POSSIBLE SOURCES OF PERCEPTUAL ERRORS IN P300-BASED SPELLER PARADIGM

Caterina Cinel[1], Riccardo Poli[2] and Luca Citi[3]

[1] Department of Psychology, University of Essex, UK
[2] Department of Computer Science, University of Essex, UK
[3] Department of Electronic Engineering, University of Florence, Italy

SUMMARY

Some perceptual phenomena can interfere with character identification in Farwell and Donchin's P300-based speller paradigm [1]: attentional blink, repetition blindness and other effects caused by attentional limits. In the paper we discuss these and provide empirical evidence for one class of perceptual errors.

INTRODUCTION

Our ability of detecting or identifying stimuli is limited and we are susceptible to different kinds of illusions or 'mistakes'. Perceptual limits are often investigated by using rapid serial visual presentation (RSVP) experiments. In a typical RSVP experiment stimuli are sequentially presented at a rate of 6 to 20 items per second and observers are asked to detect or identify a target that differs (e.g., in colour or shape) from non-target stimuli. In RSVP target identification is normally quite accurate, but there can be "intrusion" effects by which the target appears to acquire non-target features.

Within independent BCI [2], P300 potentials have provided a means of detecting user's intentions concerning the choice of objects within a visual field: an area pioneered by Farwell and Donchin [1] who developed a protocol whereby a subject is shown a characters' matrix the rows and columns of which flash randomly at high speed. Large P300 waves are observed in response to the flashing of the chosen character.

This protocol has certain features of RSVP tasks. In this paper we suggest that some of the perceptual phenomena observed in the latter, may also affect the former, thereby becoming potential sources of errors in of the P300-based speller paradigm. We discuss this in the following section.

POSSIBLE SOURCES OF PERCEPTUAL ERRORS IN P300-BASED BCI

In a particular RSVP task, observers have to identify (or detect) two targets embedded in a sequence of non-targets. If the interval between the two targets is less than about 500ms *attentional blink* (AB) can occur [3]: the first target is correctly identified, while the second is not identified or is not detected at all (unless it is the item immediately following the first). AB can occur also when targets are at different locations. So, it can be a source of errors in a P300 speller if a non-target row/column near the target attracts attention by flashing (more on this below) and does so shortly before the target is flashed.

Repetition blindness (RB) is another phenomenon observed in RSVP tasks [4]. If two identical targets in a stream of non-targets are presented at intervals of less of 500ms, the second target may be missed. RB can be a source of errors in the P300 speller paradigm whenever the target letter is flashed twice within 500ms.

In different experimental conditions, other perceptual phenomena are often observed. One is the *illusory conjunction* (IC): when two or more stimuli with different features (e.g., shapes or colours) are simultaneously presented for a short time, one of the stimuli can be perceived as having one or more features of a different stimulus [5]. This typically occurs for stimuli that are presented outside the focus of attention, but it can also occur when observers have to broaden the focus of attention on a large number of stimuli. ICs tend to occur more often between stimuli that are close and stimuli that are in the same perceptual group. ICs can certainly happen in certain BCI setups, but it is unclear whether they could affect Donchin's speller paradigm.

In *attentional cueing* tasks, observers have to fixate the centre of a visual display where a target is presented on one side after a short presentation of a cue. The task is to press a key as soon as the target appears, while ignoring the cue. Cue and target are presented on the same side of space in validly-cued trials and on opposite sides in invalidly-cued trials. When the cue appears, even thought the obsevers are told to ignore it, attention is *automatically moved* to its location [6]. As a result, the time taken to respond to the target is shorter in validly-cued trials than in invalidly-cued trials. In the first case, when the target appears, attention is already in the right location, while attention moving is required in the second case. In the P300-speller paradigm, the automatic orienting of attention to the cue location is probably quite frequent: the flashing of a row or column near the one containing the target could attract attention thereby generating a spurious P300 wave (which could in turn generate AB).

As an example which corroborates our arguments, in the next section we provide some experimental

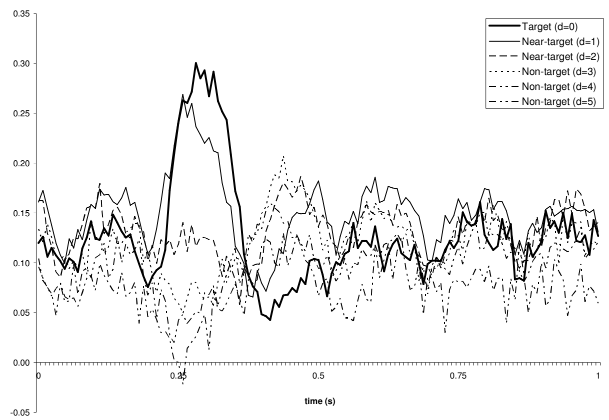

Figure 1. Average P300 signals recorded for target (d=0), near-target (d=1–2) and non-target (d=3–5) signals.

evidence for spurious P300 waves most likely due to the automatic orienting of attention in Donchin's speller paradigm.

