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Effect of Task Demand and Intrinsic Motivation on Human Vigilance Task Performance

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Maintaining alertness for prolong period of time is crucial for variety of tasks. However alertness tends to decline after certain interval of time. Several factors are responsible for this decrement in alertness. Among these factors the effect of task demand and intrinsic motivation has not been explored much. Thus, the present study examined the effects of intrinsic motivational state and task demand (in terms of event rate) on vigilance task performance. Target and non target were the square of size 3.5 cm and 3.3 cm, respectively. High and low event rate was used. Forty three undergraduate and post graduate volunteer students of Banaras Hindu University in the age range of 18 to 23 years were randomly selected for the experiment. The participant's task was to make a speeded decision about the presence or absence of the target by pressing the response key. A 2 (low and high event rate) x 2 (pre and post level of intrinsic motivation) x 4 (time period: 4 Blocks of 10 minutes each) mixed factorial design with repeated measure on the last two factors was used. Results revealed that participants employed in low task load condition (low event rate) showed better vigilance performance than participants on high cognitive load condition. Since high cognitive demand produces great task induced stress performance declined in high task load condition. Results further indicated that motivational dimension of state variables significantly got reduced after performing on vigilance task.

Keywords: Vigilance, task demand, intrinsic motivation, event rate

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The term vigilance was introduced for the first time by Head (1926), a British neurologist who defined vigilance as a state of maximum physiological efficiency in which individual try to remain alert on infrequent and unpredictable signals over longer period of time. The term vigilance is synonymous with sustained attention (Warm, 1984) or watch-keeping behavior. It is a component of various task situations, like RADAR (Radio Detection and Ranging), SONAR (Sound Navigation and Ranging) cytological screening, anesthesia gauge monitoring, nuclear power plant operation, industrial quality control, baggage screening, and detection of criminal or insurgent activity (e.g., friend or foe identification during long shifts) etc., which require sustained attention performance. Because of its importance it grapples central interest of cognitive psychologist, ergonomics specialist as well as neuroscientist. However, maintaining alertness over prolong period of time is difficult due to the fundamental limitations of human central nervous system, it's inability to sustain a high quality of information processing for an extended period of time. Consequently, the failure to maintain alertness can have severe consequences in applied settings. For example, during second world war British Radar operator's detection performance markedly declined (miss the signals of the presence of enemy submarines) lasting longer than 30 minutes that involves in frequently watching or monitoring (Mackworth, 1970).

The progressive decline in the quality of performance over the course of a watch keeping has been referred as the decrement function (Dember & Warm, 1979) or the vigilance decrement (Davies & Parasuraman, 1982) and it has been replicated in many studies (See, Howe, Warm, & Dember, 1995; Matthews, Davies, Westerman, & Stammers, 2000; Warm, 1984, 1993).

The decline in performance initially documented by Mackworth (1948) continues to be one of the most ubiquitous finding in vigilance research, both laboratory and real world settings across a variety of domains (Singh, Tiwari, & Singh, 2007). Vigilance decrement is the fundamental problem which typically occurs after 20-30 minutes of continuous work but can occur under certain conditions in as little as 5 minutes (Nuechterlein, Parasuraman, & Jiang, 1983). However, several researches (Frankman & Adams, 1962; Mackworth, 1970; Matthews & Davies, 2000) proposed different theories like inhibition (Mackworth, 1970), expectancy habituation (Mackworth, 1970), activation or arousal theory (Frankman & Adams, 1962), resource theory (Matthews & Davies, 2000), etc., to explain decrement function across time periods. Still, none of theory was able to present general models which explain reasons for progressive decline in vigil

performance over prolonged period of time. Moreover, there are some other variables that influence vigilance performance in controlled environment which includes: rate of non signal background, signal duration, intensity, inter signal interval, knowledge of results, motivation, and various personality variables (Buckner & McGrath, 1963; Davies & Tune, 1969; Stroh, 1971). Among these variables which influence vigilance, event rate is the most important and crucial one.

