The Brain Science of Bilingualism

Naja Ferjan Ramirez and Patricia Kuhl

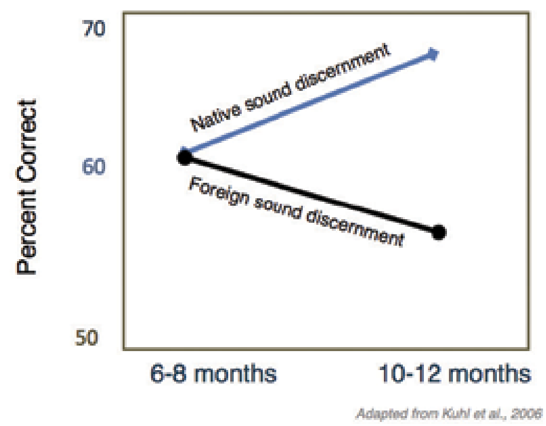
Children around the world learn their native languages naturally and spontaneously in the first few years of life. Because neither adults nor computers accomplish this task as effectively, many researchers (and teachers) would like to understand the process by which young children acquire language. One particularly interesting issue concerns bilingual learning. Children who experience two languages from birth typically become native speakers of both, while adults often struggle with learning a second language and rarely attain native-like fluency. Studies show that the infant brain is adept at learning two languages (Garcia-Sierra et al. 2011; Petitto et al. 2012; Costa & Sebastián-Gallés 2014; Ferjan Ramirez et al. 2017), and that infancy and early childhood represent the best possible time to do so (Johnson & Newport 1989; Newport 1990).

Why are babies so good at language learning?

The linguistic genius

Before exploring the development of bilingualism, let's explore *all* infants' linguistic genius. For simplicity's sake, we begin with an explanation of what happens for an infant from a family that speaks only English. Then, we will clarify how the process applies to children in bilingual families. The linguistic journey begins *in utero* and continues right after birth. Only a few hours after birth, infants can identify their mother's language and distinguish it from an unfamiliar language (e.g., Moon, Lagercrantz, & Kuhl 2013). One of infants' most impressive skills is their ability to discover the finite set of sounds that are used to make up the words in their native language. In English, for example, there are 44 sounds (having many more sounds than letters is one of the reasons why English is relatively difficult to learn to read and write). Until about 6 months of age, infants are capable of hearing the differences between the sounds that make up words across all languages. By 12 months, infants significantly improve their discernment of native language sounds, while their discernment of nonnative sounds declines (Kuhl et al. 2006). As a result of listening predominantly to their native language, infants transition from being "citizens of the world" to being "native language specialists" (see "Becoming a Native Language Specialist"). This transition is accompanied by neural commitment: the infant brain undergoes physical changes that reflect the properties of the language spoken around the baby (Kuhl et al. 2008).

Becoming a native language specialist is an important milestone in language acquisition, because it predicts mastery of many subsequent stages in language development, such as word learning and grammatical development. The better children are at discerning the sounds of their native language when they are 11 months old, the larger their vocabularies are likely to be when they are toddlers. This is because the ability to discern native sounds reinforces the detection of higher-order language patterns, such as syllables and words (Kuhl et al. 2008). At the same time, however, commitment to native language patterns leads to a reduction in sensitivity in nonnative patterns, and thus causes interference with the learning of foreign language sounds (Zhang et al. 2009; Kuhl et al. 2006). Research suggests that infants and young children are better than adults at acquiring a foreign language, because the native language learning process and the commitment to native language patterns are still incomplete. Babies born in bilingual households become native language specialists in both languages. All young children's brains go through this process of transitioning from citizens of the world to native language specialists—but babies are uniquely capable of becoming native specialists in more than one language.

