© Journal of the Indian Academy of Applied Psychology
July 2016, Vol.42, No.2, 237 - 245.

Effects of Working in Shifts on Alertness in Locomotive Drivers on Indian Railways

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The job of driving a train demands a steady level of alertness and sustained attention, which in addition to other cognitive and psychomotor attributes is crucial for ensuring safety in train operation in consonance with stipulated safety rules and procedures. Lack of alertness directly impacts safety therefore, it needs to be overcome for ensuring safe train operation. The present study was conducted with this objective in two interrelated phases. In the first phase, alertness and cortical activation were assessed in three different driving conditions before commencement and after completion of duty. Results of the first phase revealed that those who performed two consecutive night duties exhibited deterioration in overall performance as compared to their colleagues who performed one night duty and one day duty; however, drivers in all the three driving conditions showed shoddy performance after completion of duty. In the second phase, an attempt was made to enhance alertness of locomotive drivers by using an intervention module and the findings suggested that intervention improved their performance on two tasks of alertness.

Keywords: Train operation, Locomotive drivers, Alertness, Shift work, Safety.

Safe train operation depends primarily on cognitive, psychomotor and behavioral abilities and skills of the locomotive drivers responsible for driving trains in different shifts. The job entrusted to them demands a steady level of alertness, often under monotonous conditions and instant response to varying situations, many a times unpredictable. In this situation their performance remains directly proportional to alertness and situational awareness, the attributes that become crucial for successful enactment of safe train operation throughout their duty hours. Remaining attentive, alert and vigilant on sustained basis depends on various extrinsic and intrinsic factors that keep on influencing each other in different situations varying with passage of time and distance in train operation. Quite often it becomes difficult to sustain alertness and remain vigilant for long due to multiple reasons. This includes multiplicity in task performance and monotony, when the task is long, boring and uneventful or when there is little work to be performed. Sometimes remaining alert for longer period itself becomes stressful, resulting in a drop in alertness (Warm, Parasuraman, & Matthews, 2008). This limitation of human ability gets intensified by monotony, distraction and unfavorable cab environment such as noise levels and extreme temperatures that add up to their fatigue level and cause a drop in alertness, which may have repercussions in train driving. Analysis of various accidents has revealed that lack of alertness among locomotive drivers have been one of the main attributing factors in many consequential and indicative train accidents affecting safety on Indian Railways. Cognitive performance including alertness gets impaired due to lack of adequate sleep, the duration of which varies considerably among the drivers ranging from 6 to 8 hours per day. Effects of sleep deprivation on alertness and cognitive performance are mainly due to a decline in brain activities and functions, primarily in the thalamus, which monitors alertness and attention, and the prefrontal cortex, a region also related with alertness, high order cognitive processing and performance (Thomas et al., 2000). Both short and long-term sleep deprivation reduce alertness and deteriorate performance on simple tasks such as reaction time, vigilance and attention

(Dinges & Kribbs, 1991; Gillberg & Akerstedt, 1998; Horne, 1993; Koslowsky & Babkoff, 1992) and complex tasks including working memory, verbal fluency, speech articulation, logical reasoning, creative and flexible thinking, planning, decision making and judgment (Horne 1993; Harrison & Horne, 2000). These performance deficits can occur during the first night without sleep (Angus & Heslegrave, 1985; Monk & Carrier, 1997) and gets amplified after two-to-three nights without sleep (e.g. Horne & Pettit, 1985; Koslowsky & Babkoff, 1992). In human beings sleep-wake cycle is regulated by interacting process of homeostasis and circadian rhythmicity (e.g. Achermann, 2004). Sleep, being important for body restitution, regulation of metabolic processes, energy conservation, thermoregulation and upkeep of immune response, is equally essential for cognitive performance. As such, those who suffer from sleep loss, experience decline in cognitive performance that adversely affects their well-being, safety and productivity leading to failures and accidents in real situations. A study conducted by the Psycho-Technical Directorate of Research, Designs and Standards Organisation (RDSO), Ministry of Railways, Government of India on duty hours of running/ station staff and effects of night shift has revealed that the basic mental functioning gets influenced by diurnal variations, and after the night shift and before signing 'on' for the next duty, adequate sleep of minimum 7 hours is essential (Study Report Number PT 83.1, 1983). Another study on fatigue indicated towards building up of physiological fatigue after duty and impact of diurnal variations and night duties on mental stress (Study Report Number PT 77.1, 1977). Shift work has also been found to impair performance leading to cognitive and affective disorder (Taffinder et al., 1998). These studies suggest that different shifts during work especially night shift disrupts the sleep-wake cycle and deteriorates cognitive functioning.