Event Rate and Human Vigilance

In experimental studies task demand has been manipulated in term of event rate. Event rate is defined as number of events occurring per minute and it has been identified as one of the most crucial and critical factor in taxonomic analysis of vigilance tasks (Jerison & Pickett, 1964). Parasuraman and Davies (1977) through a taxonomic analysis of vigilance tasks found that event rate and target discrimination could be the cause of decrement in vigilance performance across time periods. They defined rates of 24 events per minute or greater as high, and rates under 24 as low. They proposed that under high event rate condition decline in performance was associated with loss of perceptual sensitivity (*d'*) while increase in response criterion *(β)* is usually associated with decline in performance during low event rate condition. Davies and Parasuraman (1982) further reported that vigilance decrement was more pronounced under high event condition with successive discrimination type of task than low event condition with same type of task because vigilance tasks are stress-inducing (Temple et al., 2000) which closely related to psychophysical demands (Galinsky, Rosa, Warm, & Dember, 1993) that permits little autonomy for action (Hancock, 1998). Moreover, Warm and Jerison (1984) confirmed that performance efficiency is inversely related to event rate which is supported by several experimental studies (Singh et al., 2006). However, Singh et al. (2006, 2007) recommended that both type of tasks (low cognitive demand and high cognitive demand) had different effect on the vigilance performance and not only stress affect performance but also stress states play critical role in vigilance. Motivation is a significant factor of transitory stress state.

Vigilance and Motivation

Human performance in a given situation depends on a large number of personal factors as sleep and rest cycle, motivation,

excessive fatigue, stress, intake drugs, etc. which interfere with the human ability to act and react on impulses, both with regards to efficiency and effectiveness. Among these personal characteristics, motivation is a crucial variable which affects human vigilance performance. In fact, intrinsic motivation is of special interest in the field of human-computer interaction, especially in usability studies (Malhotra & Galletta, 2004; Voiskounsky, 2008) as well as in vigilance. It is also well known in cognitive research that participants vary widely in their motivation to perform well in neurocognitive tests (Locke & Braver, 2008).

There are a growing number of studies that have investigated the effects of motivation on various aspects of attention (Delgado, Locke, Stenger, & Fiez, 2003; Delgado, Nystrom, Fissell, Noll, & Fiez, 2000; Locke & Braver, 2008; Pessoa, 2008, 2009). Small et al. (2005) found that monetary incentives enhanced performance on a visual-spatial attentional task.

Motivational states channel information processing by modulating selective attention (Derryberry & Tucker, 1991, 1994; Rothermund, 2003; Rothermund, Wentura, & Bak, 2001). Motivation known as a push or pull aspect of human, is also considered in vigilance paradigm where, task orientation and interest is essential. Taylor et al. (2004) found a trend towards better target detection in the higher motivation condition.

Smith (1966) was the first who identified the role of motivation in vigilance performance in term of willingness. In his theory interaction of monotony and motivation provided an explanation of both of these phenomena. Internal influences arise from characteristics of the subject relating to his desire to do well and from inherent properties of the task itself. Further, Locke and Braver (2008) investigated the effects of motivation on executive control and found that financial incentive lead to an increase in executive control (indicated by increased activity in related brain areas) which significantly reduced RT (Reaction Time). It is uncertain how the alerting element of attention would be affected by motivation due to a paucity of research, though there have been suggestions that motivation can increase sustained attention (Sohlberg & Mateer, 1989) in young adults (Tomporowski & Tinsley, 1996), which shares similarities with the alerting component of Fan, McCandliss, Sommer, Raz, and Posner (2002) model.

The recent upsurge in the area of attention in the cognitive neuroscience literature is on the impact of reward incentives on brain activity and behavior. A wealth of imaging studies has identified brain

regions responsive to reward, in the signaling, prediction, and representation of incentives (Breiter & Rosen, 1999; O'Doherty, 2004). However, researches have begun to address what a motivational state entails, and how motivational systems in the brain interact with other motivational systems in the brain contribute to performance improvement (Gilbert & Fiez, 2004; Pochon et al., 2002; Small et al., 2005; Taylor et al., 2004).