"NEAR-TARGETS" IN P300-BASED SPELLER PARADIGM

We used the 2nd Wadsworth BCI Dataset from the BCI2003 competition [7] acquired using the P300-based speller paradigm. To study the possible influence of perceptual errors we first split the signals into (partially overlapping) trials lasting 1s and starting from a stimulus (the flashing of a row or a column of letters on the screen). We then grouped the trials in the dataset into 12 classes on the basis of which of the 6 rows and 6 columns flashed. The trials representing each row (column) where further subdivided on the basis of the row (column) of the target chosen by the subject, thereby producing 12×6=72 classes. In order to reduce noise we averaged the trials within each class.[1] We concentrated our analysis on both the signals recorded in the Cz channel and the weighted difference $\Delta=0.1\times C4-0.159\times T6$ between channels T6 and C4, which we have shown in previous research [8] to have high significance for the purpose of P300 detection.

What should one expect to see when plotting the averaged signals for each class? In theory, out of all the trials where column *c* flashed, only those where column *c* actually contained the target should present a P300 and likewise for the rows. Indeed this is what we observed, as illustrated in Fig. 1, where the solid thick plot (d=0) represents the Δ signal averaged over all the trials where the row containing the target flashed, which confirms the presence of P300s (similar results were obtained for Cz). However, the solid thin plot (d=1), which represents the Δ signal averaged over all the trials where the row that flashed was *adjacent* to the one containing the target, differs significantly from the remaining plots (representing situations where the target was further away from the flashing column), effectively presenting a large P300-like wave peaked at 300ms.[2]

What generated these P300-like waves in the presence of *near-target* stimuli? A plausible explanation is to attribute these to perceptual errors, where the subject's visual system, being unable to focus attention only on precisely the target letter, generated P300 (surprise, attentional orienting) signals. We suspect these perceptual errors may be a reason for the limited single-trial performance shown by automated P300 detectors. This, of course, drammatically increases the number of repetitions needed for reliable recognition.

However, as Fig. 1 suggests, EEG signals may contain information regarding the *degree of targetness* of stimuli. So, spurious P300s will not necessarily work against BCI if, in the future, we will be able to exploit this information.

CONCLUSIONS

Various types of perceptual phenomena might adverse P300-based BCIs. In the paper we analysed these and showed empirical evidence for one type of error which may generate spurious P300s. These errors can be reduced by psychologically-informed stimulus design. Also, these phenomena if properly exploted may even aid BCI. These are two directions for our future work.

REFERENCES

[1] Farwell LA, Donchin E. Talking off the top of your head: toward a mental prothesis utilizing event-related brain potentials. Electroenceph. Clin. Neurophysiol. 1988; 70:510–523.

[2] Wolpaw JR, Birbaumer N, McFarland DJ, Pfurtscheller G, Vaughan TM. Brain-computer interfaces for communication and control. Clin. Neurophys. 2002; 113:767-791.

[3] Raymond, JE, Shapiro, KL, and Arnell, KM. Temporary suppression of visual processing in a RVSP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance*, 1992: 18:849-860.

[4] Kanwisher, NG. Repetition blindness: Type recognition without token individuation. *Cognition:* 1987: 27:117-143.

[5] Treisman, A, and Schmidt, H. Illusory conjunctions in the perception of objects. *Cognitive Psychology*: 1982: 14:107-141.

[6] Posner, MI, Snyder, CRR., Davidson, BJ. Attention and the detection of signals. *Journal of Experimental Psychology: General:* 1980: 109:160-174.

[7] Schalk, G. Documentation 2nd Wadsworth BCI Dataset, BCI Competition 2003, http://ida.first.fraunhofer.de/projects/bci/competition/albany_desc/albany_desc_ii.pdf

[8] Citi, L., Poli, R., and Sepulveda, F. An evolutionary approach to feature selection and classification in P300-based BCI (submitted to BCI Workshop and Training Course 2004, Graz, 2004).

---

[1] Different rows and columns had different numbers of stimuli, namely: 180, 165, 75, 165, 0 and 0 (top to bottom) for the rows, and 150, 150, 105, 30, 75 and 75 (left to right) for the columns.

[2] Stimuli at distance 2 seem to also contain some information on the whereabouts of the target.