Alertness and attention are the outcomes of neurophysiological changes in the human brain and the autonomic nervous system, which prepares an individual to respond to new situations for receiving information rapidly and efficiently, thus, equipping for prompt response to particular information. The primary sensory pathways, associated areas of cerebral cortex and reticular activating systems in human brain (Davies & Parasuraman, 1982; Warm, 1984) coordinate with each other in highly synchronized manner while registering an incoming sensory signal, evaluating its contents and activating brain resources in response to the demands, which accounts for a sustained level of involvement with the environment. Any deficit in this neurophysiological mechanism leads to reduction in alertness. Attempts have been made to improve alertness and cognitive functioning through application of various methods involving changes in the mechanism and structures of the brain. Exposure to nature has been shown to be a useful method for improving attention (Tang & Posner, 2009) and in many studies aerobic exercise has been shown to have broad effects on cognition including attention (Hillman, Erickson, & Kramer, 2008). Takeuchi et al. (2010) found that working memory training produce changes in white matter structures of brain, which is important not only for working memory, but also for other cognitive abilities. Studies also suggested that practicing action video games also improved performance on attentional and higher order cognitive tasks (Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Green & Bravelier, 2005). Attention can also be improved by extensive practice of a specific task, probably video games or computer exercises that involves an attention network or by exercise and meditation that changes the state of the brain. Meditation has also been shown to improve executive attention, reduce stress and fabricate specific brain changes (Posner, Rothbart & Tang, 2015). A study conducted by RDSO yielded that the CRAMP technique (a compressed training module for learning the route on the framework of Comprehension, Reflex, Attitude, Memory and Procedure) was useful in enhancing the vigilance capacity of drivers (Study Report Number PT 9, 1999). All these studies suggest that physical as well as mental exercise and meditation produce positive changes in the network of the brain and improve cognitive functioning including alertness.

Purpose of the present study

Since, a decrease in alertness has been one of the major causes of failures on the

part of locomotive drivers leading to safety issues at workplace and accidents. Empirical studies examining the issue of alertness in real situations of train operation within the existent organizational environment in Indian Railways have been scarce, it was considered essential to understand this issue from a psychological perspective to find out the practical measures that could help in combating this problem effectively. The present study was conducted with twin objectives of studying the issue of crew alertness in the present context and suggesting measures to enhance alertness in the setting of Indian Railways and its conditions. It was hypothesized that the three different driving conditions would affect performance of the locomotive drivers differently and intervention through mental skill development module would improve their performance.

Method

Sample

This study was conducted in two interrelated phases on 209 male locomotive drivers (104 in the first phase and 105 in second phase) posted at different locations on Northern, North Eastern and North Central Railways and deployed to run different types of trains having different time schedules. The age of locomotive drivers ranged from 40 to 55 years (M_{Age} = 45.5 years) having 10 to 20 years of experience of train driving. Random sampling method was used in selecting locomotive drivers for this study. All the drivers had normal or corrected to normal vision and normal hearing capability.

Phase I

The first phase of this study was oriented towards examining the effects of performing duties in diurnal condition on alertness in terms of performance on two tasks. The crew links of different crew booking points were studied in order to screen the locomotive drivers performing duties in daytime, one night and two consecutive nights. The tests were administered on the identified drivers when they signed 'on' for their duty and after they signed 'off' from their duty. Comparison of the effects of driving trains during daytime, one night and two consecutive nights was studied by measuring the impact on their fatigue and psychomotor functioning.

Apparatus and Tools used

Critical Flicker Fusion (CFF) Test: It measures the rate at which successively presented light stimuli appear to be steady and continuous. This rate, expressed in Hz, is commonly referred to as the threshold or threshold frequency, which provides a measure of the ability to distinguish discrete sensory events - an index of Cortical Arousal or Central Nervous System activity. It was used to measure reduction in alertness in terms of sleep deprivation, fatigue and disturbance/change in cerebral neo-cortical excitation, known to adversely affect thinking, decision making, judgment and discrimination.