Although there is substantial literature available on motivation and human performance in occupational settings (Kanfer, 1990) but research on the intrinsic motivation in vigilance paradigm until recently, has been limited in scope.

Intrinsic motivation is a unique form of motivation in which the force of act comes from internal side of an individual in a form of pleasure and interest or the sense of satisfaction that gets from the task itself in completing or even working on a task. Thus the intrinsic motivation plays crucial role in vigilance (Begleiter, Porjesz, Chou, & Aunon, 1983). It has been suggested that the level of difficulty of a vigilance task can influence subjects' commitment to perform the task and that cognitively demanding vigilance tests are intrinsically more motivating for subjects, to perform than are simple signal-detection vigilance tests which are monotonous and resource demanding. Due to its monotony and repeatedness, the typical vigilance situation provides little intrinsic motivation. According to Smith (1966) the manipulation of the task characteristics can reduce monotony and increase intrinsic motivation but what about the fluctuation of intrinsic motivation during task none was able to present a general fact that would account for all. Evidences from studies (Sansone, Weir, Harpster, & Morgan, 1992; Sansone, Wiebe, & Morgan, 1999) also reveal the same trend. None of the theories discussed so far regarded intrinsic motivation as the most important determinant of either the decrement or the overall level of performance. Therefore, motivational state perspective provides a novel dimension of explanation for individual differences in performance on laboratory test of sustained attention (Warm, 1984). Also, motivational states have been proposed to have an effect on the accessibility of goal-related or task-related information (Goschke & Kuhl, 1993; Marsh, Hicks, & Bink, 1998; Rothermund, 2003).

Many researches on motivation (Delgado, Locke et al., 2003; Delgado, Nystrom et al., 2000; Derryberry & Tucker, 1991, 1994; Locke & Braver, 2008; Rothermund, 2003; Rothermund et al., 2001; Pessoa, 2008, 2009) had correlated sustained attention with stress (Hockey, 1983; Scerbo, 2001) but result move to fail toward define the intrinsic motivational states and strain effect on vigilance performance. Hence, lack of intrinsic motivation or a tendency to non

willingness to do so is a great cause of decline in performance of vigil. Several attempts have been made to assess the role of motivation but researchers cannot correlate it with stress states of the participants. Moreover, the researches on the transitory state of stress, until recently had revealed inconsistent findings on vigil performance which connote that intrinsic motivation are of limited use in predicting stress reactions. Thus, a better understanding of the consequences of intrinsic motivation on vigilance performances needs to be examined. The main objective of the present study is to examine the effects of intrinsic motivational state on sustained attention task performance.

The present study was an attempt to examine the effects of intrinsic motivational states and event rate in term of cognitive demand on the vigilance task performance. The following hypotheses were tested in this study:

1. Participants would show better vigilance performance under low cognitive demand condition than in high cognitive demand condition.
2. Participants' motivation would have positive effect on sustained attention task performance.

Method

Sample

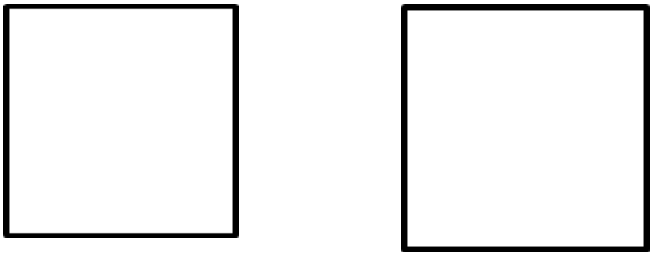
Forty three undergraduate and post graduate students of Banaras Hindu University were randomly selected on the basis of volunteered participation. All the students were listed and then using the random number tables they were selected to participate in the experiment. Seventeen participants were randomly employed in high event rate and 26 participants employed in low event rate experimental condition. Analyses of performance could not be taken from participants who did not initially perform the task to criterion. Thus, two participants who performed below the initial accuracy cut off (at least 75% or more on correct detections) during the practice session of the sustained attention task were excluded from all analyses. Data from the remaining 43 participants are presented here. All the participants had normal, i.e., 20/20 or corrected to normal visual acuity which was tested on Snellon chart (Snellen, 1962) in the cognitive science laboratory (CSL). All the participants were healthy, non smokers with no neurological insult history. The age of the participants ranged from 18 to 25 years with mean age of 23.3 years.

