# Vigilance Enhancement Using Computerized Techniques

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## Abstract:

This paper presents a review on vigilance enhancement using computerized means and discusses their contradictory findings. It highlights the key differences between research findings and argues that variations in experimental protocol could be a significant contributing factor to the controversial results. In this paper, we found that, computerized means of enhancement are reliable and have significant effects on reducing vigilance decrement. The paper discusses the challenges toward the enhancement techniques and suggests several alternative strategies to reduce vigilance decrement. Furthermore, this review provides evidence to use computerized means of enhancement on vigilance studies, regardless of their practical challenges.

## 1 Introduction

Sustained attention or vigilance is a higher brain cognitive state which allows us to accurately detect and respond to external stimuli over long periods of time. Humans differ in their ability to handle vigilance and cognitive workload. We may suffer a drop in cognitive efficiency due to the excessive working memory demand and switching between multiple tasks. On the other hand, it is quite intriguing to note that vigilance decrement caused by monotonous stimuli may also lead to a drop in cognitive efficiency. Monotonically repetitive or quasi-static types of stimuli can lead subjects to withdraw attentional effort and disengagement from the monitoring task leading to a drop in cognitive performance and increased error. Research shows that target detection performance decreases by 15 percent in 30 minutes of a monotonous task. But in modern human computer interface environment, systems should be optimized to help humans make the “correct” decision at the right time. Examples of jobs that are influenced by vigilance decrement include driving for long distances such as lorry drivers, military surveillance, industrial control, air traffic control and power plant operation. Vigilance decrement can lead to fatal consequences. Driver fatigue is a concerning problem, causing many car fatalities every year. Over 800 fatalities and 30,000 injuries from car crashes were due to fatigue driving in the United States in 2009. In China, 1768 fatalities were attributed to fatigue driving in 2007. Previous research has reported that fatigue was responsible for 20–30% of the total road fatalities [1, 2]. In the following section, we present the state of the art of enhancement techniques using computerized machine.

## 2 State of the arts

The following sub-sections discuss in details the findings obtained by different studies and highlight the key differences between them taking in consideration several factors that affect vigilance.

### 2.1 Video Game

Nowadays, Action Video Game (AVG) has become a routine activity among children and adolescents. Green and Bavelier defined AVG by those that have "fast motion and required vigilant monitoring of visual periphery and simultaneous tracking of multiple targets" [3]. Researchers have found positive effects of AVG on basic mental processing such as perception, sustained attention, memory, cognitive skills and decision-making [3-10]. These studies showed significant improvement in the cognitive abilities of gamers compared to no-gamers as reported by detection rate of targets/accuracy, response time and false alarm. Trick et al.,[11] found that AVG improved the ability of children and adults to keep track of a set of moving objects that were visually identical to other moving objects in the visual field. Anguera [12], demonstrated in an experiment conducted on 179 subjects, that cognitive abilities including sustained attention and preservation of multitasking of the subjects who received computer game training has significantly improved. Another study by Green [5] found that AVG improved performance at locating targets presented in rapid rate and at tracking several moving items in the presence of distractors.

Several studies have reported that, training, getting knowledge of results (KR), and expertise level of the gamer made an important contribution to sustained attention [12-19]. Kluger et al. reported that, receiving feedback on the performance not only has an informational function, but also has motivational properties that have an important influence on learning [14]. Complete feedback provides player with information about signal characteristics in the task, particularly Hit and False Alarm (FA) rates. When players alerted to signals in this way, they tend to maintain sustained attention and the proportion of correct detections will be high while the number of FA committed remains low. Others demonstrated that KR provided during a vigilance task improved performance over time and transferred to a task similar to the training task [15-17]. In facts, getting KR improved the overall performance during training as well as during subsequent test session in which feedback had been withdrawn [20-23]. Analysis of previous studies revealed that action video game players (AVGPs) showed significant advantages over non-video game players (NAVGPs) as it relates to vigilance performance (i.e. proportion of correct detections, response time, false alarms, etc.). Additionally, workload analysis showed that AVGPs rate the task lower than NVGPs in terms of total or global perceived workload [24].

Interestingly, AVG studies on sustained attention up to date has not found a systematic gender differences [25-27]. For instance, [26] did not find any difference in vigilance performance of male and female children aged between 3 and 7 years, and [25] found no gender differences in auditory and visual vigilance tasks in both participants, child and adult. Another study found that, a 10-h training in AVG was enough to compensate for baseline gender differences in spatial attention, and to reduce the gap in mental rotation skills [28]. Whether the initial difference was innate or a product of lesser exposure to this kind of activities in women is a matter of debate [7]. Although, AVG has demonstrated its potential in enhancing cognitive abilities, we believe that the use of computer games as a means to enhance vigilance might not be very practical and doomed to failure as it may take the attention off the current task at hand.

### 2.2 Transcranial Direct Current Stimulation

Transcranial direct current stimulation (tDCS) is a neuromodulatory technique that applies a small current in the range of 1 to 2 mA to the scalp and is considered safe for periods up to 30 min [29]. The tDCS causes changes in neuronal excitability through membrane polarization and the changes in synaptic strength [30, 31]. The direction of the cortical effects mainly depends on the polarity and the waveform of the applied current. For example, anodal stimulation typically depolarizes the resting membrane potential, bringing neurons closer to their firing threshold, while cathodal

stimulation decreases neuronal excitability [32]. Changes in cortical excitability lasted over one hour and have been demonstrated after few minutes of stimulation [33]. Interestingly, there has been an increasing amount of research in the use of tDCS on cognition and clinical studies [34-36].

