Exploring the Causal Underpinnings of Determination, Resolve, and Will

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In this issue of *Neuron*, Parvizi et al. (2013) show that mild electrical stimulation using depth electrodes in the brains in human patients reliably elicits a highly specific configuration of cognitive-emotional-motivational responses to persevere in the face of danger. The underlying mechanisms involve distributed networks, both cortical and subcortical.

As the cruise ship *Costa Concordia* ran aground off the coast of Tuscany, passengers would have felt foreboding along with the feeling of marshaling inner resources to cope with impending catastrophe. No one would have mistaken these feelings for the peacefulness enjoyed while watching the soft munching of cows in the barn on a snowy morning, or even for the horror while a watching video of the tsunami washing ashore in Fukushima. Mustering the gumption to overcome a threat involves not just general recognition of the perceived situation as threatening; required also is recognition of the nature of the particular threat and the appreciation of the threat as something one can confront. This entails the presence of suitable motivation, planning, and modulation of fear, in a sort of cognitive-emotional-motivational-self-control bundle.

In their technically exacting study of two human patients undergoing exploratory stimulation in preparation for surgery for refractory epilepsy, Parvizi et al. (2013) found that mild electrical brain stimulation (EBS) of the midregion of the anterior cingulate cortex (mACC) resulted in a remarkably specific conscious experience (Parvizi et al., 2013), much like that experienced by passengers on the *Costa Concordia*.

Upon stimulation, each subject felt an autonomic response involving sensations in the chest, followed by the experience of impending ominous events and the experience of willful preparation to meet the challenge. The more voluble of the two patients describes at length the experience as that felt in the face of an approaching storm, where you need to drive over the hill through the storm (see the video in Supplemental Information of Parvizi et al., 2013). Unprompted, he goes on to distinguish his EBS experience from that of a football player readying to go out on the field to try for a touchdown. The two sorts of experience may share the sensation of arousal and determination, but they differ in the "ominous challenge" aspect. Also in the mix is some kind of pleasure, since he forthrightly describes the experience as positive. The self-same cluster of emotional responses was reliably elicited on each of the six stimulation trials and none of the sham trials. The precise location of the stimulating electrode mattered; EBS tests in adjacent regions of mACC failed to elicit the will to persevere or the cluster of foreboding feelings.

Specificity in response to external stimuli has been revealed elsewhere in the brain in clinical human subjects. For example, using intracranial electrophysiological recordings, Shum et al. (2013) found that visually presented numerals (e.g., "5," "9") activated neurons in a circumscribed region of the inferior temporal gyrus (ITG), whereas visual words for the same numerals ("five," "nine") did not, nor did phonetically similar words. Additionally, an adjacent region of the ITG showed more activation to false numeral-*looking* items than to actual numerals. Using fMRI, Mur and colleagues (2012) investigated category specificity and boundaries for faces in the fusiform face area, finding a high degree of regional specificity. This specificity in perception also coheres with the specificity of motor output seen in nonverbal animals, for example by EBS or by optogenetic techniques (Churchland et al., 2012). The current Parvizi et al. (2013) results are especially intriguing, in that they involve specificity of a cognitive-emotional-motivational response, a remarkably complex effect not elicited by EBS hitherto.

Does specificity imply tight localization of function? Does it imply the existence of a module for feeling-ominous-threats-and-mustering-courage? The hypothesis that specificity is owed to an autonomous module whose operations are sufficient for the function has lost ground over the last few decades as widespread interactions with putative modules have been documented. As Parvizi and colleagues (2013) observe, earlier studies on emotions had shown linkages between the ACC and fronto-opercular regions, a distributed set of areas sometimes referred to as an emotional salience network (Seeley et al., 2007). To explore this matter with their two patients, Parvizi et al. (2013) used resting-state fMRI to chart the connectivity profile. Concordant with earlier studies, they found linked areas in the frontoinsular and frontopolar regions, as well as linked subcortical areas. This strongly suggests that a distributed network sustains the functional specificity verbally reported.

The prevailing hypothesis in neuroscience is that experienced specificity, shifting from moment to moment, reflects shifting activation patterns across the participating networks. That is, shifting activity patterns correspond to differing specific inner feelings; for example, panic versus calm determination. Hence the same neuron may be involved in many cognitive-emotional experiences, but its activity profile will vary. This suggests that in EBS studies, the more confined the stimulus in the mACC, the more probable that the elicited response reflects a unique attractor in the activity space of the participating networks.

Although this general approach to explaining the wherefore of specificity is plausible, detail concerning mechanism is sparse. If specificity is achieved by orchestrating a unique pattern of neuronal activity in the participating networks, how exactly is the coordination problem solved? To understand the mechanisms whereby specificity of feeling and pattern recognition are used to generate specific behavioral outcomes, further detailed mapping will be required.

Another issue that is raised by the Parvizi et al. (2013) paper concerns the possibility of progress on philosophically ''off-limits'' topics such as the capacity for consciousness and free will. Even in this century, some philosophers have grandly announced that consciousness, for example, cannot possibly be a property of the human brain (Nagel, 2013). For all the philosophical finger wagging, however, it is more than modestly auspicious that a few milliamps of current applied to the human mACC can spawn a complex cascade of conscious feelings, feelings that vanish with cessation of the current. In a different study, again using EBS of presurgery human patients, Parvizi and colleagues found that milliamps of current applied to part of the fusiform face area caused an alert patient to see a distortion to faces, but only to faces—not to other perceptions (Parvizi et al., 2012).

So far as anyone knows, nonphysical souls do not respond to milliamps of current. Moreover, these patients are verbal, alert, awake humans. They can cogently report their experiences, an achievement not to be waved off as a mere reflexive response, as a sneeze might be. To be sure, no single experiment will explain all the features of conscious experience that puzzle us. Nevertheless, the results from Parvizi et al. (2013) are one beautiful illustration that progress is being made.

And can free will be real if the resolve to face up to a threat can be *caused* by EBS? Note first that the experiences of the EBS subjects have the same quality as that enjoyed by you or me as we muster our courage to cope with a threat. This is so even though they know full well that they are receiving EBS. This qualitative similarity undermines the claims of some philosophers that the very feeling of ''willing'' counts as evidence of a will that acts independently of any physical causes.

The philosophical insistence that free will requires freedom from all causality is misguided. The Parvizi et al. (2013) data suggest that both the typical experience and the EBS experience have causal antecedents. In the EBS case, the causal route is unusual, but causality there must surely always be, EBS or not. Smokers who want to quit but reach for another cigarette do not have a kind of ''puppet'' experience, as though their hand is being moved for them. They feel that they are exercising their free will to defer quitting. Their inner experience of choice is not relevantly different from that of a nonsmoker who picks up a toothpick. In contrast, involuntary behavior, such as a startle response, *does* feel different. Not surprisingly, it has a very different set of causal antecedents. Operating in a causal vacuum would be utterly mysterious, as David Hume in the 18th century wisely pointed out. What distinguishes the involuntary from the voluntary is not the *existence* of inner causes but the *kinds* of inner causes (see Churchland, 2013).

Implanted electrode data that contribute to mapping the human brain are, of necessity, relatively rare, as they require clinical justification. Although animal studies continue to be essential in neuroscience, direct stimulation and recording data from human brains are very special and particularly valuable, as this study clearly demonstrates.

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