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A brain filter for clear information transmission

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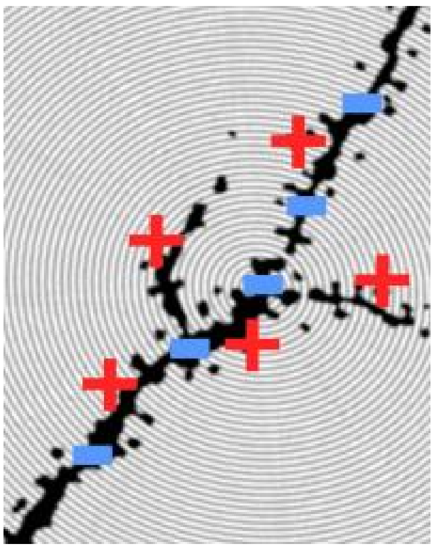

Neuronal Processing of Inhibition and Excitation in smallest nerve cell prolongations. Schematic representation of a tiny nerve cell prolongation (dendrite) that processes exhibitory and inhibitory signals. Credit: C. Müller

Every activity in the brain involves the transfer of signals between neurons. Frequently, as many as one thousand signals rain down on a single neuron simultaneously. To ensure that precise signals are delivered, the brain possesses a sophisticated inhibitory system. Stefan Remy and colleagues at the German Center for Neurodegenerative Diseases (DZNE) and the University of Bonn have illuminated how this system works.

"The system acts like a filter, only letting the most important impulses pass," explains Remy. "This produces the targeted neuronal patterns that are indispensible for long-term memory storage."

How does this refined control system work? How can inhibitory signals produce precise output signals? This was the question investigated by Remy and his colleagues. Scientists have known for some time that this inhibitory system is crucial for the learning process. For instance, newest research has shown that this system breaks down in Alzheimer's patients. Remy and his team investigated the nerve cells of the hippocampus, a region of the brain that plays a crucial role in memory formation.

The information we learn or remember is processed in the brain through nerve impulses. Incoming signals enter the cell as excitatory signals. Here, they are processed via branched structures, known as dendrites, and are sent selectively to neighboring neurons. The dendrites in this brain region serve as efficient amplifiers for synchronous signals.

"We were able to show that in specific dendrites, the 'strong' dendrites, clustered signals are amplified very well. 'Weak' dendrites only transmit signals in certain phases," says Christina Müller, postdoctoral student in Remy's working group and the lead author of the study to appear in *Neuron*. Dendrites are excitable to differing degrees. 'Strong' dendrites transmit synchronous excitatory signals precisely and very reliably. They can resist any inhibition. Thus ensures specific signals, perhaps most relevant for learning and memory, are reliably transmitted. This results in defined patterns of activity that are repeated regularly, creating simultaneous excitation and a combination of specific cell groups (assemblies).

"It is assumed that this coactivation of cell assemblies is a cellular correlate for learning," says Müller. If associations are to be stored in long-term memory, certain neuronal groups must be precisely and repeatedly activated in the same order. These activity patterns are enabled by the inhibitory system. It explains why the absence of this system in Alzheimer's patients has such dramatic consequences. Without it, the storage of associations in long-term memory cannot take place.

Signals that are received via 'weak' dendrites can only be passed forward during phases of weak inhibition. They can however be transformed into 'strong' dendrites during this process. According to Remy and his colleagues, only then can these dendrites provide precise signal transmission. Scientists call this "intrinsic plasticity". "This makes sense. Because this is how neuronal networks can be coupled with each other and the coupling made permanent," explains Remy. "This is a totally new learning mechanism. Here the change does not take place at the synapse – where it's already been observed – but at the dendrite." This mechanism mostly takes place during phases of heightened activity, such as when we experience something new.

The findings of Remy and his colleagues represent an important step toward better understanding the mechanisms of learning and memory.

More information: Christina Müller, Heinz Beck, Douglas Coulter & Stefan Remy. Inhibitory control of linear and supralinear dendritic excitation in CA1 pyramidal neurons. *Neuron*. doi: 10.1016/j.neuron.2012.06.025

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