

It would be an overgeneralization at this point to conclude that plume theory must be discarded, but the study by Hirano *et al.* proves, beyond a reasonable doubt, that at least one chain of hot-spot volcanoes is not produced by a plume. Therefore, it is time to critically reexamine the widespread interpretation of midplate volcanism in terms of mantle plumes and all the geodynamic, geophysi-

cal, and geochemical inferences that have been built on the plume paradigm.

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## PSYCHOLOGY

# Is She Conscious?

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“Is she understanding my words and feeling my caresses?” is a question constantly asked by relatives and caregivers of comatose and vegetative state patients in intensive care units throughout the world. Probing residual mental function in such critical situations poses major medical and ethical issues. Our current answers to this question are mainly based on detailed behavioral and neurological observations, but this approach may be blind to inner active mental processes. Since the late 1980s, several neurophysiological correlates of cognitive processes have been proposed to better assess the existence of this covert mental life (1). This approach has aimed to discriminate among comatose or vegetative state patients those who are still cognitively active. On page 1402 of this issue, Owen *et al.* (2) use functional magnetic resonance imaging (fMRI) to infer the psychological processes at work in such patients during mental imagery tasks that do not elicit otherwise observable behavior.

The authors studied a 23-year-old woman who sustained a severe traumatic brain injury in a road traffic accident. After an initial comatose state (defined as an unarousable unresponsiveness state), she opened her eyes and demonstrated sleep-wake cycles. However, even during the waking periods, she was unresponsive (for example, to visual or auditory stimuli) and did not manifest spontaneous intentional behaviors. These signs are diagnostic of a vegetative state.

In a first experiment conducted 5 months after the accident, Owen and colleagues presented spoken sentences to the patient while

recording neural responses with fMRI. Speech-specific brain regions were clearly activated while the patient listened to these sentences, as compared to acoustically matched noise sequences. Moreover, sentences containing ambiguous homophone words (for example, creak/creek) activated an additional left inferior frontal lobe region known to subservise the selection of semantic knowledge among competing alternatives (3). In sharp contrast to her behaviour, which was suggestive of poor cognitive abilities, this patient could process external auditory information involving language.

In a second experiment, the authors engaged the patient in two mental imagery tasks by asking her either to “imagine visiting the rooms in your home” or to “imagine playing tennis.” The result of this second fMRI investigation is quite spectacular. Patterns of brain activation observed during the 30-s period of each task were highly suggestive of an active mental performance relevant to the task. In the spatial mental imagery task, Owen *et al.*

Brain imaging reveals unexpected activity in a patient clinically diagnosed as being in a vegetative state, raising questions about the properties of consciousness.

observed neural activations within a network including the parahippocampal gyrus, posterior parietal cortex, and lateral premotor cortex. When the patient was asked to imagine playing tennis, strong activations were recorded in the supplementary motor areas that control motor responses.

The observed brain activation patterns are the classic neural correlates of these two mental imagery tasks. Indeed, statistical parametric maps of brain activation observed in the patient were indistinguishable from those recorded from a group of conscious control subjects.

Despite the patient's very poor behavioral status, the fMRI findings indicate the existence of a rich mental life, including auditory language processing and the ability to perform mental imagery tasks. On one hand, this single case makes a strong argument for the development of fMRI and other neurophysiological tools (such as monitoring electroencephalogram brain responses to external stimuli) to evaluate cognition in such patients. On the other hand, we should not generalize from this single patient, who suffered relatively few cerebral lesions, to most other vegetative state patients, who typically have massive structural brain lesions.

Is this woman conscious? Most current behavioral and neuroimaging evidence suggests that conscious processing is abolished during a vegetative state. Such patients do not report mental states, nor do they spontaneously engage in intentional actions or interactions with their environment, two key properties of con-



Imaging imagination. Shown is part of the engraving, “The Physician Curing Fantasy,” by Mathaus Greuter (1564–1638).

