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Toward a Brain Interface for Tracking Attended Auditory Sources

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Introduction: Auditory-evoked noninvasive electroencephalography (EEG) based brain-computer interfaces (BCIs) could be useful for improved hearing aids in the future. This work investigates the role of frequency and spatial features in building an auditory based BCI specifically for the purpose of detecting the attended auditory source in a cocktail party setting. An initial closed loop design for possible EEG-augmented hearing aids has been tested. Two cross correlation and signal modeling based features which use EEG and speech envelope is shown to be useful to discriminate attention in the case of two different speakers. Results indicate that, on average, for speaker and direction (of arrival) classification, the presented approach yields %91 and %86 accuracy, respectively. Accuracy of correct classification in online setting yields %65.

Material, Methods, and Results: Two sets of experiments have been designed and conducted to test source detection feasibility in an offline setting, and to test an initial online auditory attention classification setup. In the first set of experiments, based on findings reported in the literature on cortical entrainment of EEG measurements to the temporal envelope of speech [1], crosscorrelation between EEG and speech envelope is used to extract features to classify auditory attention. Classifying sources as attended or unattended, based on their frequency or direction of arrival were also attempted, via diotic and dichotic sound presentation paradigms [2]. To localize selective attention responses, single channel classification analysis was performed using a Regularized Discriminant Analysis (RDA) classifier. Discriminant scores from RDA were used to estimate ROC curves and area under the ROC curve (AUC) as a measure of potential classification accuracy. Figure 1 shows scalp topography maps of AUC for both diotic and dichotic auditory presentations. The estimated AUC for the RDA classifier that attempts to detect the attended speech source ranges between 86% and 95% in diotic and dichotic cases, respectively. For the classification of the direction of attended speech, AUC values between 82% and 89% were obtained for female and male narrators, respectively. In the second sets of experiments, the user was asked to amplify a target speech by paying attention to it. To enable this, we designed a closed loop system, which adjusts the convex linear combination parameters of two speech sources presented to the user, based on the estimated probability of each sound being desired (attended) given recent EEG evidence. These estimated probabilities of intent to attend were calculated using class conditional distributions calibrated based on supervised EEG data obtained in a preceding calibration session. RDA scores were used as one dimensional EEG features, and converted to class conditional likelihoods using kernel density estimation. In the on-line session, the convex linear combination weights of sound sources were dynamically adjusted every 10 seconds to be proportional to the posterior probability of each source being attended. Posteriors were updated recursively using Bayes rule. Users attempted to amplify the designated target speech with their auditory attention using this brain interface in 20 one-minute-long trials. Figure 2 shows the average weights (over 20 trials) of attended and unattended speech over the course of one minute, for male and female narrators. While for the female target narrator, users were able to increase the weight of this sound source through this brain interface, for the male target narrator, initial good task performance was followed by incorrect amplification of the nontarget female narrator towards the end of the trials. We suspect, this was due to distraction of subject to the female voice as he confirmed that female sound was catching his attention because of her intonation. In future experiments we take the role intonation factor into account in order to remove attention biases of sources which might occur.

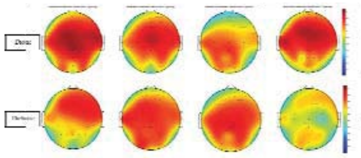

Figure 1: Topographic scalp map for the classification accuracy (measured with AUC) for EEG-based estimation of attended speaker.

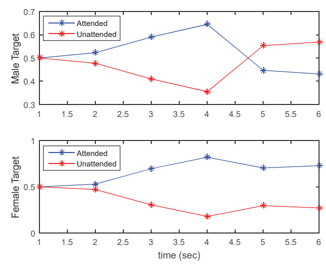

Figure 2: Online weight controlling of subject for attended and unattended speakers.

Discussion: We investigated the feasibility of online classification of auditory attention using EEG. Initial experimental data presents mixed, but motivating results for further research on EEG-guided sound modulation.

Significance: This is a step towards hearing aids that use EEG evidence to estimate user auditory attention.

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