Recent studies have examined the effects of tDCS on vigilance, attention and at alleviating problem at workplace [34, 35, 37-43]. However, the effects of tDCS depends on the period of stimulation as well as the electrode placement on the brain areas. For example, [37] applied 1mA to the dorsolateral PFC (in the F3 and F4 position) for 10 minutes reported vigilance enhancement in a simulated air traffic controller task. The tDCS increased target detection performance and operator discriminability as well as increased cerebral blood flow velocity and oxygenation when compared with a sham condition. Similarly, [44] applied 2 mA to the left dorsolateral PFC (in F3 position) for 30 minutes and used the right upper arm as reference while people doing Mackworth Clock Test and Psychomotor Vigilance Task. The results showed improvements on vigilance, to the same or greater extent than caffeine. [45] studied the effects of tDCS on sustained attention task, reported an increment in the mind wandering but no effects were found on accuracy or reaction time. These findings indicate that tDCS may be well-suited to enhance performance degradation and showed that the frontal lobe play a major role in mind-wandering behavior. Study in [46] applied tDCS to the parietal lobes of healthy adults during visual vigilant task with numerical characters, showed enhancement of numerical proficiency. Another studies stimulated the parietal lobes during training of a vigilance numerosity task showed improvements on discernable effects up to weeks [39-41]. The technique has reported positive impact on improving cognitive function of people with cognitive impairments by reducing symptoms of attention deficits [35, 42, 43] and alleviate vigilance problems at work [38].

However, not all studies showed positive effects of tDCS on sustained attention. Study in [47] applied 2 mA to parietal cortex for 30 minutes and found that tDCS negatively affected performance on the final block of a reaction time task. Other studies employing a go/no-go task and found no effects of tDCS on performance when increased demand was placed on inhibitory control and set shifting abilities [48-50] for review refer to [51]. The studies reported that, genetic factors modulate effects of tDCS on cognitive performance. Therefore, genetic variability should be considered in the design and analysis of future tDCS studies. Additionally, it seems that tDCS effects are most apparent at higher levels of task difficulty but not simple target detection [52]. While tDCS appears to be quite versatile and non-invasive, there risk of triggering epileptic seizures and the effects of long-term measurement are not yet known. It is still doubtful whether tDCS will ever be practically useful enhancement method.

### 2.3 Music Stimulation

Music plays a major role in self-regulation of emotion and cognitive abilities by modulating arousal and mood [53, 54]. Studies have shown that music is able to improve attention and concentration, which resulted in better performance at work [55, 56]. Wokoun, attempted to improve vigilance performance using background music in industrial settings [56]. The author reported vigilance improvement through music listening by creating and administrating a music program designed to increase tempo at peak fatigue times. Similarly, Davies, [57] showed that background music increased the percentage of target detection in a visual vigilance task, particularly, when conditions were more difficult which suggested a specific modulation of the alertness state caused by listening to music. Scheufele, [58]introduced background music into a

job training and found background music can help trainees focus and completed the job assignments more quickly.

Corhan and Gounard [59] investigated the effects of different types of music on visual vigilance such as "rock" and "easy-listening" music, and found that vigilance performance is best when background stimulation is discontinuous and contains elements of uncertainty as the case of rock music. Since Corhan and Gounard [59] reported vigilance enhancement under rock music, the enhancement may be attributable to the subjects' familiarity with the type of music rather than to its properties of discontinuity, rigor, and uncertainty. Indeed, Wolf and Weiner [60] have suggested that, familiarity probably plays a large role in performance. Fontaine et al. [61, 62] and[63] reported that, listening to familiar music significantly increased arousal and detection rate on a vigilance task, as well as reduced vigilance decrement. They also reported the important of psychological characteristics of noise in determining level of vigilance performance. Konz and McDougal's [64] suggested that familiarity increase arousal and improve vigilance performance regardless of the type of music played. Similar study in visual neglect also found that preferred music enhanced patient's performance on a perceptual report test by improving patients' attention and vigilance [65]. Patients showed enhance visual awareness when completing the task with preferred music as compared to non-preferred music and silence, suggested that music decrease visual neglect by increasing attention resource. Recent studies [66-69] reported that music preference had a differential effect on miss rates where those who liked the music less tended to have increased false detection rate while those who at least moderately like the music improve their detecting rate. They suspect that non-preferred music was distracting and participants' unawareness of the distraction led to poorer performance.

Other researchers investigated the effects of specific type of volume and music on drivers' vigilance. They found loud volumes affect simple vigilance, reaction time and movements whereas hard rock music affect tasks involving concentration and attention [70-72]. Music tempo may also influence the heartbeats of listeners and accelerate performance. According to recent survey, fast-tempo background music increased performance compared with slow music while performing vigilance task[73]. Moris, reported that, playing music increased the speed and accuracy of task performance by surgeons, for review [74]. It showed that music reduced heart rate, blood pressure, and muscle effort of surgeons while at the same time increasing the accuracy of surgical tasks. This might be due to that Mozart's music was able to activate neuronal cortical circuits related to attentive and cognitive functions [75, 76]. In fact, different types of music (preferred, fast tempo, classical, etc.) could improve performance in areas beyond vigilance tasks. Music enhance concentration, cognitive function and maintain alertness and vigil resulted in improving detection rate and reduce false alarms [77-79].

Although, music has found to improve performance during vigilance tasks it degrades performance in others [79]. Furnham and Strbac [80] found in a cognitive test, participants performed best in silence, background music was second best for performance, and background noise was lowest results. Compared to silence, both background music and background noise negatively affect work performance. Another finding revealed that playing background music with lyrics are likely to have significant negative effects on the concentration and attention of worker [81]. Future studies of music on vigilance should take in consideration the impacts of valence, tempo, familiarity and personal preference during the design and analysis.

