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EEG with a reduced number of electrodes: Where to detect and how to improve visually, auditory and somatosensory evoked potentials

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ABSTRACT

The measurement of evoked potentials has become a standard tool to test new hardware and software for electroencephalography (EEG). In this study, we investigate where to detect and how to improve visually, auditory and somatosensory evoked potentials with a reduced number of electrodes. We measured a total of 50 evoked potentials in healthy subjects, and we were able to detect visually, auditory and somatosensory evoked potentials with just three electrodes. We also investigated where to measure a combination of visually, auditory and somatosensory evoked potentials and found the best positions to be Oz, O1, O2, TP9 and TP10. In the second part of this study, we analyzed how the evoked potentials depend on the segmentation frequency selected to superpose EEG responses. We found that the detection of visually evoked potentials requires the segmentation frequency to match the stimulus frequency with an accuracy of at least 99.92 percent. The detection of auditory evoked potentials and somatosensory evoked potentials requires a matching of at least 99.95 percent. Therefore, a correct matching of the segmentation frequency with the stimulation frequency is the primary key to improving the quality of evoked potentials.

1. Introduction

Electroencephalography is a well-established clinical technique to investigate the activity of the brain and to diagnose neurological malfunctioning [1]. But the recording of an electroencephalogram (EEG) always involves a lot of effort: Frequently 32 or more electrodes are fastened to the scalp [2,3]. Each of these must be checked manually for a very good electrical contact to the skin—a very time-consuming procedure that is unacceptable for a fast clinical diagnosis. The many wires connected to these electrodes often cause cable clutter that must be cleaned up for the next measurement. The subsequent sterilization is very time-consuming too and carries the risk of breaking cables.

Recently more and more applications have been designed that require EEG signals from selected areas of the brain only, for example brain–computer interfaces [4–6] and neurofeedback [7–9]. In many of these applications, sensory perceptions

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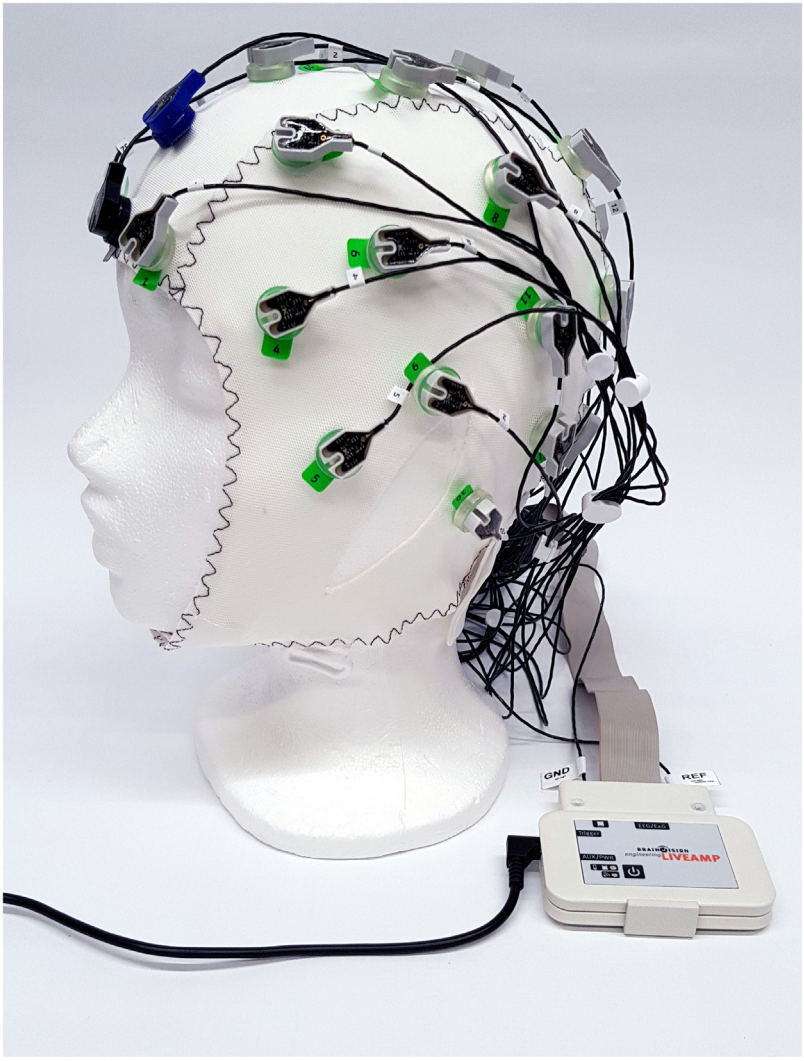

Fig. 1 – Mobile 32-channel device with electrode cap and trigger cable.

are to be detected such as visually, auditory and somatosensory evoked potentials [10]. Apparently the number of electrodes can be significantly reduced here, thereby minimizing the wiring effort and the amount of data to be analyzed [11,12]. We are well aware of the fact that reducing the number of electrodes will result in a loss of information [13]. But we are confident that with our strategy we can better focus on the relevant information. Most likely a reduction in EEG channels will trigger many new applications with a mobile hardware (so-called ''wearables'').

In this study, we investigate the positions on the scalp that are best suited for the measurement of evoked potentials. Most importantly we show at which positions all three kinds of evoked potentials (visually and auditory and somatosensory) can be detected. We also describe how sensitive the detection is with regard to selecting the correct segmentation frequency. Evoked potentials can be detected only as a superposition of many repeated single responses. If the segmentation frequency of the superposition does not exactly match the repetition frequency of the stimuli, the evoked potential will completely dissolve within the noise.

2. Evoked potentials

Generally speaking, evoked potentials (EP) are expressions of electrical activity within the brain that occurs with a temporal delay after a specific event. These can be sensory or mental events. In this study, we focus on sensory EP only. They are classified as visually evoked potentials (VEP), auditory evoked potentials (AEP) and somatosensory evoked potentials (SEP), respectively.

First experiments in 1875 already demonstrated that visual stimuli cause small electrical potentials within the brains of apes [14]. But it was not until Hans Berger's work on encephalography in 1929 [15] und the subsequent development of non-invasive signal detection techniques, that VEP, AEP and SEP could be measured in the human brain [16]. At the beginning of EP research, these signals were very difficult to detect because the very first EPs were single responses only. The primary task was to distinguish the small evoked EEG activity from the much stronger non-evoked brain activity. It was George Dawson who first used electrical superposition