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Special Feature

Effects of Target Expectancy and Cognitive Demand on Vigilance Performance

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This study examined the effects of target expectancy and cognitive demand on the vigilance performance. 40 students of the Banaras Hindu University were participated in this study. A square of 3.5 cm and a square of 3.0 cm were used as target and non-target, respectively. All targets were presented at the rate of 15 events per minute (low cognitive demand condition) and 30 events per minute (high cognitive demand condition). The ratio of target and non-target in the low target expectancy was 20:80 and in the high target expectancy it was 80:20. There were six 10-min blocks in each of the four experimental conditions. Subjects were instructed to press a designated key on the response pad immediately after detecting a target and to ignore non-target. A 2 x 2 x 2 x 3 mixed factorial design was used. Speed and accuracy were recorded as performance measure. Results revealed better vigilance performance in low cognitive demand and in high target expectancy condition.

Keywords: Target expectancy, Cognitive demand, Decrement function, Perceptual sensitivity, Response criterion

Vigilance (or sustained attention) tasks require observer to detect predetermined critical signals that occur unpredictably over prolonged periods of time, often lasting 30 min to several hours (Davies & Parasuraman, 1982; Warm, 1984). The central issue of vigilance research has been the decline in performance across time periods which may be known as the vigilance decrement (See, Howe, Warm & Dember, 1995). Although vigilance has been and remains an important part of many contemporary work environments, it has assumed significantly greater importance with the introduction of many 9/11-mandated security systems such as by the Transportation Security Administration's (TSA) need to screen 100% of all baggage at all US airports (Harris, 2002; Hancock & Hart, 2002). In these tasks, observer has to sustain his/her attention over prolonged periods of time to detect the critical signal, which occurs infrequently and aperiodically. It is somehow not possible for an operator to focus attention on one source of information for long periods of time.

Parasuraman and Davies (1977) identified event rate as one of the most important factors that affecting vigilance performance. They defined rates of 24 events per minute or greater as high, and rates under 24 as low. Moreover, performance efficiency is inversely related to event rate (Warm & Jerison, 1984; I. L. Singh, Tiwari & A. L. Singh, 2006). Several researches suggested that there would not be a single accepted explanation for deterioration in sustained attention performance across time periods (Davies & Parasuraman, 1982; Singh et. al., 2006). There could be a variety of explanations, several of which would have some validity, at least for some types of sustained attention task. Similarly, signal detection theory analyses of vigilance showed that vigilance decrement might sometimes be associated with loss of perceptual sensitivity (indexed by ä), and at other time with an increase in response criterion (indexed by â). In this latter case, the person becomes increasingly reluctant to respond, but perceptual efficiency would not change. It has also suggested that low demanding (low cognitive demand) and high demanding (high cognitive demand) tasks had different effect on the vigilance performance (Singh et. al., 2006). The vigilance decrement on low event rate tasks was usually associated with an increment in â (beta), rather than decline in perceptual sensitivity (ä) but decline in ä was found in high event tasks, if processing demands were sufficiently high (I. L. Singh, A. L. Singh, & Tiwari, 2004). The sensitivity decrement on demanding tasks had been attributed to depletion of attentional resources (Parasuraman, Warm & Dember, 1987). Several mechanisms for performance change on low event rate tasks had been proposed, but none of them fully explained the empirical evidence (Singh et. al., 2006).

Moreover, See, Howe, Warm, and Dember (1995) defined signal probability (Target expectancy) as the ratio of critical signals to the total number of events that occur over a given time period. Most studies have demonstrated that higher target expectancies result in greater receptivity to critical signals (Baddeley & Colquhoun, 1969; Parasuraman & Davies, 1976). Consequently, higher target expectancy typically maximizes the accuracy and speed of signal detection (Jenkins, 1958; Warm & Alluisi, 1971). The signal probability has been considered as a determinant of target expectancy and its effect has been examined on sustained attention performance (Craig, 1978, 1987; Vickers & Leary, 1983). The temporal target expectancy was experimentally manipulated through variations in density or the number of critical signals (targets). The more frequently such targets occur within a fixed time period, the less the observer's average uncertainty as to when they will occur. The variations in critical signals density might influence the speed with which critical signals are being detected. The temporal certainty may also be manipulated through variations in the intervals of time between critical signals. These intervals can be made to be highly regular and therefore easily predictable.

In the present study an attempt has been made to examine the effects of signal probability in terms of target expectancy and event rate as cognitive demand on the vigilance task performance. Two hypotheses were tested in this study: (i) participants would show better vigilance performance under high target expectancy condition than in low target expectancy across blocks, and (ii) participants would also exhibit higher vigilance performance in low cognitive demand condition than in high cognitive demand across blocks.

Method

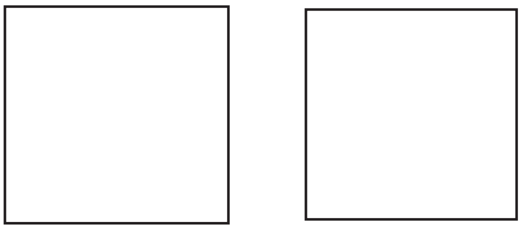
Sample:

40 undergraduate students of the Banaras Hindu University were randomly selected in this experiment. The age of the participant varied from 18 to 21 years, with mean age of 20 years. All participants had normal or corrected-to-normal vision. The participants had no earlier exposure of this task.

