BRAIN-COMPUTER INTERFACING USING SELECTIVE ATTENTION AND FREQUENCY-TAGGED STIMULI

P. Desain[1], A.M.G. Hupse[1], M.G.J. Kallenberg[1], B.J. de Kruif[1,2] & R.S. Schaefer[1]

[1] Music, Mind, Machine Group, NICI, Radboud University Nijmegen, The Netherlands
[2] Department of Biophysics, Radboud University Nijmegen, The Netherlands
E-mail: desain@nici.ru.nl

SUMMARY: Selective attention can offer new possibilities for Brain Computer Interfacing (BCI) by separating compound streams of presented stimuli. An added watermark in the stimuli that can easily be extracted from the EEG signals yields possibilities for increased reliability in classification. The effect strength of the watermarks on cerebral activity is influenced by purposefully directed attention.

INTRODUCTION

Imagining temporal patterns (auditory, tactile, motor) as a cognitive task is a viable means of driving a BCI. As such, no stimulus is needed. However, asynchronous BCI analyses, not needing information on when a pattern of brain activity is generated, are complicated because of the weak and noisy signals, and thus some synchronization, or time-lock, is used. However, the time-lock in such tasks often becomes rather loosely coupled to brain activity, as the lock is only based on a prompting cue. Due to the high frequency and the short duration of the waveforms, the jitter in the time-lock should however be kept minimal.

For patterns which can be represented on a regular temporal grid (such as a musical rhythm) the grid can be presented (e.g. as a metronome), inducing a framework against which to imagine the pattern, thus minimising the jitter. Instead of imagining events that strictly fall on this grid, the cognitive task can be shifted to focusing attention on only part of the stimulus presented by the metronome. The task of BCI analysis is to distinguish between attended and non-attended events. In the auditory domain sequential selective attention occurs spontaneously in the so called clock-illusion, in which an identical train of isochronous beats is heard as a 'tick-tock' percept [1]. This has been shown to elicit attention-modulated differences in EEG P300 traces [2]. Adding to sequentially varying attention, one can also selectively attend to one of several simultaneously presented stimuli, consisting e.g. of a mixture of tones, tactile stimuli, or spatially divided auditory sources. Natural cognitive mechanisms that mute non-attended streams of information from the environment can be used towards driving a BCI. Imprinting the different streams with unique and easily identifiable watermarks, the BCI only needs to detect the strongest watermark and as an added advantage, the time-lock will be tight.

The auditory stimulus used here is a combination of two frequencies. The subject is instructed to focus on one of them, each is watermarked by an AM modulation of a different frequency. Although the fundamental pitch of a presented tones may not be easily recovered from measurement of brain activity, the AM frequency can be detected, making this a suitable method for hearing tests [3]. For BCI, the AM frequency tag is used as a watermark whose salience is modulated by selective attention [4]. Likewise, the trill-frequency of vibration can be used for the tactile sense [5, 6]. The signal processing needed for detection of such tags is relatively easy (filtering at a known frequency, power and phase estimation) and the BCI performance depends on the amount and robustness of the modulation of these signals by attention, and the classification of these features (albeit possibly in many channels and with a specific spatio-temporal evolution).

MATERIALS AND METHODS

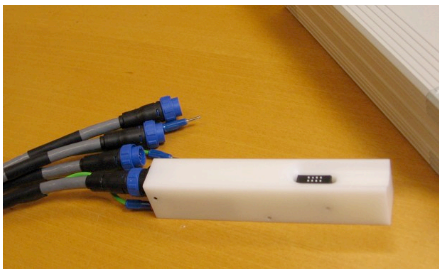

Figure 1: Tactile stimulator

Apparatus: Frequency tagged stimuli are presented in two modalities; auditory (presented through passive loudspeakers) and tactile. For the tactile stimuli, a device was designed and made using 8 separately moveable pins that produce braille-like patterns that can be presented to one or more fingers in parallel, using different frequencies of stimulation (see Fig 1.).

Data-analysis: When attending to a frequency-tagged stimulus, the EEG signal is processed in two steps (see Fig. 2): First two filters are applied in parallel to the data, each with a pass-band of one of the frequencies that have been added to the stimulus. Second, a Hilbert transform is applied, which -by taking the absolute value and the angle respectively- yieds the amplitude and phase of the frequency of interest. These features are then fed to a classifier.

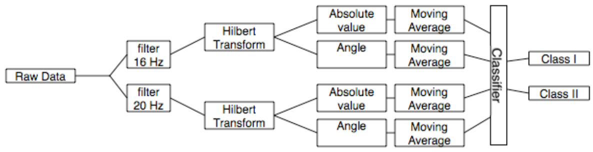

Figure 2: Data analysis schema

RESULTS

In order to examine the proper configuration of the data-analysis, a simulation was performed. Here, the two attention effects reported in the literature (an increased power and a phase-shift of the oscillation of the AM frequency in a frequency tagged sine tone) are implemented.

