Answering questions in Prolonged disorders of consciousness with a brain-computer interface

1-C-20 Answering questions in Prolonged disorders of consciousness with a Brain-Computer Interface

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Introduction: A gold standard assessment tool for Prolonged Disorders of Consciousness (PDOC) is yet established and fallacious diagnoses are allegedly as high as 40%. Standard neurobehavioral rating scales: the JFK Coma Recovery Scale-Revised (CRS-R) and Wessex Head Injury Matrix (WHIM) depend on consistent overt behaviours and may have subjective bias. Sensorimotor rhythm (SMR)-brain-computer interface (BCI) augment behavioural assessments. SMR-BCIs enable intentional EEG modulation learning via motor imagery, and potentially communication or therapeutic technology interaction [1]. We present results of SMR-BCI awareness assessment; multisession stereo-auditory feedback BCI training; and a pilot question-answer system tested on PDOC patients. Material, Methods, Results: The study involved two male participants with Minimally Conscious (E) and Vegetative (JC) state diagnoses. Ethical approval granted by National Rehabilitation Hospital of Ireland. Informed assent given by participant's families. JC had no previous BCI experience. E had 20 BCI feedback training sessions(2011-2014)[2]. EEG was recorded via Fp1, Fp2, F3, Fz, F4, C3, Cz, C4, P3, Pz, P4 (gnautilaus 16 channel amplifier with active electrodes (g.tec)). Session 1 included block design assessment. Participants were asked to imagine one movement per block, cued with an auditory tone circa every 8s (6 blocks, 15 trials/block, E: right hand vs lift both feet; JC: left hand vs lift both feet). Blocks were combined and leave p-out cross validation (LpOCV; p=2 i.e, one trial from each class) was performed to determine average time-varying accuracy (see [2] for details). Pre-cue and peak accuracies were compared to determine activation significance, indicating patients may be aware of tasks and followed commands. Ensuing assessment, real-time feedback was given. E's visual acuity was unclear and JC was registered blind so stereo auditory feedback was given as broadband (pink) noise or music samples (see [1] for details), with 3-4 sessions of 1-5 runs (60 trials/run, randomized equal number per class) cued with voice command e.g. "left", "feet" or "right" to matching ear via earphones: cue at 3s, feedback at 4-7s. Feedback was modulated by continually varying the sound's azimuthal position between ±90° via imagined movement. Peak offline cross validation accuracies compared to baseline accuracy and online single-trial accuracies are reported in Figure 1. In session 4 a question-answer system based on a recent study in Amyotrophic Lateral Sclerosis was evaluated [2]. Biographical questions with known answer were posed. Most "yes" questions had semantically similar "no" questions e.g., "You are 33 years old" vs "You are 47 years old". Recordings of family members reading questions were played back to participants in timed paradigm. Participants responded for yes/no with respective hand/feet imagery. Figure 1 shows cross-validation analysis of EEG responses to 40 questions/run. E and JC scored median values of 6 and 4 (CRS-R) and 6/15 and 3/13 (WHIM) respectively, indicating behavioural unresponsiveness/communication inability. Yet both participants produced peak accuracies significantly higher than baseline during assessments, feedback and questions (4/5 runs), ($p<0.05$: Wilcoxon test), signifying wilful modulation of SMR. Discussion: The CRS-R and WHIM indicated indistinct visual acuity but preserved auditory startle, supporting stereo auditory feedback utility for PDOC patients, [1] but challenges with bias/nonstationarity due to artefacts attributed to reflexive movements/teeth-grinding/wheezing/capmovement remain. While offline/online accuracy trends upwards, more sessions are vital to improve performance afore participants undergo open question sessions. Significance: Despite lack of behavioural responses, participants showed capacity to apply SMR strategies to answer questions: the first evaluation of multi-question system in PDOC. Trials are ongoing with larger cohort involving online feedback to questions. References: [1] D. Coyle, J. Stow, K. McCreadie, J. McElligott, and Á. Carroll, "Sensorimotor Modulation Assessment and Brain-Computer Interface Training in Disorders of Consciousness," Arch. Phys. Med. Rehabil., vol. 96, no. 3, pp. S62-S70, Mar. 2015. [2] U. Chaudhary, B. Xia, S. Silvoni, L. G. Cohen, and N. Birbaumer, "Brain-

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