Complex Reaction Time (CRT) Task: This task was used to assess the psychomotor ability of drivers to quickly and correctly identify appropriate signals and respond in complicated visual field including repetitive changes in the aspects of signals. It was a computerized task, in which the drivers were required to press an appropriate key mentioned in the response box to bring the light on computer screen and then, they had to press corresponding buttons (e.g. yellow button for yellow light). Reponses i.e. reaction times were recorded in milliseconds.

Experimental Design

Three (driving conditions) x Two (test sessions) mixed factorial analysis of variance was used with repeated measure on the last factor for both tasks (i.e. CFF and CRT). Performance of the locomotive drivers working in three different driving conditions - day, one night and two nights were recorded both before commencement and after completion of duty.

Phase II

This phase of study was oriented towards looking at whether any intervention can improve alertness level among the locomotive drivers. Two tasks were administered on the experimental group both before and after the application of an intervention module, whereas the control group did not undergo the intervention. Both the tasks used in this phase of study were related to assessment of alertness as an endeavor to examine the effect of intervention on alertness.

Apparatus and Tools

Complex Reaction Time Task: It was the same task used in the first phase of study.

Group Bourden Task (GBT): This is a computerized task, intended to measure the concentration of loco pilots, which is a feature inherent in the job of train driving. It is also known as Dots Test, in which the subjects need to cross out all groups of four dots while leaving out groups of three dots and five dots. A task of this type is widely used for measuring concentration of train drivers at the time of their screening. Accuracy on it was considered as a performance measure.

Since, in this phase cortical arousal was not required to be measured to assess fatigue level, CFF used in Phase I, was not used in Phase II. However, GBT was used to measure the level of concentration after application of the said intervention module in the experimental group in order to find out any change in the level of alertness.

Intervention Module: Intervention was provided only to the experimental group in six sessions lasting about 30-40 minutes in six consecutive days. The module consisted of 25 questions related to verbal reasoning, spatial reasoning, numerical reasoning, observation power and spatial scanning. They were provided to each participant of experimental group to solve during the intervention session.

Experimental Design

In Phase II pre and post research design was used and performances of drivers were compared before and after the intervention sessions. Drivers were subjected to CRT and GBT tasks both prior to and after the intervention session and their performance on both the tasks in two different conditions were recorded. It was hypothesized that use of this intervention would enhance cognitive functions including alertness and improve their performance on the two tasks.

Results

Phase I

The means and SDs were computed for performance on each driving conditions in two observation sessions of the two tasks (as shown in Table 1). A separate three (driving conditions) x two (test sessions) mixed factorial analysis of variance (ANOVA) was used with repeated measure on last factor for each task, CRT and CFF. The ANOVA for CRT revealed a significant main effect of test session, F (1, 101) = 225.833, $p < .001$, $\eta_p^2 = .691$, indicating that the reaction time increased after the completion of duty irrespective of the driving condition. The interaction between the driving condition and the test session was also found significant, F (2, 101) = 23.245, $p < .001$, $\eta_p^2 = .315$, which

Table 1. Means and SDs (in parenthesis) on the Performance of CRT and CFF in Three Different Driving Duty Conditions Before Commencement and After Completion of Duty

Task/ Test	Driving conditions	N	Before commencement of duty	After completion of duty
CRT	Day	49	764.20 (101.39)	785.56 (96.01)
	One night	32	741.63 (52.99)	766.66 (58.89)
	Two consecutive nights	23	730.74 (80.96)	790.09 (73.18)
CFF	Day	49	30.83 (2.38)	29.14 (2.43)
	One night	32	30.05 (2.52)	27.83 (2.60)
	Two consecutive nights	23	30.69 (2.57)	28.83 (2.62)

suggested a huge increase in reaction time after driving for two consecutive nights (8.12%) than after driving for one night (3.38%) and during the daytime (2.8%).The main effect of the driving condition was not found to be significant (p =.67). The ANOVA with CFF indicated that the main effect of the test session, F (1, 101) = 257.076, p < .001, η_p^2 = .718, was significant. This finding clearly indicates that CFF value declined after the completion of duty across all the three driving conditions showing a decreased cortical arousal and increased fatigue after performing the driving duty. The mean of CFF results indicated greater decline after performing one night duty (7.39%) followed by two consecutive night duties (6.06%) and day duty (5.48%). However, none of other main and interaction effect was found to be significant.

