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Courtney Lab studies prefrontal cortex and cognitive control

By [SHIVNI PATEL](#) | October 31, 2019  



Imagine walking into a busy restaurant with a friend, sitting down and discussing what you will both be ordering tonight. In the booths next to you, bustling conversations about sports and work are happening, but you do not pay much attention to them. Your attention is on the task at hand, on ordering your meal and chatting with your friend.

Your awareness is on your meal and your friend rather than the many other distractions around you because your brain is orchestrating an organized response to the situation around you. Professor Susan Courtney of the Psychological and Brain Sciences Department explained how this works.

"How do you inhibit what is irrelevant, and how do you enhance what is relevant? What are you trying to ultimately achieve with the task? What are the rules by which you have to accomplish a particular task? The process that keeps you focused is what is called cognitive control," Courtney said in an interview with *The News-Letter*.

The Courtney Lab currently studies changes in cognitive control and working memory in order to comprehend the functional organization of the prefrontal cortex, a key part of our brain with a key role in "higher cognition." According to Courtney, the prefrontal cortex subserves the process of cognitive control, which exemplifies how our brains engage the prefrontal cortex in our day-to-day lives. The prefrontal cortex is a key part of the brain that facilitates what are called "higher level cognitive tasks," which include complex tasks such as problem-solving, planning, abstract thought, creativity and impulse control, rather than "lower level cognitive tasks" which include following simple procedures, or routine tasks that require minimal thinking.

Courtney noted that the prefrontal cortex is particularly helpful for novel tasks.

"The prefrontal cortex is important particularly when you are trying to achieve something new. If you are doing the same thing over and over again, you use automatic habits, and stimuli," Courtney said.

Often when considering issues in memory recall and proper cognitive function in the brain, diseases such as Alzheimer's come to mind. Courtney explained that those diseases affect the recall of long-term memories, while the functions of cognitive control and working memory are affected by multiple other factors, including sedentary lifestyles, smoking, high-fat diets, and even aging.

"A lot of people don't think of that with aging, because we automatically think about Alzheimer's. But the more common issue is an increase in distractibility, or what people refer to as slow speed of processing," Courtney said. "It would take you longer to remember somebody's name, or make you forget the name of someone in the middle of a conversation. For instance, you may go from one room in your house to another, and by the time you are in that room, you forget why you had to go there in the first place."

Currently, the Courtney Lab is publishing their results on a project studying the slow-synchronization between the prefrontal and sensory cortex. The lab tested individuals both young and old on mental arithmetic tasks by giving the subjects two numbers at the top of a screen, and third number at the bottom. If they were doing addition, they were supposed to answer yes or no if the third number was the sum of those two top numbers or not. If they were doing multiplication, they were supposed to reply yes or no if the third number was the product of those two numbers. Courtney explained why the results of the study are of particular interest.

"Turns out, old people were actually just as good, if not better, at the mental arithmetic than the young people. But if you had to switch back and forth between addition and multiplication, they had a harder time with what we call 'false unrelated problems,'" Courtney said.

If the subjects were told they were to be performing addition and were given a two and a three as the two numbers at the top, and six as the number at the bottom, they were supposed to answer no, even though that would have been the right answer if multiplication was supposed to be performed. Here, Courtney explained that her lab found that older individuals had greater difficulty quickly distinguishing between the related and "false unrelated problems."

"Older individuals were slower to say, 'No that's not right because I'm supposed to be doing addition,'" Courtney said.

The Courtney Lab then analyzed the slower speed of processing in the brain activity of older individuals by analyzing the connection between the two parts of the brain communicating during the exercise — the prefrontal cortex and the visual cortex. The lab looked at the ongoing vibrations between the prefrontal cortex at the front of the brain, and the visual cortex at the opposite side of the brain while the subjects were performing the exercises. Courtney explained how the initial experiment allowed for the connection between the different parts of the brain to be observed.

“You see these three numbers and know what you need to inhibit and when, so you need this communication between visual and prefrontal. When you switch between addition and multiplication, that oscillating connection between those two brain areas changes,” she said.

“It gets disrupted and then it comes back. When you are changing tasks, this connection turns off and then turns on again when your mind realizes that you have switched to another task.”

According to Courtney, the slow-synchronization between the prefrontal cortex and the sensory cortex could be explained by variety of factors.

“Some people are better in terms of speed on this, and some are not. If they have had a lifetime of smoking, sedentary behavior and high blood pressure, all of that can degrade that pathway which I refer to as a ‘pothole.’” Courtney said. “You can get where you are going, but you have to slow down because it gets noisy and busy. If you have a pothole anywhere along that whole road between your prefrontal cortex and your sensory cortex, then you’re in trouble.”

Although there has been headway in understanding the function of this part of the brain, Courtney believes that there are still many questions to be answered in the study of the prefrontal cortex. Regarding how exactly the brain knows when to start engaging the prefrontal cortex, Courtney noted that the answer to that question is still unknown.

“One thing that we know happens is conflict detection, which involves the anterior cingulate, the middle part of the prefrontal cortex, which seems to respond most when there are two alternatives, two possible answers to the question and you do not know which one is right. The prefrontal cortex comes on and comes to remind you which one is relevant and which one is not,” Courtney said.

Courtney’s interest in studying the functional organization of the prefrontal cortex was piqued by a variety of factors after she began graduate school in a Bioengineering PhD program.

“In graduate school, I was studying color vision and trying to make a computer simulation of how our color perception works. I started reading more about color perception and all the various things that can affect our color perception, including attention and expectations and semantic knowledge about the objects that we are looking at. None of that could be explained bottom up,” Courtney said.

When Courtney completed her graduate program, she looked around for post-doc positions when the technique of functional magnetic resonance imaging (fMRI) was being developed. With a background in engineering, Courtney felt the pull towards labs using fMRI in their studies.

“I realized I could use my engineering background to help develop the method, and in the process I started studying working memory and prefrontal cortex/visual image interactions,” Courtney said.

Courtney partly began research on the topic due to her own interest, but also due to the wealth of data that she realized was available for analysis.

“In part, I began studying it because I was interested in it, but also because the time course of fMRI is a few seconds. You only get an image of changes in brain activity every two seconds. With working memory, you are presented an image for one second, then you wait for 10 seconds and you present another picture,” Courtney said.

“The person has to say if that picture was the same or different. It is those 10 seconds in between when the memory is going on, and 10 seconds is a great period of time to look at a change in an MRI signal when you only get a couple of data points every few seconds.”

The combination of studying perception and the many factors that affect it, as well as having a new tool (fMRI) to study the interactions between attention, working memory, and perception rooted Courtney’s interest in the study of the prefrontal cortex and its role in higher-level cognition. In 1999, Courtney joined the Department of Psychological and Brain Sciences Department at Hopkins and has been here ever since.

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