METHOD AND SYSTEM FOR PREDICTING HUMAN COGNITIVE PERFORMANCE

This application is a continuation of U.S. application Ser. No. 10/377,602, filed on Mar. 4, 2003, now U.S. Pat. No. 6,740,032, which is a continuation of U.S. application Ser. No. 09/844,434, filed on Apr. 30, 2001, now U.S. Pat. No. 6,530,884, which is a continuation-in-part of PCT Application No. PCT/US99/20092, filed Sep. 3, 1999 (which designates the United States and was published on May 11, 2000), which claims priority from U.S. provisional Application Ser. No. 60/106,419, filed Oct. 30, 1998, and U.S. provisional Application Ser. No. 60/122,407, filed Mar. 2, 1999; and U.S. application Ser. No. 09/844,434 claims the benefit of U.S. provisional Application Ser. No. 60/273,540, filed Mar. 7, 2001. These patent applications are hereby incorporated by reference.

I. FIELD OF THE INVENTION

This invention relates to a method for predicting cognitive performance of an individual preferably based on that individual's prior sleep/wake history, the time of day, and tasks (or activities) being performed by the individual.

II. BACKGROUND OF THE INVENTION

Maintenance of productivity in any workplace setting depends upon effective cognitive performance at all levels from command/control or management down to the individual soldier or worker. Effective cognitive performance in turn depends upon complex mental operations. Many factors have been shown to affect cognitive performance (e.g., drugs or age). However, of the numerous factors causing day to day variations in cognitive performance, two have been shown to have the greatest impact. These two factors are an individual's prior sleep/wake history and the time of day.

Adequate sleep sustains cognitive performance. With less than adequate sleep, cognitive performance degrades over time. An article by Thorne et al. entitled "Plumbing Human Performance Limits During 72 hours of High Task Load" in Proceedings of the 24th DRG Seminar on the Human as a Limiting Element in Military Systems, Defense and Civil Institute of Environmental Medicine, pp. 17-40 (1983), an article by Newhouse et al. entitled "The Effects of d-Amphetamine on Arousal, Cognition, and Mood After Prolonged Total Sleep Deprivation" published in *Neuropsychopharmacology*, vol. 2, pp. 153-164 (1989), and another article by Newhouse et al. entitled "Stimulant Drug Effects on Performance and Behavior After Prolonged Sleep Deprivation: A Comparison of Amphetamine, Nicotine, and Deprenyl" published in *Military Psychology*, vol. 4, pp. 207-233 (1992) all describe studies of normal volunteers in which it is revealed that robust, cumulative decrements in cognitive performance occur during continuous total sleep deprivation as measured by computer-based testing and complex operational simulation. In the Dinges et al. article entitled "Cumulative Sleepiness, Mood Disturbance, and Psychomotor Vigilance Performance Decrements During a Week of Sleep Restricted to 4-5 Hours Per Night" published in *Sleep*, vol. 20, pp. 267-277 (1997), it is revealed that on fixed, restricted daily sleep amounts, cumulative reduced sleep also leads to a cognitive performance decline. Thus, in operational settings, both civilian and military, sleep deprivation reduces productivity (output of useful work per unit of time) on cognitive tasks.

Thus, using computer-based cognitive performance tests, it has been shown that total sleep deprivation degrades human cognitive performance by approximately 25% for each successive period of 24 hours awake. However, it also has been shown that even small amounts of sleep reduce the rate of sleep loss-induced cognitive performance degradation. Belenky et al. in their article entitled "Sustaining Performance During Continuous Operations: The U.S. Army's Sleep Management System," published in 20th *Army Science Conference Proceedings*, vol. 2, pp. 657-661 (1996) disclose that a single 30-minute nap every 24 hours reduces the rate of cognitive performance degradation to 17% per day over 85 hours of sleep deprivation. This suggests that recuperation of cognitive performance during sleep accrues most rapidly early in the sleep period. No other factor besides the amount of sleep contributes so substantially and consistently to the normal, daily variations in cognitive performance.

In addition to sleep/wake history, an individual's cognitive performance at a given point in time is determined by the time of day. In the early 1950s, Franz Halberg and associates observed a 24-hour periodicity in a host of human physiologic (including body temperature and activity), hematologic, and hormonal functions, and coined the term 'circadian' (Latin for 'about a day') to describe this cyclic rhythm. Halberg showed that most noise in experimental data came from comparisons of data sampled at different times of day.

When humans follow a nocturnal sleep/diurnal wake schedule (for example, an 8-hour sleep/16-hour wake cycle, with nightly sleep commencing at approximately midnight), body temperature reaches a minimum (trough) usually between 2:00 AM and 6:00 AM. Body temperature then begins rising to a maximum (peak) usually between 8:00 PM and 10:00 PM. Likewise, systematic studies of daily human cognitive performance rhythms show that speed of responding slowly improves across the day to reach a maximum in the evening (usually between 8:00 PM and 10:00 PM) then dropping more rapidly to a minimum occurring in the early morning hours (usually between 2:00 AM and 6:00 AM). Similar but somewhat less consistent rhythms have been shown from testing based on various cognitive performance tasks. Thus, superimposed on the effect of total sleep deprivation on cognitive performance noted above was an approximately ±10% variation in cognitive performance over each 24-hour period.

Various measures have been shown to correlate, to some extent, with cognitive performance. These include objective and subjective measures of sleepiness (or its converse, alertness). Some individuals familiar with the art use "sleepiness" to indicate the opposite of "alertness" (as is the case in the present document). "Drowsiness" often is used interchangeably with "sleepiness" although some familiar with the art would argue that "sleepiness" pertains specifically to the physiological need for sleep whereas "drowsiness" refers more to the propensity or ability to fall asleep (independent of physiological sleep need) or the subjective feeling of lack of alertness. The term "fatigue" has been used as a synonym for "sleepiness" by the lay population, but those familiar with the art do not consider "fatigue" to be interchangeable with "sleepiness"—rather, "fatigue" is a broad term that encompasses more than just the effects of sleep loss per se on performance. Likewise, "cognitive performance" has been defined as performance on a wide variety of tasks, the most commonly used being vigilance tasks (tasks requiring sustained attention). From vigilance and other tasks, some researchers use accuracy as their measure of cognitive performance, while others use reaction time (or its inverse, speed). Still others use a measure that is calculated as speed multiplied by accuracy, that is the amount of useful work performed per unit of time (also known as throughput). Those familiar with the art generally agree that vigilance tasks are