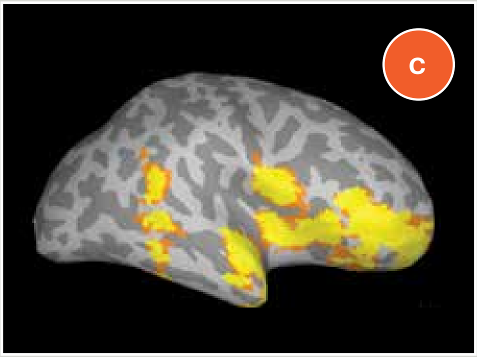


Becoming a Native Language Specialist
The blue line represents babies' ability to discern native language sounds, and the black line represents babies' ability to discern foreign language sounds. The baby's age is plotted on the bottom of the graph. Until about 6 months of age, babies are equally good at discerning native and foreign language sounds; they are "citizens of the world." Between 6 and 12 months of age, infants' ability to hear the difference between the sounds in a foreign language decreases and their ability to hear the differences between the sounds of their native language increases. By the end of the first year of life, babies have become "native language specialists." (Adapted from Kuhl et al. 2006.)

How is the process of becoming a "native language specialist" affected by exposure to two languages? Is it possible to specialize in two languages, or does this confuse children?

A peek inside the baby brain: Monolingual versus bilingual development

With the advance of noninvasive, child-friendly neuroimaging and brain recording techniques, scientists have recently been able to gain insight into



The MEG Setup and Sample Results

MEG is a safe, noninvasive, and completely silent methodology.

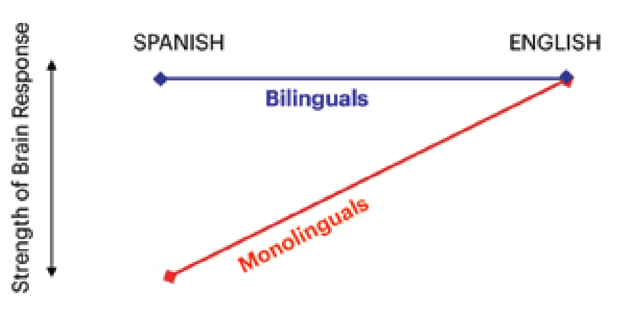
Image A. Preparation for a MEG session: researchers use a digitizing pen to track the shape of the baby's head, which allows them to continuously monitor the baby's head position as she moves in the MEG machine.

Image B. A baby during a MEG session: a custom-made, adjustable chair places the baby in the optimal position during the MEG recording.

Image C. A baby's right-hemisphere neural responses to language sounds: MEG measures magnetic changes given off by active nerve cells. It allows researchers to accurately determine the location and timing of brain activity.

monolingual versus bilingual development by studying the infant brain. A method particularly well suited for this purpose is magnetoencephalography (MEG), which measures magnetic changes given off by active nerve cells. Unlike other brain-imaging methods, MEG can precisely pinpoint both the timing and the location of activity in the infant brain. It is also completely silent and allows the child to sit in a highchair with a parent nearby (see "The MEG Setup and Sample Results").

In a recent study, researchers compared the brain responses to language sounds in 11-month-old babies from bilingual Spanish–English households with the brain responses of age-matched babies from monolingual English households (Ferjan Ramirez et al. 2017). At this age, the monolingual baby brain was specialized to process the sounds of English, but not the sounds of Spanish (an unfamiliar language). The brains of babies from bilingual households, on the other hand, were specialized to process the sounds of Spanish and English (both native languages). This shows that the baby brain specializes in whatever language *or languages* are present in the environment. By 11 months, the brain's responses to language sounds reflect the child's language experience. Importantly, the brain responses to the English sounds were equally strong in bilingual and monolingual babies, indicating that these two groups of babies were learning to discern English sounds at the same rate. (See "Brain Responses Depend on Language Experiences.")



Brain Responses Depend on Language Experiences

This schematic shows the strength of brain responses to language sounds in 11-month-old babies from bilingual Spanish–English households (blue line) and monolingual English households (red line). The monolingual baby brain is specialized to process the sounds of English; the bilingual baby brain is specialized to process the sounds of Spanish *and* English—both native languages.

Bilinguals split their time between two languages

A common concern for parents, teachers, and caregivers of bilingual children is whether they are learning enough language. This is particularly true before the onset of speech, when it is difficult to know what the baby is thinking.