All the participants gave their written informed consent to participate in the study. The participants had no earlier exposure of this task.

Successive Sensory Vigilance Task

Participants performed on the successive sensory visual vigilance task in this study. The task consisted of different size of squares. Each participant was given a square of 3.5 cm. and a square of 3.3 cm. as target and non target, respectively (see Figure 1). The experiment was planned on Super-Lab Software and all the stimuli were displayed on a 15" super video graphics array normal resolution color monitor (refresh rate of 63 Hz) via computer at a spatial resolution of 800x600 pixels with 32 bits of color quality. The square was displayed in black color on the white background on the same system.

There were two experimental conditions i.e., high demand and low demand conditions. These two conditions were chosen on the basis of previous researches (Parsuraman & Davis, 1977; Singh et al., 2007). The high demand condition had 60 events per minute, whereas low demand had 15 events per minute. Each participant was given the practice session of 40 minutes before the final task of 40 minutes. Each block of 10 minutes comprised 150 events in low cognitive demand while 600 events on high cognitive demand. The ratio of target and non target was 1:4 in both conditions. The target probability was 20 percent. In both the conditions tasks were presented in successive manner on visual modality. There were four 10 minutes blocks in the current experiment condition.



Non target 3.3 cm^2 Target 3.5 cm^2

Figure 1: Successive Sensory Vigilance Task

Design

A 2 (low and high event rate) x 2 (pre and post level of intrinsic motivation) x 4 (time period: 4 blocks of 10 minutes each) mixed factorial design with repeated measure on the last two factors was used.

Measures

Multidimensional Stress States Questionnaire. The measure used was Multidimensional Stress States Questionnaire (MSSQ) for the assessment of the motivational stress states. MSSQ is the Hindi adaptation of the Dundee Stress States Questionnaire (DSSQ; Matthews et al., 1999, 2002), and a multidimensional, self-report instrument for assessing transient stress states. It comprises measures of mood, cognitive interference, perceived workload, and motivation. This version of the DSSQ comprised 10 factor analytically determined scales. MSSQ was administered in two sessions: A pre-vigil questionnaire completed prior to the practice period and a post-vigil questionnaire completed after the vigil.

Motivation Scale. Motivation Scale (Mathews et al., 1995) was administered to measure the aspiration level to achieve successful performance as well as to access the interest in the task at hand. The shortened adaptation of the Motivation Scale (Mathews et al., 1995) was administered immediately upon completing the main vigilance task. It was administered before and after final sensory vigilance task session for measuring pre- and post-intrinsic motivation levels of the participants. It contains eight items which assess an immediate urge to achieve, should be represented across a variety of goals and subgoals, which may vary with context. Items were written to represent two major aspects of motivation in performance settings: task interest and strivings to achieve successful performance. It contains items such as "*According to you what is the nature of task*?" Each item is measured on a 10-point scale i.e., moving from low to high gives sufficient opportunity to pin point their precise level of satisfaction or willingness during task.

Procedure

On arriving at the cognitive science laboratory each participant was required to fill up the consent form. Before participating in the

experiment each participant completed a biographical questionnaire, which had several questions about their age, weight, education, and socioeconomic status, knowledge about computer, and frequency of practice on a computer. All participants were also tested for their normal vision on Snellon vision chart in the laboratory.

All the participants were divided randomly into two different groups in accordance with condition of experiments. After that the online instructions with brief introduction about the task were provided clearly to all the subjects. The queries of the subjects, if any, were properly attended.

