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What is This?
Two Languages in Mind: Bilingualism as a Tool to Investigate Language, Cognition, and the Brain

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Abstract
A series of discoveries in the past two decades has changed the way we think about bilingualism and its implications for language and cognition. One is that both of the bilingual’s languages are always active. The parallel activation of the two languages is thought to give rise to competition that imposes demands on the bilingual to control the language not in use to achieve fluency in the target language. The second is that there are consequences of bilingualism that affect the native as well as the second language: The native language changes in response to second-language use. The third is that the consequences of bilingualism are not limited to language but appear to reflect a reorganization of brain networks that hold implications for the ways in which bilinguals negotiate cognitive competition more generally. The focus of recent research on bilingualism has been to understand the relations among these discoveries and their implications for language, cognition, and the brain across the life span.

Keywords
psycholinguistics, cognitive neuroscience, bilingualism, cognitive control

In many locations in the United States, English is spoken as the only language, so it comes as a surprise to some Americans that in most places in the world, and increasingly in the United States, the use of two or more languages is prevalent. The past two decades have witnessed a virtual explosion of research on bilingualism (e.g., Kroll & Bialystok, 2013). Bilinguals, long considered a special group of language users because monolinguals were assumed to be the norm, have now become a focus of research in cognitive psychology, linguistics, and cognitive neuroscience (e.g., Kroll, Dussias, Bogulski, & Valdes Kroff, 2012). Much of the new research shows that it is a misconception to think that bilingualism complicates language and cognition, that children raised with input from two languages are disadvantaged, or that mixing two languages is pathological (e.g., Bialystok & Craik, 2010; Byers-Heinlein, Burns, & Werker, 2010; Kroll et al., 2012). To the contrary, the recent evidence demonstrates that bilinguals develop a high level of cognitive control that enables them to negotiate the activity of the two languages. The experience of being bilingual comes to influence not only language but also cognition more generally and the brain networks that support language and cognition.

In this article, we describe three discoveries that we believe reveal the reasons for the recent enthusiasm about research on bilingualism. The first is that both of the bilingual’s languages are always active. The parallel activity of the bilingual’s two languages can be observed in reading, listening to speech, and preparing to speak one language alone (e.g., Dijkstro, 2005; Kroll, Bobb, & Wodniecka, 2006; Marian & Spivey, 2003). Cross-language activation means that bilinguals are constantly juggling the competition that results when one of the two languages must be selected. The second discovery is that the consequences of bilingualism are not limited to language but appear to reflect a reorganization of brain networks that hold implications for the ways in which bilinguals negotiate cognitive competition more generally. The third discovery is that the language system is highly adaptive. Being bilingual is not

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only about acquiring and using a second language (L2) but also about the ways in which the native or dominant first language (L1) changes in response to the L2. These changes have been observed at every level of language use, from the lexicon to the grammar and phonology. Moreover, they do not depend on acquiring both languages from early childhood; observed adaptation on the part of adult L2 learners shows that cross-language interactions may depend as much or more on L2 proficiency than on the age of acquisition. The third discovery is that bilingualism shapes the structure and function of the brain across the life span. Learning to negotiate cross-language competition and to use the two languages in a variety of contexts may enable bilinguals to develop special expertise that extends beyond language into cognition, shapes the brain networks that support cognitive control, and provides cognitive resources that are protective when individuals are old or cognitively impaired.

**Parallel Activation of the Bilingual’s Two Languages**

There is evidence that both of a bilingual’s languages are active regardless of his or her intention to use one language only. In reading, the degree of parallel activation of the bilingual’s two languages has been examined using cognates or interlingual homographs. Cognates are words whose form and meaning are similar across two languages (e.g., *piano* in Spanish and English), whereas interlingual homographs are words with similar forms but different meanings (e.g., *pie* in Spanish means “foot” in English). Many studies have demonstrated that bilinguals recognize cognates more quickly but interlingual homographs more slowly than control words (e.g., Dijkstra, Grainger, & van Heuven, 1999). Monolinguals do not show these effects. These results suggest that lexical information is activated in both the target and nontarget languages. Cross-language coactivation has been observed even when the nontarget language is not processed explicitly (e.g., Thierry & Wu, 2007) and when two languages differ in modalities—for example, when signers read English words (e.g., Morford, Wilkinson, Villwock, Piñar, & Kroll, 2011). Moreover, these interactions across the bilingual’s two languages are not seen only in effects from the L1 to the L2; as individuals become more proficient in the L2, their effects are present from the L2 to the L1 (e.g., Lagrou, Hartsuiker, & Duyck, 2011; Schwartz, Kroll, & Diaz, 2007).

