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Does Low Cognitive Load Lead to Delayed Performance?

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Abstract

Cognitive load refers to the demands on the individual's abilities for processing information in any task. The purpose of the present study was twofold- first to investigate how the individual manages different levels of cognitive load and second, to explore how positive and negative distractors have an effect on the individual performance. Thirty five healthy Indian adults were selected from university of Delhi for the experiment. The study examined the effect of three different levels of cognitive load (low, moderate and high) and two types of emotional distractors (positive and negative) on a working memory task. The positive and negative emotional distractors were selected from International Affect Picture System (IAPS). The individual's performance of working memory task in different cognitive load conditions was measured by a letter search task. A two-way repeated measure ANOVA revealed that increase in the cognitive load leads to decrease in the reaction time taken by the participant to perform the letter search task. Furthermore, the performance was recorded better in the presence of negative distractors.

Keywords- Cognitive load, Positive distractors, Negative distractors, Working memory

Public Significance Statement- Present study holds a different orientation towards deadlines and work pressure as an opportunity to improve the performance; and how being exposed to some negative stimuli could help us focus better on the task at hand. The findings are more applicable for the educational field. As we see, there has been an intricate work done to simplify the curriculum for the students to help them learn better. The current findings suggest to maintain an optimum level of difficulty to help students perform even better and help them to excel in their academic performance.

Introduction

Current age is characterized by a mounting demand for responding to multitasking environments, where one has to divide his/her attention between a large numbers of tasks simultaneously. Human beings are pressed relentlessly to operate with a complex world of stimuli. Therefore, he/she is increasingly required to be programmed to do so. When multiple challenges occur in a rapid succession, the individual may find his coping mechanism insufficient; and end up feeling overwhelmed. Precisely, this is an indication of high 'cognitive load'. Cognitive load is defined as demands on the information processing ability of the individual, while engaging in any cognitive activity. Complexity of the task largely determines the level of cognitive load. This has become an area of interest to many researchers for its implications in the human information processing.

In the process of selective attention, cognitive capacity plays a crucial role. Lavie's load theory (Lavie, 1995) offers an explanation as to why selective attention fails. It distinguishes between cognitive and perceptual load. Cognitive load is mediated by factors like demands on working memory and factors like display size modulate perceptual load. According to this theory (Lavie, Hirst, Fockert, & Viding, 2004), the effectiveness of selective attention depends upon the variations in cognitive load and perceptual load. Another study proposes that the distractor cognizance was low in high load conditions; this is because of perceptual load (Whiteley and Sahani, 2012; Lavie et al., 2014). On the other hand, According to Sweller (1988, 1989), Cognitive load is a process that relies on and utilizes cognitive resources in problem-solving. Neuroimaging studies showed that the accurate allocation of attention to primal target location involves task-related knowledge with a primal precedence to working memory; there is a chance of increase in distractor processing when there is high working load as it will impair the priority of target (Parks et al., 2013; Torralbo et., 2016).

The “salience hypothesis” argues that not the perceptual load per se but the presence of distractors ascertain selective attention and processing of distractors (Eltiti,Wallace, & Fox, 2005). Other studies have also reported that significant stimuli can grab attention and be less prone to blindness due to inattention (Carmel et al., 2011; Ohta et al., 2012). Damasio (1994) states that thought and rationality actually necessitate emotional input. Specifically, the integrated processing of cognition and emotion in the brain had been suggested by researchers for a long time now (LeDoux and Brown, 2017). Researchers suggest that “complex cognitive – emotional behavior emerges from the rich, dynamic interactions between brain networks” (Murphy and Greene, 2016) but at times, emotions could also act as extraneous cognitive load and compete for working memory’s resources as it would require extra processing. If induced emotions spontaneously start retrieving information that is not currently useful for ongoing task, irrelevant task processing takes place and thus, leads to inducement of extraneous load (Seibert & Ellis, 1991) or distraction. Generally, both positive and negative emotions can create extraneous load if it results in task irrelevant processing (Pekrun & Linnenbrink- Garcia, 2012). Given its social relevance, emotional stimulus affects major cognitive functions like perception and attention. Therefore, exposure of both positively and negatively arousing stimuli may result in attentional interference (Schimmack, 2005); as they impact differently with attentional or memory processes (Frischen, Eastwood & Smilek, 2008; Srinivasan and Hanif, 2010).

