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Effects of Task Load and Cue Validity on Simultaneous Sustained Attention Search Task Performance

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The present study aimed to examine the effect of task load on visual search sustained attention task performance. Cue works as a signal and may facilitate or deteriorate the performance. These effects depend on cue validity and its temporal properties. Present study used cue validity to observe the effect of cue on participant's performance. Ninety participants were randomly assigned into different experimental conditions. A 2 (Task load: High and Low event rate) X3 (Cue validity: Valid, Invalid and Neutral) X4 (time block: 10 minutes each) mixed factorial design with repeated measure on the last two factors was used. Correct detection, incorrect detection and reaction time were recorded as performance measures to analyze sustained attention task performance. Results revealed that correct detection and perceptual sensitivity was higher under low task load condition in comparison to high task load condition. Moreover, response latency was found better under low task load condition than high task load. Ample evidences have proven that attentional tasks are resource demanding, when the temporal load of task increases it works as a catalyst to diminish our ability to perform on task. The present study holds promises to counter such decrement with the help of cue.

Keywords: Attention, Cue, Cue Validity, Temporal Load, Response Latency.

The speed at which advancement in technology is progressing, role of humans has shifted from active participants to a passive observer who must remain alert to detect critical signal or changes in the system status. Attending to them well, we need to focus on a desired stimulus while cancelling others. This ability to concentrate and focus is a core feature of human cognition (MacLean, Aichele, Bridewell, Mangun, Wojciulik & Saron, 2009). Such ability to concentrate attention for a longer period of time is known as sustained attention. Sir Henry Head (1923) used the term vigilance and described it as a physiological state of readiness of the nervous system to react in a certain way. Sustained attention or vigilance refers to "a state of readiness to detect and respond to certain small variance occurring at random time interval in the environment" (Parasuraman & Davis, 1984). Numerous researches stated that, the alertness is an effortful and resource demanding process that cannot be maintained for a prolonged time periods (Desmond, Matthews & Bush, 2001). Posner and Boies (1971) explained sustained attention with two primary characteristics; first was the alertness of observer towards stimuli and second one was the ability to focus on one source of information over other. The most widely accepted criteria for sustained attention were propounded by the McGrath (1963) and Warm (1977, 1984). They discussed four core attributes of sustained attention task which make them unique and establish a criterion to distinguish it from other attentional tasks. The criteria were (i) the task should be of long duration (ii) the signals must be clearly perceivable when the participants are alert to detect (iii) signals must occur randomly, infrequently (iv) occurrence of signals must have no impact on observer's response. The vigilance task must constitute all these four criteria.

Visual simultaneous sustained attention task

Several studies conducted on cognitive functions have suggested that task of simultaneous discrimination type played an important role in vigilance decrement (See, Howe, Warm, & Dember, 1995; Singh, Singh & Tiwari, 2004). It is a kind of task in which all critical information required to make decision between noise and signal are presented in the current field. For example, observers might be asked to detect green colour triangle among squares presented simultaneously in the visual field. In real world scenario, individuals also select the relevant information by ignoring the rest. With this rational in concern, simultaneous task was best suited for our study as a replica of real world scenario. The task recorded three direct performance measures such as time taken by participants to detect signal or target (RT), false alarm rates and hit rates. Singh and Singh (2014) used simultaneous discrimination task to find out the effect of cue validity on participants performance. Their study revealed that cue has best effect during 550 milliseconds (ms) stimulus onset asynchrony (SOA).

Task Load

Every task we exhibit has some load or difficulty. Here, in the present experiment event rate was manipulated to vary task load for sustained attention. Bakan (1959) did an experiment in which participants had to report the presence of either three identical digits (low complexity) or an odd-even-odd sequence (high complexity). The result revealed high rate of vigilance decrement in more complex task than low complex task as the task complexness increased. Altering the task load by manipulating event rate was also studied by Jerison and Pickett (1964). They compared two event rates detection to find out the effect of load. Results revealed that as the event rate of task elevated the performance decreased rapidly. Several other researchers had also reported similar results augmenting decrement in performance as a function of event rate during vigilance task performance (Parasuraman, 1979; Singh, Tiwari & Singh, 2007). Mishra, Naveen, Singh, Singh and Tiwari (2016) studied the effect of warning cue on sustained attention task performance. They used low event rate (15 events per minute) during vigilance task and found facilitation effect of warning cue.

While considering all the literature it was inferred that cue has an impact on performance, but very few researchers had utilized simultaneous task in their studies. Thus, the purpose of the present study was to find out how the different loads of simultaneous discrimination task affect vigilance performance across time periods. It was hypothesized that participant's vigilance performance would decline in high task load condition than low task load conditions.