The output of the analysis of these simulated data is shown in Fig. 3. The top plot of the figure shows the simulated EEG measurement. It consists of a 16 Hz and a 20 Hz sine wave, corrupted by noise. In the first half, the 16 Hz was larger in amplitude and leading in phase, while for the second half the 20 Hz component was larger in amplitude and leading in phase. This is predicted when shifting the focus from the 16 Hz modulated sine to the 20 Hz modulated sine [3].

The second plot from the top shows the output of the bandpass filters, while the third plot shows the estimate of the phase and magnitude of both filter outputs. The bottom plot shows the amplitude and phase for 100 repeated trials.

DISCUSSION

The analysis on the simulated data shows that the data-analysis is able to reveal the effects that have been described in the literature. Although these simulated results do not yield any conclusive evidence, they support the feasibility of using selective attention towards driving a BCI device given the reported findings of the processing of frequency-tagged stimuli. Eventually, the combination of two modalities could produce binding effects that can improve classification even further. That possibility is, however, still to be investigated.

CONCLUSION

By using stimuli to respond (or attend) to when driving a BCI device, the problem of synchronization or time-locking of EEG activity is tackled in an efficient and natural way. As the time dimension is extremely precise in EEG measurements, not exploiting this in developing methods for BCI appears to be a missed opportunity for increased reliability and speed.

REFERENCES

[1] London, J. Hearing in time, Psychological aspects of musical meter, Oxford University Press, 2004

[2] Brochard, R., Abecasis, D., Potter, D. Ragot, R. & Drake, C. The “ticktock” of our internal clock: Direct brain evidence of subjective accents in isochronous sequences. Psychological Science 2003;14(4): 362-366

[3] Picton, T.W., Skinner, C.R., Champagne, S.C., Kellett, A.J.C. & Maiste, A.C. Potentials evoked by the sinusoidal modulation of the amplitude or frequency of a tone. Journal of the Acoustical Society of America, 1987;82(1): 165-178

[4] Ross, B., Picton, T.W., Herdman, A.T., Hillyard, S.A. & Pantev, C. The effect of attention on the auditory steady-state response. Neurology and Clinical Neurophysiology 2004;22: 1-4

[5] Bauer, M., Oostenveld, R., Peeters, M. & Fries, P. Tactile spatial attention enhances gamma-band activity in somatosensory cortex and reduces low-frequency activity in parieto-occipital areas. The Journal of Neuroscience, 2006; 26(2): 490-501

[6] Müller-Putz, G., Scherer, R., Neuper, C. & Pfurtscheller, G. Steady-state somatosensory evoked potentials: suitable brain signals for Brain-Computer Interfaces. IEEE transactions on neural systems and rehabilitation engineering, 2006; 14(1), 30-37

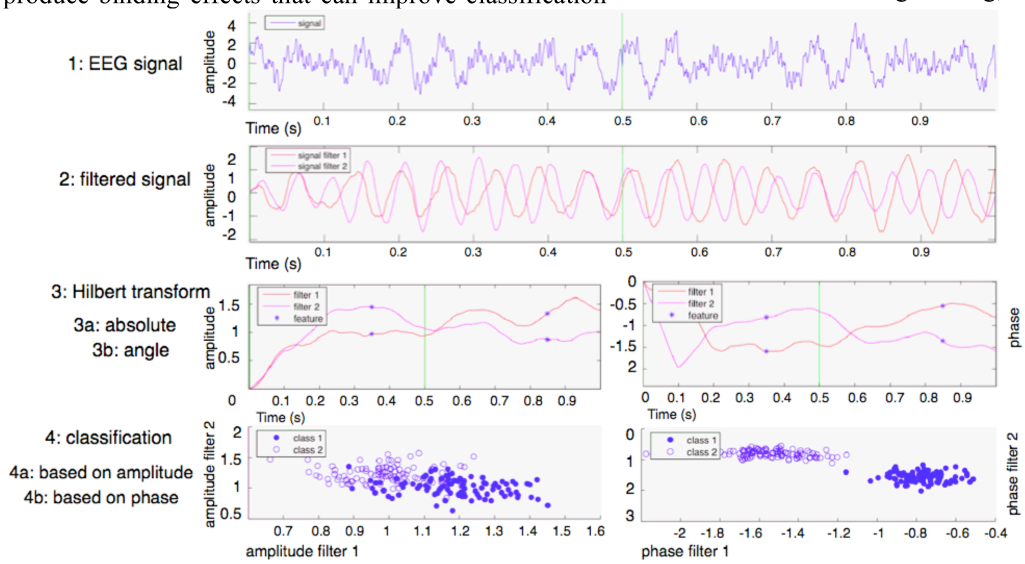

Figure 3: Data-analysis on simulated data