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## Reader comments

DR. WALLING AND MR. HICKS:

Your article, "Dimensions of consciousness," is informative and well written and describes a valuable approach to unraveling the mysteries of consciousness. As you state, consciousness is hard to define, and I think of it as a kind of anomaly in current neuroscience, much as natural selection and the equivalence of gravitational and inertial mass would have been at an earlier time. Your approach from the vantage point of nonlinear computation, with correlates in phase space, provides an exciting mathematical perspective that may help make the breakthrough we need.

I have two questions. First, how did you arrive at objective numerical values for fractal dimensions of the EEGs of the different animals? And second, is it feasible to derive values for fractal dimensions of EEGs from dogs and humans at various stages of anesthesia and in different sleep stages? These comparisons might help clarify the contribution of the neocortex to consciousness.

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THE AUTHORS RESPOND:

DR. DIMIJIAN:

We thank you for your letter regarding "Dimensions of consciousness." The electroencephalogram (EEG) signals were digitized at 240 bits per second using a 194 data acquisition card (Dataq Instruments) and then stored on compact disks in DAT format for later analysis. There are multiple ways to measure fractal dimensions in phase space. We considered the correlation dimension to be the most suitable for our data and used the modification suggested by Grassberger and Procaccia (1).

We have recorded our own EEGs under different conditions. From sitting quietly blindfolded to sitting with eyes open to per-

forming mental arithmetic and on to mental multitasking, fractal dimensions increased from about 2.5 to 4.5. The brain seems to slide effortlessly from dimension to dimension depending upon the number of sensory and memory streams necessary for the synthesis of each moment of consciousness. A simple example is afforded by closing and then opening one eye. The change from 3-dimensional to 2-dimensional visual consciousness and back is rapid and subtle but real.

We suspect that with the onset of dreamless sleep or general anesthesia, the phase space architecture may disappear along with measurable fractal dimensions. The "motor" is still running, but the "transmission" is not engaged. We hope to explore this possibility because if it is true, our hypothesis that consciousness is intimately related to a construct in phase space will be supported.

Regarding the neocortex of man versus his dog: If dimensions of fractals in phase space may be used as a *measure* of consciousness, then our dogs would appear to be about as conscious as we are. Dog consciousness is presumably predicated upon dog sensory input and dog memories and is probably qualitatively different from ours. We think and worry about consciousness a lot more than our dogs do. This mixed blessing is afforded by our larger neocortex.

—PETER WALLING AND KENNETH HICKS  
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1. Grassberger P, Procaccia I. Characterisation of strange attractors. *Physical Review Letters* 1983;50:346–349.

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