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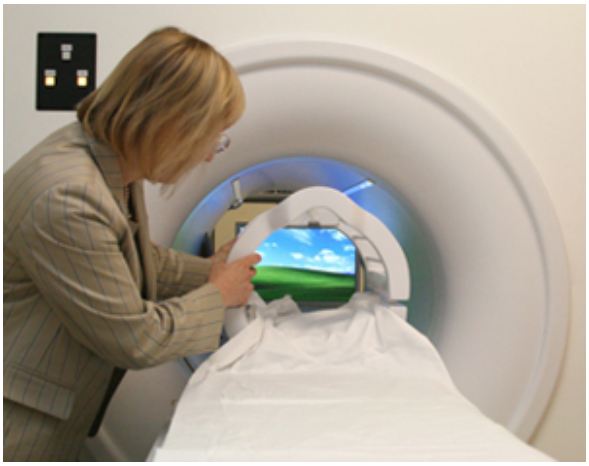
Penn State's Center for Language Science studies the benefits of the bilingual brain.

On a warm, sunny May morning, a group of students and researchers from Penn State's Center for Language Science (CLS) gathers in the basement of Chandlee Lab for safety training on operating the functional magnetic resonance imaging machine (fMRI). Susan Lemieux, MRI physicist and safety officer, ensures that all present have removed watches and jewelry before entering the inner chamber. The room is cool, and the tunnel-shaped machine is white and bright, sleek and shiny. The air hums. Lemieux asks each of the researchers to put a hand to the machine's opening while they hold a set of keys. In turn, each person startles at the subtle but definite strength of the magnetic pull.



Susan Lemieux demonstrates how the mock scanner

The fMRI is a powerful tool and one that provides social scientists with an entirely new level of research opportunities. The fMRI produces a high-resolution image of the brain at work using a noninvasive method, unlike other techniques such as CAT and PET scans. And the scientists at the CLS are very interested in the brain at work—more specifically, the bilingual brain.

Ping Li, professor of psychology and linguistics and co-chair of Penn State's graduate program in neuroscience, was the first member of the CLS to use the University Park fMRI, which has been up and running in the Social, Life, and Engineering Sciences Imaging Center since 2009. Li, like many in the group, is interested in learning how two languages compete in the mind and brain, among other

prepares human subjects for the MRI machine.
Jill Shockey

research topics.

"How does the brain really support the use of two languages?" asks Li. "We put Chinese speakers into the scanner, and we put English speakers into the scanner to see how they process the same kinds of words or sentences. Given the differences that exist between languages, how do these differences actually impact the way we speak, especially if we speak two languages? Does the brain have a way of handling each language differently, or does the brain develop an extra system for handling each language?"

Li points out that he would not have been able to address these questions when he was in graduate school. "We are able to turn out the next generation of scientists with the first-hand knowledge of the fMRI, language science, and electrophysiology," he says. "They will come of age with the new technology as well as the traditional knowledge of psychology, linguistics, and related sciences."

Big Ideas in the Purple Lab

The Center for Language Science, which boasts international partners, 30 doctoral students and 15 faculty members at Penn State, hundreds of research projects, and research support from the National Science Foundation and the National Institutes of Health, had its humble beginnings in conversations of like-minded researchers. When Judith Kroll, director of the CLS and distinguished professor of psychology, linguistics, and women's studies, came to Penn State in 1994, there were few studying bilingualism on campus. That didn't stop her from talking about it.

Judith Kroll, distinguished professor of psychology, linguistics, and women's studies
M. Scott Johnson

In 1995, Kroll inherited a lab in the Moore Building that had belonged to the late Hersch Liebowitz, a distinguished vision researcher, who had painted the walls black to reduce ambient light for experiments. She had been told that there was a six-month backlog of painting projects. Unable to abide a Goth workspace for that long, Kroll and her students decided to buy paint that would cover the walls in one coating: the Purple Lab was born.

