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A Novel, Modular and Hybrid Method and Software for the Reduction of AEP Artifacts in TMS-EEG Studies

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Extended Abstract

TMS can contaminate concurrent EEG recordings with Auditory Evoked Potentials (AEPs) which are caused by the perceived impulsive acoustic noise of the TMS coils. These percepts may be formed either by air- or bone-conducted hearing [1]-[3].

To overcome this issue, previous research has proposed two general directions for AEP artifact reduction/removal, namely, EEG signal processing-based elimination and/or AEP suppression using various auditory masking stimuli [1], [4].

Herein, we are introducing an alternative hybrid approach, which features:

a. Psychophysically-driven continuous wide-band noise (WBN) masking stimulus, matched to the TMS clicks' characteristics and measures of the subject's hearing acuity.

b. Acoustic isolation of airborne/bone sound using insert earphones with highly effective insertion loss.

c. A complete adaptive procedure for optimal masking level determination and AEP reduction, together with a GUI-based software for the automation and standardisation of the procedure.

All three features operate in tandem in order to provide a maximally efficient solution for AEP artifacts, by reducing the subject's exposure both to the TMS click and the masking noise.

The generation of psychophysically-matched WBN masking stimulus is performed after acoustic noise recordings using a Bruel & Kjaer BK-4128 HATS, and recordings of bone conducted skull transmission at teeth, using a widely available MEMS accelerometer device (Analog Devices EVAL-ADXL1005Z) and a National Instruments signal acquisition interface. Hearing acuity data (e.g., pure-tone audiogram) may also be incorporated for the determination of the masking noise pattern and presentation level.

The main acoustic isolation of the cochlear partition is achieved by using a pair of insert earphones (Etymotic ER3XR) of adequate sensitivity and (well-specified) high insertion loss. We have also examined the effect of using layers of various materials between the skull and the TMS coil, which is of importance since TMS coils are in contact with the head/skull structures. The importance of acoustic isolation in reducing noise exposure is also highlighted by the characteristics of the acoustic TMS click noise, which is impulsive by nature. The potential of more harmful effects on hearing of impulsive and impact noises in comparison to continuous noises has been shown in the literature [5]-[7].

A specially designed, GUI-driven automation software (based on National Instruments' LabVIEW) is used for the realisation of an adaptive procedure for optimal placement of masking noise level, optimising both the subject's comfort and the degree of AEP reduction. The proposed adaptive procedure also takes into account the combined effect of TMS intensity level and any available hearing acuity data (such as pure-tone audiogram (PTA) data mentioned previously). An additional software/hardware interface for the communication and/or control of TMS equipment with the GUI software will afford the fully-automated coordination of the standardization procedure across subjects and TMS facilities, thus offering a highly individualised application in the framework of precision medicine.

In order to assess the efficacy of the proposed method in reducing the acoustic effects of TMS with the H7 coil (Brainsway Ltd., Jerusalem, Israel), we performed TMS-EEG recordings with a 60 channel TMS-compatible EEG system in a cohort of healthy subjects (n=10) and patients with epilepsy (n=10) under four conditions (i.e., resting EEG with and without acoustic mask and sham TMS-EEG with and without acoustic mask at various stimulus intensity levels).

Preliminary encouraging results of the proposed approach in terms of maintaining masking noise at comfortable levels and efficiency of AEP suppression are presented.

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