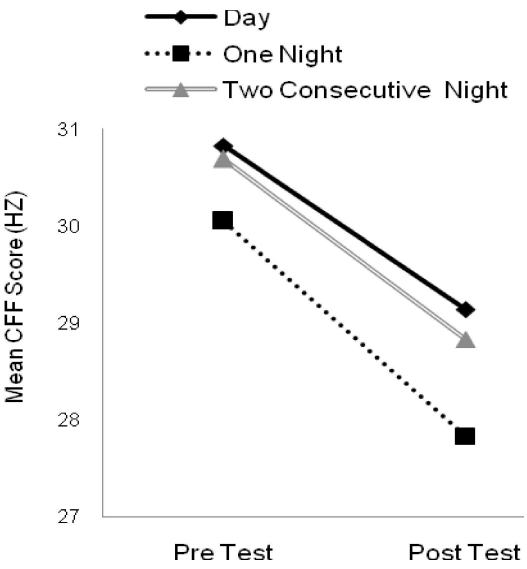

Fig 2: Mean values on Pre and Post CFF tests as a function of driving condition.

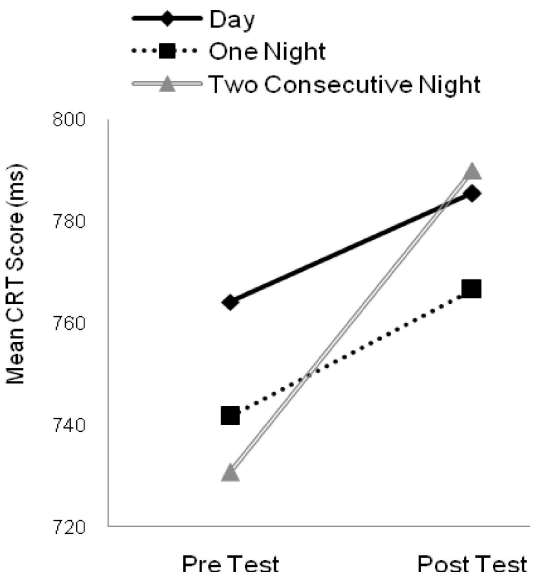

Fig 1: Mean values on Pre and Post CRT task as a function of driving condition.

Phase II

In this phase the effect of intervention was examined. For this the means and SDs were computed for both pre and post intervention sessions for CRT and GBT. To inspect the significance of difference between the mean performance of pre and post session, 't' test was computed as the aim of Phase II study was to examine the effect of intervention on the performance. Drivers in two conditions matched each other on variables, such as age, experience, educational qualification, length of service and supervisor's rating. However, they did not match on initial scores due to unavailability and work pressure.

The findings obtained are presented in Table 2 and graphically displayed in Figure 4 and 5. Findings in this phase that involved intervention for enhancement of mental skills revealed a significant increase (t (80) = 3.087, p = .003) in the mean values (26.8) from pre (202.94) to post (229.74) intervention on GBT in the experimental group, whereas increase in the control group was minuscule (1.91) and non-significant, t (23) = .248, p = .806, which indicated that the intervention module for development of mental

Table 2. Means and SDs (in parenthesis) on the Performance of CRT And GBT Before and After the Administration of the Intervention Module

Experimental Tasks	Groups	N	Pre Session	Post Session
CRT	Experimental Group	81	1153.79 (186.39)	1036.73 (176.67)
	Control Group	24	1009.87 (144.04)	974.42 (144.66)
GBT	Experimental Group	81	202.94 (45.73)	229.74 (55.93)
	Control Group	24	214.38 (44.86)	216.29 (42.32)

skill was effective in increasing alertness and concentration. Similarly, analysis of the mean values of CRT indicated a significant decrease ($t(80) = 4.27$ $p < .001$) in CRT values from pre (1153.79 ms) to post (1036.73 ms) session for experimental groups. However, the differences in performance in pre (1009.87 ms) to post (974.42 ms) session was not significant, ($t(23) = 1.84$ $p = .08$) for the control group. In this phase increased performance in the experimental group depicts increased alertness on account of effectiveness of the intervention module.

