EDITORIAL

The promise of neurotechnology

The various brain initiatives for producing new tools, with the goal of advancing neurological therapies, have led to widespread attention on neurotechnology. Perhaps the most exciting aspect of this rapidly expanding field is the prospect of propelling experiments beyond scientific dogma to discover how the brain generates behavior. A sharper focus on this challenge will help direct the development of tools that can elucidate fundamental operations of the brain.

"... new computational approaches...will revolutionize neuroscience."

Generally, contemporary brain research views anatomical connectivity as critical for understanding how the brain works. But there is a growing appreciation that identifying and characterizing structural minutiae cannot, by itself, explain brain function. It is unlikely that the nervous system has modular design principles analogous to those of machines, in which each component performs a discrete operation. When a machine malfunctions, the failed component can be diagnosed because its missing function has clear causal consequences. The rules governing communication between neurons are based on statistics with unknown probabilities, thus invalidating simple causality. Every neuron has multiple functional roles, with each function carried out by many neurons in ways that vary over time. With a system of this complexity, comfortable assumptions about brain mechanisms based simply on brain structure are misplaced. Effective investigation of brain function necessitates moving beyond the structure-function concept in the brain-machine analogy.

This shift in perspective underlies recent progress in neural prosthetics, achieved largely when complexity is not only recognized but used to advantage. These devices are predicated on the idea that individual neurons encode multiple parameters with different strengths, and that movement intention can be decoded from populations of neurons. Population algorithms enable the robust extraction of movement parameters from brain activity, even though they may be poorly encoded by individual neurons. The elucidation of this population principle, combined with technology for large-scale recordings of single-neuron activity patterns, has led to demonstrations of paralyzed people operating prosthetic devices to replace their lost capabilities. This exciting success, which has now advanced to intentionally driven movement of the arm, wrist, and fingers, is based on a description of how movement parameters are encoded. Still, this description is not enough to truly understand how the brain controls behavior. For this, we must address the complexity of neuronal interaction that leads to encoding and the way signals converge to generate action.

There can be little doubt that new computational approaches (tools), backed by an increasing capability for recording ever-larger populations of neural signals, will revolutionize neuroscience. Examination of correlated firing within a recorded sample of neurons can help scientists define groups of functionally interacting neurons as well as the so-called latent drivers that induce the correlation. These drivers might arise, for instance, from stimulation acting simultaneously on neurons that work together to begin a behavior, or they could result from neurons firing in harmony within a specific brain location. Such glimmers of the functional network are exciting to contemplate, because they require no a priori assumption of putative function or assignment to anatomical structure. Rather, studies can begin to describe the joint and conditional probabilities that characterize the fundamental operations of the nervous system.

After the human genome sequence was revealed, researchers found that the nebulous causality between genes and molecular action needed to be addressed before revolutionary disease treatments could be developed. By now directing neuroscience research and technology efforts toward understanding the systematic interactions between neurons and the conditions necessary for these to take place, we can fulfill the promise of new neurological therapies in a timely manner.

– **Andrew Schwartz**

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