Working memory has limited 'slots'

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A new study by researchers at UC Davis shows how our very short-term "working memory," which allows the brain to stitch together sensory information, operates. The system retains a limited number of high-resolution images for a few seconds, rather than a wider range of fuzzier impressions.

Humans rarely move their eyes smoothly. As our eyes flit from object to object, the visual system briefly shuts off to cut down visual "noise," said Steven J. Luck, professor of psychology at the UC Davis Center for Mind and Brain. So the brain gets a series of snapshots of about a quarter-second, separated by brief gaps.

The working memory system smoothes out this jerky sequence of images by retaining memories from each snapshot so that they can be blended together. These memories typically last just a few seconds, Luck said.

"We use working memory hundreds of thousands of times each day without noticing it," Luck said. The system also seems to be linked to intelligence, he said.

Luck and postdoctoral researcher Weiwei Zhang wanted to test whether working memory stores a fixed, limited number of high-resolution images, or is a more fluid system that can store either a small number of high-resolution images or a large number of low-resolution images.

They showed volunteers a pattern of colored squares for a tenth of a second, and then asked them to recall the color of one of the squares by clicking on a color wheel. Sometimes the subjects would be completely unable to remember the color, and they just clicked at a random location on the color wheel. When subjects could remember the square, however, they usually clicked on a color that was quite close to the original color.

Zhang developed a technique for using these responses to quantify how many items a subject could store in memory and how precise those memories were.

"It's a trivial task, but it took us years to realize that we should use it," Luck said. The researchers began the work at the University of Iowa; Luck moved to UC Davis in 2006, and Zhang in 2007.

The evidence shows that working memory acts like a high-resolution camera, retaining three or four features in high detail. Those features allow the brain to link successive images together. However, while most digital cameras allow the user to choose a lower resolution and therefore store more images, the resolution of working memory appears to be constant for a given individual. Individuals do differ in the resolution of each feature and the number of features that can be stored.

People who can store more information in working memory have higher levels of "fluid intelligence," the ability to solve novel problems, Luck said. Working memory is also important in keeping track of objects that are temporarily blocked from view, and it appears to be used when we need to recognize objects shown in unfamiliar views.

Work by Lisa M. Oakes, another psychology professor at UC Davis and colleagues has shown that very young infants have fairly primitive working memory abilities. Between the ages of 6 and 10 months, however, they rapidly develop a much more adult-like working memory system.

Outside the visual domain, working memory is used for storing alternatives or intermediate values, for example when adding a string of numbers together, Luck said. It also appears to play an important role in learning new words, perhaps by allowing the sound of a new word to remain active in the listener's brain until a long-term memory of the word can be formed.

Luck compared the working memory system to the internal memory registers on a computer chip that allow it to make a series of calculations in between referring to the main memory. Our more familiar long-term memory, in contrast, can be used to store large quantities of information for long periods of time, but it is accessed much more slowly, like a computer's hard drive.

The paper is published online April 2 by the journal *Nature.*

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