The coactivation of the bilingual’s two languages has also been demonstrated in listening comprehension. Marian and Spivey (2003) asked Russian-English bilinguals to follow spoken English instructions to pick up individual objects in four-object displays. The researchers examined eye fixations to the objects in the displays. The critical comparison was between two conditions: one in which the display included a between-language competitor—an object (e.g., a dress) whose name in the nontarget language (*plát’ě*) was phonologically similar to the name of a target object in the target language (e.g., *plug*)—and one in which there was no object whose name was phonologically similar to the name of a target object in either language. The result showed that bilinguals looked longer at between-language competitors than at the controls, suggesting parallel activation of the nontarget language.

Although speech production is initiated by a bilingual’s intention to speak in a given language, cross-language interactions are also present when speech is planned. Because speaking requires that one language be selected, bilinguals must develop a means to control the language not in use. One option is to inhibit the activation of the language not to be spoken (e.g., Green, 1998). The evidence for inhibition comes from studies on language mixing (e.g., Christoffels, Firk, & Schiller, 2007). In this paradigm, bilinguals name pictures either in only their L1 or their L2 (blocked naming) or in both their L1 and L2, depending on the presentation of a cue (mixed naming). If the L1 is active when speech is planned in the L2, then forcing it to be active in the mixed condition should incur a cost to the L1 relative to blocked picture naming but should have little effect for the L2. It is precisely this asymmetric pattern of results that has been reported in mixed-language naming experiments and under conditions of language switching (e.g., Meuter & Allport, 1999). Moreover, when the L1 is spoken after the L2 has been produced for a period of time, there is inhibition that for some bilinguals appears to reflect global suppression of the entire L1 (e.g., Misra, Guo, Bobb, & Kroll, 2012; Van Assche, Duyck, & Gollan, 2013).

**The Bilingual’s Language System Is Adaptive**

When we think of adult L2 learning, we immediately think of the difficulty of the process and of how the phonology or syntactic structure of the L1 may leave their mark on the L2 in the form of an accent or incomprehensible sentences. What may be surprising for some is that it is not only the L2 that changes during learning. The language system is permeable in both directions, so that L2 learning comes to affect the L1, especially when the learner achieves L2 proficiency. Dussias and Sagarría (2007) investigated sentence-parsing preferences of Spanish-English speakers while they read complex Spanish sentences. Given the sentence “El policía arrestó a la hermana del criado que estaba enferma desde hacía tiempo” (“The police arrested the sister of the young man who was ill for some time“), a native Spanish speaker
would say that it was the sister who had been ill. In English, however, the sentence would indicate that the young man had been ill. Dussias and Sagarra found that bilingual Spanish-English speakers adopted a parsing strategy in their native Spanish that was consistent with English (i.e., that the young man had been ill), but only after having been immersed in an English-speaking environment for a long time. Thus, the L1 changed in response to L2 use. These results strongly suggest that the newly learned lexicon of words and its syntactic structure are not built up in isolation but interact with the existing language in a dynamic way to change the language system as a whole. A common finding is that the two languages begin to converge, with changes to the L1 as well as the L2 (e.g., Ameel, Storms, Malt, & Sloman, 2005). In effect, each language begins to resemble the other, with bilinguals looking less like monolinguals in either language as cross-language contact and proficiency increase.

To see these bidirectional language effects on the bilingual language system, L2 learners may need to first develop high levels of L2 proficiency. One such situation occurs when students study abroad in an L2 environment. A study by Linck, Kroll, and Sunderman (2009; see also Baus, Costa, & Carreiras, 2013) compared L2 learning in immersion and classroom contexts. They tested native English speakers learning Spanish on comprehension and production tasks. Although immersed learners were matched to the classroom-only learners on overall L2 proficiency, they performed the tasks differently than their classroom-only counterparts. Comprehension results suggested that L2 immersion experience had changed the way the learners processed their L1. Immersed learners also had more difficulties speaking English than classroom learners did, which suggests that immersed learners suppress their native language. Strikingly, these effects on the L1 persisted 6 months after the immersed learners returned to their L1 environment, but only for the comprehension task. In spoken production in the L1, performance rebounded. Linck et al. interpreted these findings as supporting the idea that L2 learners attenuate L1 activation while immersed in the L2, and that the same degree of L1 suppression does not occur in the classroom.

These studies illustrate cross-language interaction at the level of words as well as grammar. The scope of the changes to the native language is broad: Related evidence has been reported for other grammatical structures (Dussias & Cramer Scalz, 2008) and for the phonology of the native language (e.g., Chang, 2013). Research on priming has also shown that sentence processing is changed by a recent occurrence of a similar syntactic structure, even when the prime and target sentences cross from one of the bilingual’s languages to the other (Bernolet, Hartsuiker, & Pickering, 2007; Kantola & van Gompel, 2011). The presence of cross-language syntactic priming suggests that aspects of the grammar are shared across the bilingual’s two languages. The evident permeability of the bilingual language system, both with respect to language coactivation and language reorganization, raises the possibility that the influence of bilingualism is not isolated to the linguistic system but effectively reconfigures the cognitive network as a whole (Kroll & Bialystok, 2013).