Sensory Vigilance Task

A square of 3.5 cm. and a square of 3.0 cm. were used as target and non-target, respectively in this study. The experiment was planned on SuperLab Software for Windows v. 4.0 and was displayed on a 15" SVGA colour monitor of a Pentium IV computer (see Figure-1). In low cognitive demand condition, targets and non-targets were presented at the rate of 15 events per minute, whereas in high cognitive demand condition targets and non-targets were presented at the rate of 30 events per minute. Each block of 10 minutes comprised 150 events in low cognitive demand condition and 300 events in high cognitive demand condition. The ratio of target and non-target in low target expectancy was 20:80 and in high target expectancy the ratio of target and non-target was 80:20. There were six 10-min blocks in each of the four experimental conditions

Figure 1: Sensory Vigilance Task



Target ($3.5\ cm^2$) ***Non-target*** ($3.0\ cm^2$)

Design:

A 2 (low and high target expectancy) x 2 (low and high cognitive demand condition) x 2 (30-min sessions) x 3(10-min blocks) mixed factorial design was used in the present study.

Procedure:

All subjects were required to fill-up a consent form to participate in this experiment. They also completed a biographical questionnaire, which had several questions about their age, education, socio-economic status, knowledge about computer and frequency of practice on a computer. Subjects were also tested for their normal vision on Snellon vision chart in the lab. The on-line instructions with brief introduction about the task were imparted lucidly to all subjects as follows: "The present experiment is related to the vigilance performance. In this study you will see two squares of different sizes at the center of the PC-monitor after a display of plus (+) sign for 500 ms. You are required to press a designated key on the response pad immediately after detecting a big square, which is regarded as target and to ignore small square which is called as a non-target. Correct detection of target (hit rates), incorrect detection (false alarms) of target and reaction time (RT) will be recorded as performance measures. Is it clear to you? If you have any question, please do not hesitate to ask."

The queries of the subjects, if any, were properly attended to by the experimenter. Each subject received a demo of 3-min of sensory vigilance task to get acquaint with task. All subject received 10-min common practice on task. At the end of 10-min practice, feedback was given to each participant about all three dependent measures. Participants, who scored 75% or above on hit rates (accuracy) criterion, were randomly assigned in each of the four experimental conditions of a six 10-min blocks.

Results and Discussion

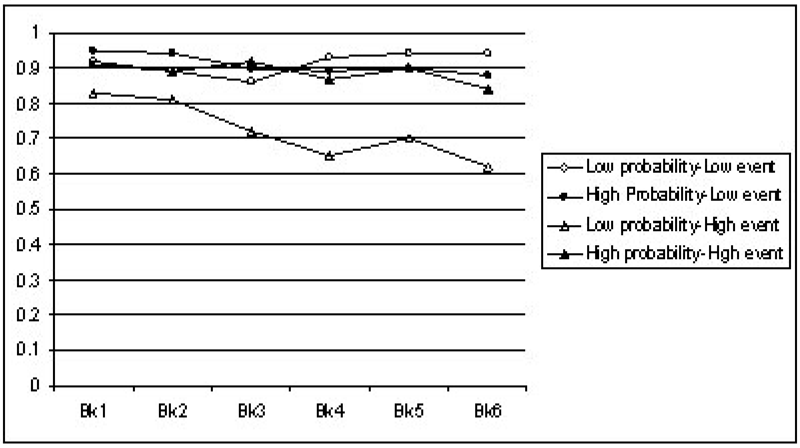
Mean hit rates performance indicated that better vigilance performance was obtained in low cognitive demand condition (M= 0.91; SD= 0.03) than high cognitive demand condition (M= 0.80; SD= 0.03). Similarly, subject detected more targets in high target expectancy condition (M= 0.90; SD = 0.03) than in low target expectancy condition (M= 0.81; SD= 0.03). Decrement in vigilance performance is also found across time periods.

The data were then submitted for the 2 x 2 x 2 x 3 analyses of variance with repeated measures on the last two factors. The ANOVA of the hit rates performance gave significant effects for cognitive demand, $F(1, 36) = 6.39$, $p< .01$; target expectancy, $F(1, 36) = 3.78$, $p < .06$; cognitive demand x target expectancy $F(1, 36) = 4.03$, $p < .05$; cognitive demand x session, $F(2, 72) = 6.67$, $p <.01$ and target expectancy x cognitive demand x session, $F(1, 36) = 7.33$, $p < .01$, target expectancy x cognitive demand x block, $F(2, 72) = 3.72$, $p< .02$ (see Figure 2). Results revealed benefits in detecting signals under high target expectancy and in low cognitive demand across time periods.

