

## **Why do bilingual stroke patients sometimes recover only one language?**

**When a person suffers from a stroke, the blood flow to certain areas is rapidly disturbed either because a blood vessel starts bleeding (haemorrhage) or because a blood vessel is blocked. If the stroke affects brain areas which are important for language, then the language functions can be partially or fully lost. This condition is called aphasia, but it is sometimes reversible at least to some degree with time, treatment and rehabilitation. Bilinguals, that is, people who speak more than one language, are known to recover from aphasia in a number of different ways. The most common case is when the bilingual patient similarly recovers both languages equally well as in parallel aphasia. In some cases, however, the recovery of bilingual is disproportionately favouring one of his/her languages and this type of recovery is called selective aphasia.**

**The case of selective aphasia made researchers initially believe that each language of a bilingual person must be located in a different brain area, given that one language recovers better than the other after the stroke. However, with the help of brain imaging scans we now know that this idea is not correct. On the contrary, when a person speaks many languages, they all activate a common network of brain areas. While the whole picture of how the brain generates multiple languages is still partly unclear, we do know a number of factors that seem to influence to what extent the languages of a bilingual patient will recover after a stroke. If a person is less proficient in one of the two languages, this language may not recover as good as the more proficient language. This means that the more automatic a skill is, the easier it is to recover it, whereas something that takes effort such as language that one only speaks rarely is harder to recover. Social factors and emotional involvement are also important if we want to understand which language will recover after a stroke, for instance how often a specific language is used, or what emotions are associated with a specific language. However, it is still unclear exactly how these factors interplay in predicting the recovery success.**

**One of the current theories on why bilingual aphasics may disproportionately recover one language better than the other suggests that this happens when the stroke damages specific control mechanisms in the brain. When a bilingual person knows two languages, he/she needs to suppress or 'switch off' one of the languages while using the other language. If the mechanisms that control this switch are damaged during the stroke, the aphasic patient may no longer be able to similarly recover both languages as the ability to control the language use has been lost. In this case the person may appear to have completely lost one of the languages, but the problem is actually one of control. Recently researchers found that the control mechanisms are more impaired in bilinguals with selective aphasia who recover only one language than in bilinguals with parallel aphasia who recover both languages. Interestingly, when languages recover after stroke, the connections between language and control areas in the brain are re-established. While this interesting finding supports the theory linking selective aphasia to impaired control mechanisms, it is only one of several theories and researchers are currently trying to better understand what other causes may also underlie the surprising recovery patterns that can be seen in bilingual aphasia.**

**In an increasingly globalised world, there are many practical benefits to speaking two languages rather than one. Even in the US, which is largely monolingual, more than 20 percent of the population is now thought to speak a second language.**

**Early research on bilingualism, conducted before the 1960s, however, linked bilingualism with lower IQ scores, cognitive deficiencies and even mental retardation. These studies reported that monolingual children were up to three years ahead of bilingual children in both verbal and non-verbal intelligence. From these studies, there grew a perception among the general public that bilingualism led to a 'language handicap'.**

**"Speaking with my own students about their childhood experiences, I found that many of them were discouraged from speaking two languages while growing up. This was based on a misperception that doing so would delay development," says Assistant Professor Yang Hwajin, a cognitive and developmental psychologist from the Singapore Management University (SMU) School of Social Sciences.**

**Since then, these early language studies have been widely discredited, and linguists no longer believe that bilingualism results in cognitive deficiencies. "What we have found in the last three decades is that bilingualism has substantial impact on cognitive function -- the way that we think, make decisions, perceive things, solve decisions, and so on," she notes.**

**In fact, multi-lingualism can confer a very beneficial form of cognitive training, says Professor Yang. "For example, I speak Korean and English. When I speak English, I have to inhibit thoughts about Korean grammar, and focus on English grammar, as the two languages do not share any grammatical structure. Speaking these two languages has trained me to inhibit distractions and focus better."**

**Professor Yang's research into bilingualism grew naturally from her interest in the factors that influence executive function. The brain's executive function directs the processes that allow us to solve crossword puzzles, deconstruct the latest Game of Thrones episode, or recall what we had for dinner last week. Being bilingual has been shown to improve the brain's executive function, and even delay the onset of dementia or Alzheimer's disease.**

