interactive processes.

Kroll and Bialystok (2013) propose adopting a multivariate view to better consider the full range of cognitive consequences of bilingualism. Using this approach, Vega-Mendoza, West, Sorace, and Bak (2015) examined a range of cognitive processes in monolinguals and bilinguals with different levels of L2 proficiency. Measures included different aspects of attention, category and letter verbal fluency, picture naming, and a language history questionnaire. In a cross-sectional design, bilinguals overall outperformed monolinguals in measures of selective attention requiring inhibition of irrelevant stimuli. Furthermore, while there was no difference between monolinguals and bilinguals at initial stages of L2 learning on measures of attentional switching, a bilingual advantage emerged in participants in their fourth year of language instruction that was absent in the monolingual group. Contrasting results were also found for letter verbal fluency: while both groups performed equally at first, monolinguals outperformed bilinguals at later stages of language learning. These findings illustrate the complexity involved in the characterization of the bilingual experience. Rather than reducing the effects of bilingualism to the presence or absence of advantages on a single process, the critical question becomes how particular aspects of language experience can influence the range of cognitive consequences as well as the interactions between them.

Given these findings, it is not surprising that cognitive differences in bilinguals emerge under some circumstances but are absent under others. The identification and contrast of factors that trigger adaptive changes in control processes are key to understanding what characterizes the complexity of the language control network (Luk & Bialystok, 2013). Further research is needed toward understanding which

factors mediate the recruitment of language and cognitive processes in bilinguals. Factors such as experimental context (Abutalebi et al., 2008), language proficiency (Costa & Santesteban, 2004), and immersion context (Linck, Kroll, & Sunderman, 2009) may modulate adaptive changes in cognitive control. In an ERP study investigating the effect of experimental context on cognitive control, Wu and Thierry (2013) reported that bilinguals' ability to resolve interference was modulated by implicit contextual language cues. They manipulated a nonlinguistic conflict resolution task by intermittently presenting words in either one language or in two languages. Bilinguals showed a reduced P300 amplitude, an index of cognitive interference, when exposed to a dual language context relative to a single language context. These findings suggest an interaction between nonlinguistic cognitive interference and language context such that the processing of conflict is enhanced when the bilinguals are exposed to their two languages.

In an attempt to theoretically characterize the circumstances underlying differential outcomes among bilinguals, Green and Abutalebi (2013) proposed the Adaptive Control Hypothesis (ACH). The ACH holds that bilingualism places demands on language control processes on the basis of the behavioral ecology of the bilingual speaker. This measure is operationalized in terms of the interactional contexts of language use framing the experiences of speakers. Specifically, the model distinguishes between three interactional contexts with different patterns of conversational exchanges: a single-language context in which one language predominates and the other language is exclusively used in a distinct environment; a dual-language context in which both languages in the same environment; and a dense-codeswitching context in which bilinguals customarily alternate between languages. The contexts differ in the explicit presence of other languages and in how interference between languages is resolved. While speakers in single- and dual-language contexts must avoid interference from the non-target language, speakers in a codeswitching context have the freedom to use either language. Such circumstances will impose speakers to establish and maintain a control state that is either *competitive* (to restrict entry of non-target language) or *cooperative* (to permit opportunistic responses from either language). The Control Process (CP) model (Green & Wei, 2014) elaborates further on the distinction between states of language control: while a competitive control state exploits the resources of a single language, a cooperative control state exploits the resources from one language or both. The CP model assumes that while bilinguals in single- and dual-language contexts typically establish a competitive relationship between languages, bilinguals in a codeswitching context establish a cooperative relationship for managing the demands of speech production. The CP model specifically predicts that differences in speakers' interactional behaviors are associated with distinct control states.

Beatty-Martínez and Dussias (2017) conducted a study to empirically test the predictions of the ACH framework. They specifically examined the consequences of adaptation in language processing in codeswitching and non-codeswitching bilinguals. Using ERPs, they compared the processing of different types of codeswitches that were either rarely- or commonly-attested in bilingual corpora. For codeswitching participants, rarely-attested codeswitches evoked an N400 effect relative to common codeswitches, suggesting greater difficulty with lexical integration. Non-codeswitching bilinguals, on the other hand, processed these two types of codeswitches with similar difficulty. Furthermore, they showed greater frontal electrophysiological activity in response to switching, regardless of switch type, most likely reflecting detection of a language change during early monitoring stages of language processing. Beatty-Martínez and Dussias interpreted this response modulation as reflecting a shift from a competitive to a cooperative control state, as proposed in the CP model. Overall, what these results suggest is that the bilinguals' differential sensitivity to codeswitched stimuli was due to differences in their language experience. An important implication of this work is that the form of language use can affect language processing; future research is needed to evaluate whether the neural networks that characterize this relationship are also involved in cognitive control more generally (Abutalebi & Green, 2016).

In this paper, we have reviewed the literature on the consequences of bilingualism and its implications for both language and domain-general cognition. What becomes apparent in light of these findings is that bilingualism research is inherently complex. Although the characterization of the consequences of the bilingual experience is far from complete, there have been significant efforts in the field towards a multidimensional view that takes the impact of the bilingual experience and individual differences into account. Bilingualism research poses several unique challenges, but in this respect, it gives us the opportunity to gain a better understanding of the relations between the brain, mind, and behavior.

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