

Abstract of Presentation to Associated Professional Sleep Societies

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DETECTION OF ELECTROENCEPHALOGRAPHIC INDICES OF DROWSINESS IN REALTIME USING A MULTI-LEVEL DISCRIMINANT FUNCTION ANALYSIS

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Introduction:

Electroencephalographic (EEG) parameters are sensitive indicators of drowsiness and have proven to correlate with performance on a second-by-second basis (Makeig, 1995). Acquisition of high-quality EEG recordings in workplace environments, such as airplane cockpits, long-haul truck cabins and train-operator's quarters suggest the feasibility of a real-time EEG drowsiness monitor. In this study, a discriminant function analysis (DFA) model designed to classify one-second epochs of EEG on a continuum from highly vigilant to sleep onset was validated. This model utilized methods to overcome between-subject variability in alpha generation as well as distinguish theta activity at sleep onset from frontal midline theta during mental performance tasks (Takahashi 1997).

Methods:

EOG and EEG (CzPz and CzOz) were recorded in fifteen healthy subjects (5 male, 10 female, aged 19 – 52). When fully rested and seated, subjects engaged in challenging mental performance tasks (MPT) and 10-minute sessions using a finger-tapping task to provide behavioral measures of sleep onset (Casagrande 1997) with Eyes Open (EO) and Eyes Closed (EC). Approximately 14 hours after awakening from partial sleep deprivation, subjects completed baseline finger-tapping sessions while seated with Eyes Open (SD-EO) and Eyes Closed (SD-EC). Extended-duration finger-tapping sessions were also conducted periodically throughout the night, with subjects reclining in a dimly lit room and attempting to remain awake. Data representing 344 Sleep onsets (SL) were selected from these sessions based on agreement of the finger-tapping procedure and visual scoring conducted blindly by two certified polysomnographers.

Procedures were utilized to identify and decontaminate eye blinks in the EEG without the use of EOG recordings, and epochs contaminated with other physiological artifacts were identified and eliminated. Predictive variables were selected from the power spectra of one-Hz bins between 1 and 24 Hz and the EEG band, and median Hz bands using step-wise analysis. Randomly selected data from the MPT, EO, and EC were used to assign each subject to one of three databases using cluster analysis. Individualized DFA coefficients were derived from the respective database inverse-covariances and centroids computed from a sub-set of one-second epochs recorded during the MPT, EO, EC and SL conditions; the DFA then classified each one-second epoch as High-Vigilance (HV) or Low-Vigilance (LV), Eyes Closed or Sleep, respectively. A sleep-onset identification rule required either two consecutive epochs to be classified as Sleep or one epoch classified as Eyes-Closed followed by a Sleep epoch.

Results:

The distribution of epochs classified as HV or LV, EC or SL for each condition is presented in Table 1. The model correctly classified 97.5% of the fully-rested epochs and 83.6% of the sleep-deprived epochs as awake. 93.4% of the sleep epochs were classified as SL and over 99% of the sleep episodes were accurately identified. Minimal misclassifications occurred between MPT vs. SL and SL vs. HV.

Conclusions:

The results from this study provide initial validation for the DFA model, designed to run in real-time using digital signal processing technology and resolve many of the problems associated with quantifying EEG, thus providing the first step in the development of a portable EEG drowsiness detection device.

References:

- 1) Makeig S, Jung T: Changes in alertness are a principal component of variance in the EEG spectrum. *NeuroReport*,7,213-216,1995.
- 2) Takahashi N, Shinomiya S, Mori D, Tachibana S: Frontal midline theta rhythm in young healthy adults. *Clinical Electroencephalography*,Jan 28(1),49-54,1997.
- 3) Casagrande M, De Gennaro L, Violani C, Braibanti P, Bertini M: A finger-tapping task and a reaction time task as behavioral measures of the transition from wakefulness to sleep: Which task interferes less with the sleep onset process? *Sleep*,20(4),301-312,1997.

Table 1
Distribution of Classifications of One-Sec Epochs

	HV	LV	EC	SL	# Epochs
Fully-Rested Sessions					
MPT	74.8%	21.6%	1.0%	2.6%	7,366
EO	14.9%	76.2%	7.7%	1.2%	4,354
EC	1.4%	11.4%	83.6%	3.6%	4,300
Sleep Deprived Sessions					
SD-EO	22.6%	62.0%	5.2%	10.2%	2,766
SD-EC	1.6%	10.7%	76.1%	11.5%	1,763
P-SO	10.0%	36.2%	34.3%	19.5%	1,834
SL	2.4%	3.6%	0.6%	93.4%	2,723

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