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scious processing in humans. Moreover, several studies have reported residual local and specific brain activation patterns in vegetative state patients, whereas long-range neural integration observed during conscious processing was lacking (4, 5). Nevertheless, on the basis of their findings, Owen *et al.* argue that the patient in their study was probably conscious of herself and her surroundings during fMRI testing. This hypothesis opens another issue: If this patient is actually conscious, why wouldn't she be able to engage in intentional motor acts, given that she had not suffered functional or structural lesion of the motor pathways?

The debate over whether vegetative state patients can engage in conscious processing is reminiscent of the Turing test in artificial intelligence: Can we distinguish a conscious human from a computer solely on the basis of a question-answer method (6)? Adapting the Turing test to the present debate, we might ask: Can we determine whether a person is conscious solely on the basis of a question-brain activation method? Whereas these questions have stimulated intense philosophical debate about artificial intelligence, most cognitive

neuroscientists have adopted a more naturalistic approach. Consciousness is univocally probed in humans through the subject's report of his or her own mental states. A subject who reports, "I read the word consciousness on this page," can be considered as conscious (7). The ability to report one's own mental state is the fundamental property of consciousness.

Owen *et al.* did not directly collect such a subjective report. When conscious reporting is not possible, an alternative solution is to examine the three other psychological attributes of conscious processing: (i) active maintenance of mental representations; (ii) strategical processing; and (iii) spontaneous intentional behavior (8). Clearly, one of the most impressive aspects of the work by Owen *et al.* is the demonstration that activation of task-related neural networks is actively maintained. During each experimental task, instructions were delivered only once, and the corresponding neural network remained activated throughout the entire 30-s period. In contrast, unconscious mental representations observed in many clinical and experimental contexts are fleeting, lasting a few seconds or less (9–11).

Though not totally convincing on the issue of consciousness, the Owen *et al.* work paves the way for future functional brain-imaging studies on comatose and vegetative state patients. One can imagine probing each of the psychological properties of conscious processing listed above, and even trying to collect subjective reports by modifying the experimental paradigm.

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## ECOLOGY

# How Does Climate Change Affect Biodiversity?

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Over the past 100 years, Earth's climate has become warmer and precipitation regimes have changed. Can biologists predict the effects of these changes on the distributions of species?

Conservation strategies for managing biodiversity have traditionally assumed that species distributions change relatively slowly, unless they are directly affected by human activities. However, there is a growing consensus that these strategies must anticipate the impacts of climate change (1, 2). Conservationists must therefore assess both current and future distributions of species. Numerous new bioclimatic models estimate relationships between the distributions of species and climate. However,

the decision of which model to use has generally been ad hoc, and there is little consensus regarding the relative performance of these models.

Bioclimatic modeling has been driven by a pragmatic desire to obtain results that are useful for biodiversity management (3, 4). The models are based on some problematic ecological assumptions—for example, that species distribution and assemblages are in a constant steady-state relationship with contemporary climate—that, despite being clearly acknowledged (5), remain unresolved. However, there has been even less emphasis on understanding which models best predict species distributions and why.

The proponents and architects of some of the most prominent bioclimatic models recently joined forces to test the predictive uncertainties of their models and to identify the techniques best suited for modeling current species distributions. Elith *et al.* have now published the first results in *Ecography* (6). Sixteen models were tested on climate

The most recent and complex bioclimate models excel at describing species' current distributions. Yet, it is unclear which models will best predict how climate change will affect their future distributions.

and species distribution data from five continental regions. In contrast to many previous studies, data for testing the models were collected independently.

The models with the best performance were the most recent and complex ones and fell into two groups: machine-learning programs that seek to obtain a stable selection of predictors from a larger range of alternatives, and community models that simultaneously analyze all species in relation to environmental parameters and then calibrate model coefficients for individual species. In contrast, some of the most widely used models for modeling species distributions, such as GARP (which uses a genetic algorithm) and BIOCLIM (which uses an envelope approach), performed poorly under the criteria used to evaluate them.

One critical question is whether models that can successfully predict current species distributions also provide robust predictions of future distributions under climate change. (This question is not addressed by Elith *et al.*,

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