**The Consequences of Bilingualism for Cognition and the Brain**

An early observation in neuroimaging research was that the same neural tissue supports the function of both of the bilingual’s two languages (e.g., Abutalebi, Cappa, & Perani, 2005). Given the behavioral evidence we have reviewed, that finding may not seem surprising. When there are differences in brain activity in using the two languages, it is likely that they arise from the requirement to engage control mechanisms that regulate the use of the more dominant language and enable the engagement of the weaker language (e.g., Abutalebi & Green, 2007). Critically, brain areas that control language overlap with areas that control cognitive functioning more generally (e.g., Garbin et al., 2010; see also Abutalebi & Green, 2007). Behavioral research has shown that there are correlations between the ability to switch between languages and the ability to switch between nonlinguistic tasks, which suggests that they tap into the same mechanisms of cognitive control (e.g., Prior & Gollan, 2011). An interesting observation is that language processing in multilinguals, who use more than two languages, appears to follow patterns of parallel activation and control similar to those observed for bilinguals, with the relative effects of the three or more languages determined by proficiency and language dominance (e.g., Linck, Schwieter, & Sunderman, 2012; van Hell & Dijkstra, 2002).

Recent neuroimaging studies have suggested that not only are control areas of the brain activated in both linguistic and nonlinguistic tasks, but bilinguals appear to use these control networks more efficiently than monolinguals, even when the task is purely cognitive. For example, Abutalebi et al. (2012) compared brain activity in bilinguals and monolinguals as they performed a nonverbal conflict-monitoring task (see Bialystok, Craik, & Luk, 2012, for an illustration of some of the tasks that have been used in these studies). Abutalebi et al. found that both bilinguals and monolinguals revealed activity of the anterior cingulate cortex, a brain region that has been implicated in cognitive control, but bilinguals were more efficient than monolinguals, requiring less activation to resolve the same level of conflict. Although comparisons of bilinguals and monolinguals are necessarily
The differences between bilinguals and monolinguals appear to grow as individuals age and as cognitive resources become more difficult to recruit. Gold, Kim, Johnson, Kriscio, and Smith (2013) conducted an fMRI study using a nonlinguistic switching task to compare younger and older adult bilinguals and monolinguals. They found little evidence for a bilingual advantage for younger adults, but a clear effect for older adults on both behavioral and neural measures. Like the Abutalebi et al. (2012) results, the pattern of brain activation for older bilinguals suggested that they were more efficient than monolinguals in resolving conflict. That efficiency has been demonstrated in healthy aging bilinguals, but in what is arguably the most dramatic evidence on the cognitive consequences of bilingualism, recent studies have shown that in the presence of pathology, such as dementia, these more efficient control mechanisms may play an important role in protecting bilinguals from the symptoms of disease (e.g., Bialystok, Craik, & Freedman, 2007). Bilinguals present with symptoms of Alzheimer’s-type dementia 4 to 5 years later than monolinguals (e.g., Alladi et al., 2013), and their brains at the point of diagnosis are more diseased than those of monolinguals (e.g., Schweizer, Ware, Fischer, Craik, & Bialystok, 2012).

Conclusions

The pattern of cognitive consequences associated with bilingual experience across the life span suggests that bilinguals use language in ways that exercise brain networks responsible for cognitive control. It is appealing to think that the discoveries we have described, including the openness of the language system, the cross-language competition present at all levels of language processing, and the adaptive nature of each of the bilingual’s two languages, create a dynamic system that modulates the demands on cognitive resources. But there may not be a single way in which the juggling of the two languages produces the observed consequences (e.g., Baum & Titone, in press; Green & Abutalebi, 2013; Kroll & Bialystok, 2013). As Green and Abutalebi (2013) have noted, bilinguals who are equally proficient may differ in the demands placed on control networks depending on whether they frequently code switch between their two languages and on the context in which code switching occurs. Bilinguals often speak to others who themselves are not bilingual or not bilingual in the same languages. Being bilingual therefore requires skill in negotiating the discourse context for both speakers and listeners. The research agenda for investigating the demands and benefits associated with bilingualism is broad and complex, but the implications are exciting. The ways in which bilinguals’ minds and brains change provide a model for investigating aspects of adult plasticity that would otherwise be obscured in speakers of one language alone.

Recommended Reading


Declaration of Conflicting Interests

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