Nature Reviews Neuroscience | AOP, published online 25 January 2012; doi:10.1038/nrn3188

CONSCIOUSNESS

Effective detection

> Three patients moved from a vegetative state to a minimally conscious state and then regained full consciousness, and this was associated with a TMS-induced complex neural activation pattern that indicates intact effective connectivity

In patients emerging from coma, the presence or absence of awareness is currently measured using behavioural criteria. However, this assessment is notoriously difficult, and patients may be misdiagnosed, which has serious implications for treatment decisions. A new study published in *Brain* reports a method involving transcranial magnetic stimulation (TMS) and electroencephalography (EEG) that can detect the presence of 'effective connectivity' within thalamocortical circuits — which has been proposed to be required for consciousness — and thereby provides a non-behaviour-based diagnosis at the patient's bedside.

Patients who are diagnosed as being in a vegetative state show no non-reflexive behaviour; but in some of them, neural activity can be detected by EEG or functional MRI (fMRI) in response to sensory stimulation, commands or questions, suggesting that these patients are actually in a minimally conscious state. However, these methods require intact sensory pathways or an ability to understand questions, which some patients with brain injuries may not have. In addition, fMRI is too costly and impractical to be used as a standard diagnostic tool. On the basis of the assumption that consciousness requires functional interactions — or effective connectivity — between cortical areas, Rosanova *et al.* tested whether assessing such connectivity using TMS and EEG could distinguish different states of consciousness.

In a first experiment, Rosanova *et al.* measured effective connectivity in patients who had been diagnosed as being in a vegetative state, a minimally conscious state (showing some non-reflexive behaviours) or as having locked-in syndrome (in which patients are fully conscious but cannot move) after severe brain injury. In patients in a vegetative state, TMS over a particular gyrus induced a simple, localized EEG response, which is indicative of impaired cortico–cortical interactions — that is, a breakdown of effective connectivity. (One patient showed no response at all.) This localized EEG response was similar to the TMS-induced responses that were observed during deep sleep and anaesthesia in healthy subjects in an earlier study. By contrast, in patients in a minimally conscious state and in patients with locked-in syndrome, TMS evoked a complex EEG response in which neural activity shifted from the stimulation site to other cortical areas.

In a second experiment, the authors performed TMS and EEG in five patients 48 hours after they emerged from coma into a vegetative state. In all patients, TMS triggered an EEG pattern similar to that in the first experiment. In the two patients who remained in a vegetative state, subsequent sessions showed no change in the TMS-evoked EEG pattern. The other three patients moved from a vegetative state to a minimally conscious state and then regained full consciousness, and this was associated with a TMS-induced complex neural activation pattern that indicates intact effective connectivity.

In addition to providing evidence for the proposed link between effective connectivity and consciousness, this study presents a new 'bedside' method to discriminate between different states of consciousness in patients with brain injury. The use of this method may prevent patients who have regained some consciousness but cannot communicate from being misdiagnosed as being in a vegetative state.

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ORIGINAL RESEARCH PAPER Rosanova, M. *et al.* Recovery of cortical effective connectivity and recovery of consciousness in vegetative patients. *Brain* 5 Jan 2012 (doi:10.1093/brain/awr340)
FURTHER READING Owen, A. M. & Coleman, M. R. Functional neuroimaging of the vegetative state. *Nature Rev. Neurosci.* **9**, 235–243 (2008)