With interested students and colleagues dropping in to chat, Kroll says, "The room took on a life of its own." At the point where Kroll feared the Purple Lab would become a fire hazard with the number of people attending its meetings, the Language Science Research Group at Penn State formed in 2003. Three years later, largely propelled by the interest, energy, and engagement of graduate students, the Center for Language Science was formalized.

One of the first people to stop by the Purple Lab was Giuli Dussias, then recently hired in the Department of Spanish, Italian, and Portuguese. "Giuli was studying eye tracking with bilingual speakers, which was a radical thing for someone teaching Spanish," says Kroll. "Her department head asked if I would share my lab space with her, and I said, 'No. She needs her own lab.' That's when a real culture shift began, and people began to understand that someone in a traditional humanities department could be doing scientific work."

Dussias is now one of two co-directors of the CLS. The other is Carol Miller, associate professor of communication sciences and disorders and linguistics. Dussias studies Spanish–English bilinguals and uses an eye tracking device—a tiny camera mounted at the bottom of a computer that records eye movements to

determine which sentences give her subjects trouble when they are reading. During the course of her research, she made an important observation.

"We discovered that your first language not only influences your second language but the second language also influences the first," says Dussias. "When people travel abroad and come back to the U.S., they often say that they forgot how to speak English. They report difficulty in retrieving words. We knew something was going on, but we didn't know that the first language could be affected in profound ways. We're now looking at what aspects of grammar are more vulnerable. Are there certain things that are more entrenched in one's first language that take longer to be affected by the second language?"

Talk to the Hand

Dussias also is one of several Center researchers looking at American Sign Language (ASL). She says, "For the deaf, their second language is written. We are interested in learning how this is different from people whose second language is spoken."

Deaf individuals are bilingual.
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The CLS has two domestic partners, Haskins Laboratories at Yale University and Gallaudet University (for the deaf) in Washington, D.C. Kroll says that Gallaudet reached out to Penn State and was immediately embraced. Gallaudet is the site of a Science of Learning Center funded by the National Science Foundation. Kroll says, "One of the ideas—and it's really changed the research agenda—is that instead of looking at deafness as a deficit, to recognize that deaf individuals are actually bilingual. They use sign language to communicate. Then they have to learn how to read and write in a written language. So, they are bimodal bilinguals. There are some fascinating questions being raised about the nature of their bilingualism."

Janet van Hell, professor of psychology and linguistics and director of the program in linguistics, points out the term "bimodal bilingual" has arisen in the literature fairly recently. Van Hell came to Penn State from the Netherlands, where she worked with deaf bilingual children who tend to make errors with the written language. Because van Hell considered sign language and written language as two different language systems that deaf children acquire, she took into consideration that the children's first language, signing, affected the learning processes in reading and writing the second language.

"You realize the errors are a part of the developmental process," she says. "When the children become proficient in both languages, they will be better able to separate them. Considering the errors as a transfer effect is a completely different way of looking at the problem."

Around the World

Van Hell visited the Purple Lab when she was a graduate student at the University of Amsterdam in the Netherlands. She later returned to Penn State as a faculty member at Radboud University in Nijmegen, in the Netherlands. She says that although the Netherlands is a destination for those who want to study

bilingualism, she was attracted to the Penn State program because of the dynamic environment. "The program here is organic and evolving," she says. "We think of ourselves as an emergent species with new ideas and room to grow."

Today, Radboud University is one of the center's eight international partner universities, and she and Dussias, Li, and Kroll are co-PIs on a five-year project called, "Understanding the bilingual mind and brain: An interdisciplinary program in cognitive psychology, linguistics, and cognitive neuroscience."

Errors are part of the developmental process.
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Last fall, the center received a $2.8 million research and training grant from the NSF's Partnership for International Research and Education (PIRE) to support this project. This summer, the center sent a cadre of eight undergraduate and three graduate students to conduct research at partner institutions including the Max Planck Institute in Leipzig, Germany; Radboud University, the University of Granada and Universitat Rovira I Virgili in Spain; and Beijing Normal University in China.

