Decoding consciousness in comatose states using BCI approaches

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INTRODUCTION

Lack of evidence of awareness of surrounding or physical matter is itself an evidence of being in coma. In the hierarchy of comatose states, an intermittent response to an instruction may be considered as a clinical marker for minimally conscious state (MCS). For instance, a vertical eye movement repeated to a instruction. In the case of Vegetative state (VS), no evidence of awareness or speech recognition is observed despite the patient being awake.

Clinical diagnosis of these patients requires them to either 'move' or 'speak'. Such diagnosis is prone to error because of its highly subjective nature. The work presented here uses brain computer interface (BCI) paradigm on these patients for twofold objectives: (a) to devise an objective solution for detection of awareness (b) feasibility of usage of BCI to nurture any typical EEG responses to such a paradigm.

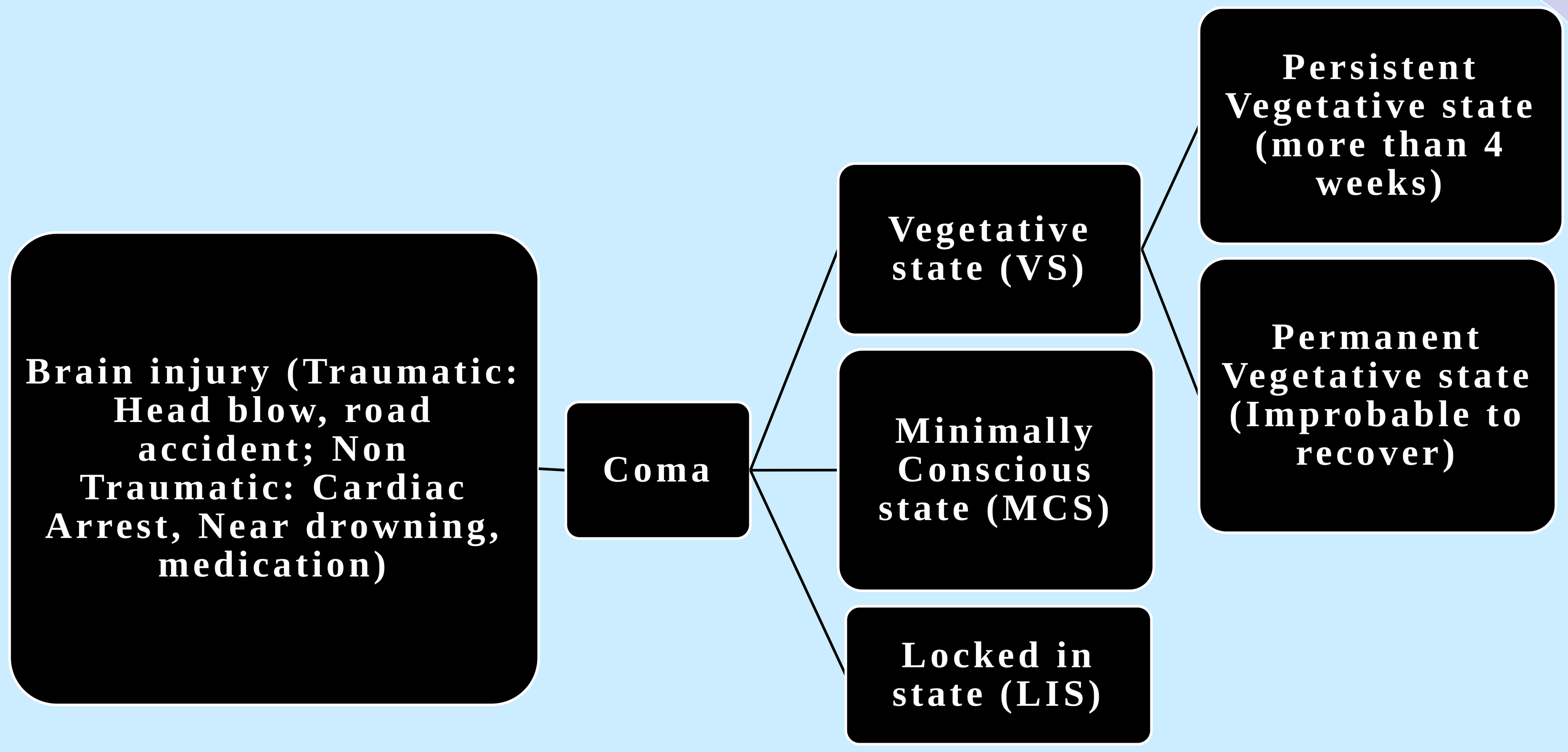

Figure 1: Pictorial representation of the hierarchy of the coma states .

