

Vigilance Enhancement Using Traditional Methods: A Review

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Abstract: This paper presents a review on vigilance enhancement using traditional methods and discusses their contradictory findings. The review highlights the key differences between research findings and argues that individual differences could be a significant contributing factor to the controversial results. In this paper, we found that, traditional enhancement methods are reliable and have significant effects on reducing vigilance decrement. The paper discusses the challenges toward the enhancement techniques and provides evidence to use the traditional enhancement on vigilance studies, regardless of their variations with individual differences.

1 Introduction

Vigilance, or sustained attention, involves the ability to maintain focus and remain alert for prolonged periods. The term vigilance occurs across a range of work settings including air traffic control, power-transmission control operation, nuclear power plant operation, closed circuit television security monitoring, automated vehicle driving, and airport baggage screening [1]. Vigilance requires hard work and it is stressful. Converging evidence using behavioral, neural, and subjective measures shows that vigilance requires hard mental work and is stressful.

The vigilance decrement is defined as the decreased probability of detecting critical trials in such tasks as time on task increases. A substantial empirical literature has demonstrated that the magnitude of the vigilance decrement is impacted by a variety of task factors, including the stimulus presentation time, the degree of memory involved in the task, stimulus presentation rate, and sensory modality [2]. Vigilance, or sustained attention, involves the ability to maintain focus and remain alert for prolonged periods. The term vigilance occurs across a range of work settings including air traffic control, power transmission control operation, nuclear power plant operation, closed circuit television security monitoring, automated vehicle driving, and airport baggage screening [3]. Particularly, the application of vigilance is widespread and potentially ubiquitous for semi-automated, automated, and autonomous system interaction [4]. The vigilance decrement is thought to have caused or contributed toward numerous operational failures. Extreme cases include airplane crashes due to missed mechanical faults during routine inspection, close calls with terrorist agents when security screeners miss suspicious cues, and military casualties due to poor detection performance by surveillance personnel.

Traditional neuropsychological assessment of attention include the so-called vigilance tests, which typically involve the sequential presentation of stimuli such as letters or numbers over a period of time, and the subject must indicate in some way when a given stimuli is perceived. For instance, the Continuous Performance Test II (CPTII) requests subjects to indicate when a letter other than X appears in the screen; scoring in this test takes into consideration both errors of omission and of commission (accuracy data), as well as reaction times. The CPTII takes over 14 min, which is sufficient time for evaluating sustained attention. Long formats of the Stroop Test can also be used for detecting problems with sustained attention—subjects with impairments in sustained attention slow down as they proceed. Other possibility to assess attention span is the Test of Variables of

Attention (TOVA). However, the main criticism to those traditional tests is that they are far to be ecologically valid. The following section discuss the state of art on vigilance enhancement using traditional methods.

2 State of the art

The following sub-sections discuss in details the finding obtained by traditional enhancement techniques. Only most effective traditional enhancement techniques involved in this review for fair comparison with unconventional means in term contradictory findings, effectiveness, and cost.

2.1 Caffeine

Caffeine is one of the most consumed psychoactive substance in the world [5]. The use of caffeine to stay awake and alert is a long-standing habit with a daily amounts of approximately 1.6 billion cups [6]. The stimulant effects of caffeine on the central nervous system have been known for centuries [7]. Several studies have reported that low to moderate doses of caffeine have positive effects on vigilance performance [8-13], and the speed of reaction to task response [12, 14-16]. However, the duration of action on vigilance may depend on the amount of caffeine intake. Doses of caffeine ranging from 32 to 256 mg have shown to improve auditory and visual vigilance, detection rates and reduced reaction time to stimuli in individual adults performed vigilance task for several hours [12, 17]. Fine et al. [16] confirmed and extended these findings by demonstrating that caffeine affect visual vigilance in 24 rested young males. In this study, an amount of 200 mg of caffeine significantly and consistently improved the number of correct responses and decreased the reaction time to stimuli in comparison to placebo for a total duration of 2-h of testing. Lanini,[18] reported that personalized individual caffeine doses from 25 mg to 300 mg improved vigilance of 60 young adults performed psychomotor vigilance task. In this study, caffeine significantly reduced the mean reaction time and led to less variable response times from the beginning to the end of 10 min performance of vigilance task.

