Streams of Consciousness

Alumit Ishai

When investigating the neural correlates of consciousness, neuroscientists distinguish between "conscious state" (being awake as opposed to asleep or in a coma), which is regulated by brainstem and thalamic nuclei, and "conscious representation" (awareness of specific phenomenal experience). The advent of functional brain imaging techniques, especially fMRI, enables the noninvasive inquiries of the mechanisms underlying conscious experience, particularly in the visual system. To date, most experimental paradigms designed to study consciousness contrast the response during conscious visual experience with the response during unconscious visual experience (the so-called blindsight phenomenon), or record patterns of brain activation during binocular rivalry, perception of bistable figures, and visual mental imagery. The current data suggest that activity in high-level areas of the ventral visual pathway, but not in V1, are necessary for conscious visual experience. Moreover, visual awareness requires parietal and prefrontal regions (for a recent review, see Rees, Kreiman, & Koch, 2002). The neural correlates of conscious vision, therefore, parallel the distributed cortical networks that modulate visual attention and visual imagery. As most researchers confuse "awareness" with "consciousness," the reported differential activity during consciousness is currently indistinguishable from that of other higher cognitive functions.

In his article, "Functional fMRI and the Study of Human Consciousness," Dan Lloyd uniquely combines a conceptual analysis of consciousness with neuroscientific methods, in order to characterize the neural manifestations of consciousness (Lloyd, 2002). Lloyd adopts Husserl's criteria, according to which the phenomenology of consciousness is based on three essential principles: intentionality (the external world as it is experienced and not as it is); superposition (sensory and nonsensory properties are present in perception); and temporality (all objects share perception of present, past, and anticipated future). If indeed these aspects of consciousness are implemented in the brain, the empirical evidence should include temporal flux (with passing time, the multivariate differences between images should increase) and superposition (images sharing task or stimulus conditions should be similar). Lloyd's methodological approach includes three constraints. First, time points in a scan series are considered individually, because temporality implies that consciousness at each point in time is distinct from the preceding and the proceeding points. Second, subjects are considered individually, because intersubject averaging could eliminate individual expression of consciousness. Finally, brain states are considered globally, seeking distributed patterns of activation that encompass large cortical areas, rather than assuming localized responses.

To test his predictions, Lloyd reanalyzes four data sets (Hazeltine, Poldrack, & Gabrieli, 2000; Ishai, Ungerleider, Martin, & Haxby, 2000; Mechelli, Friston, & Price, 2000; Postle, Berger, Taich, & D'Esposito, 2000) provided by The fMRI Data Center. The studies, published in the December 2000 issue of the *Journal of Cognitive Neuroscience*, included a variety of cognitive tasks (target tracking, passive viewing, delayed matching, reading, and spatial working memory), stimuli (faces, objects, words, pseudowords, 2-D arrays of squares, colored circles), and motor responses (button presses and saccades). Needless to say, none of the original studies was designed for or aimed at underpinning the neural mechanisms of "neurophenomenology." Nevertheless, Lloyd preprocesses and reanalyzes the raw data to test his predictions about the general structures of consciousness, which by their nature are task and stimulus independent. Using multivariate distance analysis and artificial neural networks, he shows a time–distance effect (i.e., as the time series progressed, the distance between images increased) and that the past and future brain states, retention and protention, respectively, are embedded in present brain states. As time passes, suggests Lloyd, the brain is changing "globally, incrementally, and monotonically."

Previous fMRI studies of consciousness compared one state of awareness with another, assumed localization, and ignored the temporal flux. Lloyd's original approach proposes methodological and conceptual advantages. Traditionally, fMRI data analysis focused on two parameters, namely the spatial extent of the activation and the amplitude of the response within an activated region. The data are usually displayed as statistical maps indicating the location and size of significant activation, and graphs or histograms showing the percent fMRI signal change. Given the spatial and temporal resolution of the technique, extracting temporal information about the "tripartite temporality" (i.e., the experienced present of

National Institutes of Health

an object is influenced by the past and the future) is problematic. The hemodynamic function presents a serious challenge, as each time point is contaminated by the immediately preceding response. Lloyd's correction—that is, excluding 10 seconds before and after each time point—is thus necessary. Moreover, he trains artificial neural networks to reconstruct the temporal information encoded in each time point. In all subjects, the neural networks succeeded in recovering information about the preceding volume (retention) and the following volume (protention). Lloyd assumes distributed patterns of activation (Ishai, Ungerleider, Martin, Schouten, & Haxby, 1999; Ishai et al., 2000); however, his current analysis does not include spatial localization. Further investigation is therefore required to determine which brain regions mediate the temporal manifestations of consciousness.