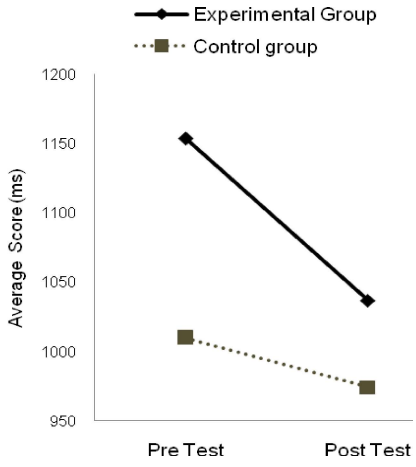

Fig 3: Mean performance of control and experimental group on CRT as a function of test session.

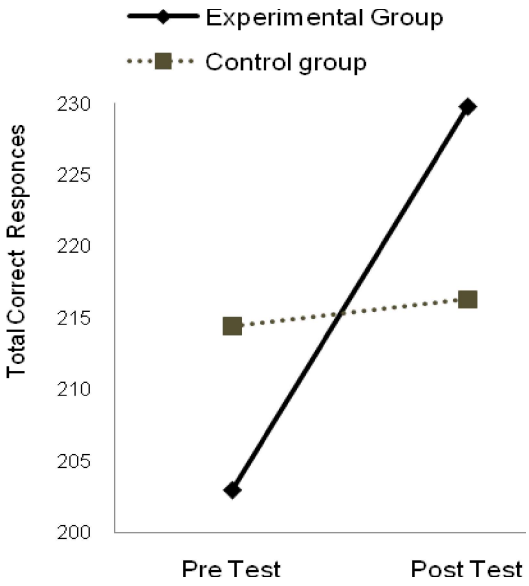

Fig 4: Mean performance of control and experimental group on GBT as a function of test session.

Discussion

The present study was conducted in two phases with two different aims. In Phase I, effects of different shifts on the performance of locomotive drivers were investigated through the two tasks (CFF and CRT) to know whether working on different time schedules affects attentional functions. CRT task measures psychomotor ability whereas CFF is applied to study cortical arousal, fatigue, visual fatigue, visual health and vigilance (Wilson, Benjamin, & Sreenivasan, 2003), which are the imperative areas of human performance of considerable

relevance to occupational health and safety. Literature reveals that CFF frequency is affected by various extrinsic factors, such as time of the day, sleep deprivation, shift-work, work with visual display terminals, acute effects of addictive substances (Bhattacharya & Tripathi, 1989, Hindmarch, 1982; Hindmarch, Quinlan, Moore, & Parkin, 1998; Kozeny & Prochazkova, 1992; Leonard, Fanning, Attwood & Buckley, 1998; Murata & Araki, 1996), and also different intrinsic factors that include age, intelligence and gender (Amir & Ali, 1989; Misiak, 1951). The result of Phase I indicated that irrespective of the driving conditions the reaction time (on CRT) increased after the completion of duty. However, a significant interaction between the driving condition and the test session suggests an increase in reaction time after driving for two consecutive nights. Similarly, irrespective of the driving conditions, the performance of drivers decreased on CFF after completion of their duty. The interaction between the driving condition and the test session was not found to be significant. However, a larger decline in attention was found after performing night duty rather than daytime duty. Driving during the night time generally disrupts sleep pattern and thus, reduces psychomotor ability and cortical arousal, which are apparent in this study. Thus, findings of CRT support the first hypothesis that three driving conditions would differently affect performance across the test sessions. These findings also have similarity with the research studies, which suggested that sleep disturbance is related with a decrease in alertness (Angus & Heslegrave, 1985; Dinges & Kribbs, 1991; Gillberg & Akerstedt, 1998; Harrison & Horne, 2000; Horne & Pettit, 1985; Horne, 1993; Koslowsky & Babkoff, 1992; Legault, 2011; Monk & Carrier, 1997).