METHODS

Paradigm

Brain Computer interfacing (BCI) opens up a communication channel by convert electrophysiological output in terms of brain signals such as EEG into control signals without the use of any muscular effort. A typical example of such an interface is by eliciting event related potentials (ERPs) through oddball paradigm strategy. For instance, in this experiment, a 6×6 matrix containing alphanumeric characters is presented to the subject. The rows and columns of the matrix are illuminated randomly. In the event of a rare occurrence, for example, the flashing of a row or column containing particular letter, on which subject is focussed, produces a peak in the EEG ideally after 300 ms of this occurrence.

How can this peak be detected

P300 could be detected over a number of trials through signal averaging. A learning algorithm, Linear Discriminant Analysis (LDA) was trained to detect the target letter in the matrix. The letter on which the subject concentrated was predicted as the one which appeared at the intersection of flashes of rows and columns.

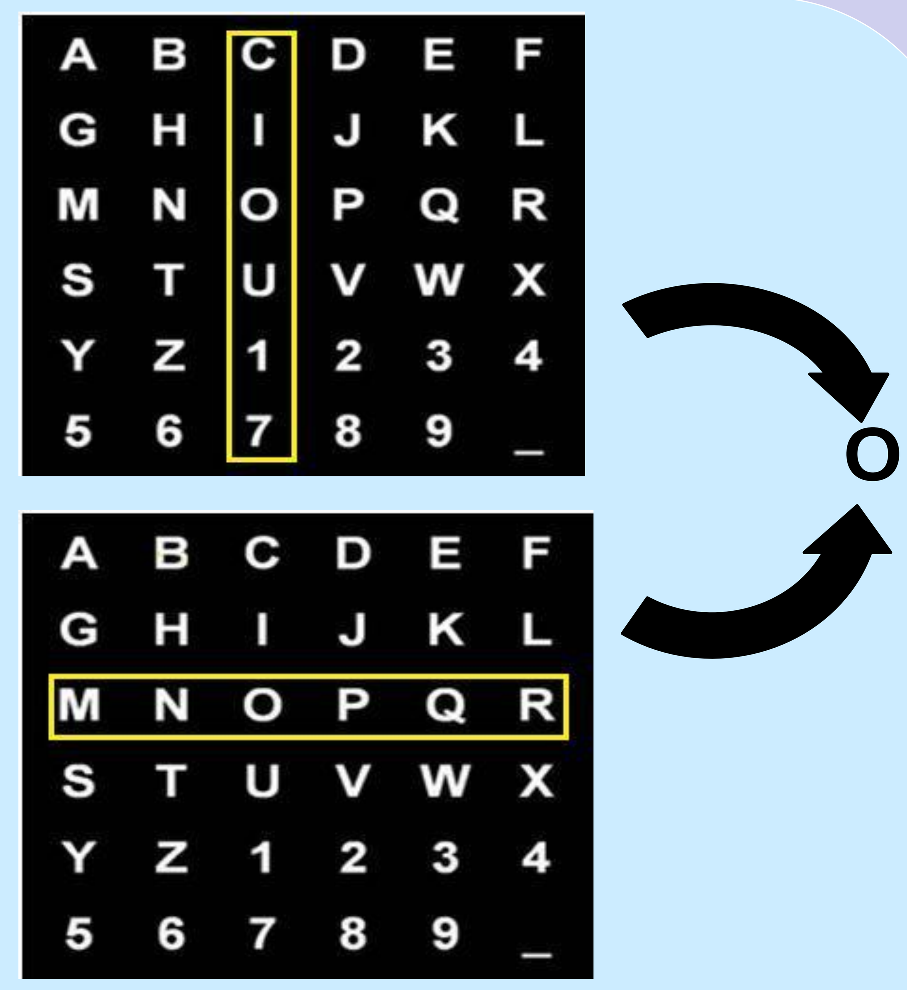

Figure 2: The flashing matrix used for stimulation. The intersection of 3rd row and 3rd column implies that the letter in focus is 'O'. The illumination of these two (target stimulus) is expected to elicit a different EEG response (P300) than all the other rows or columns (Non target stimulus)

OUTCOMES

This paradigm was tested with four patients who were clinically diagnosed to be either in MCS or VS. The vast differences in neurological history meant that they were studied as separate case studies. The highlights of results are:

- Three patients were able to detect letters correctly in some runs but not all the letters in a word could be predicted correctly. For instance, a patient was able to predict two letters correctly out of a four letter word.
- 'Close misses' were observed such that the predicted letters belonged to either the same row or the same column as the target letter but just one away in the speller matrix.
- Statistically, within the limits of associated patient conditions, the accuracy of predicted letters was able to reject the null hypothesis ($p<0.05$).
- A late differential response was observed which can be associated to the target letters or the 'close misses'. The differential response using oddball paradigms for this patient group has been reported as '*a large parietal wave with a latency of 350-500 ms often preceded by a brief negativity*' .

