Medical Xpress

Human knowledge is based upon directed connectivity between brain areas

August 6 2007

Which brain processes enable humans to rapidly access their personal knowledge" What happens if humans perceive either familiar or unfamiliar objects" The answer to these questions may lie in the direction of information flow transmitted between specialized brain areas that together establish a dynamic cortical network. This finding is reported in the latest issue of the scientific journal PLoS ONE published on August 1st, 2007.

Fruit or vegetable, insect or bird, familiar or unfamiliar – humans are used to classify objects in the world around them and group them into categories that have been formed and shaped constantly through every day's experience. Categorization during visual perception is exceptionally fast. Within just a fraction of a second we effortlessly access object-based knowledge, in particular if sufficient sensory information is available and the respective category is distinctly characterized by object features.

The precise neural mechanisms behind this brain function are currently not well understood. Several theoretical models are available, but empirical data and detailed measurements of brain processes in humans are still rare. In the last years of research evidence has accumulated to regard the brain as a parallel system with highly specialized compartments, so that different processing stages take place at different brain sites. According to the prominent theory of neuronal synchronization, cooperation between different brain areas is realized through synchronization of their rhythmic activity (30-100 Hz) leading to emergence of short-lasting dynamic networks.

An international team of scientists that includes biologists, engineers, physicists and psychologists has now investigated this network in humans by measuring electrical brain currents (EEG) and by applying the most advanced analysis techniques currently available.

”Human knowledge is definitely not stored in one single brain area. Access to knowledge results from the cooperation of several brain areas that jointly build a dynamic brain network. In this study we were not only able to confirm that recognition of familiar and unfamiliar objects activates a set of distributed brain areas. Rather, importantly, for the first time we have measured in humans how brain areas communicate with each other by directed information transfer, depending whether object-specific knowledge was available or not,' tells co-author and initiator of the study, Thomas Gruber of the Department of Psychology of the University of Leipzig.

The participants in Gruber's study were asked to categorize objects that were subsequently presented on a screen either as familiar or unfamiliar during the registration of their brain waves (EEG). Unfamiliar objects represented complex visual patterns, physically resembling the familiar ones in every possible way, except for familiarity. Familiar objects represented objects of every day's life such as cup, dog or violin. Actually, in the experiment only the factor familiarity was manipulated. Both conditions just differed in the possibility of the subjects to access specific, object-related knowledge in the course of recognition. Based on previous studies the scientists expected to find not only a different level of brain activation in a set of distributed areas but also a different number of interactions between these areas.

“We expected that a larger number of brain interactions, a stronger degree of connectivity occurs, whenever a perceived object is familiar, that is whenever specific knowledge is available and can be used for processing. The contribution of our study is that by using a new method of signal analysis we succeeded in measuring the directionality of neuronal interactions. Cooperating brain areas forming a dynamic network are not just connected, but rather each area can be engaged either in receiving or sending signals or both. Until now this has been difficult to investigate, but our analysis suggests that most areas are involved in both during access to object-related knowledge," states first author Gernot Supp with the Department of Neurophysiology, University Medical Center Hamburg-Eppendorf and the Max-Planck Institute of Human Cognitive and Brain Science, Leipzig, Germany.

"Traditional methods of analysis are insensitive to the true directionality of information flow. Here, for the first time, we investigated object recognition in humans by applying a new method, which in fact represents a measure of causality. With this measure, we were able to distinguish between feed-forward and feed-backward information flow and quantified the interaction between brain areas in greater detail", reports Alois Schlögl, expert for biomedical signal processing at the University of Technology Graz, Austria and at the Fraunhofer Institute Berlin. He has made this new type of coupling analysis freely available for the scientific community in his open-source software-project BioSig (biosig.sf.net).

Together with the new method of directional coupling analysis these results may open a new perspective on brain processes. For the accurate execution of brain functions it might be crucial not only which brain areas are involved but, perhaps even more importantly, how they cooperate with each other. The investigation of this new dimension in brain research is just beginning.

Link: http://www.plosone.org/doi/pone.0000684