



## Interventions for sleep deprivation induced cognitive dysfunction

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### ABSTRACT

Cognition is a complex phenomenon that involves the higher order mental processing and integration. The cognitive functions of any individual are prone to be altered in various physiological and pathological conditions. In particular, sleep deprivation produces cognitive impairments affecting over all well-being and performance. In various professionals prolonged working hours and sleep deprivation is an unavoidable reality. Such sleep deprivation caused by occupational demands decreases work efficiency and growth. Several strategies have been designed to optimize cognitive functions during sleep deprivation. Specifically, various cognitive enhancers have been used extensively to improve most crucial cognitive domains. The recent approaches include mainly pharmacological or non-pharmacological interventions. This review focuses on such countermeasure for sleep deprivation induced cognitive impairments. We concluded that all the available interventions can be used to improve cognitive functions depending upon the duration of sleep deprivation and the target population. Most of these are cost effective with minimal adverse effects.

**Keywords:** Interventions, sleep deprivation, cognitive dysfunction

### OVERVIEW

Cognition refers to the higher mental process involved in thinking, language, memory, attention, perception, planning, intelligence and problem solving [1]. They are subjective in nature and may be affected by various neuropsychiatric disorders and physiological stress [2]. Sleep is indispensable to human survival and needed for optimal health and performance. Sleep deprivation produces range of cognitive impairments in humans including deficits in attention, executive function, non-declarative and declarative memory, as well as emotional reactivity and sensory perception [3-4]. In various professionals such as industrial shift workers, medical and ancillary staff in hospitals, workers in transport and telecommunication sectors, trans-meridian pilots, and armed force personnel, prolonged working hours is an unavoidable reality. Sleep deprivation caused by occupational demands associates with the diminished cognitive function and contributes to decreases in work efficiency that has large financial and social costs [5-6]. Therefore, the need to evolve appropriate strategies for sustained and optimum mental performance during irregular work schedules has been realized. Cognitive enhancers are molecules or methods that improve some aspect of brain function or cognition [7]. They may be Pharmacological (i.e. herbal medicine or pharmaceutical drugs) or non-pharmacological (i.e. physical exercise, meditation, computer training and brain stimulation).

### Non-Pharmacological Intervention

#### Napping

Nap is one of the effective countermeasures to prevent decreasing alertness during sleep deprivation [8-9]. Recent research has examined various kinds of napping strategies to counteract the problem among night shift workers. One such strategy is taking a prophylactic nap before the night of sleep deprivation, another strategy is taking a morning-, forenoon- or afternoon nap following night of sleep deprivation, and the third strategy is taking a nap during the night of sleep deprivation [10-12]. Naps taken during late afternoon and early evening fall in the 'forbidden zone', which occurs at the peak of the alerting phase of the circadian rhythm whereas nighttime nap has been considered more effective as it prevents the disturbance of circadian rhythm [13]. Long naps of 30-120 min duration are more beneficial for cognitive performance than short ones (i.e.15 min) after total sleep deprivation [14]. A recent study by our group used 30-min nap as a countermeasure during one night's sleep deprivation reduces cognitive decline and improves the relevant

electrophysiological function in terms of the latencies of P300 and CNV responses, along with a reduction in subjective sleepiness [15-16].

### **Meditation training**

Meditation is a discipline by which one attempts to get beyond the conditioned; “thinking” mind into a deeper state of relaxation or awareness. Meditation is known to have beneficial effects on various psycho-somatic profiles [17-18]. Meditation practice has been emphasized to promote mental well-being, enhance attention and other cognitive capacities [19-20]. A number of reviews revealed positive effects of meditation on attention, memory, executive function, processing speed, and general cognition in age related cognitive decline, neurodegenerative disorders and other mental illness [21-23]. We used Brainstem auditory evoked potentials, Event related potentials: middle latency response, P300- and contingent negative variation and standard neuropsychological tests, Conner’s Continuous Performance Test – II, PGI battery, Stroop’s Colour Word Interference, Maze tracing and Raven’s Advanced Progressive Matrices to evaluate cognitive impairment after total sleep deprivation (SD) and to study the impact of 2 months of meditation training as an intervention. The study showed that practice of meditation for two months reduces the various aspects of cognitive decline including different components of memory, attention, vigilance and others as assessed by Postgraduate Institute of Brain Dysfunction, Stroop’s Color World Interference, middle latency response and P300.

