Picower: 1 skull + 2 brains = 4 objects in mind

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(Medical Xpress) -- In the 1983 movie "A Man with Two Brains," Steve Martin kept his second brain in a jar. In reality, he had two brains inside his own skull - as we all do, one on the left and one on the right hemisphere. When it comes to seeing the world around us, each of our two brains works independently and each has its own bottleneck for working memory.

Normally, it takes years or decades after a brand new discovery about the brain for any practical implications to emerge. But this study by MIT neuroscientists could be put to immediate use in designing more effective cognitive therapy, smarter brain games, better "heads up displays," and much more. The study will appear on the website of the Proceedings of the National Academy of Sciences on Monday, June 20, 2011.

Researchers have known for over a hundred years that we can only hold about four things in our minds at once. This capacity limitation of our working memory (our mental sketchpad) varies somewhat among individuals, and the more you can hold in mind at once, the more complex your thoughts and the higher your IQ tends to be. But although this limitation is a fundamental feature of cognition and intelligence, researchers knew nothing about its neural basis.

Monkeys, amazingly, have the same working memory capacity as humans, so Earl Miller, the Picower Professor of Neuroscience in MIT's Picower Institute for Learning and Memory, and Timothy Buschman, a post doctoral researcher in his lab, investigated the neural basis of this capacity limitation in two monkeys performing the same test used to explore working memory in humans. First the researchers displayed an array of two to five colored squares, then a blank screen, and then the same array in which one of the squares changed colored. The task was to detect this change and look at the changed square.

As the monkeys performed this task, Buschman recorded simultaneously from neurons in two brain areas related to encoding visual perceptions (the parietal cortex) and holding them in mind (the prefrontal cortex). As expected, the more squares in the array, the worse the performance.

"But surprisingly, we found that monkeys, and by extension humans, do not have a general capacity in the brain," says Miller. "Rather, they have two independent, smaller capacities in the right and left halves of the visual space. It was as if two separate brains - the two cerebral hemispheres - were looking at different halves of visual space."

In other words, monkeys, and by extension humans, do not have a capacity of four objects, but of two plus two. If the object to remember appears on the right side of the visual space, it does not matter how many objects are on the left side. The left may contain five objects, but as long as the right side contains only two, monkeys easily remember it. Conversely, if the right side contains three objects and the left side only one, their capacity for remembering the key object on the right is exceeded and so they may forget it.

This study resolves two long-standing debates in the field. Does our working memory function like slots, and after our four slots are filled with object we cannot take in any more; or does it function like a pool that can accept more than four objects, but as the pool fills the information about each object gets thinner? And is the capacity limit a failure of perception, or of memory?

"Our study shows that both the slot and pool models are true," says Miller. "The two hemispheres of the visual brain work like slots, but within each slot, it's a pool. We also found that the bottleneck is not in the remembering, it is in the perceiving." That is, when the capacity for each slot is exceeded, the information does not get encoded very well. The neural recordings showed information about the objects being lost even as the monkeys were viewing them, not later as they were remembering what they had seen.

This effect in visual working memory may not hold for other forms of memory, but visual perceptions is one of the primary ways that humans process the world, so its impact is both far reaching in terms of understanding the brain and human consciousness and in practical terms.

"The fact that we have different capacities in each hemisphere implies that we should present information in a way that does not overtax one hemisphere while under-taxing the other," explains Buschman. "For example, heads-up displays (transparent projections of information that a driver or pilot would normally need to look down at the dashboard to see) show a lot of data. Our results suggest that you want to put that information evenly on both sides of the visual field to maximize the amount of information that gets into the brain."

Likewise, cognitive therapies for improving working memory (and in brain games designed to keep it young and nimble) should present information in a way that trains each hemisphere separately. Biomedical monitors that currently have one column of information should balance it in right and left columns, and security personnel could take in more information if displays scrolled vertically rather than horizontally, which wastes the independent capacities on the right and left. The researchers are forming collaborations to develop many of these ideas.

Their next basic research project is to discover why this perceptual bottleneck occurs in the first place, Miller says. "That would give us a deep understanding of how the brain represents information and would give us the first real insights into consciousness."

More information: Neural substrates of cognitive capacity limitations, www.pnas.org/content/early/201 … /1104666108.abstract

Abstract
Cognition has a severely limited capacity: Adult humans can retain only about four items "in mind". This limitation is fundamental to human brain function: Individual capacity is highly correlated with intelligence measures and capacity is reduced in neuropsychiatric diseases. Although human capacity limitations are well studied, their mechanisms have not been investigated at the single-neuron level. Simultaneous recordings from monkey parietal and frontal cortex revealed that visual capacity limitations occurred immediately upon stimulus encoding and in a bottom-up manner. Capacity limitations were found to reflect a dual model of working memory. The left and right halves of visual space had independent capacities and thus are discrete resources. However, within each hemifield, neural information about successfully remembered objects was reduced by adding further objects, indicating that resources are shared. Together, these results suggest visual capacity limitation is due to discrete, slot-like, resources, each containing limited pools of neural information that can be divided among objects.

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