### 2.4 Auditory Binaural Beats

Binaural beat is an auditory illusion perceived by the brain when two slightly different frequencies of sound played separately into each ear. For example, when you play a 250 Hz tone in the left ear and a 260 Hz tone in the right, it yields a beat with a frequency of 10 Hz. The brain then uses a process known as frequency following response (FFR) to follow along at the new frequency (10 Hz). Low frequency binaural beats are associated with mental relaxation and high frequency beats with alertness and attentional concentration [82]. A number of reports have suggested that listening to binaural beats can reduce vigilance decrements [83-87].

For example, Lane reported that, exposure to binaural beats for 30 min has led to reducing vigilance decrement [83]. The study tested participant performance during a 1-back vigilance test while listening to either delta 1.5 Hz, theta 4 Hz or beta 16 Hz range binaural beats. Participants showed improvement in target detection, and decreased in false alarms, task-related confusion, and fatigue while listening to beta binaural beat. Frederick, [84] investigated the effects of beta binaural beat at 18.5 Hz on vigilance task with short period of 5 min. The study found an increased in the magnitude of beta electroencephalography (EEG) rhythm by 21%. The increase of EEG rhythm was in the range of 13 Hz to 21 Hz with highest increase in amplitude located at 18.5 Hz. Beauchene [88], investigated three different binaural beats at 5 Hz, 10 Hz and 15 Hz on vigilance task of delayed match-to-sample for a period of 5 min. The result reported that, the 15 Hz binaural beat increased the response accuracy as well as improved connectivity across brain regions. Within the gamma band, the largest EEG steady state responses occurred with a binaural beat of 40Hz and primarily activated the frontal and parietal lobes [89]. Jirakittayakorn,[90] investigated high frequency gamma binaural beats at 40 Hz on vigilance performance while doing word list recall task for 30 min. The study found that, listening to 40 Hz binaural beat for 20 min enhanced working memory function and improved mood state. Reedijk,[85] have recently shown that binaural auditory beats affect people control and monitor their visual attention. Participants listened to binaural beats at 10 Hz and 40 Hz while performing an attentional blink (AB) task, which assesses the efficiency of allocating attention over time. The AB reduced by the binaural beats in some participants, which suggests that beats have a specific impact on how people allocate their attention over time.

Unfortunately, Goodinet.al., failed to meet the same conclusion as Lane using different protocol [91]. In particular, Goodin assessed theta at 7 Hz and beta at 16 Hz in short time of 13 min presented in 2 min tone. The author reported no significant differences in cortical frequency power during the period of binaural beats stimulation compared to using a white noise signal. The discrepancies may be due to the use of short-time stimulation and the choice of carrier tone may influence upon the efficacy of beat stimulation. Robust effect of binaural beat on vigilance could be obtain with the use of lower carrier tone as well as beat frequencies. Lorenza, [92] suggest that listening to high-frequency binaural beat of 40 Hz bias the individual attentional processing towards a reduced spotlight of attention. The inconsistency in the results of the previous studies might be due to several variables including time duration of the experiment, individual differences, carrier frequency, specific frequency to fluctuate the cortical activities, cognitive test/vigilance task, attention to stimuli, sensory modality, spatial limitation as the case in EEG, age, circadian rhythm, and hearing ability. These factors should be taken in considerations when conduction the experiment as well as during the analysis framework.

### 2.5 Haptic Stimulation

The haptic stimulation comprises two types of feedback: tactile and kinesthetic. The tactile feedback addresses the tactile perception from the skin, such as vibrations whereas; kinesthetic feedback is based on our own muscular effort. Haptic stimulation has been established as a technique to enhance attention and its technologies deployed in cars revealed significant improvements on driving performance. The haptic stimulation delivered at various areas of the car, such as the steering wheel, the seat, or the pedal, see review [93].Theses type of stimulations used as an alarm to warn the drivers of dangers (like going out of the main road, crossing the traffic light, et..), so that they can pay more attention. Several studies have investigated the effects of haptic stimulation on sustained attention. Study in [94] found that 15 Hz haptic stimulation increased human sensorimotor rhythm band power as well as enhanced short-term attention to vigilance task. The results showed that, the stimulation improved the attention level to stimuli, reaction speed and accuracy. Another study showed that, haptic stimulation enhanced vigilance level of pilots during stimulation flying task [95]. The study also demonstrated that, tactile feedback provide a higher detection rate and shorter responses times to unexpected events than visual feedback. However, haptic stimulation is affected by age and sensitive to gender difference [96]. It is well known that, human haptic performance decreases as a function of age but the neural mechanism underlying these changes still not yet elucidated. Future studies on vigilance should take in consideration several factors when developing experimental protocol, design and analysis including age, gender, time-on-task and skin sensitivity, which could be affected by skin diseases.

### 2.6 Visual Modulation

Visual modulation technique is recently proposed to reduce vigilance decrement in video surveillance paradigm [97]. The technique was based on integrating primary vigilance task with a visual noise in the form of artificial simulated rain. The effects of integrating the challenging events (simulated rain) into the primary task demonstrated significant enhancement on vigilance performance and reduced the reaction time to stimuli. It seems that, this type of enhancement increased the workload into a certain level, which in turns increased engagement of attentional resource and resulted in improving the vigilance level. However, the effects after stimulation on performance still not yet explored. More studies with large sample size are needed to further support the effectiveness of this technique on reducing vigilance decrement.