While we've seen that sound discernment develops at the same rate for mono- and bilingual babies, what about the acquisition of vocabulary and grammar? Young children who are bilingual typically begin producing their first syllables and their first words at the same age as children exposed to a single language. Furthermore, bilingual vocabulary and grammatical growth looks very much like the trajectory followed by children who are monolingual (Conboy & Thal 2006; Parra, Hoff, & Core 2011). It is important to understand, however, that bilingual children split their time between two languages, and thus, on average, hear fewer words and sentences in each language. Studies consistently show that bilingual children *do not lag* behind monolingual peers *when both languages are considered*. For example, bilingual vocabulary sizes, when combined across both languages, are equal to or greater than those of monolingual children (Hoff et al. 2012; Hoff & Core 2013). Research also shows that children who are bilingual can catch up on monolingual norms by elementary grades when adequate support for both languages is provided (McCabe et al. 2013). As in monolingual development, the rate of vocabulary and grammatical growth in bilingual children—as well as their brain activity in response to each language—correlates with quality and quantity of speech that they hear in each language (Conboy & Mills 2006; Place & Hoff 2011; Ramírez-Esparza, Garcia-Sierra, & Kuhl 2016).

Language mixing

Another frequent concern is that bilingualism causes confusion. This concern arises due partly to code switching (also called code mixing), which is the practice of combining words or phrases of two or more languages. For example, a child who is simultaneously learning English and Spanish might produce sentences such as "Can I play afuera?" (*afuera* means *outside* in Spanish). It is important to understand that code switching is a natural behavior for bilingual children and adults because bilinguals often know certain words better in one language than in the other. Instead of being a sign of language confusion, code switching is used to facilitate communication. Bilingual children as young as 2 years old are sensitive to the language of their conversational partner. In conversation, they increase the proportion of words they use from the language of the person they are speaking with (Genesee, Nicoladis, & Paradis 1995). Interestingly, although code switching mixes languages, children nevertheless adhere to grammatical rules in the mixed-language sentences. Language mixing adheres to predictable rules, and bilingual children follow the same rules as bilingual adults (Paradis, Nicoladis, & Genesee 2000). This is further evidence that code switching is not a haphazard mix of words, but rather a strategic tool employed by children who are bilingual.

The bilingual advantage

Year after year, researchers are finding more benefits of bilingualism (Bialystok & Feng 2011; Barac & Bialystok 2012). A growing body of evidence suggests that bilinguals ranging from young children to mature adults exhibit enhancements in both executive functioning—a set of cognitive processes that includes attentional and inhibitory control skills—and cognitive flexibility, which aids problem solving and planning. These boosts in executive functioning and cognitive flexibility appear to result from the exercise the brain gets in switching from one symbolic code to another, and from the effort of constantly managing attention to the target language, which enhances and strengthens various brain networks. Recent studies indicate these language-driven differences in brain activity related to executive functioning are present at an early age (Ferjan Ramírez et al. 2017) and persist throughout the school years (Arredondo et al. 2016) and into adulthood (Abutalebi et al. 2012; Stocco & Prat 2014). Interestingly, the accumulating effects of dual language experience have been linked to more robust cognitive abilities with increased age and to a lower rate of diagnosis of Alzheimer's disease (Craik, Bialystok, & Freedman 2010). Note, however, that some studies suggest that this line of research suffers from a publication bias (in which studies that show a relationship are more likely to be published than those that find no relationship; see De Bruin, Treccani, & Della Sala 2015), and that further research is needed.

Research also shows that managing attention to two languages fosters children's metalinguistic skills (i.e., encourages them to think about language per se) (Bialystok 2007). Bilingual infants as young as 7 and 12 months have been shown to be more flexible learners of language patterns compared with monolingual infants (Kovács & Mehler 2009; Graf Estes & Hay 2015). In addition, 2- and 3-year-olds who are bilingual are more flexible learners of additional labels for previously known actions or objects (such as learning *tennis shoes* after learning *sneakers*), whereas children who are monolingual often find it difficult to add new labels for actions or objects that already have a name (Yoshida 2008).

Finally, studies show that bilingualism is beneficial from an economic standpoint. Across most sectors of the economy, businesses overwhelmingly prefer to hire multilingual employees (Porras, Ee, & Gándara 2014) and, among the millennial generation, multilingual employees earn more on average (Rumbaut 2014).

Creating bilingual brains

Being bilingual has become a highly desirable asset, creating an increasing demand for bilingual education programs (Garcia 2015; Williams et al. 2016), starting from a very young age. What does it take to create bilingual brains?