Similarly, study in [19] reported that 200 mg dose of caffeine significantly improved the lane-tracking performance of subjects during monotonous, 2-h afternoon and early-morning drives in an automobile driving simulator. Kilpelainen et al [20] studied the effect of caffeine on vigilance and cognitive performance of 15 military pilots who received either placebo or 200 mg of caffeine twice a day during extended wakefulness of 37-h. The results showed that, caffeine group hit more targets than the placebo group suggesting that the overall caffeine group's vigilance was slightly better. Kamimore [14], tested the effectiveness of repeated four 200 mg doses of caffeine on cognitive function and live-fire marksmanship with 20 soldiers performed PVT, field vigilance, and logic reasoning tests during three successive nights of sustained wakefulness. The results showed that, caffeine maintained speed on the PVT, improved detection of events during PVT, increased number of correct responses to stimuli and increased response speed during the logic-reasoning test. Doan[21], investigated whether moderate doses of caffeinated tube food (200 mg) would enhance performance of 12 pilots in a simulated U-2 mission. The results showed that caffeinated tube food improved cognitive performance, vigilance and mood of pilots over 9 h. McLellan [22], examined the effects of 100 mg, and 200 mg of caffeine on physical, vigilance and marksmanship tasks in 30 soldiers during a sustained 55-h field exercise. The study concluded

that, caffeine was an effective strategy to sustain vigilance and psychomotor during military operations.

Similar improvements were also found in 101 hemodialysis patients of habitual coffee consumption when they received 120 mg dose of caffeine validated beneficial impact on cognitive function in hemodialysis patients due to selective enhancement of attention and vigilance [23].

However, the effects of caffeine on higher cognitive functions remained under debate. While caffeine may increase the ability to stay awake, it does not necessarily help in making good decision, a skill that is critically important to military and driving occupations. It is also not clear whether caffeine has positive or negative effects on mood and emotional state. It is necessary to investigate another form of fatigue countermeasure to enhance alertness and performance. Some studies have shown the effectiveness and safety of caffeine but for some vulnerable populations, excessive intakes may increase the risk of dehydration, cardiovascular function, headache and sleep disturbances, and substance use, for reviews refer to [24-28].

The research findings of caffeine on vigilance still conflicting and its effects dependent on the individuals and the amount of doses. Study in [10], reported that 500 mg dose impaired performance of 12 healthy subjects at 45 min post-administration time. Nevertheless, it seems that, low doses of 40 mg to moderate 300 mg doses improve alertness, vigilance, and reduce reaction time, but less consistent effects are observed on memory and higher-order executive function, such as judgment and decision making [29-31].

2.2 Fragrance Administration

The sense of smell plays an important role in the physiological effects of mood, attention and working capacity. Studies have reported that introducing certain type of fragrance can improve attention, vigilance performance and reduce stress [32-38]. Administering high-valence odors of peppermint and cinnamon showed improvements in vigilance and reaction time to stimuli [39, 40]. Several studies have investigated the effects of olfaction on human behavior while doing cognitive vigilance tasks. Study [41] investigated the effects of the presence of ambient scents while doing vigilance task of anagram and word completion tests and found significant reduce in vigilance decrement and improved attention, mood and cognition. Another study by [42] explored the effects of olfaction on human behaviors while doing three different vigilance tasks namely: clerical tests typing, memorization, and alphabetization, in either a non-scented or a peppermint-scented condition. The results showed significant improvement in the speed, and accuracy on the typing and alphabetization, with peppermint scent associated with increased performance.