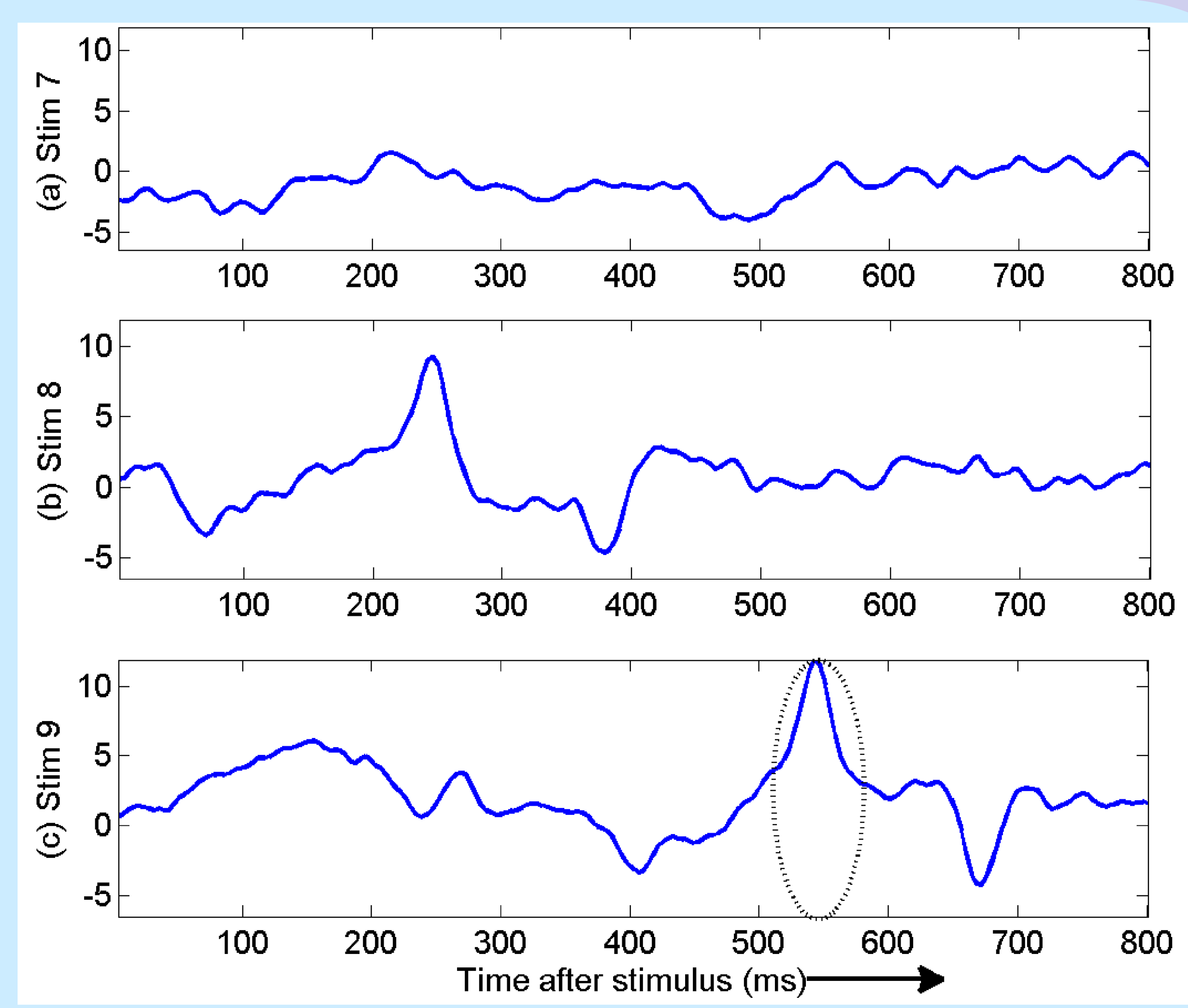

Figure 3: The time courses of the EEG response to the flashing of (a) first (Stim 7), (b) second (Stim 8) and third (Stim 9) columns in the speller matrix. The third column contained two target letters, hence, a differential response is seen in (c) (Stim 9)

CONCLUDING REMARKS

As Kotchoubey *et al.* rightly suggested '*In some instances, interpretation of clinical ERP research is theory-free'*, it may be difficult to explain morphology of the time courses. But the prediction of correct letters by patients exhibited their residual brain abilities to respond to a oddball stimulus to differentiate between letters. Modifications to the paradigm, especially in terms of the stimulus presentation may achieve better prediction accuracies. Further details of this work is reported in upcoming publications.

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