It is evident that emotion can have both enhancing as well as deteriorating effects on executive functions based on its significance to the task. (Pessoa, L. 2009). It is archaic to say that processing irrelevant information can be intruding, based on the interaction between the distraction and the task at hand. In a visual search task, Srinivasan and Gupta (2010) provided improved memory recognition even in high load condition with happy mood distractors in comparison to sad mood. Fredrickson’s (2004) broaden-and-build theory correlates positive emotions with a wide range of focus. On a similar note, using real faces in visual experiment, Williams, Moss, Bradshaw, and Mattingley (2005) have noticed an edge for happy faces in comparison to sad faces. Notwithstanding, in another study, it was found that negative faces draw attention more effectively than positive ones (Frischen et al., 2008).

Based on these pieces of evidence, we can say that the relationship between emotion and cognition can be reciprocal. Studies also indicate that there could be a two-way link between perceptual focus and emotion (Duncan & Barrett, 2007; Srinivasan & Hanif, 2010). In another study on visual search, it was espied that negative distractors grab attention better than positive distractors (Eastwood, Smilek, & Merikle, 2001; Frischen et al., 2008). Further, Eastwood and colleagues contemplated that the search function slopes for locating sad faces immersed in a framework with neutral faces is shallower than the search function slopes for locating happy faces embedded in a neutral facial background. Contrary to this, Williams et al. (2005) revealed that while using real faces, there is an advantage in the favor of happy faces in comparison to sad faces. Thus, it is apparent that the plethora of studies on the hitherto field of inquiry (i.e. Cognitive load) fail to provide a satisfactory answer to the fundamental question rose about the relationship between cognitive load and emotional valence.

It is interesting to see that major researches in similar paradigm till date have used facial stimuli to incorporate emotional distractors, but is there any difference in the general pattern of findings when non-facial or pictorial stimuli are deployed? These findings provide enough support to establish the fact that performance varies with the amount of cognitive load given on any task, also the nature of the task and the content of distractor play their part to affect the performance. The second question that was raised whether the task of the higher cognitive load would be any less prone to irrelevant attentional capture?

In the present study, we thus aimed to examine the differential effect of levels of cognitive load on a letter search task (in which target letters are embedded in between distractor letters). In order to achieve the understanding of the effect of cognitive load on performance, we set out to manipulate cognitive load at three different levels and the nature of distractor was categorized as positive and negative distractors (considering two valences of emotion). The images for positive and negative emotional distractors were derived from International Affect Picture System (IAPS).

Hypotheses:

Based on previous researches, we hypothesized that

1. In comparison to higher cognitive load, participants would take longer reaction time for responding to lower cognitive load in a letter search task.
2. In comparison to positive distractors, participants would take longer reaction time to respond in negative distractor condition in a letter search task.

Method

Participants- Thirty five healthy postgraduate student volunteers (16 male and 19 female) participated in the experiment. The mean age of the participants was 26.5 years of age (range = 22-31). They were briefed about the experiment and informed consent was obtained from each one of them. The participants also reported to have no medical or psychological condition. The methodology for the study was approved from Departmental Research Committee of University of Delhi.

Apparatus and Stimuli- The experiment was designed and conducted on SUPERLAB 5 (Cedrus Corporation). It is a computer software package designed to assist in the generation of computer based experiments. It is the stimulus presentation software for Mac OS X and windows. The responses in the form of reaction time (RT) were recorded by each microsecond to a response sheet which was used for further analysis.

For emotional distractors, sixty four pictures (32 positive and 32 negative valence) were randomly selected from the International Affective Picture System (IAPS) (Lang, Bradley, & Cuthbert, 2005). Pictures that were selected for standardization contained sceneries, human faces, situations or events depicting both positive and negative emotional state. Following the protocol developed by Lang and Colleagues, all images were assessed on a 1-5 scale in terms of valence (*from positive to negative*) and arousal (*from high to low*) prior to the experiment from a set of 50 participants representing the characteristics of the target population. From the sixty four rated images, highest rated thirty two pictures (16 positive and 16 negative valence) were selected for the final experiment. All the pictures contained sceneries, situations or life events for both, positive and negative valence.

Letter search task- Stimuli were displayed on a 15-inch color monitor. The letters were presented in black color on a white background. The font size was 14 point *Times New Roman* font. Two target letters (A or X) and eight non-target letters (‘O’ in the low-load condition, ‘K’, ‘Z’, ‘W’ in the medium load condition and additional ‘L’, ‘F’, ‘M’, ‘Q’ in the high-load condition) were presented randomly.

