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Media release

The dialogue happening in our heads: New study decodes how regions in the brain communicate with each other

Researchers at the Inselspital, Bern University Hospital, and the University of Bern have, for the first time, directly measured how the human brain exchanges probing signals when asleep and when awake. Using electrodes temporarily implanted in the brain for clinical reasons, they were able to track the flow of signals between deep brain regions and the cerebral cortex with millisecond accuracy over a period of 24 hours. The study provides new insights into the way brain networks communicate and could enable the development of more precisely targeted brain therapies in the long term.

The human brain consists of billions of nerve cells that communicate with each other via complex networks. Exactly how signals flow between deep brain regions, which are important for emotions and memory, and the cerebral cortex, which is responsible for higher thought processes, was only inadequately understood until now. Earlier studies were mostly based on indirect or time-averaged measurements. Hitherto, direct, high-resolution long-term data from the human brain was, to all intents and purposes, unavailable.

World's first study relying on precise spatiotemporal brain signals

A research team at the Inselspital's Department of Neurology has, for the first time, studied how deep brain regions communicate with the cerebral cortex, and tracked the signal flow over 24 hours with high temporal and spatial precision. The study was based on so-called intracranial EEG measurements, made by inserting fine electrodes directly into the brain to record electrical signals in a particularly precise manner for clinical reasons.

The data comes from 15 adult patients with epilepsy whose clinical assessment involved wearing electrodes to localize and trigger epileptic seizures. Use of these electrodes forms part of the routine medical care. With the patients' consent, the research team were able to piggyback on this unique clinical situation to take scientific measurements. This enabled millions of individual neural signals to be directly recorded and evaluated in the awake and sleeping human brain.

In order to investigate the signal flow in a targeted manner, the researchers stimulated particular brain regions with short, imperceptible electrical impulses and observed how these signals were distributed in the brain during sleep and wakefulness. In this way, the team was able, for the first time, to systematically map the signal flow between limbic structures such as the hippocampus and amygdala as well as the cerebral cortex and to analyze the direction in which signals flow and how stable these patterns remain over time.

Memory and emotion centers control signal flow

The study showed that the hippocampus and amygdala, central regions for memory and emotions, send about twice as many signals as they receive during sleep as well as wakefulness. Unlike earlier studies on rodents, the researchers found no reversal of signal flow during sleep. "Our results show that human deep brain regions play a role in broadcasting signals, regardless of whether we are asleep or awake. This means that memory and emotion centers not only process information, but also disseminate the flow of information in the brain," according to Prof. Maxime Baud, Senior Consultant of the University Hospital's Department of Neurology and the last author of the study.

Previous methods, such as functional magnetic resonance imaging or EEG, were able to show which brain regions are active at the same time, however they could not reliably establish the direction in which the signals flow. The chosen approach makes it possible for the first time to measure signal flow directly and causally. This brings the researchers closer to a long-held goal: a "dynamic map" of brain connections that shows how information is actually transmitted from region to region.

Significance for research and medicine

The results raise new questions about how the brain works, such as whether there is a connection between the direction of brain signals and thinking, learning, and memory. Clinically, it is particularly relevant to know whether the signal flow changes in patients with neurological diseases and whether it can be influenced in the future by targeted brain stimulation, for example in cases of epilepsy or neuropsychiatric disorders.

To fully understand signal flow in healthy as well as diseased brains, extensive scientific work will still be needed. Ultimately, what is involved is the fundamental mechanisms of an organ that shapes memory, emotions, and behavior. Prof. Baud sums it up: "In the long term, we need to understand how every single signal arises that the brain processes every millisecond. The next step will be to link this signal flow to the actual function the brain is performing. Only then will it be possible to develop effective and precise neurostimulation devices that intervene in a targeted manner in dysfunctional brain networks.

Link
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