Computer simulations explain the limitations of working memory

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Researchers at the Swedish medical university Karolinska Institutet (KI) have constructed a mathematical activity model of the brain's frontal and parietal parts, to increase the understanding of the capacity of the working memory and of how the billions of neurons in the brain interact. One of the findings they have made with this 'model brain' is a mechanism in the brain's neuronal network that restricts the number of items we can normally store in our working memories at any one time to around two to seven.

Working memory, which is our ability to retain and process information over short periods of time, is essential to most cognitive processes, such as thinking, language and planning. It has long been known that the working memory is subject to limitations, as we can only manage to "juggle" a certain number of mnemonic items at any one time. Functional magnetic resonance imagery (fMRI) has revealed that the frontal and parietal lobes are activated when a sequence of two pictures is to be retained briefly in visual working memory. However, just how the nerve cells work together to handle this task has remained a mystery.

The study, which is published in the journal *PNAS*, is based on a multidisciplinary project co-run by two research teams at KI led by professors Torkel Klingberg and Jesper Tegnér. Most of the work was conducted by doctors Fredrik Edin and Albert Compte, the latter of whom is currently principal investigator of the theoretical neurobiology group at IDIBAPS in Barcelona.

For their project, the researchers used techniques from different scientific fields, applying them to previously known data on how nerve cells and their synapses function biochemically and electrophysiologically. They then developed, using mathematical tools, a form of virtual or computer simulated model brain. The computations carried out with this 'model brain' were tested using fMRI experiments, which allowed the researchers to confirm that the computations genuinely gave answers to the questions they asked.

"It's like a computer programme for aircraft designers," says Fredrik Edin, PhD in computational neuroscience. "Before testing the design for real, you feed in data on material and aerodynamics and so on to get an idea of how the plan's going to fly."

With their model brain, the team was able to discover why working memory is only capable of retaining between two and seven different pictures simultaneously. As working memory load rises, the active neurons in the parietal lobe increasingly inhibit the activity of surrounding cells. The inhibition of the inter-neuronal impulses eventually becomes so strong that it prevents the storage of additional visual input, although it can be partly offset through the greater stimulation of the frontal lobes. This leads the researchers to suggest in their article that the frontal lobes might be able to regulate the memory capacity of the parietal lobes.

"The model predicts, for instance, that increased activation of the frontal lobes will improve working memory," continues Dr Edin. "This finding was also replicable in follow-up fMRI experiments on humans. Working memory is a bottleneck for the human brain's capacity to process information. These results give us fresh insight into what the bottleneck consists of."

More information: 'Mechanism for top-down control of working memory capacity', Fredrik Edin, Torkel Klingberg, Pär Johansson, Fiona McNab, Jesper Tegnér and Albert Compte, *PNAS*, online early edition 30 March - 3 April 2009.

Watch lecture by Albert Compte: videolectures.net/eccs08_compte_mftdcowmc/

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