Article

9 **Internally generated preactivation of single neurons in human medial frontal cortex predicts volition.**

Fried I, Mukamel R, Kreiman G
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Comments

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Evaluations

Classification Key

Evaluated by Aviva Ellenstein and Mark Hallett 23 Mar 2011 | Elisa Filevich and Patrick Haggard

Dr Fried and colleagues have contributed valuable, new, information to the complicated study of intentional movement. Following the behavioral paradigm from the 'classic' Libet clock experiment and measuring cortical activity with depth electrodes, they found that neuronal firing patterns in the supplementary motor area could predict the reported time of intention to make a movement.

This study advances both the anatomic and temporal electrophysiologic characterization of voluntary movement. In 1965, Kornhuber and Deecke identified the Bereitschaftspotential (BP), a rising negativity over frontal areas measured by surface electroencephalography (EEG) that precedes voluntary movement by about one second {1}. In 1983, Libet et al. published the first and now classic study attempting to measure the subjective time of the intention to make a movement {2}. Named 'W' for 'will', this time reflects the subjects' report of the time on a clock when they intended to move and occurs about 250msec prior to the actual button press time 'P'. That the BP onset precedes W is well-established; however, their specific relationships to attention, decision making, motor planning, and 'free will' remain the topic of debate. Earlier works by Fried and others applying direct electrical stimulation to the cortex has further described the roles of parietal and premotor areas in movement perception and intention, respectively {3,4}.

In this study, Fried et al. reproduced the Libet clock experiment in a group of twelve patients with medically refractory epilepsy who were undergoing EEG evaluation with depth electrodes, which provided single neuron activity measurements in areas of the anterior cingulate cortex, pre-supplementary motor area (SMA), SMA proper, amygdala, hippocampus, parahippocampal gyrus, entorhinal cortex, and superior temporal gyrus. As has been previously demonstrated, the authors reproduced the timing of W and P. By measuring firing patterns in the different areas, the authors demonstrated that either increased or decreased firing rates in collections of neurons in SMA proper preceded W by more than two seconds and similar firing changes in pre-SMA followed W.

In their clear discussion, the authors appropriately note that the direction of change does not indicate the nature of the cortical activity in relation to movement intention. It would be interesting to know whether the firing rates of neurons that did not change during the study might have actually differed from a resting baseline when the brain was not generally engaged with the performance of a voluntary motor task. Among the strengths of the report is the clear description of the study's limitations. For example, the authors appropriately note that neither the entire brain nor all areas previously implicated in voluntary movement were measured. Likewise, they acknowledge that changes in SMA firing may not be the first event that reflects movement intention. Another contribution of this study is that the authors used a sampling of SMA neuron firing patterns preceding W to train a model that when applied to a different collection of SMA neuron firing patterns could predict W with a high degree of accuracy up to 700msec before W occurred.

Although this result does not describe the precise nature of activity in the SMA, this predictive power lends support for the idea that the SMA plays a causal role leading to awareness of movement intention. The close coupling of W and P remains a potentially complicating factor of the Libet paradigm in distinguishing cortical activity associated with intention and that associated with movement;

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Rating 8
Must Read

however, the power of EEG to predict movement was also recently demonstrated by modeling the EEG (please see reference {5} on which I am an author). Further studies are needed to characterize electrophysiologic correlates of movement will and action. This topic is interesting not only to neuroscientists and philosophers but also to neurologists and psychiatrists tasked with the difficult job of caring for patients with debilitating psychogenic movement disorders, which are not subjectively voluntary (please see reference {6} on which I am an author).

References:
{1} Kornhuber and Deecke, Pflugers Arch Gesamte Physiol Menschen Tiere 1965, 284:1-17 [PMID:14341490].
{2} Libet et al. Brain 1983, 106:623-42 [PMID:6640273].
{3} Fried et al. J Neurosci 1991, 11:3656-66 [PMID:1941101].
{4} Desmurget et al. Science 2009, 324:811-3 [PMID:19423830].
{5} Bai et al. Clin Neurophysiol 2011, 122:364-72 [PMID:20675187].
{6} Hallett M, Curr Neurol Neurosci Rep 2006, 6:269-71 [PMID:16822346].

Competing interests: No potential interests relevant to this article were reported.

Cite this evaluation

In this fascinating paper, Fried et al. relate recordings from single neurons in the human medial frontal cortex to the experience of conscious will.

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Rating 6
Recommended

Neurons were recorded from depth electrodes in the pre-supplementary motor area (pre-SMA), SMA proper, and cingulate cortices of 12 patients undergoing evaluation for neurosurgical treatment of intractable epilepsy. The authors combined this rare clinical opportunity with a well-known but controversial task originally used by Benjamin Libet. In this task, participants make voluntary hand movements at a time of their own choosing and use a rotating clock hand to report the time of their conscious intention when they first 'feel the urge' to move. Fried et al. show that the experience of conscious intention can be reliably predicted from the activity of rather small numbers of medial frontal neurons.

The paper is interesting because the single unit data provide a much more detailed window into the mechanism of human volition than previous studies using population methods such as electroencephalography (EEG) and functional magnetic resonance imaging (fMRI). First, the authors found that activity in SMA proper was more strongly associated with the experience of volition than activity in the more rostral pre-SMA. This is consistent with a hierarchical model in which voluntary actions are initiated by activity in anterior medial frontal areas but only trigger conscious experience when they progress to more posterior frontal areas, closer to action execution. Second, and intriguingly, the majority of neurons involved in the task decreased their firing rates prior to the moment of conscious volition. These decreasing neurons actually allowed earlier predictions of conscious experience than increasing neurons. Voluntary action may depend on balance of inhibitory and excitatory activity in the medial frontal cortex, confirming the intuition that self control is a key component of human 'free will'. For article abstract, click here.

Competing interests: No potential interests relevant to this article were reported.

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