Design- 3×2 within subject design was taken. The design included three blocks containing increasing order of cognitive load: Low load, moderate load, and high load condition(s) (block i, ii, iii,), and two types of emotional distractors based on two valences (positive and negative). The stimulus display consisted of an emotionally- laden distractor image (i.e. sceneries, situations or life events) for both positive and negative. Distractor images were randomly presented in each trial of all the three blocks. Each block consisted of 48 trials, 24 for each valence of distractor(s). The block order, target and distractor positions were counterbalanced across all participants. The order of trials within each block was random.

Procedure- Each trial began with a centrally presented fixation point (+) for 500ms, followed by a 700ms presentation of a stimulus (distractor image) display valence at the center of the screen. After the stimulus, a letters string was presented for 500ms, containing one target (either A or X) and other distractor letter(s), Except for the high cognitive load condition in which letter string was presented above and below the distractor picture to increase the cognitive load. The participants were asked to search the letter string for the target letter (either A or X) and make a speedy response using the alphabetic keypad by pressing the key 'A' if the target was an A and key 'X' if the target was an X in the string. Participants were asked to ignore the distractor image. The response window recorded the response time for correct responses given by the participants on each trial.

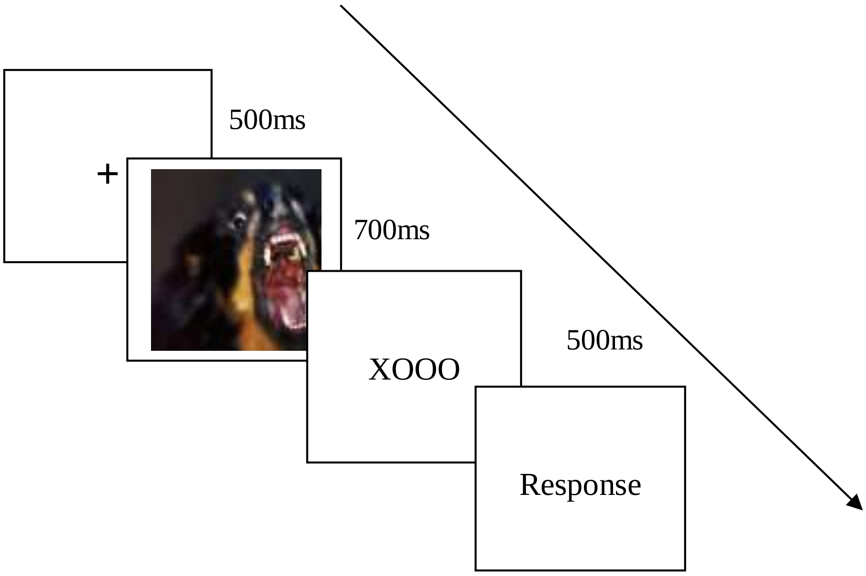

Figure 1: Schematic illustration of stimulus sequence and duration in a single trial.

Analysis-

According to the levels of increasing cognitive load, the trials in the test session were classified as three conditions: low, moderate and high. Based on the nature of distraction, trials in the test session were also tagged as positive or negative. SPSS (Version 16.0) was used to perform statistical analysis. The distribution of data was normal, and parametric tests were used. A two-way repeated measure analysis of variance (ANOVA) was used to analyze reaction time. The entire statistical threshold was set at the alpha level of 0.05. The data of five participants had to be discarded from the analysis due to their increased reaction time for more than 20 per cent in consecutive twenty trials. The final analysis was performed on thirty participants (14 male and 16 female). Post hoc analysis was done to comprehend pair-wise comparison using Bonferroni correction and in the cases of violation of sphericity, Mauchly's corrected values were reported.

Results and Discussion

The results were focused on participants' reaction time for 144 trials including blocks- i, ii, iii wherein a target was present among different numbers of distractors depending upon the three levels of cognitive load. Emotional distractors were categorized into two conditions- positive and negative. 3×2 within-subject repeated measure ANOVA was performed on the participants' response time.

Two hypotheses were made to see the main effects of levels of cognitive load and emotional distractors on working memory performance. The interaction effect of these two variables was also tested on working memory performance in terms of reaction time taken by the participants in performing the letter search task.