**"I was interested in the factors influencing such executive control, as they can in turn shape our performance in work, school, and other parts of our life. After all, most critical cognitive functions affect our lives in various settings, regardless of age," she says.**

**Language power**

**Professor Yang is particularly impressed by the high extent of bilingualism in Singapore, which is a contrast to her homeland of South Korea where most of the population is monolingual. There, speaking two languages is limited mostly to those with high socioeconomic status. "Whenever I speak even to taxi drivers here, they often speak multiple languages -- English, Mandarin, and one or more Chinese dialects," she says.**

**Singapore, as such, has proven a fertile ground for Professor Yang to study the relationship between multi-lingualism and cognition, though she has faced challenges in collecting data.**

**"I study bilingual children, and sometimes even infants raised in a bilingual context. Since parents are busy people, we visit day care centres and ask for parental consent for the children to be involved in research. But parents and day care teachers are reluctant to do so, as there is still a tendency to disbelieve the potential impact of such research," she notes.**

**Professor Yang's work with children has already seen results, however. One study saw her examine the impact of being raised in a bilingual versus monolingual household for children of low economic status. "Children of low socioeconomic status generally have lower cognitive function than those with high socioeconomic status. This might be because both parents are out working to earn money, leaving them home alone and without intellectual stimulation," she explains.**

**Here, bilingualism appears to be a form of intervention to promote executive function. Professor Yang found that low socioeconomic status children who spoke two languages performed much better in behavioural tests than their monolingual counterparts. Interestingly, she uncovered similar observations in another study that involved infants, instead of children, of low socioeconomic status.**

**"Since infants cannot verbalise or express themselves, we define bilingual infants via the number of languages they are exposed to. For example, an infant exposed to English 60 percent of the time, and Mandarin 40 percent of the time, would be considered bilingual," she says.**

**"Surprisingly, we found that even bilingual infants from low socioeconomic status demonstrated greater cognitive development than monolingual infants of the same status. This implies that bilingualism could help the development of children in deprived environments."**

### **Boosting brain power with bilingualism**

**Other studies have shown that bilingualism can be used in a clinical setting to help children diagnosed with attention deficit hyperactivity disorder, or patients with**

**impaired cognitive function. Professor Yang also hopes to demonstrate its benefits to individuals who do not demonstrate cognitive impairment.**

**Another area that Professor Yang would like to explore is the biology behind second language acquisition. Specifically, do bilingual speakers exhibit different patterns in their brain anatomy and physiology?**

**"So far we have focused on behavioural data, such as job performance and aptitude. We have not yet touched on neuroscience -- the brain -- particularly in the Asian context. For example, it would be interesting to examine what changes bilingualism has made to my brain in the last 20 years, and if that can in turn be associated with my behaviour," she muses.**

**Research on the bilingual brain has gone through several stages over the years: the study of aphasic polyglots, experimental work on language lateralization in bilinguals, and now brain imaging studies that examine language processing and neural structures and connections between them. One of the leading researchers in this field is Dr. Ping Li, Professor of Psychology and Linguistics at Pennsylvania State University. He works on the neural and computational bases of language representation and learning and has kindly accepted to answer a few of our questions. We wish to thank him wholeheartedly.**

**Before addressing the issue of what is different in the bilingual brain, as compared to the monolingual brain, can you quickly go through what is clearly similar?**

**It may be helpful to say at the outset that we are talking about the human brain, bilingual or not, which is the only brain that can learn and use complex natural languages for communication. No brain of any other species on our planet has language like ours, despite claims that other animals may also have sophisticated communication systems.**

**Against this backdrop, then, the similarities between the bilingual and monolingual brains will be more important than the differences. For example, given the physical constraints of the human brain—its neuroanatomical substances—we must be using more or less the same neural structures to learn and use different languages, whether these are English, Chinese, French, or Spanish. In other words, we cannot imagine that each of the world's 7000+ languages occupies a different part of the brain. Now, this is not to deny that different languages will engage the neural structures in different ways, a position I myself dearly embrace and which you described elsewhere (see here).**

**Does evolution also play a role?**

**From an evolutionary perspective, human language has had a long history—at least one hundred thousand years—and has evolved into a very complex communicative system.**

Evolution has determined that something as complex as human language simply cannot be supported by a single area in the brain. Rather, a great deal of brain resources needs to be dedicated to language. Recent neuroimaging evidence shows that language processing involves not only the classical Broca's and Wernicke's areas but the entire brain, from frontal to temporal to parietal lobes.