Lloyd's finding that performance is better when the network recovered information about the past than the future was perhaps not surprising, due to the asymmetry between the known immediate past and the unknown future. One could assume, however, that ''top–down'' effects such as expectation, anticipation, and attention should modulate ''future'' patterns of activation. For example, Kastner, Pinsk, De Weerd, Desimone, & Ungerleider (1999) have shown that in the absence of a sensory stimulus, anticipation modulated the response within both sensory and control areas. Furthermore, when subjects are engaged in a block design experiment with predicted context, for example, while viewing chair stimuli for several seconds, they expect to see a new chair as the next stimulus, be it a rocking chair or an office chair, but definitely do not expect an object of a different category such as a table or a face. It is highly likely that under certain experimental conditions, the neural correlates of protention could also be detected. Task-dependent analysis of the temporal structures of consciousness is therefore inevitable.

Lloyd is not looking for the loci of consciousness, nor does he identify regions of interest in the human brain. Rather, he analytically defines the characteristic features of consciousness, and tests whether distributed patterns of activation that mediate the phenomenal structures of consciousness could be detected. Because conscious awareness is implicated in all cognitive functions, he utilizes data sets from four different cognitive studies and ''stripped'' them of their specific experimental details. These independent and unrelated studies did have something in common: they used the fMRI technique and their data sets were (and still are) available at the fMRI Data Center. The fMRI Data Center was established to provide a publicly accessible repository of peer-reviewed fMRI studies and their accompanying data in order to facilitate understanding of cognitive processes and the underlying neural substrates. Since January 2001, the fMRI Data Center has received more than 50 complete data sets that include all the information necessary to interpret, analyze, and replicate those fMRI studies. Lloyd, a philosopher from Trinity College in Hartford, successfully demonstrates how one could empirically investigate the neural manifestations of structures of consciousness, concepts that were proposed more than 100 years ago, by reanalyzing existing data sets.

''We can not step in the same stream of consciousness twice,'' writes Lloyd. His award-winning article has shown that we could step in the same data set twice to shed new light on human cognition, as ''upon those that step into the same rivers different waters flow'' (Heraclitus, fragment 12).

Reprint requests should be sent to Alumit Ishai, PhD, Laboratory of Brain and Cognition, National Institute of Mental Health Building 10, Room 4C104, National Institutes of Health, Bethesda, MD 20892, USA, or via e-mail: alumit@ln.nimh.nih.gov.

REFERENCES

Hazeltine, E., Poldrack, R., & Gabrieli, J. D. (2000). Neural activation during response competition. *Journal of Cognitive Neuroscience, 12,* 118–129.

Ishai, A., Ungerleider, L. G., Martin, A., & Haxby, J. V. (2000). The representation of objects in the human occipital and temporal cortex. *Journal of Cognitive Neuroscience, 12,* 35–51.

Ishai, A., Ungerleider, L. G., Martin, A., Schouten, J., & Haxby, J. V. (1999). Distributed representation of objects in the human ventral visual pathway. *Proceedings of the National Academy of Sciences, U.S.A., 96,* 9379–9384.

Kastner, S., Pinsk, M. A., De Weerd, P., Desimone, R., & Ungerleider, L. G. (1999). Increased activity in human visual cortex in the absence of visual stimulation. *Neuron, 22,* 751–761.

Lloyd, D. (2002). Functional fMRI and the Study of Human Consciousness. *Journal of Cognitive Neuroscience, 14,* 818–831.

Mechelli, A., Friston, K. J., & Price, C. J. (2000). The effects of presentation rate during word and pseudoword reading: A comparison of PET and fMRI. *Journal of Cognitive Neuroscience, 12,* 145–156.

Postle, B. R., Berger, J. S., Taich, A. M., & D'Esposito, M. (2000). Activity in human frontal cortex associated with spatial working memory and saccadic behavior. *Journal of Cognitive Neuroscience, 12,* 2–14.

Rees, G., Kreiman, G., & Koch, C. (2002). Neural correlates of consciousness in humans. *Nature Reviews Neuroscience, 3,* 261–270.