ALERTNESS/DROWSINESS AND COGNITIVE CAPACITY INDEX

This patent application is a continuation-in-part application of PCT Application No. PCT/US2007/014541 filed on Jun. 22, 2007 and published in the English language on Dec. 27, 2007. PCT Application No. PCT/US2007/014541 claims the benefit of U.S. provisional patent application No. 60/815,565 filed on Jun. 22, 2006 and U.S. provisional patent application No. 60/823,172 filed on Aug. 22, 2006.

I. FIELD OF THE INVENTION

The invention relates to using EEG information to calculate an index score that is indicative of the ability of an individual to perform a cognitive task.

II. BACKGROUND OF THE INVENTION

Sleep deprivation is inevitable in the military environment where the battlefield situation often involves 24 hours or more of continuous operation. Maintaining a high level of alertness and cognitive performance under demands of constant readiness around the clock is not only individually difficult, but also impossible to assess without a means of direct monitoring. The U.S. Army has long been concerned about the potential for catastrophic outcomes as consequences of sleep deprivation which result in poor judgment and performance on the part of military personnel whose decision making ability is impaired. This concern has been realized in the immediate past with the capture of soldiers in Iraq who took a wrong turn on a road and found themselves in unknown enemy territory It was later revealed that the soldiers on this expedition had been without sleep for longer than 24 hours, were cognitively impaired and unaware that they had misread the map. Boot, M., *The new American way of war*, Foreign Affairs, July/August 2003.

Consequential incidents due to sleep deprivation and sleep restriction pertain not only to the military, but also to the public sector in areas of transportation, nuclear facilities, emergency support, and health care providers among the more immediate concerns. Many incidents or near accidents occurring in the public arena are not publicized especially those involving pilot fatigue. Congress is currently investigating why these incidents are not reported to the public and cites the case on Mar. 4, 2004, where both pilot and co-pilot flew three sequential "red eyes" between Denver and Baltimore with only one hour in between flights. During the last 45 minutes of the third flight as it was approaching Denver, both pilot and co-pilot were sound asleep and missed all calls from the air traffic controller while the plane was traveling at 590 mph instead of less than 290 mph. Fortunately, the pilot did suddenly awake to hear the air traffic controller's frantic calls and was able to follow his instructions resulting in a safe landing. Foxnews.com, *Pilot 1st Officer Slept While Approaching Denver, Lawmaker Says*, Oct. 31, 2007.

Even more alarming are the results from a 1992 survey of tractor trailer truckers which found that 19% of the truckers admitted to having fallen asleep at the wheel in the previous month. Braver, E R et al., *Long hours and fatigue: a survey of tractor-trailer drivers*, Journal of Public Health Policy, 1992, Vol. 13, No. 3, pp. 341-366. A report from the Center for National Truck Statistics in 1994 included the disturbing statistic that annually over 5,000 fatalities and 110,000 injuries resulting from motor vehicle accidents involve commercial trucks in the United States. Center for National Truck Statistics, *Truck and bus accident factbook* 1994, Federal

Highway Administration Office of Motor Carriers, 1996 (Report no. UMTRI-96-40). Knipling estimated that the percentage of vehicle crashes in which fatigue was a factor could be as high as 56%. Knipling, R R et al., *Crashes and fatalities related to driver drowsiness/fatigue: research note*, National Highway Traffic Safety Administration, 1994. Although the Department of Transportation (DOT) regulates work hours permitted for truck drivers, pilots, airport controllers and railroad engineers, there is no routine checking for status of alertness (hence being well rested) just prior to start of duty or during duty hours.

A more recent example documented security guards in a Pennsylvania nuclear plant were regularly asleep on the job for periods exceeding one hour. This public exposure resulted in loss of employment and dismissal of the security company providing the staff, but offered no remedy as to how this could be prevented in the future. (Weinberger, 2007).

Brain electrical activity, commonly referred to as electroencephalogram (EEG), is the manifestation of neuronal communication which may be discerned and recorded at the surface of the scalp by electrode sensors and subsequently displayed, measured, and analyzed. Clinically, the EEG is used for detection of brain pathology such as tumors, epileptic seizures, and behavioral abnormalities such as narcolepsy and attention deficit hyperactive disorder (ADHD). The brain signals, collectively referred to as an electroencephalograph, are analyzed for their constituent frequencies (rhythmic oscillations) and/or selective characteristic wave shapes to detect deviations from normal. In the sleep research laboratory, the EEG is used not only for determination of sleep/wake states and for quantification of sleep amount during nighttime sleep but also to track sleepiness level during the course of sleep deprivation studies of normal, healthy individuals.

Polysomnography is the methodology for defining the awake and sleep states from observation of EEG signals over an extended time period. As its name implies, other physiological measures are recorded synchronously with the EEG to aid in differentiating the awake from the sleep state as well as marking the different stages of sleep. Multiple electrode sensors are attached to the scalp, face, and body of the individual under study to record both the neurophysiological (EEG) and basic physiological measures such as electrooculogram (EOG) for recording eye movements; submental electromyogram (EMG) from the chin for detecting muscle movement; and electrocardiogram (EKG) for heart rate. Although the EEG is the main determinant of sleep characteristics, the EOG and EMG aid in defining Rapid Eye Movement (REM) sleep more commonly known as the dream stage in which it is conjectured that memory consolidation occurs. REM is thus distinguished from non-Rapid Eye Movement (NREM) sleep which defines all other sleep stages. Rolling eye movements observed in the EOG are characteristic during REM simultaneously with muscle atonia as noted in the EMG. During night time sleep, the REM state alternates with non-REM sleep in ultradian cycles of approximately 90 minutes and increases in length as non-REM length decreases in the progression towards the end of the sleep period. The EKG provides continuous monitoring of heart rate not only to assure normal functioning, but also to confirm the deeper sleep stages when the reduced rate of heart beats indicates slowing of body functions.

Although the frequency realm of EEG is in cycles per second or Hertz (Hz) and several orders of magnitude higher than that of ultradian frequencies (i.e., cycles/24 hours), the same fundamental principles of rhythmic behavior apply. The EEG signal as visually observed in its entirety is a combination of all the frequencies selected for recording in the acqui-