## 3 CONCLUSION

We conclude that great progress has been made in exploring several computerized means of enhancements on vigilance. While findings of most enhancement techniques up to date are either solitary or contradictory, recent computerized enhancement techniques exert a positive effect on vigilance. Besides, the effects of enhancement seems to be influenced by several factors such as time-on-task, and overall experimental protocol and do not last so long and the underlying neural mechanisms still yet not fully elucidated. Understanding how and where the enhancement percepts are generated and which cortical network are highly affected will help in optimization of the enhancement techniques to modulate overall cognition and mood states. Further studies with more accurate reporting of experimental protocols, will help to clarify the most promising effects.

**References**


[1] F. Al-Shargie, U. Tariq, H. Mir, H. Alawar, F. Babiloni, and H. J. B. s. Al-Nashash, "Vigilance decrement and enhancement techniques: a review," vol. 9, no. 8, p. 178, 2019.

[2] X. Wang, C. J. A. A. Xu, and Prevention, "Driver drowsiness detection based on non-intrusive metrics considering individual specifics," vol. 95, pp. 350-357, 2016.

[3] C. S. Green and D. J. N. Bavelier, "Action video game modifies visual selective attention," *Nature,* vol. 423, no. 6939, p. 534, 2003.

[4] C. S. Green and D. J. J. o. e. p. H. p. p. Bavelier, "Effect of action video games on the spatial distribution of visuospatial attention," *Journal of experimental psychology,* vol. 32, no. 6, p. 1465, 2006.

[5] C. S. Green and D. J. C. b. Bavelier, "Learning, attentional control, and action video games," *Current Biology,* vol. 22, no. 6, pp. R197-R206, 2012.

[6] R. L. Achtman, C. S. Green, and D. Bavelier, "Video games as a tool to train visual skills," *J Restorative neurology neuroscience,* vol. 26, no. 4, 5, pp. 435-446, 2008.

[7] M. W. Dye and D. J. V. r. Bavelier, "Differential development of visual attention skills in school-age children," *J Vision Research,* vol. 50, no. 4, pp. 452-459, 2010.

[8] A. C. Oei and M. D. J. F. i. s. n. Patterson, "Are videogame training gains specific or general?," *Frontiers in Systems Neuroscience,* vol. 8, p. 54, 2014.

[9] P. Cardoso-Leite and D. J. C. o. i. n. Bavelier, "Video game play, attention, and learning: how to shape the development of attention and influence learning?," *J Current Opinion in Neurology,* vol. 27, no. 2, pp. 185-191, 2014.

[10] B. Bediou, D. M. Adams, R. E. Mayer, E. Tipton, C. S. Green, and D. J. P. b. Bavelier, "Meta-analysis of action video game impact on perceptual, attentional, and cognitive skills," *J Psychological Bulletin,* vol. 144, no. 1, p. 77, 2018.

[11] L. M. Trick, F. Jaspers-Fayer, and N. J. C. D. Sethi, "Multiple-object tracking in children: The “Catch the Spies” task," *Cognitive Development,* vol. 20, no. 3, pp. 373-387, 2005.

[12] J. A. Anguera *et al.*, "Video game training enhances cognitive control in older adults," *J Nature,* vol. 501, no. 7465, p. 97, 2013.

[13] A. J. Latham, L. L. Patston, and L. J. J. F. i. P. Tippett, "Just how expert are “expert” video-game players? Assessing the experience and expertise of video-game players across “action” video-game genres," *Frontiers in Psychology,* vol. 4, p. 941, 2013.

[14] A. N. Kluger and A. J. P. b. DeNisi, "The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory," *Psychological Bulletin,* vol. 119, no. 2, p. 254, 1996.

[15] M. L. Dittmar, "Effects of knowledge of results on performance in successive and simultaneous vigilance tasks: A signal detection analysis," Doctoral dissertation, University of Cincinnati, 1984.

[16] E. M. Hitchcock, W. N. Dember, J. S. Warm, B. W. Moroney, and J. E. J. H. f. See, "Effects of cueing and knowledge of results on workload and boredom in sustained attention," *Human Factors,* vol. 41, no. 3, pp. 365-372, 1999.

[17] G. W. Teo, T. N. Schmidt, J. L. Szalma, G. M. Hancock, and P. A. Hancock, "The effects of feedback in vigilance training on performance, workload, stress and coping," in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 2013, vol. 57, no. 1, pp. 1119-1123: SAGE Publications Sage CA: Los Angeles, CA.

[18] A. D. Castel, J. Pratt, and E. J. A. p. Drummond, "The effects of action video game experience on the time course of inhibition of return and the efficiency of visual search," *J Acta Psychologica,* vol. 119, no. 2, pp. 217-230, 2005.

[19] A. B. Becker, "Specific and nonspecific transfer effects in training for vigilance," 1995.

[20] W. S. Helton, T. Shaw, J. S. Warm, G. Matthews, and P. J. A. Hancock, Stress, Coping, "Effects of warned and unwarned demand transitions on vigilance performance and stress," *Anxiety, Stress, Coping,* vol. 21, no. 2, pp. 173-184, 2008.

[21] J. S. Warm *et al.*, "Effects of training with knowledge of results on diagnosticity in vigilance performance," in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 2009, vol. 53, no. 17, pp. 1066-1070: SAGE Publications Sage CA: Los Angeles, CA.

[22] J. L. Szalma, P. A. Hancock, W. N. Dember, and J. S. J. B. J. o. P. Warm, "Training for vigilance: The effect of knowledge of results format and dispositional optimism and pessimism on performance and stress," *British Journal of Psychology,* vol. 97, no. 1, pp. 115-135, 2006.

