UC San Diego

Wired to Think

UC San Diego leads study to advance knowledge of brain signaling with breakthrough sensors

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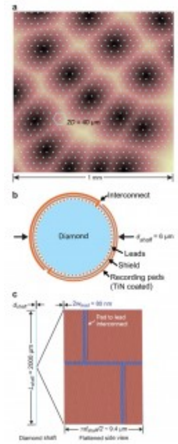

Credit: Figure courtesy of David Kleinfeld, UC San Diego

Figure 1. Schematic of the Proposed Stiff Probe. (A) A grid of the proposed electrodes superimposed on top of mouse cortex; the dark regions correspond input from individual whiskers from the mouse. (B) The electrode is constructed of a diamond shaft that is covered with five layers: electrode leads; m conducting shield; mineral insulation; electrodes. (C) The multi-electrode shaft with an expanded view of the face to show the arrangement of the

Newswise — To understand how humans think, it comes down to the wiring. For 60 years, scientists have used metal electrodes—recording sensors—to study cognition by capturing and measuring electrical spikes of a few neurons during brain activity. This gives them a partial picture of brain signals. To get a full picture of thought processes at work, however, UC San Diego Neurophysicist David Kleinfeld asserts that new electrode sensors that make use of exotic structures are needed.

To prove the point, Kleinfeld and a team of researchers analyzed the anatomical, electrical, mechanical, physiological, signaling and thermal constraints that need to be considered for the case of measuring electrical spikes from all neurons in the cortex of model mammalian brains, using microwire electrodes. They concluded that it is possible to fabricate rigid shanks with multiple electrodes—notably microscopically slender diamond needles—that record electrical signals from every neuron in the cortex at the same time. Their study, published recently online in Neuron, also supplies a blueprint for a future generation of electrode sensors that utilizes existing yet nontraditional materials and fabrication procedures.

“It simply blows your mind to realize that atoms and molecules have coalesced to form living matter that not only reproduces, but seeks to understand its own properties,” said Kleinfeld. “We need to understand the nature of this intelligence. Technological innovation is a key component of forward progress.”

With inspiration from two workshops—a 2014 National Science Foundation (NSF)-funded workshop, called “Limits of Measurements from Brains,” co-organized by Partha Mitra of Cold Spring Harbor Laboratory, and a subsequent workshop at the Howard Hughes Medical Institute (HHMI) Janelia Research Campus in 2017, co-organized by Kleinfeld, Mitra and Professor Timothy Harris of HHMI—Kleinfeld and a team of senior scientists and technologists asked the question: Can one concurrently record electrical spikes from every neuron in the brain?

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“Far from a philosophical issue, the answer to this question stands as an essential guide toward deciphering the nature of signal processing between brain cells and estimating the computational power of the mammalian brain,” said Kleinfeld.

According to Mitra, a Harvard-trained theoretical physicist, brains pack a very large number of electrical signal-carrying “wires” (i.e., axons) together into a small space; so the approach proposed does not violate any physics principles, and it is a worthwhile engineering challenge.

Kleinfeld, a professor with appointments in the Department of Physics and the Section of Neurobiology at UC San Diego, said that after physically unfeasible approaches like embedding a dense array of nanoradios were set aside, attention was largely focused on optical imaging techniques.

“However, the natural light scattering properties of live brains gives rise to fundamental physics limits that constrain such an

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