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Noninvasive EEG-Based Auditory Attention Detection for Online Modulation of Sound Sources

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Abstract

Noninvasive EEG-based auditory attention detection has the potential to revolutionize the field of hearing aids. This study presents a novel investigation into the feasibility of online modulation of sound sources through probabilistic detection of auditory attention, utilizing a noninvasive EEG-based brain-computer interface. The proposed online system achieves modulation of upcoming sound sources by employing gain adaptation based on soft decisions from a classifier trained on offline calibration data. During calibration sessions, EEG data were collected while participants listened to two sound sources, one attended and one unattended. Cross-correlation coefficients between the EEG measurements and the envelope of the attended and unattended sound sources were analyzed to reveal differences in neural response sharpness and delays for attended versus unattended sound sources. Salient features were identified from the correlation patterns to distinguish attended sources from unattended ones and used to train an auditory attention classifier. The results of this study contribute significantly in two aspects. Firstly, the high offline detection performance of the auditory attention classifier was demonstrated using shorter duration single-channel EEG measurements, outperforming existing approaches that employ a larger number of channels and longer EEG recordings. Secondly, the performance of the online sound source modulation system, utilizing the classifier trained offline, was evaluated. The findings indicate that the online system effectively maintains a higher level of the attended sound source compared to the unattended source. This research paves the way for advancements in the development of improved hearing aids incorporating noninvasive EEG-based auditory attention detection.

Keywords: EEG, auditory attention, noninvasive, brain-computer interface, sound source modulation

I. Introduction

One of the common challenges faced by hearing aid users is difficulty in understanding speech when there is background noise. Studies have extensively examined the effects of interfering sounds on speech intelligibility and audibility. People with hearing loss may require up to 30 dB higher signal-to-noise ratio (SNR) compared to individuals with normal hearing to achieve the same level of speech understanding in the presence of background noise [1]. Hearing aids aim to amplify the target signal and reduce unwanted noises and interferences to enhance hearing, increase speech clarity, and improve listening comfort. Identifying the desired signal in the presence of noise is a crucial step in hearing aid design. However, this task can be challenging in complex auditory environments, such as a cocktail party scenario, where multiple sound sources resemble speech and can switch roles based on the listener's attention, making them difficult to detect based on predefined assumptions about signal and noise characteristics [2-4]. Our brain uses various cues, such as spectral profile, harmonicity, spatial and temporal characteristics, to distinguish between different audio sources and focus on the desired sound in a cocktail party effect. Efforts have been made to computationally model auditory attention in a cocktail party setting, either from a bottom-up or top-down perspective, and these approaches are discussed in an overview paper [5].

Brain/Body Computer Interface (BBCI) systems can enhance current hearing aids by distinguishing between attended and unattended sound sources [6-9]. These systems can provide external evidence based on top-down selective attention of the listeners. Attempts have been made to incorporate both bottom-up and top-down attention evidence in hearing aid design. For example, there are direction-based hearing aids that detect the direction of attention through eye gaze and amplify sounds coming from that direction [10]. Additionally, electroencephalography (EEG)-based brain-computer interfaces (BCIs) have been explored for identifying attended sound sources. EEG is commonly used in BCI designs due to its high

online system maintains a higher level of the attended source, despite statistical changes in the online data compared to the offline data used for training the classifier.

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