Method

Participants

Ninety participants (52 males and 38 females) with the age range from 18 to 29 years (M = 22.34, SD= 3.56) of Banaras Hindu University took part in the study. Participants were randomly assigned into different experimental conditions. Participants with any kind of known psychological and neuropsychological disorder were excluded from the sample. Prior to assigning the participants in any experimental conditions, it was assured that their visual acuity was normal (6/6) or corrected to normal (6/9) level.

Research design

A 2 (Task Load: Low and High) × 3 (Cue validity: Valid, Invalid and Neutral) × 4 (Time Block: 10 minute each) mixed factorial design with repeated measure on last two factors was used. Different task loads were treated as between group factor, whereas cue validity was manipulated as within group factor.

Material and Apparatus

A Dell Inspiron (Machine Inspiron 580s with Intel i3 processor) with 15-inch color monitor was used for the presentation of stimuli. Stimuli were presented electronically using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) and responses were recorded through keyboard.

Experimental task

The task started with a fixation (+) sign, displayed centrally on the screen for 500 milliseconds (ms) followed by a cue presented spatially on any of the four or all the four directions as per the experimental design. The exposure to target/non-target stimulus was given for a very brief time period (viz. 150 ms). Response screen was presented after the target/non-target for 2400 ms to let participants decide about the appearance of target/non-target and to mark their response participants had to press space bar as soon as possible. The ratio of the target and non-target was kept at 20:80. A flicker stimulus with black and grey color was used as an exogenous cue. Cue validity for valid, invalid, and neutral ratio was kept 80:10:10 across the time blocks. The flow chart of vigilance task is presented in Figure-1.

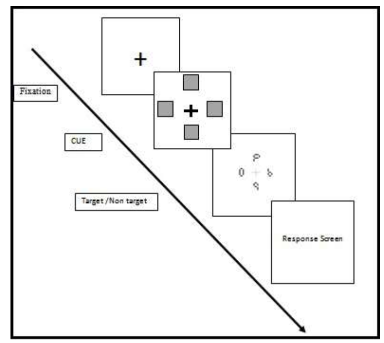

Figure 1: Flow chart of experimental task

Procedure

Participants were made comfortable to the laboratory environment before starting the experimental session. Biographical information and informed consent were taken after establishing essential rapport with them. All the participants who gave their written consent were tested for their visual acuity. Those who fulfilled inclusion criteria, were randomly assigned to one of the two (i.e. low & high task load) experimental conditions. Each participant received instruction for the task and was given demonstration of three minutes. Further, participants were engaged in a 10 minutes practice session followed by main task of 40 minutes duration. All the participants were required to attain 80% accuracy to proceed further for the main task. The study subsumed data from only those participants who passed these criteria.

Results

Response Measures

In the present study, task load and cue validity were manipulated to examine its interactive effect on sustained attention task performance. Reaction time, correct detection (hits), and incorrect detection (false alarms) were recorded as a behavioural measure during sustained attention task. Perceptual sensitivity (d') was derived from the true scores of correct detection and incorrect detection.

Statistical Analyses

Means and standard deviations were calculated for all the response measures under each experimental condition. To examine effect of task load the obtained data were submitted to 2 (Task Load: Low and High) × 3 (Cue validity: Valid, Invalid and Neutral) × 4 (Time Block: 10 minute each) repeated measure analysis of variance (ANOVA). Task load was treated as between subject factor, whereas cue validity and time periods were within subject factor. The alpha level of 0.05 was used for all statistical unless otherwise stated. Greenhouse- Geisser and Huynh-Feldt correction was applied where assumption of sphericity was not fulfilled.

Vigilance Task Performance

Reaction Time

The mean reaction time performance revealed that participants took less time to detect target under low task load condition (M = 557.06; SD = 169.41) in comparison to high task load condition (M = 760.87; SD = 138.56). The high task load constrained response latency of the participants. Results further revealed that the cue validity was also influenced by task load variation. Participants performance was found better under valid cue with low task load (M= 466.20, SD= 145.91) compared to high task load condition (M = 721.21; SD = 119.43). During invalid cue condition participants took more time to respond under high task load condition (M = 802.79; SD = 142.17) compared to low task load

