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Auditory High Entropy Response (A-HER): a new paradigm with high amplitude for Potential auditory-BCI application

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Introduction: Steady-State Visual Evoked Potential (SSVEP), for its high signal-to-noise ratio (SNR), is one of the most popular paradigms in Brain-Computer Interface (BCI)[1]. In contrast, Steady-State Auditory Evoked Potential (SSAEP), also known as Auditory Steady-State Responses (A-SSR), on the other hand, is challenging to use in BCI applications due to its poor SNR[2]. In this work, Auditory High Entropy Response (A-HER) is proposed with high SNR in the brain wave modulation for the potential non-visual BCI application.

In information theory, Shannon entropy is a measurement of the uncertainty of a sequence. By delivering high entropy sequence instead of the certainty stimulus sequence in A-SSR, A-HER can modulate brain rhythms in the prefrontal theta band, in which the effect of repetition suppression has been reduced greatly. A description of A-HER is introduced in Fig. 1(A).

Material, Methods and Results: 20 subjects were taken participated in the experiment with two sessions. In each session, there were 10 runs with the repeated auditory stimuli with frequencies of 0.5Hz, 1Hz, 2Hz, 5Hz, 8Hz, 10Hz, 12Hz, and 20Hz. Auditory stimuli were delivered with the fixed pure tone of 800Hz in session 1 for the A-SSR paradigm, and random tone selected a whole hundred pitch from 300-1200Hz in session 2 for the A-HER paradigm. As is shown in Fig. 1(B), the A-SSR paradigm with fixed tone stimulation in session 1 did not have a clear frequency response. By using the random tones in the A-HER paradigm instead of the fixed tune, the response would appear around the frontal theta band.

Significance: A new type of paradigm, named Auditory High Entropy Response (A-HER) has been proposed in this work. By using the high uncertainty stimulus sequence instead of the deterministic stimulus sequences, A-HER could effectively reduce the effect of repetition suppression for frontal theta band EEG modulation. With the high SNR, A-HER could ideal candidate for non-auditory BCIs, which also has the potential application of clinical sensory diagnosis and psychological research.

References:

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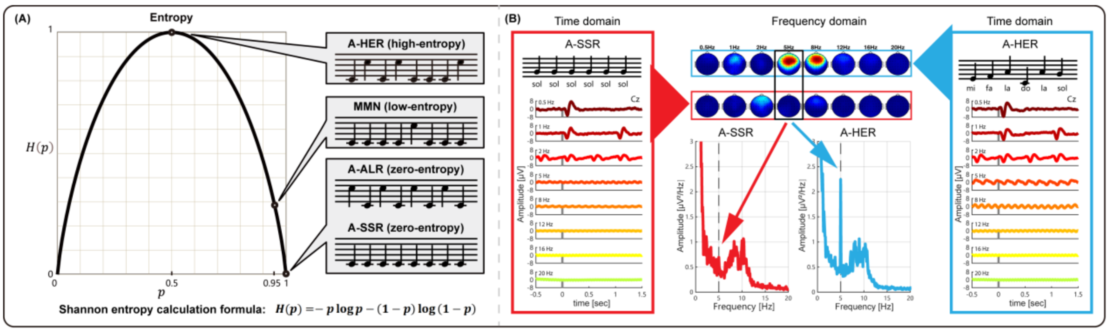

Figure 1(A) . The auditory stimulus sequence for A-HER, MMN, A-ALR, and A-SSR with their entropies. For A-SSR, with the prior probability p=1 for the standard stimulus, we have the entropy of the whole sequence H(X)=0. For A-ALR, with two types of stimuli come alternative, the whole sequence is also deterministic with the entropy H(X)=0. For MMN, the standard stimulus with a larger probability p=0.95, so the entropy of the whole sequence is also small H(X)=0.29. For A-HER, two types of stimuli come with the equal probability p=0.5, so the entropy reaches the maximum H(X)=1. Figure 1(B) . A-HER and A-SSR response in time domain and frequency domain. In the time domain, with the increase of stimulus frequency, the decay speed of the A-HER is slower than that of the A-SSR. In the frequency domain, the response would appear around the frontal theta band in A=HER but the A-SSR cannot.