MindBEAGLE: An EEG-based BCI developed for patients with disorders of consciousness

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Introduction: Patients with disorders of consciousness (DOC) maintain a circadian sleep-wake cycle, but suffer from severe awareness deficits, ranging from complete unawareness (vegetative state/ unresponsive wakefulness syndrome patients) to minimal awareness (minimally conscious state patients). By definition, these patients are unable to communicate. A third group of patients (emerged from the minimally conscious state) could functionally communicate or use objects, but suffer from severe mental and physical disabilities. At present, diagnosis is mainly based on behavioral assessment. Impaired cognition, sensory deficiencies, aphasia, sleep, and awareness fluctuations, are some of the possible causes of misdiagnosis [1]. Misdiagnosis could mean that a patient is mistakenly considered unconscious and incapable of communication. Patients may thus be ignored by friends, family and medical staff who might otherwise interact with them about issues including environmental preferences (as temperature, music, and bed position), or important life decisions. Here, we aim to detect objective signs of consciousness in DOC patients, measured by auditory (AUD) and vibrotactile (with two stimulators, VT2) P300 responses, and to establish binary communication by employing the VT P300 with 3 stimulators (VT3). These paradigms have been proven successful in a group of locked-in patients who are completely conscious, but behaviourally unable to demonstrate consciousness [2].

Material, Methods and Results: 11 patients (4 unresponsive patients, 5 minimally conscious patients, and 2 patients emerged from the minimally conscious state, all diagnosed through profound clinical evaluation) were evaluated with the mindBEAGLE (Guger Technologies OG, Graz, Austria). Patients were assessed with the AUD P300 and the VT2 P300. Whenever a significant difference between the target and non-target responses was found, the VT3 P300 was tested, intending to establish communication (as described in [3]).
A P300 (AUD or VT2) to target stimuli was observed in 3 patients (one unresponsive and two minimally conscious). More importantly, a patient in the minimally conscious state attained a median accuracy of 70% in the VT3 paradigm (Fig. 1). We are currently advancing the efforts to establish communication.

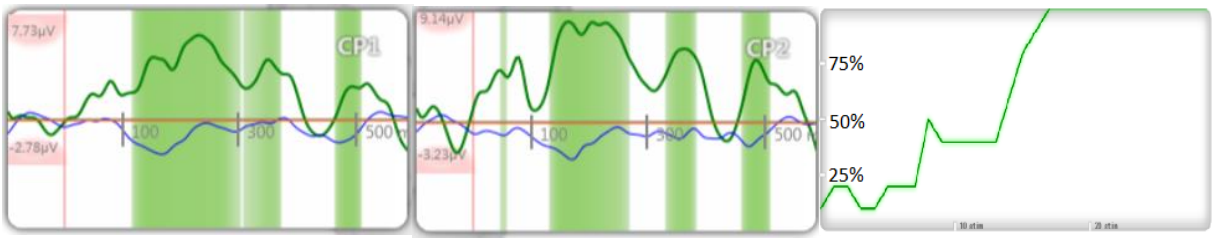

Figure 1: *The P300 in the left and right hemisphere (left and middle images) to VT stimulation with 3 stimulators. The green and blue lines reflect activity elicited by target and nontarget stimuli, while green shaded areas show significant differences. Classification accuracy (right image) reaches 100% after about 18 stimulation sequences with 8 single trials each.*

Discussion: The presented work potentially reduces misdiagnosis of DOC patients, improving their treatment and prognosis. Ultimately, it could empower patients to communicate. A limitation of our approach is that the absence of a response does not directly imply the absence of awareness, as the assessment depends on the patient's level of participation, and thus multiple sessions for assessment and communication are often required.

Significance: This is the only plug-and-play BCI developed for DOC patients, a patient group that might benefit considerably from the capabilities it offers.

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References

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