Concerning this, note that there is an area in the brain that we can call 'the visual cortex' (for visual processing), but there is no such area that we can call 'the language cortex', to the disappointment of some who look for a 'language gene' or a 'language area'. Because of this, there is also no 'monolingual cortex' or 'bilingual cortex'. The most plausible scenario, as has been argued by David Green and his colleagues, is that the brain uses the same neural structures and resources to handle different languages, but in different ways, even in the same individual.

For many years, we were led to believe that bilinguals were language lateralized differently than monolinguals? Is there any truth to that?

Although the idea of different brain lateralization patterns for bilinguals versus monolinguals made sense initially, like many intuitively appealing ideas, the more we know about the linguistic brain, the more unlikely this view has now become.

I want to illustrate my point with one simple example. Take monolingual English speakers who learn Chinese and acquire lexical tone, an essential aspect of the language for listening and speaking Chinese. Now, we know that native Chinese speakers typically use the left hemisphere to process lexical tones (although the right hemisphere is also engaged to some degree), given that tones are phonological units marking different word meanings (for example, /pa/ means 'squat' if pronounced in Tone 1 and 'crawl' in Tone 2).

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**Native English speakers learning Chinese initially treat such tonal differences simply as acoustic variations (high pitch in Tone 1 and low-then-high pitch in Tone 2), and use the right hemisphere to process them. But once they are fluent bilinguals, they start to treat these tonal differences as phonological, and not just acoustic, variations. The difference between Tone 1 vs. Tone 2 is now just as important as that between /ba/ and /pa/. Hence, there is a stage where bilinguals shift from relying on the right hemisphere to the left hemisphere, as lexical tones become linguistically meaningful to them.**

**Tell us more about the use of the right hemisphere.**

**I mentioned above that even native Chinese speakers use the right hemisphere to some extent, so the story is even more complicated. In one of our recent studies, we found that comprehension of Chinese idioms by native speakers engages the right hemisphere much more strongly than we previously thought based on data from figurative language processing. This is because the understanding of Chinese idioms requires a lot of historical, social, and cultural background knowledge and the right hemisphere plays a huge role here in integrating such knowledge.**

**So, the dichotomy between monolinguals vs. bilinguals with regard to left-vs.-right brainlateralization, without regard to specific linguistic features or components, does not seem to be a fruitful direction for future work.**

**Over the years, what differences in neural structures and connections have clearly emerged between monolinguals and bilinguals?**

**From what has been said so far, we should be careful when we speak of ‘the monolingual brain’ versus ‘the bilingual brain’, because language is complex and the brain is complex. This said, being a bilingual does have significant implications for the brain, both for how the brain represents and processes the two or more languages (function), and for how the brain changes as a result of learning languages (structure).**

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**Bilingual experience, as compared with other types of experience, is somewhat unique in terms of neuroplasticity, i.e. functional and physical changes in the brain induced by activities performed regularly. For example, given how complex language is, you cannot learn a new language in a day despite what various commercial products claim for speedy language learning. If you are serious about learning, you have to, at the very least, remember thousands of words (lexicon), learn the sound system (phonology), acquire the writing system (orthography), learn the complex grammar (syntax), and learn the subtle ways to express yourself (pragmatics).**

**To learn all of these components of language, you need to consistently use many parts of the brain. For example, the lexicon engages the frontal and parietal cortical regions, phonology uses your frontal and temporal regions, orthography uses your occipital and temporal-parietal regions, syntax engages your frontal and subcortical regions, and pragmatics relies on both the left and the right hemispheres.**

**What impact does this have on the bilingual brain?**

**When you spend a couple of weeks, months, or even years learning a second language, the net effect of this effort is that your entire brain is exposed to, and trained by, the auditory and visual features of the language (see the Chinese tone example above).**

