BRAIN-COMPUTER INTERFACE TECHNOLOGY: THEORY AND PRACTICE

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Fluctuations in Alertness

In tasks requiring sustained attention, human alertness varies on both sub- and supra-n-finute time scales. This can have serious consequences in occupations ranging from air traffic control to monitoring of nuclear power plants. A method of objectively monitoring human operators for signs of drowsiness would by useful in those working environments. Our previous results confinned that the group averages of task performance in an auditory detection task and a visual compensatory tracking task follow similar trends. Initial near-ideal performance begins to decay after about one minute. Thereafter, group mean error rate rises steadily until I I min into the task, after which it remains more or less stable near 30%. However, individual performance on either monitoring task often tends to fluctuate irregularly with central state, including periods of from near twenty seconds to many rninutes of intermittent or complete unresponsiveness (Makeig & Inlow, 1993; Makeig & Jung, 1995; Makeig & Jung, 1996; Jung et al., 1997).

EEG-Based and Eye-Activity Based Alertness Monitoring

We have reported that changes in the electroencephalographic (EEG) power spectrum (including stable individual differences) accompany these fluctuations in the level of alertness, as assessed by measuring simultaneous changes in EEG and performance on an auditory monitoring task (Makeig & Jung, 1996; Jung et al., 1997). These papers showed that continuous, accurate, noninvasive, and near real-time estimation of an operator's global level of alertness is feasible using EEG spectrum. Our recent work suggested that eye activity (blink frequency and duration, fixation frequency and duration, pupil diameter) can also be used to detect the onset of drowsiness in a visual tracking tasks. Our current work is to compare and contrast these two complementary measurements and to discuss how to fuse multiple streams of psychophysiological information to deliver reliable information about changes in the cognitive state of operators of complex computer-based systems. At the workshop we could present the signal processing methods we have used to derive stable near-real time alertness measures and discuss their possible applications to brain-mediated control.

Spontaneous and Single-Trial EEG Signal Processing

Our recent work has focused on developing signal processing tools and methods for single-trial analysis of EEG signals that combine Independent Component Analysis (ICA) and time/frequency analysis (Makeig et al., 1996-99; Jung et al., 1998-99.). Using these techniques, we have developed methods of extracting the activities of the eyes, scalp muscles and spatially stationary brain activities into independent channels. We foresee many uses for this technology, including online artifact elimination and/or muscle and eye activity measurement. At the workshop we might demonstrate use of these tools on a PC or workstation equipped with Matlab, if one is available. The software tools we would demonstrate are publicly available to all participants through our web site (http://www.cnl.salk.edu/~scott/ica.html).

EEG-Mediated Control

Finally, with Richard Sweringen and Marwan Jabri of the University of Sydney, we have begun to explore the use of new paradigms for EEG-mediated control of a computer cursor. At the workshop we might demonstrate a portable computer and experimental data collection task we are using to gather data on this topic, and could discuss our strategy for incorporating out recent advances in EEG signal processing in this effort.

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