Manor et al., [32] found that, the performance and accuracy in detecting vigilance task increased when subjects received short whiffs of either muguet or peppermint fragrances as compared to those who received only whiffs of pure air. The vigilance task in this study involved detecting when two lines presented with a separation of 10 mm were instead presented with a separation of 12 mm. Jones [43] examined the effects of pleasant and unpleasant fragrances with the same vigilance task used by [32] study. The results confirmed that exposure to pleasant odors did enhance vigilance performance. In line with that, exposure to pleasant ambient fragrance of lemon aroma on people performing simulating driving task [34] revealed significant enhancement on driving performance and increased the level of alertness. Another study by [44] investigated the effect of the volatiles emitted from the leaves of *Laurus nobilis* at low and high doses on vigilance performance in a visual discrimination task. The result found that low concentration of *Laurus*

noblis maintained high level of vigilance performance and improved the detection rate and physiological arousal.

However, alerting properties of peppermint could be unreliable. For example, Moss et al. [45] reported a significantly higher alertness when people exposed to peppermint compared to ylang-ylang, but was not significantly greater than the non-odor condition which suggests that peppermint does not increase alertness by itself. Another studies by [46-48] reported no effects of peppermint in detecting visual signal in a vigilance task. A possible explanation for the conflict may relate to habituation. In Warm et al. [32] the odor was presented with 30 s bursts for every 5-min via a mask; whereas in Gould and Martin [46] the odor was present throughout the 20-min vigilance task as performed by Moss et al. [45]. Other factors on the effects of fragrance on vigilance could be its concentration, mood state and time-on-task and experimental protocol.

2.3 Chewing Gum

Chewing gum traditionally used to prevent sleepiness during work, learning, and driving suggesting a link between chewing and vigilance enhancement. Studies have reported positive effects of chewing gum on vigilance performance, alertness and stress [49-56]. Chewing gum maintain and increase self-rated level of alertness a factors that contribute to enhance vigilance [51, 57]. Allen, [53] investigated the effects and after-effects of chewing gum on vigilance, mood state, heart rate and brain oscillation measured by EEG. The results showed that, chewing gum reduced the reaction time to stimuli, increase the detection rate of hits, heightened heart rate and increased EEG beta power at F7 and T3 immediately after chewing. The mood state and time-on-task are important factors in the psychodynamic of gum chewing. Tucha, [58] examined the effect of 30 min chewing gum on healthy adults while performing vigilance task. The result showed that chewing gum decreased the reaction times to target stimuli during the first 20 min of vigilance task compare to control group of people who did not chew gum. Another study, [55] investigated the effects of 30 min chewing gum on people performing an auditory vigilance task involved listening to a random presentation of the digits between 1 to 9 at a rate of one per second. The result showed significant decreased in the reaction time and improved alertness in people chewed gum compared to non-gum chewing. Likewise, [59] used a variety of techniques to study the links between gum chewing and performance, alertness, and stress. The results suggested that chewing gum could reliably maintain alertness, enhance performance at work, and reduce vigilance decrement. It could be concluded that, the improvement on sustained attention, alertness and the reduce in vigilance decrement with chewing gum might be due to that gum enhanced delivery of glucose to the brain as a result of insulin secretion during mastication was responsible for the improved performance [60]. Unlike other enhancement techniques, chewing gum is an easy method for modifying cognitive function on a daily basis and does not demand any physical or mental efforts.

However, the reported effects of chewing gum on sustained attention have been rather inconsistent and still not been fully clarified. A recent review of 22 studies [52] highlighted that 64% of studies indicated positive attributes of effects on attention, 5% showed negative attribute, 23% showed both positive and negative attributes of effects on attention, and 2% showed no significant effects. This could be due to the variations on experimental protocols, brand of gum, familiarity with gum and the method used for analysis. Also, the effect of chewing gum on attention seems to be highly influenced by time-on-task and the duration of action may not last 20 min [61] or 30 min [58].

3 Conclusion

This review provides evidence that traditional means of enhancement can significantly reduce vigilance decrement. Although, these methods are highly sensitive to individual differences, using proper amount of doses can effectively elevate vigilance. The review also highlights that; the effects of enhancement will depend on the duration of action and suggest using more appropriate experimental protocol to handle that.

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