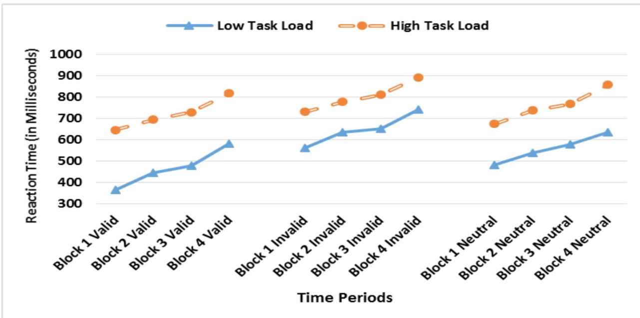

Figure 2: Reaction time as a function of task load, cue validity and time period

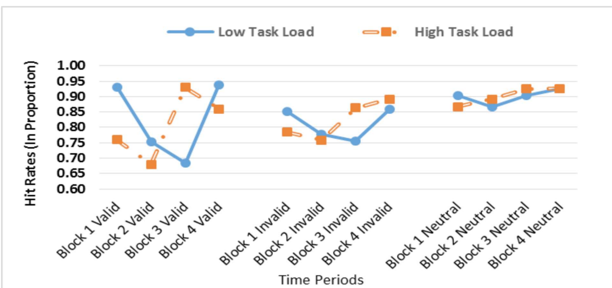

Figure 3: Correct detection as a function of task load, cue validity and time period

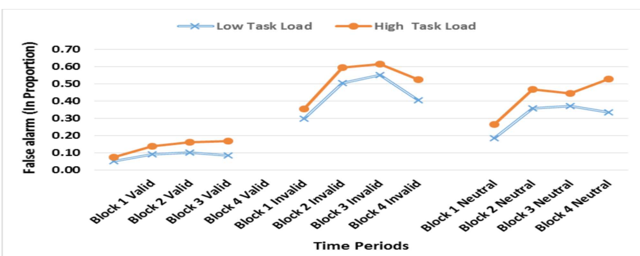

Figure 4: Incorrect detection as a function of task load, cue validity and time period

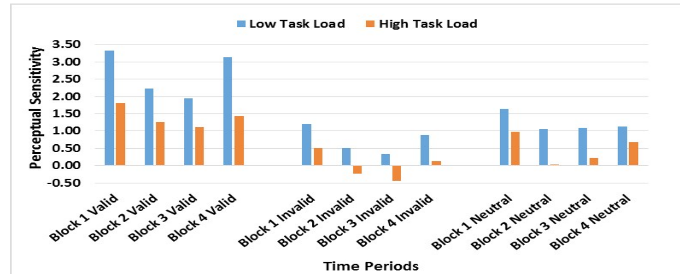

Figure 5: Perceptual sensitivity as a function of task load, cue validity and time period

(M = 646.89; SD = 170.02). Similarly, neutral cue condition also unfolded that participants took less time to detect target in neutral cue condition under low task load (M = 90.00; SD = 18.61) compared to high task load (M = 56.29; SD = 27.01) condition.

The ANOVA results revealed the significant difference between mean RT of the two groups, F (1, 88) = 81.57; p = .000. The main effect of cue validity was also found significant, F (1.86, 164.14) = 134.64; p = .000 irrespective of task load and time periods. Further, the interaction effect between task load and cue validity was also found significant, F (1.86, 164.14) = 19.28; p = .000. The main effect of time periods was found significant, F (1.90, 167.29) = 175.84; p = .000. Similarly, the interaction between task load × cue validity × time periods was also found significant, F (4.36, 384.27) = 2.38; p = .04. The obtained reaction time result has been graphically displayed in Figure-2.

Correct detection (Hits)

Means results further revealed better correct detection performance under low task load (M = 84.39%; SD = 20.82) than high task load condition (M = 53.10%; SD = 25.77). Effect of cue validity was also found similar, hit rate was higher in valid cue condition under low task load (M = 82.61%; SD = 16.70) compared to high task load condition (M = 50.60%; SD = 24.64). The mean score of hits in invalid cue condition under high task load was lower (M = 52.40%; SD = 25.41) compared to low task load (M = 81.11%; SD = 24.43) condition. ANOVA revealed significant main effect of task load, F (1, 88) = 80.95; p = .000. The main effect of cue was also found significant, F (1.73, 152.30) =11.38; p = .000. Results, further revealed significant main effect of time periods, F (2.68, 236.24) = 19.06; p = .000. Interaction between time periods × task load was found significant, F (2.68, 236.24) = 4.62; p = .005. In addition, the interaction between cue validity × time periods was found significant, F (5.99, 527.42) = 5.37; p = .000. The ANOVA results also yielded significant interaction between cue validity × time periods × task load was also significant, F (5.99, 527.42) = 9.89; p = .001. Correct detection performance results are presented in Figure-3.

