Egg Evidence of Covert Command Following and the Impact of State Fluctuations in Patients with Severe Brain Injury

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Motivation

Patients with disorders of consciousness (DOCs) following severe brain injury often have substantial motor deficits, limiting their capacity for behavioral output and, in some cases, resulting in cognitive motor dissociation (CMD). CMD is the dissociation of measured bedside behavior and laboratory investigations (Schiff, 2015).

Electroencephalographic (EEG) detection of mental imagery is a strategy to assess the level of conscious awareness independent of motor output and identify patients with CMD (Goldfine et al., 2011). The EEG changes elicited by motor commands are interpreted as the neural signatures of awareness and motor planning in the absence of overt, purposeful movements (Forgacs et al., 2014).

Methods

Patient Subjects and Healthy Controls

45 patient subjects (PSs) were enrolled in the study (17 males, 28 females, age range at time of injury 13-56 years, mean age of all subject groups 34 ± 10 years). All patient subjects suffered forms of severe brain injury, resulting in the manifestation of a disorder of consciousness (both TBI, 80% other forms of injury). Patients were designated to be within the range from coma to brain death (stage II) through evaluation of a standard behavioral assessment exam, the coma Recovery Scale (Karnow D, 1997), and modified Glasgow Coma Scale Score ≤ 8 (Hinshaw K 1986). Five healthy controls (HC) were enrolled in the study (3 males, 2 females, age range 23-59 years). All HC participated in two study visits (6-months apart) and had a history of neurological disease.

Experimental Paradigms

CCTV - EEG Recordings

24–46 Hz filtered sampling rate

Impedance ≤ 5 kOhm

Average epoch length 10-15 s

19 electrodes (F7-8, C1-2, FC5-6, CP5-6, P7-8, O1-2, FP1-2, AF8, FCz, CPz, Pz, Oz, T5-6, PO3, PO4, O1, T3-4, FC1-2, CP1-2, P3-4)

Analysis

1. Review of the EEG record with video: export of all runs/paradigm (widmark markers)

2. Picking segments through visual inspection

3. Power Spectra generated for each run

Determined: bandwidth 1–50 Hz

55% confidence bands

via multiple layer (5 taps)

Laguerre windowing using a 97 channels

implemented in MATLAB with Chenbro toolkit

Patient Subject (PS) Results (n=28)

CRITERIA FOR POSITIVE OUTCOME

We rated the PS as a primary measure to identify positive responses in a locked channel task for each subject. Two outcome measures were evaluated in order to determine whether or not a positive task-related EEG response was indicated.

Outcome measure 1 (OM1):

A) one run with significant T6-Cz result (at least 3 consecutive trials over 40–60 Hz)

B) a second run demonstrated at least a significant T6-Cz result in the same frequency and channel tested

Outcome measure 2 (OM2):

A) when all runs were combined, at least one of the individual spectral differences identified by the T6-Cz measure (significant at the 0.05 level) was observed for at least 3 consecutive trials

Positive: OM1 + OM2

Negative: No outcome measures met

Patient Demographics

Pisa EEG-CF positive during at least one study visit (n=28)

Patient Summary

A: Pisa EEG-CF Positive

B: Pisa EEG-CF Negative

State Fluctuations

A: Pisa EEG-CF negative in state observed to the last clinical examination (n=28)

B: Pisa EEG-CF positive in state observed to the last clinical examination (n=20)

CONCLUSIONS

EEG command following (EEG-CF) can help identify individuals with CMD that may be candidates for brain-computer interface (BCI) implantation.

45% of patient EEG-CF responders lacked a communication channel on CRS-R exam (CRS-R/Com subscale < 6).

Repeated testing is necessary in any evaluation of DOC patients. EEG fluctuations in state can obscure accurate assessments of cognitive reserves including EEG-CF.