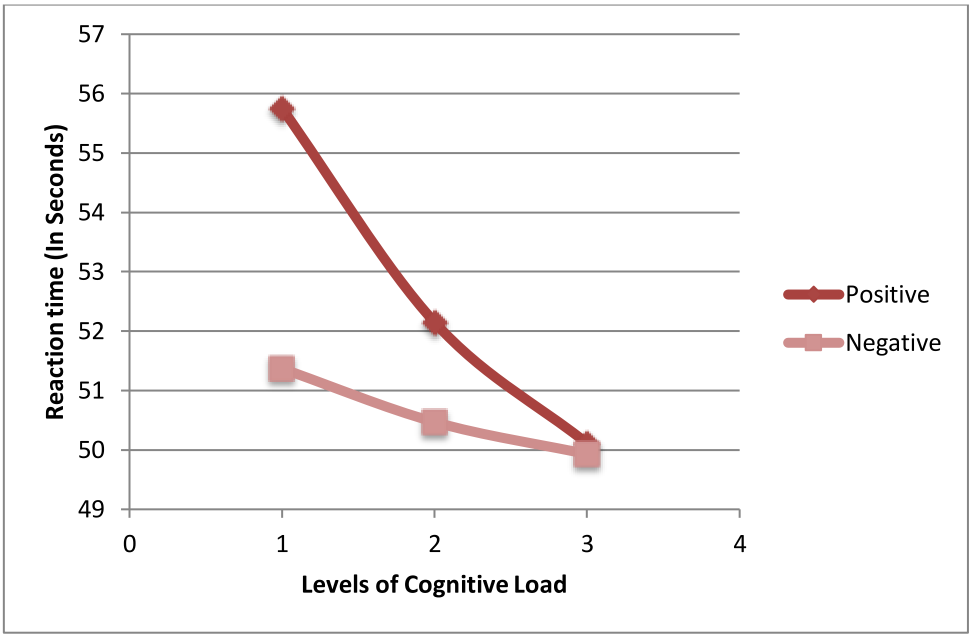

Figure 2. Mean reaction time (in seconds) for three levels of cognitive load (low, moderate and high) in two distractor conditions (positive and negative)

The above figure shows the results of mean reaction time on low, moderate and high levels of cognitive load for positive and negative distractors. The mean scores for the condition of low cognitive load for positive and negative distractors are 55.75 (SD= 8.84) and 51.37 (SD=6.30) respectively. The mean score of moderate cognitive load for positive and negative distractors are 52.15 (6.38) and 50.47 (4.61) respectively. The mean scores of high cognitive load for positive and negative distractors are 50.11 (SD=4.29) and 49.93 (SD=5.23) respectively.

The findings revealed that the participants took less time to respond to the task with high level of cognitive load vis-á-vis moderate and low level. Therefore, it can be seen here that as the cognitive load is increasing, the performance is getting better. The result is in line with the theories that support the view that the processing of stimuli, irrelevant to the task, is precluded if the perceptual task is sufficiently high in load to drain our processing ability. (Lavie, 2001; Cartwright-Finch & Lavie, 2007). Yerkes-Dodson law (1908) also dictates that with physiological or mental arousal, the performance increases up to a point. This result is also supported by Lavie’s load theory (1995, 2001) which states distractor information is processed in low load conditions but not in high load conditions, which suggests that we get more affected with irrelevant information when the perceptual load of the task is less. That may be because the process of selective attention gets more focused when our full potential is used on any task in comparison to when the task may be relatively taking less of the effort by the person.

Table 1. ANOVA scores for cognitive load, emotional distractors and their interaction effect on letter search task.

ANOVA summary table for Reaction Time

SOURCE*	Df	MS	F

Cognitive load	2	246.34	9.131**
Emotional distractors	1	41.52	.118
Cognitive load × Emotional distractors	2	90.57	.087

p<0.001

The hypothesis 1 stands rejected, as the result showed that with the increase in cognitive load, the reaction time taken by the participants to perform the task decreased (As shown in graph 1 also). The ANOVA scores showed that there is a statistically significant difference between three levels of cognitive load ($F(2, 88) = 9.131$, $p<0.005$**) with mean square 246.34 and DF = 2. The hypothesis 2 also stands rejected, the table above suggest that the ANOVA score for positive and negative distractors is not statistically significant ($F(1, 58) = .118$), with mean square 41.52 and DF = 1. Thus, the F score suggests the acceptance of null hypothesis that there is no significant difference between the reaction time of positive and negative distractors in the letter search task. The interaction effect is also not significant which suggest that there is no significant effect of interaction of these two variables on letter search task.