The findings of Phase II in this study indicate that the intervention module significantly improves the performance of locomotive drivers on CRT and GBT in the experimental group. The reaction time decreased and the scores on GBT increased only for experimental group, while the control group showed little and non-significant improvement in performance, which may be due to the practice effect. These findings confirm the second hypothesis that intervention would improve performance of drivers on alertness tasks. The locomotive drivers who underwent the intervention module performed well on the tasks of alertness on account of enhanced cognitive abilities, as they applied their mind consciously on it and this mental exercise enhanced their alertness level, suggesting the possibility of enhancing alertness among them through intervention. This finding is supported by other studies, which suggest that mental exercise such as, playing a video game, computer exercises and cognitive training improve alertness and cognitive functioning (Boot et al., 2008; Posner et al., 2015; Takeuchi et al., 2010). A study conducted by this Directorate also affirms the facilitative effect of training and intervention on vigilance performance (Study Report Number PT 9, 1999).

Shift work is inevitable and an integral part of train driving job that cannot be eliminated from the job profile of train drivers. It is, therefore, essential to understand the possible causes of decrease in alertness with an objective to enhance those factors that can foster alertness and performance. At an individual level, physical exercises, yoga practices including meditation, Pranayam and deep breathing, and having good food habits may help in keeping physical and mental health in good fettle, besides improving the quantity and quality of sleep and reducing anxiety and stress. Physical exercise and meditation tend to improve alertness by producing changes in the brain mechanism (Hillman et al., 2008; Posner et al., 2015) and it has been found that the cognitive performance of safety-critical staff can be improved by the intervention of simple yoga practices in daily routine life (Kumar, 2015). Organizations also have important contributory role in enhancing alertness and lessening detrimental effects of shift work and sleep disturbance. A fair and free flow communication between workers and management, apposite allocation of duties, recognition of work, appropriate grievance redressal, sound performance appraisal and other alleviation strategies like workshop, training, counseling, psycho-intervention program can help in adapting to the demands of work and maintaining a good work-life balance, which in turn can reduce stress and

redress the issues of sleep and alertness. To facilitate identification of the issue of a decrease in alertness among safety-critical employees on Indian Railways a two point Alertness Assessment Scale for assessment of individual factors including lifestyle, sleep pattern, mental functions and perception about their workplace and organization has been developed (Study Report Number PT 39, 2014), thus, those in need of psycho-intervention and training could be identified for improvement on a regular basis. Redressal of issues related to work overload that cause fatigue, stress and deficiency in alertness needs to be a priority action plan for Indian Railways. Some prominent warning signs including headache, sleep problem, difficulty in concentration, short temper, upset stomach, low job satisfaction are the most common and obvious symptoms of stress, which if allowed to continue, may result in serious conditions, which can be psychological (low morale, anxiety, depression), physical (sleeping disorders, headaches, hypertension, ulcers), behavioral (emotional outbursts, violence, anger and aggression) and organizational (absenteeism, reduced productivity) having disastrous consequences in due course of time.

Conclusion

The present study suggests that the highly demanding task of train driving requires higher mental efforts. Duty rosters and job conditions do affect the cognitive performance of locomotive drivers. A duty, which is more strenuous in nature and that involves sleep deficit due to working in night increases the level of fatigue leading to attentional deficit. This gets compounded and increases the chances of a decrease in performance, which is noticeable after performing consecutively for two nights. Reduced performance after night duties is an indicator of disturbance in sleep and thus, the pattern of sleep is one of the major determinants of alertness among the locomotive drivers.

Since, the duty of this nature is inevitable in railway operations, it is of paramount importance to take measures both at the individual and organizational levels. The need of physical and mental exercises that tend to improve performance on alertness and other cognitive aspects by activating specific areas of brain responsible for concentration and attention could be instilled and inculcated as a part of daily life for improving overall performance. This finding is encouraging, which needs to be verified with larger groups and for longer sessions using a variety of mental activities and follow up assessments to make a firm conception about the role of intervention in enhancing alertness and other cognitive attributes among safety-critical employees working in Indian Railways.

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Manuscript submitted on September 4, 2015
Final revision received on October 16, 2015
Accepted on November 28, 2015

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