LETTER

Reply to Greyson et al.: Experimental evidence lays a foundation for a rational understanding of near-death experiences

Greyson et al. (1) state that it is misleading to describe the rat brain as hyperaroused because the EEG power at near death was only a small fraction of that of the waking state in our study (2). However, they neglect to note that we showed that the power of EEG signals associated with consciousness increased in every rat we tested [see figure 2*A* of Borjigin et al. (2)]. Greyson et al. posit that "the pertinent question here is not whether there is any brain electrical activity at all after cardiac arrest, but whether there is activity of the type currently thought to be necessary for conscious experience." In complete accordance with their opinion, our entire study (2) is devoted to demonstrating the presence of electrical fingerprints of consciousness in the near-death brain. We report increased power and global synchrony in the gamma bandwidth, two neurophysiologic features associated with conscious processing. Moreover, this gamma band exhibits an eightfold increase in top-down information processing (thought to be a key element of consciousness) and fivefold increase in bottom-up information flow (thought to represent sensory information processing) at near death. In addition, we found tight coupling of gamma bands with both theta and alpha bands, yet another indicator of conscious information processing in the postarrest brain. Thus, our work (2) directly answers the concern of Greyson et al.

Greyson et al. claim that our findings are not consistent with EEGs of humans at near death. However, all EEG data from humans during cardiac arrest were collected using scalp electrodes. In contrast, our EEG data were collected using intracranial electrodes, which are much more sensitive (3). Moreover, the human near-death EEG data have not been analyzed using the advanced signal processing tools that are used in our study.

We are aware that various conditions could produce near-death experiences (NDE) in humans. The goal of our study (2), however, was to demonstrate the presence of signatures of consciousness under general anesthesia and under two extreme conditions (cardiac arrest and asphyxiation) that are known to produce NDEs in humans. Other conditions that produce NDEs should be explored in future studies.

Greyson et al. note that all rats in our studies demonstrated the surge of conscious brain activity at near death, whereas in humans only 20% cardiac arrest survivors report NDEs. This discrepancy can be explained in two ways. First, the population of patients in past epidemiologic studies of NDE is clinically, genetically, and physiologically heterogeneous. As such, it would be unlikely to observe a homogeneous neurophysiologic response. In contrast, we studied a genetically and physiologically similar population of healthy animals with identically induced experimental near-death situations. Second, it is possible that a larger proportion of cardiac arrest patients have NDEs but that most individuals cannot recall the experience.

In light of this information, we respectfully disagree with the opinion of Greyson and colleagues and strongly believe that our findings will contribute to a better understanding of near-death experiences.

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1 Greyson B, Kelly EF, Dunseath WJR (2013) Surge of neurophysiological activity in the dying brain. *Proc Natl Acad Sci USA* 110:E4405.

2 Borjigin J, et al. (2013) Surge of neurophysiological coherence and connectivity in the dying brain. *Proc Natl Acad Sci USA* 110(35):14432–14437.

3 Buzsáki G, Anastassiou CA, Koch C (2012) The origin of extracellular fields and currents—EEG, ECoG, LFP, and spikes. *Nat Rev Neurosci* 13:407–420.

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