Learning Causes Structural Changes In Affected Neurons

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When a laboratory rat learns how to reach for and grab a food pellet - a pretty complex and unnatural act for a rodent - the acquired knowledge significantly alters the structure of the specific brain cells involved, which sprout a whopping 22 percent more dendritic spines connecting them to other motor neurons.

The finding, published in the journal *Proceedings of the National Academy of Sciences* by Mark H. Tuszynski, MD, PhD, professor of neurosciences and colleagues at the University of California, San Diego School of Medicine, underscores the brain's remarkable ability to physically change as it learns (not just in rats, but presumably in humans too), but also reveals that the effect is surprisingly restricted to the network of neurons actually involved in the learning.

"I think it's fair to say that in the past it was generally believed that a whole cortical region would change when learning occurred in that region, that a large group of neurons would show a fairly modest change in overall structure," said Tuszynski, who is also director of the Center for Neural Repair at the UC San Diego and a neurologist at the Veterans Affairs San Diego Health System.

"Our findings show that this is not the case. Instead, a very small number of neurons specifically activated by learning show an expansion of structure that's both surprisingly extensive - there's a dramatic increase in the size and complexity of the affected neurons - and yet highly restricted to a small subset of cells. And all of this structural plasticity is occurring in the context of normal learning, which highlights just how changeable the adult brain is as a part of its normal biology."

Tuszynski said the new work improves science's basic understanding of how the brain learns. "This tells us that learning may be mediated by relatively few cells, but that these few cells exhibit a substantial or extensive change in structure." Notably, the impacted cells in the rat study were not clustered together, but widely distributed over the motor cortex of the rat brain, suggesting that learned behaviors create expansive networks of distant cells.

Whether these new connections and changes are permanent is the subject of continuing research. For a rat, reaching for and grasping food is a learned behavior that takes time and repetition to master, not unlike a person learning to ride a bike or play the piano. If the behavior isn't regularly practiced, it becomes rusty, though it may be later resumed and remembered.

"This seems to be a 'hard-wired' form of memory," said Tuszynski. "We were curious whether we could find evidence of hard-wiring as part of learning in animal brains. We designed this study and our original hypothesis seems to be confirmed.

"Whether this physically represents the formation of long-term memory is hard to say" Tuszynski said, explaining that the data are correlative. "The rats learn, and we know that the learning is mediated by the small set of cells we studied. We know that adjacent cells in the cortex, which are not required to learn the new task, do not show the structural change. So presumably the structural change is occurring only in the learning neurons, and the learning would likely not occur without the structural change."

He added that in order to determine whether the structural change is necessary for the learning to occur, scientists would need to block the expansion in spines and then observe a failure to learn. "Yet the inference is quite strong that structural change is necessary for the learning to occur."

Tuszynski said it remains to be seen how the brain changes in other types of learning, such as language-based knowledge or arithmetic-type learning.

"Types of memory that require much repetition for learning - and that don't fade away easily - likely use this modification of (dendritic) structure to accomplish the learning," he said. "Other forms of memory that are not so hard to establish - and which fade more rapidly - may not involve such extensive structural changes. These are concepts that will be pursued in future studies."

Co-authors of the study are Ling Wang, James M. Conner and Jessica Rickert, all in the Department of Neurosciences, UC San Diego.

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