[23] T. N. Schmidt, G. W. Teo, J. L. Szalma, G. M. Hancock, and P. A. Hancock, "The effect of video game play on performance in a vigilance task," in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 2012, vol. 56, no. 1, pp. 1544-1547: SAGE Publications Sage CA: Los Angeles, CA.

[24] T. N. Schmidt, G. W. Teo, G. M. Hancock, Z. Amicarelle, J. L. Szalma, and P. A. Hancock, "Action video game players and vigilance performance," in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 2013, vol. 57, no. 1, pp. 1450-1454: SAGE Publications Sage CA: Los Angeles, CA.

[25] M. Narra and B. J. I. J. o. B. C. S. Mathew, "Developmental differences on cognitive inhibition in children and adults: Evidence from vigilance task," *International Journal of Brain Cognitive Sciences,* vol. 1, no. 1, pp. 1-5, 2012.

[26] F. J. J. o. C. P. P. Levy, "The development of sustained attention (vigilance) and inhibition in children: Some normative data," *Journal of Child Psychology Psychiatry,* vol. 21, no. 1, pp. 77-84, 1980.

[27] L. M. Giambra and R. E. J. J. o. a. p. Quilter, "Sex differences in sustained attention across the adult life span.," *Journal of Applied Psychology,* vol. 74, no. 1, p. 91, 1989.

[28] J. Feng, I. Spence, and J. J. P. s. Pratt, "Playing an action video game reduces gender differences in spatial cognition," *J Psychological Science,* vol. 18, no. 10, pp. 850-855, 2007.

[29] M. Bikson, A. Datta, and M. J. C. N. Elwassif, "Establishing safety limits for transcranial direct current stimulation," *J Clinical Neurophysiology,* vol. 120, no. 6, pp. 1033-1034, 2009.

[30] A. P. Arul-Anandam and C. J. J. o. a. d. Loo, "Transcranial direct current stimulation: a new tool for the treatment of depression?," *Journal of Affective Disorders,* vol. 117, no. 3, pp. 137-145, 2009.

[31] W. Paulus, "Outlasting excitability shifts induced by direct current stimulation of the human brain," in *Supplements to Clinical neurophysiology,* vol. 57: Elsevier, 2004, pp. 708-714.

[32] M. A. Nitsche *et al.*, "Transcranial direct current stimulation: state of the art 2008," *Brain Stimulation,* vol. 1, no. 3, pp. 206-223, 2008.

[33] M. A. Nitsche and W. J. T. J. o. p. Paulus, "Excitability changes induced in the human motor cortex by weak transcranial direct current stimulation," *The Journal of Physiology,* vol. 527, no. 3, pp. 633-639, 2000.

[34] R. A. McKinley, N. Bridges, C. M. Walters, and J. J. N. Nelson, "Modulating the brain at work using noninvasive transcranial stimulation," *Neuroimage,* vol. 59, no. 1, pp. 129-137, 2012.

[35] M. A. Nitsche, P. S. Boggio, F. Fregni, and A. J. E. n. Pascual-Leone, "Treatment of depression with transcranial direct current stimulation (tDCS): a review," *Experimental Neurology,* vol. 219, no. 1, pp. 14-19, 2009.

[34] Al-Yoonus, Murthad, M. F. L. Abdullah, Mohammed Saeed Jawad, and Fares Al-Shargie. "Enhance quality control management for sensitive industrial products using 2D/3D image processing algorithms." In 2014 Electrical Power, Electronics, Communicatons, Control and Informatics Seminar (EECCIS), pp. 126-131. IEEE, 2014.

[35] Al-Shargie, Fares. "Assessment of Mental Stress Using EEG and fNIRS Features." (2019).

[36] L. Annarumma, A. D'Atri, V. Alfonsi, and L. De Gennaro, "The Efficacy of Transcranial Current Stimulation Techniques to Modulate Resting-State EEG, to Affect Vigilance and to Promote Sleepiness," *J Brain Sciences,* vol. 8, no. 7, p. 137, 2018.

[37] J. T. Nelson, R. A. McKinley, E. J. Golob, J. S. Warm, and R. J. N. Parasuraman, "Enhancing vigilance in operators with prefrontal cortex transcranial direct current stimulation (tDCS)," *Neuroimage,* vol. 85, pp. 909-917, 2014.

[38] R. K. Mehta and R. J. F. i. h. n. Parasuraman, "Neuroergonomics: a review of applications to physical and cognitive work," *Frontiers in Human Neuroscience,* vol. 7, p. 889, 2013.

[39] J. W. Schuijer, I. M. de Jong, F. Kupper, and N. M. J. F. i. h. n. van Atteveldt, "Transcranial Electrical Stimulation to Enhance Cognitive Performance of Healthy Minors: A Complex Governance Challenge," *Frontiers in Human Neuroscience,* vol. 11, p. 142, 2017.

[40] J. Elmasry, C. Loo, and D. J. R. n. n. Martin, "A systematic review of transcranial electrical stimulation combined with cognitive training," *J Restorative Neurology Neuroscience,* vol. 33, no. 3, pp. 263-278, 2015.

[41] B. A. Simonsmeier, R. H. Grabner, J. Hein, U. Krenz, and M. J. N. B. R. Schneider, "Electrical brain stimulation (tES) improves learning more than performance: a meta-analysis," *Neuroscience Biobehavioral Reviews,* 2017.

[42] P. Cruz Gonzalez, K. N. Fong, and T. J. B. n. Brown, "The Effects of Transcranial Direct Current Stimulation on the Cognitive Functions in Older Adults with Mild Cognitive Impairment: A Pilot Study," *J Behavioural Neurology,* vol. 2018, 2018.