Before starting the final experiment the participants received a demonstration of 3 minutes of sensory vigilance task to get acquaintance with task. Then participants received 10 minutes common practice on task. Participants, who scored 75% or higher on hit rates (accuracy) cut off criterion, were randomly assigned in each of the two experimental conditions of a four 10 minutes equal blocks. Further Multidimensional Stress State Questionnaire (Matthews et al., 1999) was administered to the participants before and after the final 40 minutes experimental task.

Results

Means and standard deviations for all performance measures was calculated block wise for each treatment condition. To examine the interaction effects between treatment condition and block, repeated measure ANOVA was computed for correct detection. In addition, effect size (partial eta squared η_p^2) of statistically significant effects was also reported.

In the present vigil experiment, correct detection was defined as key presses on response pad to occurrence of critical signal (big square) on the computer monitor. Along with correct detection the stress state measure in term of intrinsic motivation were also collected. For the assessment of the stress state of the participants the Multidimensional Stress States Questionnaire (Matthews et al., 1999) were administered before and after final task session. The obtained mean scores and standard deviation on intrinsic motivation factor of the MSSQ at pre and post sessions are presented in Table1.

Results presented in Table 1 shows that mean score of pre-session intrinsic motivation was found higher in high task demand condition (M = 62.30; SD = 13.38) than in low task demand condition (M = 58.5; SD = 9.63).

Table 1

Means and Standard Deviations of Intrinsic Motivation at Pre- and Post-Stress Session (N=43)

Motivation	High Demand *M (SD)*	Low Demand *M (SD)*
Pre-test	62.23 (10.12)	58.50 (9.63)
Post-test	52.67 (13.13)	52.61(13.38)

Findings of Table 1 also showed that the scores of the post session motivation for high (M = 52.18) and low (M = 52.61) task demand conditions were found to be more or less same in both conditions.

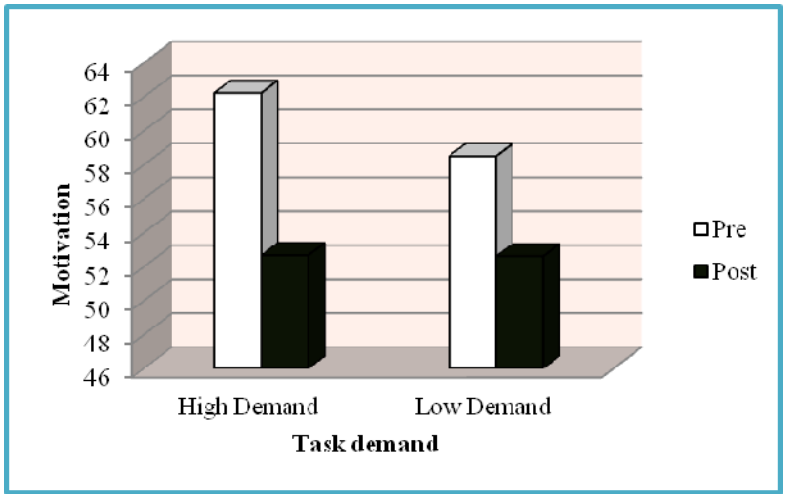


Figure 2. Motivation as Function of Task Demand after Task Performance Session

The obtained data from MSSQ were further submitted to 2 x 2 (demand x intrinsic motivational state) analysis of variance with repeated measure on last factor. Analysis of variance revealed that main effect of intrinsic motivation (pre-post) was found significant with F (1, 41) = 16.19; p < .01 whereas their interaction and main effect of task demand was non significant on p > .05. The findings are graphically presented in Figure 3. Hence, this finding supported the first hypothesis that participants' motivation would have positive effect on sustained attention task performance.