Incorrect Detection (False Alarms)

Means results on false alarm performance showed that participants committed less error under low task load (M = 27.79%; SD = 23.77) compared to high task load (M = 36.09%; SD = 39.46) condition. Participants committed less false alarm under valid cue condition (M = 10.85%; SD = 11.27) followed by neutral cue (M = 36.89%; SD = 40.46) and invalid cue (M = 48.08%; SD = 27.23) condition. ANOVA findings revealed significant main effect of task load, F (1, 88) = 4.95; p = .02. Result further revealed significant effect of cue validity, F (1.80, 158.40) = 203.49; p = .000. The main effect of time periods, F (1.88, 165.87) = 28.05; p = .000 was also found significant. In addition, the interaction between cue validity × time periods was found significant, F (1.61, 141.85) = 5.90; p = .006. Figure-4 indicates the difference in false alarm condition in low and high task load condition as a function of cue validity and time periods.

Sensitivity performance (d')

Mean sensitivity performance results revealed better sensitivity in low task load with valid cue (M = 2.65; SD = .88) compared to high task load (M =1.40; SD = 1.22) condition. With the similar trend under invalid cue condition sensitivity was found better in low task load (M = 0.73; SD = 0.85) condition compared to high task load (M = - 0.01; SD = 01.33). Furthermore, sensitivity was found better under neutral cue condition (M = 01.23; SD = 0.68) in low task load condition than high task load (M = 0.48; SD = 1.62) condition.

The obtained ANOVA results revealed significant difference in perceptual sensitivity between task loads, $F(1, 88) = 10.31$; $p = .000$. The effect of cue validity was also found significant, $F(1.01, 89.22) = 12.81$; $p = .001$. Figure-5 displays the difference in sensitivity performance across the conditions.

Discussion

The major problem to sustained attention is the decrement in performance across time periods. Many researches have addressed this issue. Some of them have intended to find out root cause of the problem and several others focused on to counter this problem. The present study has taken both the intentions into consideration. Here, we tried to find out the effect of task load on sustained attention task performance and how cue validity reacts across time periods. A square shaped flicker cue was used to orient participant's attention to a specific place or direction. Role of cue was to disengage the participants from present location and prepare them for upcoming stimulus. Further, cue validity was manipulated as valid, invalid and neutral across time periods. The task was divided into four blocks of 10 minutes each with total duration of 40 minutes. The aim for such division was to analyze the effect of time periods on participant's performance.

The obtained result on reaction time performance explains participants performance differed under task load conditions during vigilance task performance. The finding was consistent across time periods. Participants under high task load took much time to respond while detecting targets compared to low task load. The decrement in vigilance performance across time periods has been observed by several studies (Mishra et al. 2016). Groves and Thompson (1970) stated that any behavioral and physiological response may be said to habituate if it is reduced as a result of repeated stimulation. Low rate of correct detection across time period can be explained in terms of habituation theory. The consequences of such habituation reflect as a gradual decrease in cortical arousal caused by reticular activating system (RAS). According to Jerison and Pickett (1964) such reduction in performance is greater at a higher event rate. This response latency under valid cue condition was significantly better than invalid and neutral cue, irrespective of task load. Results are in agreement with previous studies (Mishra et. al., 2016; Singh & Singh, 2014). It is evident in several studies that cue stimulates the observer which leads to improvement in reaction time during vigilance task (Hitchcock, Dember, Warm, Moroney, & See, 1999; Hitchcock et al., 2003). The improvement in reaction as an after effect of cue inducement may be understood in terms of arousal theory. Further, interaction between task load, cue validity and time periods reveal that cue validity induces facilitation in performance; however, decrement in performance caused by task load was extensive. The results further revealed inverse relation between task load, hit rates and perceptual sensitivity, whereas false alarm ratio elevated as the task load increased. Such relation between task load and sustained attention task performance was found to be consistent with previous findings (Sawyer et. al., 2014). Results also explain that as the load or difficulty of the task increases, performance degrades much quicker than expected. The temporal factor in any cognitive task is highly relevant, especially when it comes to vigilance task. High rate of decrement in performance was found when the duration of critical stimuli decreased (Gartenberg, Veksler, Gunzelmann & Trafton, 2014).

Conclusion

The problem of vigilance decrement has occupied many psychologists and human

factors researchers for decades. Several critical variables that affect vigilance performance, such as event rate, discrimination type and task complexity have been reported. Present study took simultaneous discrimination vigilance task in reference to the real-world scenario and tried to find out what happens when task difficulty increases and how cue upheld performance. In sum, results of this study suggest that with the advancement in task load, participant's performance declines in all aspects especially on reaction time. Apart from it, cue validity played a crucial role in performance. Cue provided advance information about target appearance and hence reduces the spatial uncertainty resulting in better performance. The limitation of the present study was small sample size and nature of the task. Several other variables like cue-target onset asynchrony (CTOA), task nature, cue nature and cue feature may be used in future to examine its interactive effect on vigilance performance. The finding of the study may be applied in various real-life situations like driving (racing methods), assembly line worker, real time monitoring systems, close circuit monitoring systems, baggage screening etc.

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