PREDICTING FAILURES IN AUDITORY DETECTION FROM CHANGES IN THE EEG SPECTRUM

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Abstract

Humans' ability to maintain constant level of performance in low-arousal task environments is limited. This paper shows that characteristic multi-minute and 15-20 sec fluctuations in the EEG spectrum accompanying fluctuations in behavioral alertness can be used to estimate or predict individual responses in an auditory detection task.

Keywords: Auditory awareness, EEG spectrum, alertness, neural networks

Introduction

The present research extends our investigation [1, 2] of using multichannel electroencephalographic (EEG) spectral data to estimate minute-to-minute shifts in an operator's level of alertness. Recently, we [3] have shown that during drowsiness, human performance on s continuous auditory detection task tends to vary irregularly on at least two time scales, (phasic) 15-20 sec changes riding on (tonic) 4+ min performance fluctuations. On both time scales, performance fluctuations are accompanied by characteristic changes in the shape and amplitude of the EEG spectrum. By using artificial neural networks to combine tonic and phasic EEG spectral information from two scalp channels, we show here it is possible to predict with at least 75% accuracy whether or not a drowsy subject will respond to a presented auditory target.

Methods

Data Collection

Ten male adult subjects participated in three 28-min eyes-open experimental sessions each during which they pressed a response button whenever they detected an above-threshold auditory target. Target noise bursts (duration 350 ms) were presented in a 63 dB white noise background at a mean rate of 10 per min, 6 dB above detection threshold,

EEG data were recorded from two midline sites, one at the vertex (Cz) and the other at midway between parietal and occipital sites (Pz/Oz), referred to the right mastoid. After preprocessing to reject data contaminated by muscle and eye movement artifacts, power spectral estimation was carried out at 1.6 s intervals using the FFT.

Performance analysis

Auditory targets were classified as *Hits* if the subject pressed the auditory response button within 120 ms to 3000 ms of target onset, or were classified as *Lapses* if they did not.

Power Spectrum Perturbation

To investigate the relationship of subminute-scale fluctuations in auditory awareness to concurrent changes in the EEG spectrum, we applied a normalized mean time-frequency measure, the event-related spectral perturbation (ERSP [4]), to study mean perturbations in the EEG log spectrum occurring before and after detected and undetected targets, respectively. To construct the ERSPs, individual time-varying EEG log spectra time-locked to target presentations were individually normalized, prior to averaging, by subtracting a mean prestimulus log spectrum. In most subjects, undetected target (lapse) ERSPs differed from detected target (hit) ERSPs in two ways: (1) a relative increase in circa 5 Hz activity before target presentation, accompanied by a relative increase in (35-50 Hz) gamma band activity. (2) A negative trough of 10-20 Hz activity peaking a second or more after target presentation. Hit- and lapse-related ERSPs were strongly negatively correlated ($r = -0.89$).

In most subjects, EEG activity near 5 Hz began to increase about 10 sec before undetected targets and returned to baseline about 10 sec after stimulus onset, while a relative decrease in activity of similar duration preceded detected targets. Gamma band activity also varied before and after target presentation, but in the opposite direction. The time courses of these spectral perturbations were nearly identical between sessions in the same subjects, and nearly all showed well-defined 15-20 sec fast episodes surrounding target presentations during drowsiness [2]. Since changes in mean amplitude near 5 Hz and in the gamma frequency band preceded stimulus onset, and was robust within subjects, we attempted to use second-to-second changes in EEG power spectrum to predict whether or not subjects would respond to each target presentation. The goal of this study was to *predict* drowsy subjects' auditory awareness of presented targets. Therefore, only EEG log power scalp information *prior* to target onsets were used.

Auditory Response Prediction

For each session, we collected the EEG log power spectrum prior to target presentations, and smoothed them using an 95-sec exponential window to extract minute-scale (tonic) changes in the EEG spectrum. We also collected five (phasic) spectral estimates of log power in consecutive 1.6 sec (phasic) windows immediately preceding each target presentation. Principal Component Analysis was then performed separately on the tonic and phasic EEG to extract the largest directions of spectral variance. The first four principal factors from each PCA were then used to train a feedforward 3-layer backpropagation network for each session. These networks had two output units which were trained to indicate the relative likelihood that the subject would respond or fail to respond to the ensuing target. Each network was tested on EEG data from a second session from the same subject.

Results

Figure 1 plots the percentage of correct detection (correctly predicted hits and lapses). The overall percentage of correct detection over 20 sessions from 10 subjects was 76%. Performance prediction accuracy varied somewhat across subjects, as did the size of the mean spectral perturbations. When networks were also given EEG spectral information collected during and a few sec after target presentation, classification accuracy was still higher (about 85%), the improvement no doubt reflecting the well-defined ERSP features following target presentations, as well as response-related time- and phase-locked components of the event-related potential (ERP) evoked by the targets.

The ability to predict (or estimate) whether or not an operator will respond to (or has responded to) informational or warning stimuli could be of practical use in environments in which early detection of lapses in an operator's awareness of presented information could be used to improve overall safety and performance of the system the operator is monitoring. In general, *neural human-system interface* (NHSI) technology would manage interactions between complex systems and their operators based on information about operator state derived from EEG and/or other psychophysiological and behavioral measures.

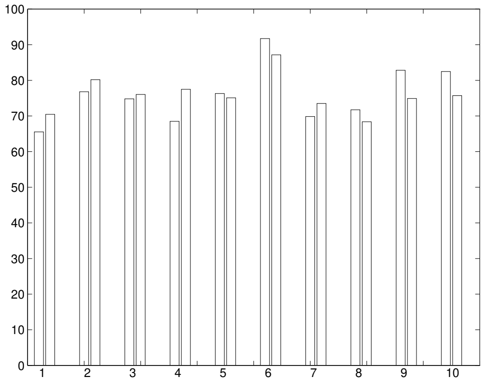

Figure 1: Percentage of correct prediction of auditory awareness in 2 sessions for each of 10 subjects.

Conclusions

We have demonstrated that second-to-second changes in EEG log spectra covary with, and can be used to predict detections and failures to detect auditory targets during a sustained detection task. Information about operator state might be used by a neural human-system interface to improve overall system safety and performance in a range of applications including transportation and plant management.

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