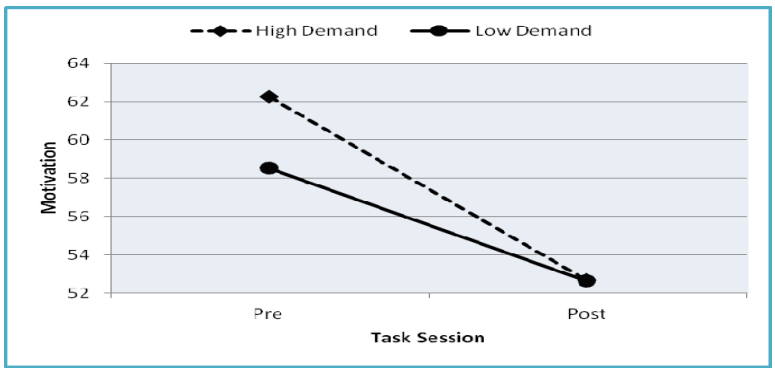


Figure 3. Intrinsic Motivation as Function of Task and Pre-Post Session Measure

Means and standard deviations for correct detection (hit rate) on vigil task were calculated for all four blocks (see Table 2) in both conditions (high and low task demand).

Table 2

Means and Standard Deviations of Accuracy as Function of Task Demand and Time Periods (N=43)

Task Demand	Blk. 1 *M(SD)*	Blk. 2 *M(SD)*	Blk. 3 *M(SD)*	Blk. 4 *M(SD)*	Total *M(SD)*
High	77.6 (.20)	71.7 (.21)	72.3 (.22)	74.4 (.21)	74.0(.21)
Low	85.7 (.12)	86.1 (.15)	87.5 (.19)	89.3 (.15)	87.1(.15)

Note. Blk. = Block

The means and standard deviations of vigil task performance were calculated for all four blocks (see Table 2) in both condition (high demand and low demand). The analysis of scores revealed that the overall detection rate in low cognitive demand condition was significantly higher than in high cognitive task demand condition. The results revealed that participants perform better on low task demand condition (low event rate) than high task demand condition (high event rate).

ANOVA result of hits performance demonstrated that the main effect of task F (1, 41) = 6.50; $p < .01$ was significant (see Figure 4). However, their interaction effect was non significant, $p > .05$. Further, performance of participants with time on task (see Figure 4) showed that in high demand condition detection accuracy declined from block 1 to block 2 but afterwards showed slight improvement in

performance in block 3 and block 4. While in low demand condition detection accuracy showed improvement from block 1 to block 4.

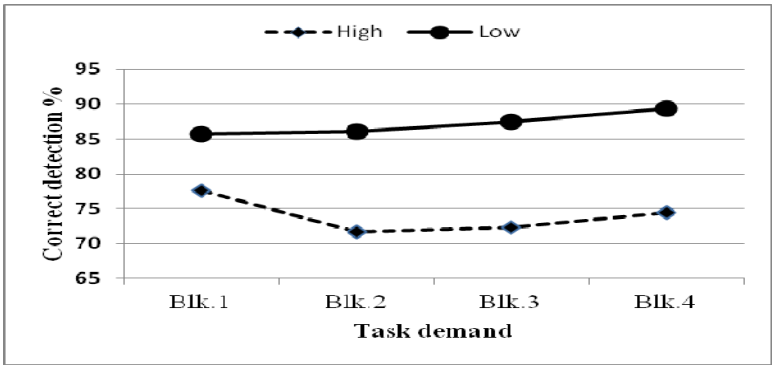


Figure 4. Mean Accuracy as Function of Tasks Demand

Discussion

Present study was an attempt to test the competing claims of various researchers by combining the vigilance and motivational factors in different task load condition. Results of the present study revealed that participants employed in low task load condition (low event rate) showed better vigilance performance than participants in high cognitive load condition. Thus, the finding confirms the first hypothesis i.e., participants would show better vigilance performance under low cognitive demand condition than in high cognitive demand condition.

The obtained result reveals that the task which is presented in low event rate condition required little resources, whereas, in high event rate task required more resources because the processing demands of high event rate task are so high. The high cognitive demanding nature of the task produces great task induced stress and required appropriate coping style and in order to maintain high alertness participants decline in their vigil or alertness capacity. The obtained result was in line with previous findings (Davies & Parasuraman, 1982). The findings of performance measure (i.e., hit rate) is also consistent with other researchers that found a vast reduction in incorrect detection and increment in correct detection on low event rate condition as compared to high event rate condition (Taylor et al., 2004).