[43] B. Manor *et al.*, "Transcranial Direct Current Stimulation May Improve Cognitive-Motor Function in Functionally Limited Older Adults," *Neurorehabilitation Neural Repair,* vol. 32, no. 9, pp. 788-798, 2018.

[44] L. K. McIntire, R. A. McKinley, C. Goodyear, and J. J. B. s. Nelson, "A comparison of the effects of transcranial direct current stimulation and caffeine on vigilance and cognitive performance during extended wakefulness," *Brain Stimulation,* vol. 7, no. 4, pp. 499-507, 2014.

[45] V. Axelrod, G. Rees, M. Lavidor, and M. J. P. o. t. N. A. o. S. Bar, "Increasing propensity to mind-wander with transcranial direct current stimulation," *J Proceedings of the National Academy of Sciences,* vol. 112, no. 11, pp. 3314-3319, 2015.

[46] R. K. Cohen, S. Soskic, T. Iuculano, R. Kanai, and V. J. C. b. C. Walsh, "Modulating neuronal activity produces specific and long-lasting changes in numerical competence," *J Current Biology: Cell Press,* vol. 20, no. 22, pp. 2016-2020, 2010.

[47] L. M. Li, R. Leech, G. Scott, P. Malhotra, B. Seemungal, and D. J. J. E. J. o. N. Sharp, "The effect of oppositional parietal transcranial direct current stimulation on lateralized brain functions," *European Journal of Neuroscience,* vol. 42, no. 11, pp. 2904-2914, 2015.

[48] C. Plewnia, B. Zwissler, I. Längst, B. Maurer, K. Giel, and R. J. C. Krüger, "Effects of transcranial direct current stimulation (tDCS) on executive functions: influence of COMT Val/Met polymorphism," *Cortex,* vol. 49, no. 7, pp. 1801-1807, 2013.

[49] V. Nieratschker, C. Kiefer, K. Giel, R. Krüger, and C. J. B. s. Plewnia, "The COMT Val/Met polymorphism modulates effects of tDCS on response inhibition," *Brain Stimulation,* vol. 8, no. 2, pp. 283-288, 2015.

[50] G. Matthews, J. S. Warm, L. E. Reinerman, L. K. Langheim, and D. J. Saxby, "Task engagement, attention, and executive control," in *Handbook of individual differences in cognition*: Springer, 2010, pp. 205-230.

[50] Al-shargie, Fares, Tong Boon Tang, Nasreen Badruddin, Sarat C. Dass, and Masashi Kiguchi. "Mental stress assessment based on feature level fusion of fNIRS and EEG signals." In 2016 6th International Conference on Intelligent and Advanced Systems (ICIAS), pp. 1-5. IEEE, 2016.

[51] Al-Shargie, Fares. "Multilevel Assessment of Mental Stress using SVM with ECOC: An EEG Approach." (2019).

[51] L. Reteig, L. Talsma, M. van Schouwenburg, and H. J. J. o. C. E. Slagter, "Transcranial electrical stimulation as a tool to enhance attention," *Journal of Cognitive Enhancement,* vol. 1, no. 1, pp. 10-25, 2017.

[52] W.-Y. Hsu, T. P. Zanto, J. A. Anguera, Y.-Y. Lin, and A. J. C. Gazzaley, "Delayed enhancement of multitasking performance: effects of anodal transcranial direct current stimulation on the prefrontal cortex," *Cortex,* vol. 69, pp. 175-185, 2015.

[53] J. A. Sloboda, S. A. O'Neill, and A. J. M. s. Ivaldi, "Functions of music in everyday life: An exploratory study using the Experience Sampling Method," *Musicae Scientiae,* vol. 5, no. 1, pp. 9-32, 2001.

[54] N. S. Rickard, S. R. Toukhsati, and S. E. J. B. C. N. R. Field, "The effect of music on cognitive performance: Insight from neurobiological and animal studies," *Behavioral Cognitive Neuroscience Reviews,* vol. 4, no. 4, pp. 235-261, 2005.

[55] R.-H. Huang and Y.-N. J. W. Shih, "Effects of background music on concentration of workers," *J Work,* vol. 38, no. 4, pp. 383-387, 2011.

[56] W. Wokoun, "Vigilance with background music," HUMAN ENGINEERING LAB ABERDEEN PROVING GROUND MD1963.

[57] D. Davies, L. Lang, and V. J. B. J. o. P. Shackleton, "The effects of music and task difficulty on performance at a visual vigilance task," *J British Journal of Psychology,* vol. 64, no. 3, pp. 383-389, 1973.

[58] P. M. J. J. o. b. m. Scheufele, "Effects of progressive relaxation and classical music on measurements of attention, relaxation, and stress responses," *Journal of Behavioral Medicine,* vol. 23, no. 2, pp. 207-228, 2000.

[59] C. M. Corhan and B. R. J. P. m. s. Gounard, "Types of music, schedules of background stimulation, and visual vigilance performance," *J Perceptual Motor Skills* 1976.

[60] R. H. Wolf and F. F. J. P. M. S. Weiner, "Effects of four noise conditions on arithmetic performance," *Perceptual Motor Skills,* vol. 35, no. 3, pp. 928-930, 1972.

[61] C. W. Fontaine and N. D. J. P. m. s. Schwalm, "Effects of familiarity of music on vigilant performance," *J Perceptual Motor Skills,* vol. 49, no. 1, pp. 71-74, 1979.

[62] L. Dorney, E. K. M. Goh, and C. J. J. o. S. B. Lee, "The impact of music and imagery on physical performance and arousal: Studies of coordination and endurance," *Journal of Sport Behavior,* vol. 15, no. 1, p. 21, 1992.

