New theory explains how beta waves arise in the brain

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Jones led a team that has posited a new theory of how beta rhythms arise in the brain, backed by evidence from humans, animal models and computer simulation. Credit: Brown University

Beta rhythms, or waves of brain activity with an approximately 20 Hz frequency, accompany vital fundamental behaviors such as attention, sensation and motion and are associated with some disorders such as Parkinson's disease. Scientists have debated how the spontaneous waves emerge, and they have not yet determined whether the waves are just a byproduct of activity, or play a causal role in brain functions. Now in a new paper led by Brown University neuroscientists, they have a specific new mechanistic explanation of beta waves to consider.

The new theory, presented in the *Proceedings of the National Academy of Sciences*, is the product of several lines of evidence: external brainwave readings from human subjects, sophisticated computational simulations and detailed electrical recordings from two mammalian model organisms.

"A first step to understanding beta's causal role in behavior or pathology, and how to manipulate it for optimal function, is to understand where it comes from at the cellular and circuit level," said corresponding author Stephanie Jones, research associate professor of neuroscience at Brown University. "Our study combined several techniques to address this question and proposed a novel mechanism for spontaneous neocortical beta. This discovery suggests several possible mechanisms through which beta may impact function."

Making waves

The team started by using external magnetoencephalography (MEG) sensors to observe beta waves in the human somatosensory cortex, which processes sense of touch, and the inferior frontal cortex, which is associated with higher cognition.

They closely analyzed the beta waves, finding they lasted at most a mere 150 milliseconds and had a characteristic wave shape, featuring a large, steep valley in the middle of the wave.

The question from there was what neural activity in the cortex could produce such waves. The team sought to recreate the waves using a computer model of a cortical circuitry, made up of a multilayered cortical column that contained multiple cell types across different layers. Importantly, the model was designed to include a cell type called pyramidal neurons, whose activity is thought to dominate the human MEG recordings.

They found that they could closely replicate the shape of the beta waves in the model by delivering two kinds of excitatory synaptic stimulation to distinct layers in the cortical columns of cells: one that was weak and broad in duration to the lower layers, contacting spiny dendrites on the pyramidal neurons close to the cell body; and another that was stronger and briefer, lasting 50 milliseconds (i.e., one beta period), to the upper layers, contacting dendrites farther away from the cell body. The strong distal drive created the valley in the waveform that determined the beta frequency.

Meanwhile they tried to model other hypotheses about how beta waves emerge, but found those unsuccessful.

With a model of what to look for, the team then tested it by looking for a real biological correlate of it in two animal models. The team analyzed measurements in the cortex of mice and rhesus macaques and found direct confirmation that this kind of stimulation and response occurred across the cortical layers in the animal models.

"The ultimate test of the model predictions is to record the electrical signals inside the brain," Jones said. "These recordings supported our model predictions."

Beta in the brain

Neither the computer models nor the measurements traced the source of the excitatory synaptic stimulations that drive the pyramidal neurons to produce the beta waves, but Jones and her co-authors posit that they likely come from the thalamus, deeper in the brain. Projections from the thalamus happen to be in exactly the right places needed to deliver signals to the right positions on the dendrites of pyramidal neurons in the cortex. The thalamus is also known to send out bursts of activity that last 50 milliseconds, as predicted by their theory.

With a new biophysical theory of how the waves emerge, the researchers hope the field can now investigate whether beta rhythms affect or merely reflect behavior and disease. Jones's team in collaboration with Professor of neuroscience Christopher Moore at Brown is now testing predictions from the theory that beta may decrease sensory or motor information processing functions in the brain. New hypotheses are that the inputs that create beta may also stimulate inhibitory neurons in the top layers of the cortex, or that they may may saturate the activity of the pyramidal neurons, thereby reducing their ability to process information; or that the thalamic bursts that give rise to beta occupy the thalamus to the point where it doesn't pass information along to the cortex.

Figuring this out could lead to new therapies based on manipulating beta, Jones said.

"An active and growing field of neuroscience research is trying to manipulate brain rhythms for optimal function with stimulation techniques," she said. "We hope that our novel finding on the neural origin of beta will help guide research to manipulate beta, and possibly other rhythms, for improved function in sensorimotor pathologies."

More information: Neural mechanisms of transient neocortical beta rhythms: Converging evidence from humans, computational modeling, monkeys, and mice, www.pnas.org/cgi/doi/10.1073/pnas.1604135113

Provided by Brown University

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