**Neuroscientists have discovered that when bilingual brains are compared with monolingual brains as a whole, specific brain regions are more active when doing specific linguistic tasks (phonology, orthography, syntax). These regions also become strengthened in terms of the amount/volume of neural substances, i.e. gray matter and white matter.**

**Thus, a recent trend in the neurosciences of bilingualism is to study how these areas become better connected in the bilingual's brain. For example, in one of our studies we showed that students learning Chinese for only six weeks display a more integrated**

**neural network that connects the superior temporal gyrus with the frontal and parietal cortex, and this contrasted with students who have not learned Chinese within the same time period.**

**Bilingualism: What happens in the brain?**

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**By Yella Hewings-Martin PhD**

**In our increasingly global society, bilingualism - or the ability to speak two languages - is on the rise. How the brains of bilingual people differ from their monolingual counterparts is an emerging area of research.**

**Both languages that a bilingual person knows are switched on, even when communicating in only one of them. How does the brain cope?**

**Attitudes toward bilingualism have changed significantly in the past 50 years. Gone are the days when using a second language in the home was frowned upon, labeled as confusing for children and supposedly holding back their development.**

**Instead, the number of bilinguals has been rising steadily. Data from the United States Census Bureau show that between 2009 and 2013, around 20.7 percent of people over the age of 5 spoke a language other than English at home.**

**This number has more than doubled since 1980, when it stood at 9.6 percent.**

**With a rising number of bilingual people comes increased research into the science that underpins this skill. Do the brains of bilinguals differ from those of monolinguals? And do bilinguals have the edge over monolinguals when it comes to cognitive functioning and learning new languages?**

**As a member of a bilingual household, I was keen to investigate.**

### **Dispelling myths**

**A 2015 review in the journal *Seminars in Speech and Language* explains how bilingual children develop their language skills, dispelling commonly believed myths.**

**According to authors Erika Hoff, a professor of psychology at Florida Atlantic University in Boca Raton, and Cynthia Core, an associate professor of speech, language and hearing science at the George Washington University in Washington, D.C., newborns can distinguish between different languages.**

**They are also capable of developing vocabulary in two languages without becoming confused. When bilinguals mix words from different languages in one sentence - which is known as code-switching - it is not because they cannot tell which word belongs to which language.**

**Interestingly, children seem to naturally develop an understanding of who in the house speaks which language early on, and they will often choose the correct language to**

communicate with a particular individual - a phenomenon I have witnessed with my daughter, who is exposed to both German and English.

Mixing languages does not seem to hold bilingual children back from learning both languages, but it takes longer to learn two languages than to learn one. While there is a tendency on the whole for bilinguals to lag behind monolinguals in their language development, this isn't true for all children.

Scientists are now starting to unravel the mysteries of the bilingual brain and shed light on the advantages that having this skill may bring.

### Competing languages

Viorica Marian - a professor of communication sciences and disorders at Northwestern University in Evanston, IL - and colleagues published a study last month in the journal *Scientific Reports*, investigating which areas of the brain are involved in language control.

The research involved 16 bilingual individuals who had been exposed to Spanish from birth and to English by the time they were 8 years old.

Prof. Marian explains in the paper that "[b]ilinguals' ability to seamlessly switch between two distinct communication systems masks the considerable control exerted at the neural level."

In fact, when a bilingual person hears words in one language, the other language also becomes activated. Scientists think that the brains of bilinguals adapt to this constant coactivation of two languages and are therefore different to the brains of monolinguals.