[61] Al-shargie, Fares, Tong Boon Tang, and Masashi Kiguchi. "Mental stress grading based on fNIRS signals." In 2016 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), pp. 5140-5143. IEEE, 2016.

[66] Al-shargie, Fares, Tong Boon Tang, Nasreen Badruddin, and Masashi Kiguchi. "Simultaneous measurement of EEG-fNIRS in classifying and localizing brain activation to mental stress." In 2015 IEEE International Conference on Signal and Image Processing Applications (ICSIPA), pp. 282-286. IEEE, 2015.

[62] Al-Shargie, Fares. "Early Detection of Mental Stress Using Advanced Neuroimaging and Artificial Intelligence." arXiv preprint arXiv:1903.08511 (2019).

[63] Mohamed, Eltaf Abdalsalam, Mohd Zuki Yusoff, Ibrahim Khalil Adam, Elnazeer Ali Hamid, Fares Al-Shargie, and Muhammad Muzammel. "Enhancing EEG Signals in Brain Computer Interface Using Intrinsic Time-Scale Decomposition." In Journal of Physics: Conference Series, vol. 1123, no. 1, p. 012004. IOP Publishing, 2018.

[63] A. B. Ünal, L. Steg, and K. J. A. A. P. Epstude, "The influence of music on mental effort and driving performance," *Accident Analysis Prevention,* vol. 48, pp. 271-278, 2012.

[64] S. Konz and D. J. H. F. Mcdougal, "The effect of background music on the control activity of an automobile driver," *Human Factors,* vol. 10, no. 3, pp. 233-243, 1968.

[65] D. Soto, M. J. Funes, A. Guzmán-García, T. Warbrick, P. Rotshtein, and G. W. J. P. o. t. N. A. o. S. Humphreys, "Pleasant music overcomes the loss of awareness in patients with visual neglect," *Proceedings of the National Academy of Sciences,* vol. 106, no. 14, pp. 6011-6016, 2009.

[66] C. L. Baldwin and B. A. J. P. o. Lewis, "Positive valence music restores executive control over sustained attention," *J PloS One,* vol. 12, no. 11, p. e0186231, 2017.

[67] R. Johansson, K. Holmqvist, F. Mossberg, and M. J. P. o. m. Lindgren, "Eye movements and reading comprehension while listening to preferred and non-preferred study music," *Psychology of Music,* vol. 40, no. 3, pp. 339-356, 2012.

[68] N. Perham and T. J. C. P. Withey, "Liked music increases spatial rotation performance regardless of tempo," *Current Psychology,* vol. 31, no. 2, pp. 168-181, 2012.

[69] F. Mori, F. A. Naghsh, and T. Tezuka, "The Effect of Music on the Level of Mental Concentration and its Temporal Change," in *CSEDU (1),* 2014, pp. 34-42.

[70] B. H. Dalton, D. G. Behm, and A. J. O. E. Kibele, "Effects of sound types and volumes on simulated driving, vigilance tasks and heart rate," *J Occupational Ergonomics,* vol. 7, no. 3, pp. 153-168, 2007.

[71] W. J. T. r. p. F. t. p. b. Brodsky, "The effects of music tempo on simulated driving performance and vehicular control," *J Transportation Research Part F:Traffic Psychology Behaviour,* vol. 4, no. 4, pp. 219-241, 2001.

[72] H. C. Beh and R. J. E. Hirst, "Performance on driving-related tasks during music," *J Ergonomics,* vol. 42, no. 8, pp. 1087-1098, 1999.

[73] H. Nittono, A. Tsuda, S. Akai, and Y. J. P. m. s. Nakajima, "Tempo of background sound and performance speed," *Perceptual Motor Skills,* vol. 90, no. 3_suppl, pp. 1122-1122, 2000.

[74] D. N. Moris and D. J. S. e. Linos, "Music meets surgery: two sides to the art of “healing”," *Surgical Endoscopy,* vol. 27, no. 3, pp. 719-723, 2013.

[75] N. Jaušovec and K. J. B. t. Habe, "The “Mozart effect”: an electroencephalographic analysis employing the methods of induced event-related desynchronization/synchronization and event-related coherence," *Brain Topography,* vol. 16, no. 2, pp. 73-84, 2003.

[76] W. Verrusio, E. Ettorre, E. Vicenzini, N. Vanacore, M. Cacciafesta, and O. J. C. c. Mecarelli, "The Mozart effect: a quantitative EEG study," *Consciousness Cognition,* vol. 35, pp. 150-155, 2015.

[76] Al-Shargie, Fares, Masashi Kiguchi, Nasreen Badruddin, Sarat C. Dass, Ahmad Fadzil Mohammad Hani, and Tong Boon Tang. "Mental stress assessment using simultaneous measurement of EEG and fNIRS." Biomedical optics express 7, no. 10 (2016): 3882-3898.

[77] Al-Shargie, F. M., Tong Boon Tang, Nasreen Badruddin, and Masashi Kiguchi. "Mental stress quantification using EEG signals." In International Conference for Innovation in Biomedical Engineering and Life Sciences, pp. 15-19. Springer, Singapore, 2015.

[76] Al-Shargie, Fares, Tong Boon Tang, Nasreen Badruddin, and Masashi Kiguchi. "Towards multilevel mental stress assessment using SVM with ECOC: an EEG approach." Medical & biological engineering & computing 56, no. 1 (2018): 125-136.

[77] P. E. Penn, R. R. J. W. Bootzin, and Stress, "Behavioural techniques for enhancing alertness and performance in shift work," *J Work,* vol. 4, no. 3, pp. 213-226, 1990.