Research shows that young infants learn foreign languages surprisingly quickly: one study shows that 9-month-olds exposed to a new language in play sessions by a live tutor learn in just six hours to discern the sounds of the new language at levels equivalent to infants exposed to that language from birth. However, *no learning occurs when the same material is presented on the same schedule via video or audiotapes* (Kuhl, Tsao, & Liu 2003). Thus, infants can—and do—learn language quickly, but frequent social interactions with people, in person, play a critical role in this process (see "Social Interactions Are Critical").

Social Interactions Are Critical
Both monolingual and bilingual children learn best in one-on-one interactions when they hear lots of infant-directed speech, or parentese.

Bilingual children's language growth is directly related to the quality and quantity of speech they hear *in each language* (Ramírez-Esparza, Garcia-Sierra, & Kuhl 2016). The youngest children learn best in one-on-one interactions with lots of infant-directed speech, or parentese, which has a higher tone of voice, an exaggerated pitch contour, and a singsong quality (e.g., "Hiiiii, babyyyyy"). In bilingual babies, the amount of infant-directed speech heard in one-on-one interactions in a particular language is directly related to the babies' growth in that language but is not related to growth in the other language (Ramírez-Esparza, Garcia-Sierra, & Kuhl 2016). Correspondingly, the strength of bilingual infants' brain responses to each language reflects the amount and quality of speech that they hear in each language (Garcia-Sierra et al. 2011).

In the United States, 27 percent of children birth to age 6 are raised in homes where languages other than English are spoken (Capps et al. 2004). These children, typically referred to as dual language learners, or DLLs (see "Dual Language Learners"), have the full potential and ability to become bilingual, learning both the home language and English. However, as has been noted in the 2016 White House policy statement supporting DLLs (US DHHS & ED 2016) and in the recently released Head Start

Dual Language Learners

According to the recent policy statement by the US Department of Health and Human Services and the US Department of Education (US DHHS & ED 2016), dual language learners, or DLLs, are children who are learning two or more languages at the same time or are learning a second language while continuing to develop the first one. Policy makers, educators, researchers, and advocates use many different terms to describe this population, including ELLs (English language learners), ELs (English learners), language learners, or bilinguals.

Program Performance Standards (US OHS n.d.), there is often a substantial mismatch between the language-learning experiences DLLs *require* to develop both languages and prepare for school, and the *current reality* in which access to either one or both languages is often limited. To prepare these children for success in school, and to offer them the opportunity to experience the full range of advantages associated with bilingualism, early childhood bilingual education will have to be further developed. These programs should be grounded in basic research on language learning and emphasize social interactions with native speakers of the target languages.

Resources

White House Fact Sheet: www.whitehouse.gov/the-press-office/2016/06/02/fact-sheet-supporting-dual-language-learners-early-learning-settings (Note: This website is now archived and no longer being updated.)

Institute for Learning and Brain Sciences, University of Washington: http://ilabs.washington.edu—I-LABS Module 11 on bilingualism (a log in is required, but it is free of charge and available to everybody)

Zero to Three: www.zerotothree.org/resources/303-dual-language-development-double-the-benefit

National Association for Bilingual Education (NABE): www.nabe.org

Concluding remarks

Brain science on children's learning suggests that all babies have the potential to become bilingual. Bilingualism does not cause confusion or language delay; children who are bilingual perform equally well or better than monolinguals *when both languages are considered*. Studies suggest that optimal learning is achieved when children begin learning two languages at an early age through high-quality interactions with live human beings (not through TV or other media), and both languages are supported throughout the toddler, preschool, and school years. Supportive environments for bilingual learning encourage caregivers to use the language in which they are most fluent and comfortable, value both languages equally, and view bilingualism as an asset.

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About the authors

Naja Ferjan Ramirez, PhD, is a research scientist at the Institute for Learning and Brain Sciences at the University of Washington, in Seattle. Her research focuses on understanding the brain-based mechanisms of language acquisition in bilingual children. naja@u.washington.edu

Patricia Kuhl, PhD, holds the Bezos Family Foundation Endowed Chair in Early Childhood Learning. She is codirector of the Institute for Learning and Brain Sciences, director of the National Science Foundation Science of Learning Center, and professor of speech and hearing sciences at the University of Washington, in Seattle.

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