Decoding fMRI Signals of Hierarchical Experiments for Assessing Disorders of Consciousness.

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Introduction:
It has recently been suggested that functional imaging studies in patients with disorders of consciousness (DOC) should be conducted hierarchically (Owen et al. 2005) beginning with the simplest form of processing within a particular domain (e.g., auditory) and then progressing sequentially through more complex cognitive functions. Furthermore, it has been proposed that pattern classification of brain activations from such tasks could also allow DOC patients to functionally communicate yes-or-no responses (Boly et al., 2007). In light of the above, the present study aimed to investigate the feasibility of using patterns of fMRI signals (Sitaram et al., 2010, Lee et al., 2010a,b) to distinguish brain states of DOC patients in a battery of experiments testing intentional control, language competence, working memory, emotions and pain sensation.

Methods:
A total of 35 DOC patients (vegetative state, VS, n=5; persistent vegetative state, PVS, n=12; minimally conscious state, MCS, n=18) patients, matching controls (n=8) and non-matching controls (n=25) have participated until now in this on-going study. We wish to report results of multivariate decoding of the 3 experiments: (1) Mental imagery experiment, consisting of randomized auditory instructions to perform specific motor-imaginations (e.g. "play tennis", "move around the house", "relax") every 30 s and repeated 6 times; (2) Emotion empathy experiment, which consisted of 20 emotional sound samples from International Affective Digitized Sounds (Bradley & Lang, 1999) depicting pain of others (10 painful; 10 neutral) presented in a block design (duration=75 s); and (3) Pain perception experiment, which consisted of electric painful stimuli given to the volunteers in a block design of alternating blocks of pain (60 stimuli; ISI=1 s) and rest. Functional images were obtained in 3T scanners (Siemens TIM Trio) and fMRI signals were classified using a linear support vector machine (SVM).

Results:
Multivariate SVM was found to perform with better-than-chance accuracy in healthy controls: (1) Mental imagery experiment: Motor Imagery vs Rest: 84.7% ("playing tennis"=84.72%, "moving around the room"=84.88%); (2) Emotion empathy experiment: Painful Sounds vs Neutral Sounds= 60.22%, neutral sounds=63.98%; and (2) Pain perception experiment: Electric Pain vs No Pain=83.1%. Effect mapping showed spatial patterns in the following major brain regions that maximally discriminated between conditions (see figure 1): (1) Mental imagery experiment: primary motor area (M1), supplementary motor area (SMA), parahippocampal place area (PPA) and
precuneus; (2) Emotion empathy experiment: superior temporal gyrus, insula, inferior frontal gyrus and putamen; and (3) Pain perception experiment: anterior cingulate cortex and post central gyrus. FMRI signals from all the DOC patients analyzed so far have resulted in classification performance at or below the chance-level, except in 3 MCS patients who showed marginally above chance accuracy (50-60%). When brain activation maps were assessed using our multivariate method of analysis (Effect mapping; Lee et al., 2010a) based on SVM, a slight but inconsistent overlap in activation was observed in the 3 MCS patients with the robust activations of the healthy controls (see figure 1).

Conclusions:
Our results indicate that a combination of classification performance (quantitative analysis) and effect maps (qualitative analysis) in hierarchical functional tasks in patients, could act as the ‘neural marker’ of the severity of the DOC, thus helping in diagnosis. A major technical challenge is the co-registration and normalization of patient functional data to the their anatomical images and to the standard MNI template, respectively. We are presently attempting to solve this problem through subject-specific search-light classification. Future work would also adapt the above paradigms to online pattern classification from real-time fMRI signals (Sitaram et al., 2010).

Disorders of the Nervous System
Traumatic Brain Injury

Abstract Information

References


Lee, S., (2010a), 'Cerebral reorganization induced by real-time fMRI feedback training of the insular cortex: a multivariate investigation'. Neurorehabilitation and Neural Repair.
