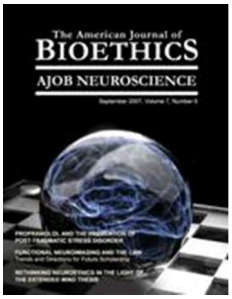

Open peer commentary on Kathrine Bendtsen's "Communicating with the minimally conscious patient": A principled argument, but not a practical one.

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Bendsten's article, "Communicating with the minimally conscious patient", (Bendsten, 2012) explores a promising avenue for applying our mental imagery method (Owen *et al.*, 2006) in the clinical setting. As this research is now evolving into the foundations of novel clinical services, both her initiation of this conversation and the optimistic appraisal of incorporating brain-computer interfaces (BCIs) in medical practice are timely contributions to the medical ethics literature. We agree with Bendsten's assertion that there are, in principle, no conditions that preclude the use of fMRI in communicating medical decisions. Indeed, applying fMRI in this manner would likely permit patients, who are behaviorally non-responsive yet retain some residual level of cognitive function, to reclaim elements of well-being lost to their initial injury. Nevertheless, a number of obstacles inherent to the assessment of disorders of consciousness (DOC) serve to complicate the practical implementation of this technique in the healthcare setting. By outlining these limitations, we seek to set realistic expectations for family members, proxy decision makers, and health care practitioners, who will be involved in the process of clinical decision-making on behalf of the patient.

The first limitation associated with this application of fMRI derives from the fact that a significant minority of patients are simply unable to remain motionless inside the MRI scanner, despite repeated efforts to settle them prior to imaging sessions. The resulting movement artifacts render the imaging data un-interpretable, thus precluding the use of fMRI to acquire useful information about residual awareness. Alternative imaging methods that are less susceptible to patient movement, such as

electroencephalography (EEG) (e.g., Cruse *et al.,* 2011), may prove more useful in these unique situations.

A second limitation stems from the fact that some patients will provide inconsistent results, which may be due to fluctuation of attention span when engaging in the mental imagery task. For example, a patient may be identified as a candidate for BCI communication based on evidence of fMRI command following in initial tests, yet provide inconsistent results during follow-up imaging sessions. While Bendsten acknowledges this problem, she does not fully consider its epistemological and ethical ramifications. From an epistemological standpoint, inconsistent results diminish our confidence in the presence of residual cognitive ability, and may negatively affect future decisions regarding a patient's suitability for BCI communication in the medical setting. From an ethical standpoint, as negative results derived from our paradigm are merely inconclusive, rather than indications of absence of awareness, disclosing inconsistent (e.g. positive *and* inconclusive) findings to family members can be a source of great confusion. Indeed, it is not at all clear what the best advice ought to be for families in the face of inconsistent results. A probabilistic model, which effectively tracks our degree of confidence that a given DOC patient possesses some degree of decision-making capacity, may help mitigate these problems.

A third limitation is the possibility of patient mental exhaustion that results from protracted imaging session required for unequivocal fMRI results. This limitation

will restrict the number of questions that can be asked during any single imaging session and may be financially prohibitive for some medical institutions given the high cost of MRI scanning time. To date, the most successful reported case of BCI communication using our mental imagery method involved a patient who answered five consecutive autobiographical questions correctly (Monti *et al.* 2010). Including the five minutes of imaging data required to interpret the answer to each question, along with the time intervals between questions and diagnostically relevant anatomical scans, this imaging session required more than one hour of imaging time. Since some medically relevant questions involve complex health-related concepts, which are often unfamiliar to patients, they may require extensive decomposition into several simpler questions that would allow the patient to fully understand the issue at hand. The result of this requirement could yield an unfeasibly long scanning session that would tax even the attention span of a *healthy* participant.

While these technical limitations may be resolved with future improvements in non-invasive imaging technologies, integrating the mental imagery method into medical practice by way of assessing decision-making capacity remains conceptually problematic. As any healthy individual's ability to provide informed consent is contingent upon the presumption of capacity, a central epistemological question is how we can ever know that a given DOC patient does, in fact, have some residual dimension of decision-making capacity intact. Though Bendsten suggests medical decision-making on behalf of children may serve as a possible solution to this question, it is not clear that this would adequately address the issue of capacity

assessment in DOC patients. For one, DOC patients exhibit no behavioral markers of residual cognitive function. Unlike the case of children, where modest levels of cognitive function can be inferred, DOC patients reveal no such information. Thus, starting from the initial point of successful responses to the mental imagery tasks, investigators must build a model of the patient's residual cognitive profile from the ground up. Moreover, as Bendsten notes, identifying capacity in DOC patients with our imaging method is complicated by several other obstacles: patients are unable to initiate their own questions and psychiatric problems secondary to neurological conditions are difficult to rule out.

One solution to this broadly epistemological problem may be to more precisely define what *decision-making capacity* amounts to in these cases, and determine how it might be operationalized in ways that are detectable through fMRI and EEG. The first step may be to take the complex set of faculties we refer to as "capacity", and describe them in terms of decomposed cognitive functions. These might include, for example, whether the patient can localize him- or herself in space and time, has any memory or knowledge of basic facts about the world, has any reasoning skills, or has retained the ability to form new memories based on experiences that occurred after the initial injury. We would then need to consider how this information could be synthesized to provide a reliable and ethically responsible overall assessment of the more complex dimensions of decision-making capacity in this patient group. If these components can be operationalized for binary assessment successfully, the mental imagery method may, indeed, be a satisfactory tool for this specific application.

While concrete resolutions to these practical and philosophical problems have yet to be worked out, we remain optimistic that solutions to these issues will emerge in the near future. Notwithstanding these obstacles, Bendsten's article successfully raises a number of important questions related to our work, including how we assess capacity in DOC patients and whether they can be included in the clinical decision-making process aided by neuroimaging BCIs. We are hopeful that, with further technical developments, these methods will yield effective and economically sustainable results, thereby mitigating many of the technical limitations discussed above. More importantly, we anticipate that in the near future a conceptual framework will be developed to accommodate the epistemological and ethical challenges that our work has generated in this area.

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