Validation of Automated EEG Quantification of Alertness: Methods for Early Identification of Individuals Most Susceptible to Sleep Deprivation

Merrill Mitler[2], Philip Westbrook[1] Daniel J. Levendowski[1], Wayne Y. Ensign[3], Richard E. Olmstead[4], Chris Berka[1], Gene Davis[1], Michelle N. Lumicao[1], Milenko Cvetinovic[1], Miroslav M. Petrovic[1]

Introduction:

Electroencephalographic (EEG) indices and neurobehavioral measures were simultaneously acquired to quantify alertness during a 44-hour sleep deprivation study. Psychomotor vigilance (PVT) and paired associate learning/memory (PAL) performance, modified Maintenance of Wakefulness Test (MWT), technician observations of drowsiness (i.e., inspection of video for eye-closures and head nods and EEG slowing) were quantified to validate the B-Alert EEG classification system[1].

Methods:

Twenty-four healthy subjects (18 males, 6 females, age 21–38) completed baseline (beginning ~09:00 on Friday) and nine, three-hour batteries between 19:00 Friday and 05:00 Sunday, with one-hour breaks between batteries and a 40-minute nap at 19:00 Saturday. Continuous EEG (CzOz-differential) and EOG recordings were acquired during: PVT, PAL and a modified MWT. EEG B-Alert classifications, technician observations of drowsiness (available for 18/24 subjects), reaction times (RT) and percentage of correct responses were averaged across each of the PVT and PAL sessions. MWT was terminated following 90 consecutive seconds of EEG evidence of sleep and absence of finger-tapping.

Results:

Repeated measures ANOVA across the 10 time-points revealed progressively increasing drowsiness in all indices as a result of sleep deprivation (B-Alert classifications, technician observations and performance) during PVT and PAL (all p's<0.001).

Pearson product-moment correlations for each subject across time-points showed good agreement. Box plots (Fig. 1) display the median of the correlations, with ~50% of the data represented by the shaded area (fourth-spread), and ~99% of the data within horizontal bars (outlier cutoff points). Since the four subjects identified as outliers exhibited strong performance across all time points, a further examination was conducted.

Thresholds were applied across time-points to the PVT, PAL and MWT measures in an effort to stratify individuals into three groups (good, fair, poor performers) based on vulnerability to sleep deprivation [2,3]. A 3(group) X 10(time-points) repeated measures ANOVA revealed significant effects between groups during the PVT for B-Alert %Sleepy ($p<0.001$) and %Drowsy ($p<0.002$), %Correct and RT ($p<0.001$). The ANOVA during the PAL revealed significant effects between groups for Technician Observation-Drowsy and -Asleep ($p<0.004$), B-Alert %Drowsy ($p<0.032$) and %Sleepy ($p<0.003$), %Correct and RT ($p<0.001$).

Pair-wise comparisons between groups showed that the RT and B-Alert %Drowsy discriminated Good and Fair groups from the Poor group ($p< 0.01$) beginning at 23:00 (See Fig. 2). The B-Alert %Sleepy discriminated the Poor group at baseline ($p<0.01$). None of the measures discriminated the Good from Fair groups.

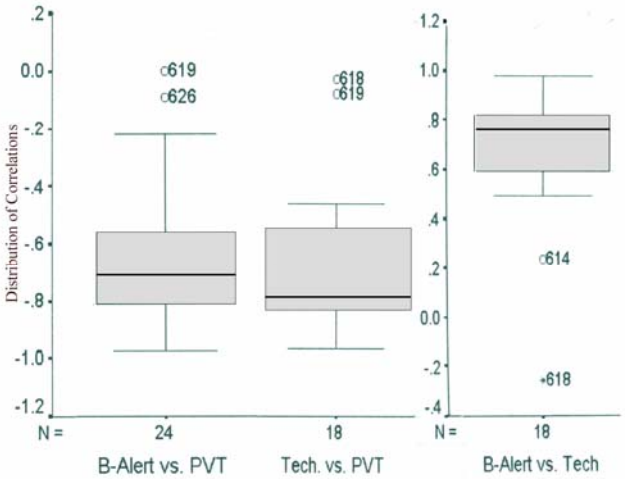

Fig 1. Box-plots of within-subject correlations during PVT at 10 time-points between B-Alert %Drowsy, %Correct and TO-Drowsy.

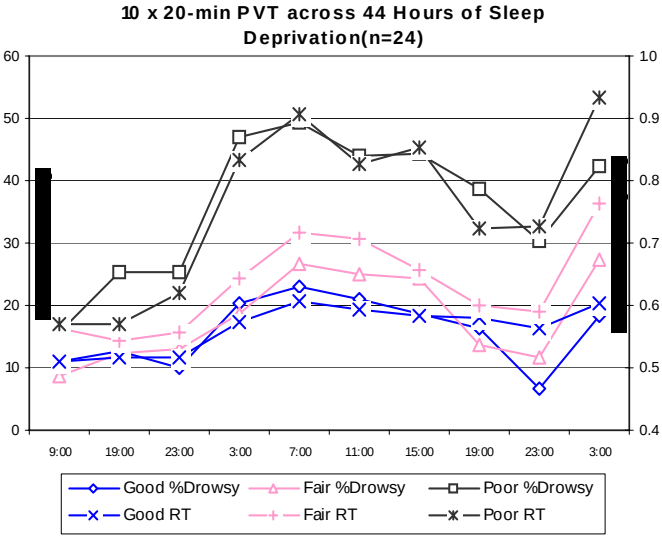

Fig 2. B-Alert %Drowsy and Reaction time for PVT at 10 time-points for three groups stratified by performance across multiple measures.

Conclusions:

The B-Alert classification system correlated with technician observations and electrophysiological and performance measures of alertness. The combination of the B-Alert classifications and neuro-behavioral measures suggest an approach that can identify individuals whose performance is most susceptible to sleep deprivation. Additional research is required to determine whether these objective measures can provide a "biobehavioral assay" to identify individuals most susceptible to sleep deprivation.

References:

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