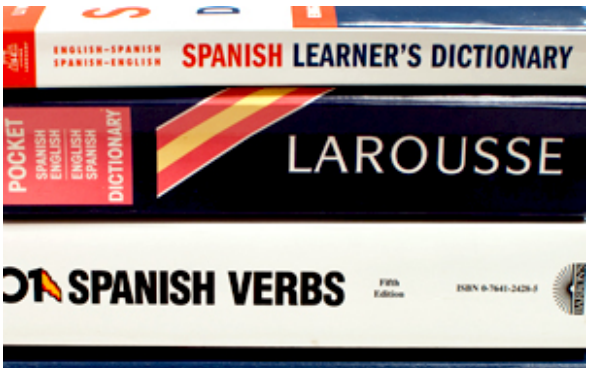
Armed with eye tracking devices, behavioral and neuroscientific tools, questionnaires, laptops and an understanding of cognitive psychology and linguistics, the students have scattered into the wind, studying bilingualism. "One of our undergraduate students is going to Beijing and will be collecting data in China from Mandarin speakers," says Miller. "Another undergraduate is collecting data from bilingual children. We're interested in finding out how different ways of measuring language ability might relate to understanding of mental states."

The summer research-abroad programs embrace the heart of the center's mission. Three things, says Li, sustain the center: "An international component, interdisciplinary research, and collaborative efforts." The next generation of language scientists is learning quickly.

Is Bilingual Better?

Kroll sheepishly admits that although she has immersed herself in more than one second language, she herself is doggedly monolingual. Yet, she praises the benefits of bilingualism. Consider Alzheimer's disease. "Our colleague Ellen Bialystok at York University in Toronto has shown that bilinguals tend to be delayed in the onset of Alzheimer-type symptoms," says Kroll. "If you look at matched groups of monolinguals and bilinguals who have similar symptoms, the bilinguals have more brain damage than the monolinguals. But because they have developed enhanced mechanisms of cognitive control, they seem to be able to compensate."

Another benefit is the instant ability to sort out relevant information from the irrelevant. "Bilingual children and adults and elderly bilinguals are advantaged in being able to ignore irrelevant information, and in being able to juggle information, and to switch from one task to another," says Kroll. "In the Center for Language Science we are asking a related question: What is it about the way that bilinguals process language that produces these advantages to cognition?"



One of the major topics in the group is code-switching—a

term that describes the process of bilinguals toggling from using the native language to the learned language. What is it that bilinguals do when they code switch? How do they decide to move from one language to the other? CLS researchers use electroencephalography (EEG)—electrodes attached to the head that provide a fine temporal resolution (as opposed to the fine spatial resolution of the fMRI)—to measure the time course of brain activation during the transitions between languages.

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Laura Stocker

"What's amazing is there are fewer costs associated with code-switching than you might expect," says Kroll. "You might think that someone who is speaking in two languages would really be stumbling. This is a high-level skill. From both a linguistic perspective and from a cognitive neuroscience perspective, we're interested in understanding how bilinguals learn to control the use of their two languages effectively."

When asked about the center's mission, Kroll often cites the 125th anniversary of the journal *Science* that identified the biological basis of second language learning as one of the top 125 questions to be answered in the next 25 years of research. If the past is prelude, the Center for Language Science will be well ahead of this deadline.

—Gigi Marino

Judith Kroll, Ph.D., is director of the Center for Language Studies and distinguished professor of psychology, linguistics, and women's studies. Ping Li, Ph.D., is professor of psychology and linguistics and co-chair of Penn State's graduate program in neuroscience. Giuli Dussias, Ph.D., is associate professor of Spanish, linguistics and psychology and associate co-director of the CLS. Carol Miller, Ph.D., is associate professor of communication sciences and disorders and linguistics and associate co-director of the CLS. Janet van Hell, Ph.D., is professor of psychology and linguistics and director of the program in linguistics.