### **Cognitive retraining**

Techniques of stimulating brain and cognition are widely practiced in ageing population, dementia and neuropsychiatric disorders. Cognitive training is an efficient method to delay cognitive decline in persons with mild cognitive impairments. Several types of cognitive trainings are available aimed at improving memory, learning, attention, executive functions or global cognition [24-27]. Moreover, a recent study showed that the computerized cognitive training improves sleep quality and cognitive function i.e. avoiding distractions, working memory, visual memory, general memory and naming in older adults with insomnia [28-29]. Some preliminary studies from our laboratory also indicate the beneficial effect of cognitive training in amelioration of cognitive deficit induced by total sleep deprivation. These line of evidences suggest that cognitive abilities can be trained and enhanced in sleep deprived individuals, and that personalized adaptive cognitive training which targets uniquely impaired functions in each individual may be particularly appropriate for the identification and rehabilitation of these impairments. However, further investigation should examine the potential long-term the beneficial effect of cognitive training for total sleep deprivation.

### **Pharmacological Approaches**

#### **Caffeine**

Caffeine has been regarded as a CNS stimulant and widely used as an effective strategy to counteract the effect of sleep deprivation on cognition. Effects of caffeine on quantitative EEG showed a significant decrease in relative alpha and theta after sleep deprivation independent of cognitive and motor performance [30-31]. These evidences show that quantitative EEG seems to be the most sensitive index of the changes produced by caffeine in the CNS. However, other studies showed that the beneficial effect of caffeine can also be manifested onto the cognitive performance. Killogore et., al showed that caffeine is an effective countermeasure in restoring simple alertness and psychomotor vigilance as well as executive functions after 44 h of continuous wakefulness [32-33]. A recent study also showed that peak power and reaction time on Wingate tests improved with caffeine ingestion after 36 h of total sleep deprivation [34]. Moreover, several efforts have been made in order to explore the cellular underlying mechanism in cognitive benefits of caffeine during sleep deprivation [35]. These studies utilizing animal model showed that chronic caffeine treatment prevents sleep deprivation-induced impairment of cognitive function, synaptic plasticity and adult neurogenesis [36-40].

#### **Modafinil**

Modafinil is a wake promoting agent and is currently prescribed for various sleep disorders to enhance cognition [41]. It has been shown to improve cognitive performance and promote wakefulness among shift workers, military personnel and health care workers [42]. Recent studies on healthy adults with total sleep deprivation reported that a single-dose of modafinil 400 mg reduced errors on the Wisconsin card sort test and interference on the Stroop’s test [43-44]. We evaluated the efficacy of modafinil as a countermeasure in the reduction of cognitive decline following 24 h of sleep deprivation on subjective sleepiness scales, event-related potential P300, and contingent negative variation [45]. The results suggest that modafinil in a dose of 400 mg/day, reduces the subjective sleepiness and cognitive decline following 24 h of sleep deprivation. A more recent observation showed that a strong activation of fronto-cortical areas involved in higher cognitive function could be found upon modafinil administration in rats at doses producing plasma level concentrations resembling those found to be efficacious in clinical studies [46]. It appears to have cognitive enhancing by activating different brain areas and circuit as compared other psychostimulants, while sharing inhibition of dopamine reuptake as a common mechanism underlying its pharmacological effects [47-51]. Recent research also identified several non-dopaminergic effects of modafinil, such as the increase of electrical neuronal coupling, or the enhancement of histamine and orexin neurotransmission that might be of primary importance to explain its efficacy as a wake-promoting agent, even in non-sleep deprived individuals [52-55].

#### **Dextroamphetamine**

Dextroamphetamine (d-alpha-methylphenethylamine), a psychostimulant is currently approved in the United States for treatment of narcolepsy and attention-deficit disorder with hyperactivity. Dextroamphetamine like other stimulants, has been shown to be equally effective in restoring alertness and vigilance following continuous wakefulness [56-58]. However, it showed differential effectiveness for sustaining specific aspects of executive functioning on tasks requiring visuospatial working memory and problem solving, while no effect was observed on perseverative responses on a complex reasoning task [59]. Sleep deprivation induced alteration in risk-related judgments, decision-making, and behavioral control are also sustained by dextroamphetamine treatment. Moreover, a recent study showed the beneficial effects of d-amphetamine on simulated driving performance before and after sleep deprivation [60].

### Concluding remarks

The available information on some pharmacological and non-pharmacological interventions on cognition during sleep deprivation has been presented in this review. All the interventions can be envisioned as somewhat effective in maintaining and sometimes improving optimal levels of cognitive capabilities. Most of these are cost effective with minimal adverse effects. The intervention can be used depending upon the duration of sleep deprivation and the target population. Modafinil and dextroamphetamine can be used during a situation demanding total sleep deprivation. Caffeine taken in a cup of coffee may be effective for a couple of hours. On the other hand, meditation and cognitive retraining can serve as general cognitive enhancers which would be beneficial in a situation of small to larger sleep deprivation. Nap taken before or during sleep deprivation of the appropriate duration i.e. shorter or longer nap depending upon the period of sleep deprivation would be beneficial for maintaining cognition.

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