Studies have also shown that vigilance tasks are stress-inducing (Temple et al., 2000) and closely related to psychophysical demands (Galinsky et al., 1993) performance efficiency had been inversely related to event rate (Jerison, 1984) indicating the performance was better in low event rate condition as compared to high event rate condition. Other researchers (Singh et al., 2006, 2007) had also recommended that both type of tasks (low cognitive demand and high cognitive demand) had different effect on the vigilance performance. Although low event rate condition requires recourse but it is not as high as in high cognitive demand task. Therefore participants on low task demand conditions are able to maintain their sustained alertness which is indicated in their correct detection (hit rate) performance. The stress which is produced by the task significantly affects the willingness and engagement of observer in while they were actively engage in the task.

An attempt was also made to investigate whether prolonged (40 minutes) vigilance performance is affected by participant's motivational state. Results demonstrated that the motivational dimension of state variables significantly got reduced after performing prolonged vigilance task. The obtained results supported the contention of Matthews, Pitcaithly, and Mann (1995), who predicted the effects of stress states during vigil task performance. Smith (1966) was the first who identified the role of motivation in vigilance performance. Motivational states channel information processing by modulating selective attention (Derryberry & Tucker, 1991, 1994; Rothermund, 2003; Rothermund et al., 2001). It is also considered in vigilance paradigm where task orientation and interest is essential. Taylor et al. (2004) found a trend towards better target detection in the higher motivation condition while Locke and Braver (2008) reported that participants vary widely in their motivation to perform well in neuro-cognitive tests. Although, it is uncertain how the alerting element of attention would be affected by motivation, it has been suggested that motivation can increase sustained attention (Sohlberg & Mateer, 1989) in young adults (Tomporowski & Tinsley, 1996) which shares similarities with the alerting component of Fan et al. (2002) model.

When the task creates cognitive load on observer, she/he feels much mental demand and requires more resources to cope with it. In this process the participant suddenly disengages with the goal of the task and become internally less motivated. The significant reduction in intrinsic motivational scores proves our last hypothesis that participants' motivation had positive effect on sustained attention task performance. While it is possible that this internal state (intrinsic

motivation) leads to poorer cognitive performance which may be due to the overlap between the emotional and cognitive regions which actually represent highly overlapping processes (Pessoa, 2008).

In sum, the obtained findings suggest that vigilance task situation creates boredom, monotony and reduce the arousal and produces fatigue in observer. These factors are also responsible for intrinsic motivation among observer. The results revealed that motivation components of multidimensional stress states significantly decreased from pre- to post-session. Thus, the reduction in willingness of to do correct response consequently produce decline in performance.

Limitations and Suggestions

Every endeavor carries some advantages along with some associate limitations which often leave the scope for further innovations and delving to strengthen the construct under investigation. Current study also has some limitations which might be an imperative consideration in future researches. Specifying the limitations it is quite evident here that the sample size was limited for representing the total population. Pertaining to methodology, studying the effect of task demand was the main heed. However, the task demand was divided merely into two levels i.e., either high or low, while a mediatory demand task would have allowed the researchers to substantiate the obtained results more pronouncedly. Finally, a more vivid picture regarding vigilance performance will be available if one incorporates psychophysiological measures like electro-encephalo graphy, event-related potentials or heart rate variability to strengthen our claim regarding motivational state differences prevalent under vigilance task performance.

Implications

The findings of the present study can be utilised in minimising the risk factor in vigilance tasks. The findings would help in understanding that an intrinsic state of mind is also fruitful in process of task interest and performance. Individuals can be categorized on the basis of motivational state and provide high demand task to high motivational state person for better performance. Additionally to get better output in applied tasks low demanded task can be designed for better alertness or concentration which may lead to better performance.

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