**In her study, Prof. Marian also sought to clarify which brain regions are involved when bilinguals are faced with words that sound similar. In monolinguals, this "phonological" competition occurs only between words from the same language.**

**But bilinguals have similar-sounding words from their second language added into the mix.**

### **Neural plasticity**

**In monolingual people, areas in the frontal and temporal language regions - more specifically, the left supramarginal gyrus and the left inferior frontal gyrus - are activated when faced with phonological competition.**

**The study results show that different areas of the brain are needed to cope with phonological competition from within the same language, compared with between-language competition.**

**"We found," Prof. Marian explains, "that the size and type of the neural network that bilinguals recruited to resolve phonological competition differed depending on the source of competition."**

**"When competition occurred between two languages, bilinguals recruited additional frontal control and subcortical regions, specifically the right middle frontal gyrus, superior frontal gyrus, caudate, and putamen, compared to competition that occurred within a single language."**

**Prof. Viorica Marian**

**She concludes that "[t]hese findings demonstrate the considerable neural plasticity that enables bilinguals to process speech in spite of linguistic competition from multiple sources."**

**Neural plasticity, or the brain's ability to adapt to the environment and new experiences, is crucial in cognitive functioning. Do bilinguals, therefore, have an advantage when it comes to cognitive function?**

### **Cognitive health**

**Ellen Bialystok, a professor of psychology at York University in Toronto, Canada, and her team study the effect of bilingualism and cognitive function using a combination of behavioral and neuroimaging methods.**

**Prof. Bialystok told me that "[t]he cognitive functions that have been shown to be impacted by bilingualism largely concern attention - the ability to focus attention on relevant information and shift attention as needed."**

**"This attentional control," she explained, "is one of the most central aspects of cognitive function throughout life and is a big part of cognitive decline with aging. Therefore, anything that boosts these attention systems has the potential to also sustain cognitive function in older age."**

***Medical News Today* reported on a study in 2013 that showed that bilinguals - even those who are illiterate - developed symptoms of dementia significantly later than monolingual individuals. These results are echoed in Prof. Bialystok's research.**

**"We attribute these protective effects to better maintained attentional control that has been developed through the ongoing use of attention needed to manage selection between two jointly-activated languages."**

**Prof. Ellen Bialystok**

## **Task switching**

**A paper written by Prof. Bialystok's group and published in the journal *Cognition* earlier this year investigated the ability of bilinguals to switch from one task to the next - a skill that serves as an indicator of cognitive functioning.**

**First study author John Grundy, Ph.D. - a postdoctoral research fellow in the laboratory of Prof. Bialystok - writes that the "experience of bilingual infants that requires them to pay attention to multiple sources of input within various linguistic contexts makes it adaptive for them to rapidly disengage attention from stimuli once they are processed so that attention can be re-engaged to currently relevant stimuli."**

**Language learning boosts brain plasticity and ability to code new information**

**Find out how language learning benefits the brain.**

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**In three studies involving a total of 145 bilingual and 126 monolingual individuals, participants completed a test to study their ability to switch between types of stimulus displays wherein different responses were required.**

**The results show that bilinguals were faster at disengaging their attention from one trial so that they could focus on the next trial when a different response was required.**

**As this ability contributes to life-long cognitive health, bilinguals may be at a clear advantage.**

**But while there is plenty of evidence showing that cognitive decline is slower in bilinguals, do they also have an advantage when it comes to learning additional languages?**

**From bilingual to polyglot**

**Earlier this week, Sarah Grey - an assistant professor in the Department of Modern Languages and Literatures at Fordham University in New York City, NY - reported in the journal *Bilingualism: Language and Cognition* that bilingual individuals learn new languages more quickly than monolinguals.**

**For their study, Prof. Grey and colleagues taught bilingual Mandarin and English speakers and monolingual English speakers an artificial language called Brocanto2.**

**Using electroencephalogram analysis, the team found clear differences in the brain waves of both groups when they were listening to sentences in the language.**

**Bilingual people showed a brainwave pattern called P600 by the end of the first day of training. This pattern is specifically found when individuals process their own language. The monolingual group only started to display the P600 brain waves by the end of the 1-week training session.**

**"We [...] find that bilinguals appear to learn the new language more quickly than monolinguals," explains Prof. Grey.**

**"Now, with this small study, we have novel brain-based data that points toward a distinct language-learning benefit for people who grew up bilingual."**

**Prof. Sarah Grey**

**Studying the brains of bilingual people is a complex task. As no two individuals are alike, no two bilinguals are either.**

**However, an increasing interest in the topic, coupled with an increasing number of bilinguals in our society, means that researchers are starting to get to the bottom of how this ability affects the brains and life-long cognitive abilities of those, such as my daughter, blessed with the skill.**