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Original Research Article

Validation of Emotiv EPOC+ for extracting ERP correlates of emotional face processing☆

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ABSTRACT

The article presents our proposed adaptation of the commercially available Emotiv EPOC+ EEG headset for neuroscience research based on event-related brain potentials (ERP). It solves Emotiv EPOC+ synchronization problems (common to most low-cost systems) by applying our proposed stimuli marking circuit. The second goal was to check the capabilities of our modification in neuroscience experiments on emotional face processing. Results of our experiment show the possibility of measuring small differences in the early posterior negativity (EPN) component between neutral and emotional (angry/happy) stimuli consistently with previous works using research-grade EEG systems.

1. Introduction

The way information is processed by the brain is still not thoroughly examined. Measuring the activity of the brain under the influence of various stimuli is one of the main methods of gaining this knowledge. Using electroencephalography (EEG) monitoring, it is possible to observe the momentary electrophysiological responses to the particular stimuli. They are called event-related brain potentials (ERPs) [1]. An ERP waveform is a sum of underlying components, such as the N170 component (its name introduced in [2] relates to the negative potential around 170 ms after stimulus display) which reflects the neural processing of faces in the temporo-occipital brain sites examined further by Eimer in [3].

The ERP measurements are much more difficult than the extraction of frequency subbands (like alpha or beta). Even while using an expensive professional equipment in a strictly controlled environment, it is necessary to average dozens of similar trials (called epochs in the ERP literature) in order to reduce noise and physiologic artefacts generated by the human body. In order to correctly average successive ERP waveforms, it is necessary to precisely determine the stimulus onset time. For this purpose, most research-grade systems use an additional event marking input which solves problems with lack of synchronization between EEG and PC clocks. Without

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this kind of extension, wireless EPOC+ heavily suffers from timing drift and jitter between consecutive trials (described in more detail in Section 3).

The primary goal of our article is to solve mentioned timing problems using our proposed stimuli marking circuit and to perform ERP measurements with the cost-effective Emotiv EPOC+ EEG system [4]. The general usability study (adaptability to different head sizes, variance in electrodes locations, connection stability) of different low-cost EEG systems, including EPOC+, can be found in [5]. Previous Emotiv EPOC+ validation studies for basic face-sensitive and late auditory ERP components detection in adults [6,7] and children [8] were the inspiration for our research. These articles introduce EPOC+ as a valid alternative to the research-grade Neuroscan SynAmps^2 system (Compumedics, USA) and they all use the wireless infrared-based marker triggering circuit as a source of temporally-reliable event markers [9]. However, this circuit has quite a complex design that could impose additional costs and problems with assembly and programming by a person without a technical background (e.g., psychologist or clinician). Our simple two-wire circuit has the same purpose but is much easier and practically cost-free to build.

The second goal of our article is to validate the modified Emotiv EPOC+ as a tool for neuroscience research based on ERP. Our study is designed not only to detect the ERP components but also to exam the possibility of measuring sophisticated differences in ERP components using this low-cost device. Specifically, the effects of emotional (angry/happy) facial expression stimuli. The selection of these specific categories was based on the experimental setup from [10] and analysis of the results from studies using different research-grade EEG systems [3,10,11] where both angry and happy face expressions modulate ERP signals in a similar manner (i.e., Fig. 2. in [11]) – by decreasing the mean value of the early posterior negativity (EPN) component described in the next section.

This paper starts with a revision of related work in Section 2 and description of our proposed hardware extension and reasoning behind it. In Section 4, details of our experimental setup and procedures are given, together with a specification of Emotiv EPOC+. The specific EEG signal processing methods are proposed in Section 5. The experimental results are presented in Section 6 and discussed in Section 7.

2. Related work

There are many recent studies analyzing event-related brain potential correlates of emotions evoked by different kinds of stimuli, including affective pictures [12,13], sounds [14,6,8], written words [15,16] and, most interestingly in the context of this article, facial expressions [3,7,17,10,11,18–21]. Authors of the articles [3,11] claim that face-sensitive N170 component mentioned in the introduction is not significantly modulated by the facial expression. Instead, they show the EPN (early posterior negativity) component as the emotion-sensitive one. According to the literature [21,11], EPN is defined as a relatively increased negativity over temporo-occipital electrodes, starting around 150 ms after stimulus onset, most pronounced between 250 and 300 ms, which typically emerges for emotional relative to neutral stimuli. However, different researchers use different definitions of the EPN: the mean activity from 260 to 320 ms [22], from 280 to 360 ms [19] or from 240 to 340 ms [10] after stimulus onset. In our article, the latter definition is used.

Studies examining Emotiv EPOC+ are focused mainly on brain–computer interfaces applications. A couple of them (specifically, the recent review in [23] reports 24 such articles) are focused on recognition of emotions, like [14,24,13,25,26] just to mention a few. The Emotiv company itself proposes so-called Performance Metrics Suite (earlier: Affective Suite) for monitoring user's emotional states [4]. However, to the best of our knowledge, none of them uses ERP features in the process. Most of them are based on oscillatory or statistical features that are more connected to the lasting mental states (like excitement, engagement, frustration or meditation in the Performance Metrics Suite) rather than momentary emotional reactions (i.e. during rapid visual presentations of faces or other affective images). ERP features could be used to measure these sophisticated brain phenomena and to significantly increase temporal resolution of classifiers.

A few articles propose methodology of using EPOC+ for measuring ERPs. As mentioned in the Introduction, some of them address problems of drift and jitter heavily experienced in our study by using custom stimuli marking circuit [6–8]. Another article proposes synchronization using a loud sound that appears in the EEG signal due to user response to it [25]. Remaining two articles do not mention or address problems with synchronization: the article [?] comparing EPOC+ with the SynAmps RT system (Compumedics, USA) and the article [27] examining EPOC+ in an oddball task for the P300 component detection.

3. Our proposed stimuli marking circuit

As mentioned in the introduction, EPOC+ (without the dedicated Extender accessory[1]) is vulnerable to effects caused by differences between stimuli timestamps saved by a PC and timestamps of samples corresponding to the actual stimuli display. These effects are timing drift (steadily increasing time difference between timestamps during measurement) and jitter (unpredictable variations of time differences between timestamps). Jitter in EPOC+ was previously examined in [28] to have a substantial 55.7 ms standard deviation, the problem is visualized in Fig. 2 and in the left part of Fig. 7.

To solve this problem, our own stimuli marking circuit was proposed and soldered to the Emotiv EPOC+ headset (design presented in Fig. 1). The whole module consists of just one meter of a twisted-pair cable connecting the BPW34 photodiode [29] with electrodes F7 and F8 isolated from the head skin by rubber pads. This module makes EPOC+ no longer wireless but is extremely easy and cheap to build. The diode needs to be attached to the part of the screen that differs in luminance significantly when a stimulus is displayed, in our case this was a little white square in the right bottom corner of each stimuli image. The transition of pixels within the square from grey to

[1] Superficially mentioned at www.emotiv.com/comparison, not available in the official shop.

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