[78] T. J. P. o. m. Lesiuk, "The effect of music listening on work performance," *Psychology of Music,* vol. 33, no. 2, pp. 173-191, 2005.

[79] C. R. Alikonis, J. S. Warm, G. Matthews, W. N. Dember, E. M. Hitchcock, and J. J. Kellaris, "Vigilance, workload, and boredom: Two competing models," in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 2002, vol. 46, no. 17, pp. 1531-1535: SAGE Publications Sage CA: Los Angeles, CA.

[80] A. Furnham and L. J. E. Strbac, "Music is as distracting as noise: the differential distraction of background music and noise on the cognitive test performance of introverts and extraverts.," *J Ergonomics*, vol. 45, no. 3, pp. 203-217, 2002.

[81] Y.-N. Shih, R.-H. Huang, and H.-Y. J. W. Chiang, "Background music: Effects on attention performance," *J Work*, vol. 42, no. 4, pp. 573-578, 2012.

[82] D. Vernon, *Human potential: Exploring techniques used to enhance human performance*. Routledge, 2009.

[83] J. D. Lane, S. J. Kasian, J. E. Owens, and G. R. J. P. b. Marsh, "Binaural auditory beats affect vigilance performance and mood," *Physiology Behavior,* vol. 63, no. 2, pp. 249-252, 1998.

[84] J. A. Frederick, J. F. Lubar, H. W. Rasey, S. A. Brim, and J. J. J. o. N. Blackburn, "Effects of 18.5 Hz auditory and visual stimulation on EEG amplitude at the vertex," *Journal of Neurotherapy,* vol. 3, no. 3-4, pp. 23-28, 1999.

[85] S. A. Reedijk, A. Bolders, L. S. Colzato, and B. J. F. i. P. Hommel, "Eliminating the attentional blink through binaural beats: a case for tailored cognitive enhancement," *Frontiers in Psychiatry,* vol. 6, p. 82, 2015.

[86] F. Al-Shargie, T. B. Tang, and M. J. B. o. e. Kiguchi, "Assessment of mental stress effects on prefrontal cortical activities using canonical correlation analysis: an fNIRS-EEG study," vol. 8, no. 5, pp. 2583-2598, 2017.

[87] F. Al-Shargie, T. B. Tang, and M. J. I. A. Kiguchi, "Stress assessment based on decision fusion of EEG and fNIRS signals," vol. 5, pp. 19889-19896, 2017.

[88] C. Beauchene, N. Abaid, R. Moran, R. A. Diana, and A. J. P. o. Leonessa, "The effect of binaural beats on visuospatial working memory and cortical connectivity," *J PloS One,* vol. 11, no. 11, p. e0166630, 2016.

[89] R. Draganova, B. Ross, A. Wollbrink, and C. J. C. c. Pantev, "Cortical steady-state responses to central and peripheral auditory beats," *J Cerebral Cortex,* vol. 18, no. 5, pp. 1193-1200, 2007.

[90] N. Jirakittayakorn and Y. J. I. J. o. P. Wongsawat, "Brain responses to 40-Hz binaural beat and effects on emotion and memory," *International Journal of Psychophysiology,* vol. 120, pp. 96-107, 2017.

[89] Al-shargie, Fares, Tong Boon Tang, Nasreen Badruddin, and Sarat C. Dass. "Prefrontal cortex connectivity under neutral-control and stress condition using fNIRS."

[90] Al-Shargie, Fares. "Quantification of Mental Stress using fNIRS Signals." (2019).

[91] Al-Shargie, Fares. "Fusion of fNIRS and EEG Signals: Mental Stress Study." (2019).

[91] P. Goodin, J. Ciorciari, K. Baker, A.-M. Carrey, M. Harper, and J. J. P. o. Kaufman, "A high-density EEG investigation into steady state binaural beat stimulation," *PloS One,* vol. 7, no. 4, p. e34789, 2012.

[92] L. S. Colzato, H. Barone, R. Sellaro, and B. J. P. r. Hommel, "More attentional focusing through binaural beats: evidence from the global–local task," *J Psychological Research,* vol. 81, no. 1, pp. 271-277, 2017.

[93] Y. Gaffary and A. J. F. i. I. Lécuyer, "The Use of Haptic and Tactile Information in the Car to Improve Driving Safety: A Review of Current Technologies," *J Frontiers in ICT,* vol. 5, p. 5, 2018.

[94] S. Zhang, D. Wang, N. Afzal, Y. Zhang, and R. J. I. t. o. h. Wu, "Rhythmic haptic stimuli improve short-term attention," *IEEE Transactions on Haptics,* vol. 9, no. 3, pp. 437-442, 2016.

[95] G. R. Arrabito, G. Ho, B. Aghaei, C. Burns, and M. Hou, "Effects of vibrotactile stimulation for sustaining performance in a vigilance task: a pilot study," in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting,* 2011, vol. 55, no. 1, pp. 1160-1164: Sage Publications Sage CA: Los Angeles, CA.

[96] T. Kalisch, J.-C. Kattenstroth, R. Kowalewski, M. Tegenthoff, and H. R. J. P. O. Dinse, "Cognitive and tactile factors affecting human haptic performance in later life," *PLoS One,* vol. 7, no. 1, p. e30420, 2012.

[97] I. P. Bodala, J. Li, N. V. Thakor, and H. J. F. i. h. n. Al-Nashash, "EEG and eye tracking demonstrate vigilance enhancement with challenge integration," *Frontiers in Human Neuroscience,* vol. 10, p. 273, 2016.