The post hoc analysis was also performed on different conditions of cognitive load and positive and negative emotional distractors to explore the pair wise comparison. The results suggested that the mean difference between low and moderate cognitive load condition (3.211*) was statistically significant at $p<0.05$ level, the mean difference between low and high cognitive load condition (3.746*) was also statistically significant at $p<0.05$ level; whereas the mean difference between moderate and high cognitive load condition (.535) and positive and negative distractors (.960) was found statistically insignificant.

As shown in fig 2, there can be seen a trend which shows, in both the cases, the reaction time is reducing with increasing level of cognitive load which means performance is actually getting better as cognitive load is increasing. Also, the mean reaction time for negative distractor condition is less than the mean reaction time for positive distractors in all three conditions. The impact of emotional distractors in the form of pictorial images seemed to make an impact on the performance. The result shows that participants performed better when the content of distractor was negative in nature than positive. At the physiological level, the perceptual information intake of unattended peripheral stimuli in the visual cortex is increased by positive emotions (Schmitz, T. W., De Rosa, E., & Anderson, A. K. 2009).

Functional brain imaging studies exploring perceptual load theory have showed that the visual cortical function relating to the existence of task-irrelevant stimuli (for instance, the parahippocampal activation correlated with the pictures of places, and activation in retinotopic cortex attributed to the presence of flickering checkerboards) have shown to be reduced under high perceptual loading (e.g., O’Connor, Fukui, Pinsk, & Kastner, 2002; Pinsk, Doniger, & Kastner, 2004; Yi, Woodman, Widders, Marois, & Chun, 2004; Schwartz et al., 2005; Bahrami, Lavie, & Rees, 2007).

Indeed pre-attention threat detection modules developed in the evolutionary aspects have been shown to capture attention on threatening cues (Pratto & John, 1991; O’hman et al., 2001a). Therefore, if there is any threat in the surrounding then survival can be maximized by interconnected attention and emotions to make sure that this information is immediately prioritized. According to this frame of reference, a negative mood state indicates a “problematic” position that needs fine and focused attention whereas a positive mood state indicates no environmental threat that leads to lowered need for detailed focus and attention. (Mitchell & Phillips, 2007)

Conclusion

The aim of the present study was to examine the differential effect of levels of cognitive load and emotional distractors on working memory task. The present study resulted that with the increasing level of cognitive load, the performance improves. This could lead us to a better understanding as to why the small deadlines helps in better performance as the attention on task at hand increases. Cognitive load is becoming a significant and vital factor in the design and appraisal of educational instruction, both traditional as well as technology based. In this context, to measure cognitive load induced by the contextual variables been a crucial issue. Instead of using other indirect and subjective methods, in recent times computer- based instruments provide direct measurement of the cognitive load. Therefore, the concept is gaining increasing importance in practical application particularly in designing multimedia instruction of people across the life span.

When we are seeing that an extra effort is being made towards making the curriculum easier and simpler for the students, present study gives a different dimension into this scenario and suggests keeping the difficulty of the curriculum high enough to maintain the motivation of the students in order to let them reach their full potential. Therefore, the result could lead us to a new orientation toward higher cognitive load tasks such as multitasking, deadline etc as an opportunity to improve our focus and effort on performance. Further, the results indicated that negative distractors are able to capture attention more effectively than positive distractors on a task, suggests that when we are in a positive mood the tendency of our mind to engage in less relevant stimuli increases.

Limitations- Though generalization of the results could be less as the sample size was limited yet it is a step further in understanding how different kinds of stimulus affect human performance and the findings could act as a catalyst for similar kinds of researches in the field of cognitive studies. With the use of psychophysiology, a better understanding of the cognitive load can be achieved in order to get more specific knowledge of the process.

Data Availability Statement- The data that supports the findings had been acquired with the SUPERLAB software system. As the data is related to ongoing PhD work, they are kept with the authors and will be provided to the reviewers as and when required.

Declarations- There is no conflict of interest to declare. The methodology for this study was preapproved by the Departmental Research committee for ethics approval to include human participants for experiment.

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