The false alarms performance was found higher in low target expectancy condition

(M= 5.45; SD= 0.03) than in high target expectancy condition (M= 0.23; SD= 0.03). Similarly, subjects committed little more false alarms in high cognitive demand condition (M = 0.18; SD = 0.03) than in low cognitive demand condition (M = 0.11; SD = 0.03) across blocks, irrespective of the tasks. Further these data were submitted to 2 x 2 x 2 x 3 analyses of variance with repeated measures on the last two factors.

Figure 2: Hit Rates Performance as a Function of Cognitive Demand and Target Expectancy



The ANOVA of the false alarm gave significant main effect for target expectancy condition, F(1, 36) = 18.15, p < .01. All other sources of variance were not significant. Results indicated that subjects committed significantly higher errors in low target expectancy condition.

Mean reaction time performance was higher in low target expectancy condition (M = 230.22; SD = 10.99) than in high target expectancy condition (M = 206.27; SD = 10.99). Similarly, reaction time was more in low cognitive demand condition (M = 226.24; SD = 10.99) than in high cognitive demand condition (M = 210.24; SD = 10.99).

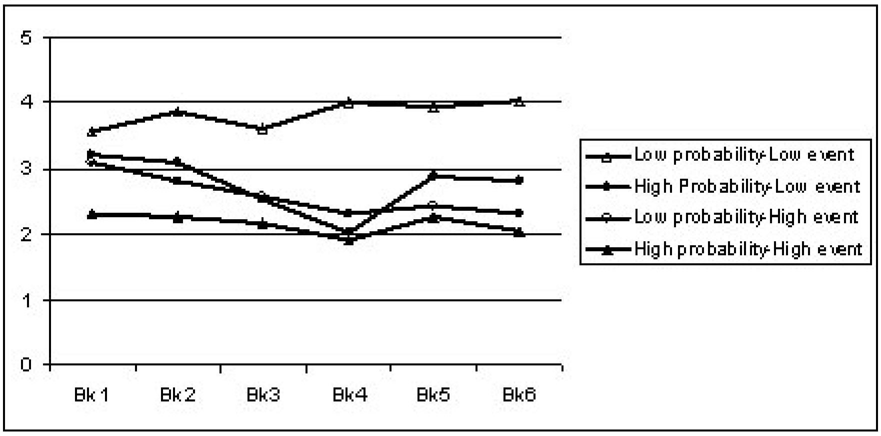
Moreover, the ANOVA of the reaction time rate showed significant effects for session and block. All other sources of variance were not significant. Results indicated that RT performance increased after 20-min and remained stable over time, irrespective of the experimental conditions.

Furthermore, the indices of sensitivity index score (ä) and response criterion (â) measures were also calculated from the proportions of correct and false alarms responses, using Tables ä and â by Freeman (1973). These data were submitted for 2 x 2 x 2 x 3 analyses of variance with repeated measures on the last two factors.

The ANOVA of the index of perceptual sensitivity showed significant effects for cognitive demand, F(1, 36) = 12.32, p < .01; target expectancy, F(1, 36) = 8.12, p < .01 and target expectancy x cognitive demand x session, F (1, 36) = 12.79, p < .01. Four way interaction among cognitive demand x target expectancy x session x block also achieved significance level, F (2, 72) = 4.28, p < .01 (see Figure 3). However, two way interactions between cognitive demands x target expectancy were not found significant. Results revealed benefits in detecting signals under high target expectancy and low cognitive demand across sessions and blocks.

The means and standard deviations of response criteria indicated that response bias increased across time periods and more beta was found in low target expectancy condition (M = 7.61; SD = 0.94 than in high target expectancy (M = 1.48; SD = 0.94) while beta was stable in cognitive demand conditions. ANOVA showed significant effect for target expectancy, F (1, 36) = 21.04, $p < .01$, which suggested that subjects were more biased in

Figure 3: Sensitivity Index (ä) as Function of Cognitive Demand and Target Expectancy



low target expectancy condition. Thus, the decrement in sustained attention performance across blocks was not due to perceptual sensitivity but it could be due to response bias in low target expectancy condition.

The findings of the present experiment confirm our hypothesis that subject would show better vigilance performance under high target expectancy condition than in low target expectancy on hit rates and sensitivity index scores. The benefit of target expectancy was maintained across session and blocks. The findings are consistent with other researchers (Jenkins, 1958; Warm & Alluisi, 1971). Moreover, the magnitude of effect is not very high due to small sample size (10 in each condition). The results involving cognitive demand also supports that accuracy decreases as the event rate increases. A high cognitive demand has been found to impose a greater resource demand than in a low cognitive demand. The trend of better performance under low cognitive demand with high target expectancy was maintained across time periods, which accept our second hypothesis that subject would exhibit higher vigilance performance in low cognitive demand task condition than in high cognitive demand across blocks. The present finding is in line with the vigilance taxonomy developed by Parasuraman and Davies (1977) which predicts a decline in performance as event rate increases.

Overall, results suggest that the observer's general level of expectancy and cognitive demand affect his/her vigilance performance. Similarly, background cognitive demand also emerged as an important factor in determining sustained attention task performance. Results further indicate that subject's high expectancy toward signal occurrence and low cognitive demands improve vigil performance over time periods.

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