Scientists find first evidence of a living memory trace

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An international team of scientists for the first time has detected a memory trace in a living animal after it has encountered a single, new stimulus. The research, done with honeybees sensing new odors, allows neuroscientists to peer within the living brain and explore short-term memory as never before, according to scientist Roberto Fernández Galán, a leading author on the report who is currently a postdoctoral research associate at Carnegie Mellon University.

Capturing these memory traces could ultimately provide a completely new way to understand how short-term memory works, stated Galán. The findings are scheduled for January publication in *Neural Computation*.

"Our findings show that an odor produces a memory trace of synchronized neural activity that lasts several minutes after a bee initially senses it," said Galán. "This is the first time anyone has revealed a short-term, stimulus-specific neural pulse within the living brain that occurs after exposure to a previously unknown stimulus."

"Future investigations along the lines of our study may reveal previously overlooked memory traces in many other neural systems," said C. Giovanni Galizia, Galán's primary collaborator, who is now a professor at Konstanz Universität in Konstanz, Germany.

Galán performed the work as part of his dissertation research while in the research group of Andreas Herz at the Humboldt University in

Berlin, Germany.

The report supports Hebb's theory of learning, a 55-year-old proposition that "neurons that fire together wire together," thereby strengthening their connections. According to the theory, a stimulus activates some neurons while inhibiting others. Once this stimulus is removed, traces of that excitation/inhibition pattern – so-called Hebbian reverberations – should remain.

"We are the first to observe this phenomenon at the network level. We are also the first to detect a distinct signature, not only of a sensory short-term memory, but one that developed after a single exposure to a previously unknown stimulus, so that there is no context," said Galán. "All previous studies in this field have observed only a sustained, non-specific increase in neural activity after a living animal is repeatedly exposed to a stimulus. These investigations haven't retrieved a signature of a stimulus, whereas we have."

The experiments were performed in the laboratory of Randolf Menzel, whose pioneering observational experiments in the 1970s and 1980s showed that honeybees exposed to an odor and rewarded with sugar could develop a memory of that odor and temporarily store it as "working memory." They also found that honeybees lost their working memory of a re-enforced odor if they were cooled down and then revived, suggesting that the memory wasn't permanently stored.

This latest study is the first to combine fluorescent dye imaging developed by Galizia, and advanced image processing and mathematical data analysis developed by Galán to actually detect a working memory trace.

In the current research, the scientists studied clusters of neurons called glomeruli within the honeybee's antennal lobe (AL), considered the

invertebrate equivalent of the brain's olfactory bulb. Team member Marcel Weidert placed fluorescent probes within different glomeruli, and imaged their activity using dyes sensitive to the opening and closing of calcium channels on neurons. The scientists created an imaging grid across the glomeruli and measured the ratio of fluorescence versus nonfluorescence over time.

Galán then used advanced mathematical techniques to process the images and create a matrix of the extent (or amplitude) of neuronal excitation and inhibition within glomeruli. He retrieved a spatial pattern of synchronized, correlated activity – the memory trace – from what appeared to be random fluctuations of neural activity.

"The trace is like a fingerprint that disappears over time. It's strongest after the honeybee's initial exposure to an odor, but you can still detect its signature features minutes afterwards," said Galán.

A future question that could be addressed using this research is addressing how short-term memory gets encoded as long-term memory over time, said Galán.

Source: Carnegie Mellon University