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Impact of Anxiety on Eye Markers: Role of Visual Task Complexity

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ABSTRACT

Vulnerability to anxiety is associated with a de- creased ability to control the allocation of attention. Literature reveals that people with high anxiety have impaired attentional control which is reflected while performing tasks. In this study relationship between trait anxiety and eye markers during visual task performance has been explored. Participants (N = 31) aged 21 to 35 completed all three visual task levels. The State- Trait Anxiety Inventory (STAI, 1983) was administered to differentiate between low, moderate, and high trait anxiety levels. NASA- TLX scores were used to analyze the cognitive load for each of the three levels of the visual task. Feature extraction and AOI (Area of Interest) notation were used to analyze eye markers. Result suggests that Eye metrics (First Fixation Duration, Time to First Fixation, Total Fixation Duration, and Total Visit Duration) can significantly differentiate different levels of anxiety (low, moderate, and high) on relevant and irrelevant information of visual tasks.

Keywords: Anxiety, Eye markers, Task complexity

INTRODUCTION

Anxiety, a multifaceted emotion characterized by tension, fear, worry, and unease, presents a complex response to perceived or actual threats, profoundly affecting individuals' daily functioning and overall well-being (American Psychiatric Association, 2000). Spielberger (1983) delineated anxiety into two forms: Trait Anxiety, reflecting an individual's inherent predisposition to respond, and State Anxiety, representing the current conscious perception of feelings, often accompanied by physiological arousal. Trait anxiety manifests as a predisposition to experience anxiety frequently, even in non-threatening circumstances (Spielberger, 1983). Individuals with anxiety tend to exhibit heightened focus on alarming information and a tendency to over-remember ambiguous details (Mathews and MacLeod, 2005). Physically, anxiety is marked by symptoms like restlessness, muscle tension, and sleep disturbances, alongside physiological manifestations such as increased heartbeat and excessive sweating. Moreover, cognitive symptoms, including difficulties in concentration, attention, and memory biases, are commonly observed in individuals with anxiety, significantly impacting their quality of life (Morton et al., 1997). This cognitive dysfunction is particularly pronounced in highly anxious individuals (Aarsland and Kurz, 2010) and affects the fronto-parietal cognitive control network, involving regions of the prefrontal cortex and inferior parietal cortices responsible for executive functions, goal-directed behaviors, and interactions with the limbic system (Barone et al., 2009; Cacioppo et al., 2000; Martens and Gill, 1976).

Anxiety does not exist in isolation but contributes to overall arousal levels in individuals (Kester and Kirschner, 2012). Moreover, cognitive tasks impose significant cognitive demands, especially in situations where working memory and information processing are challenged (Chipman et al., 2000; Sweller, 1988). The interplay between anxiety and cognitive task difficulty can influence task performance (Plass and Moreno, 2010) with research indicating that individuals with heightened anxiety vulnerability tend to fare worse in performance compared to their less-anxious counterparts (Ellis, 2005; Kuiken et al., 2007; Myles et al., 2020). Additionally, anxiety affects perception of external stimuli, influencing visualization patterns and task performance (De Lemos et al., 2008). Recent studies, such as Tsai An Hsian's research in 2021, have established significant correlations between learners' task performances, information anxiety, and eye-tracking measurements in online information problem-solving (OIPS) (Tsai and Wu, 2021).

Eye tracking technology, utilized in these studies, provides valuable insights into cognitive processes underlying human behavior by objectively recording (Van Orden et al., 2007; Wang et al., 2015) and analysing visual behavior through monitoring eye movements and determining points of gaze (Schrader et al., 2021). This technology allows for the examination of visual behavior and cognitive processes with precision and accuracy, offering insights into oculomotor and visual task performance through metrics like fixations and saccades (Gehrer et al., 2018).

1. To examine the relationship between different levels of Trait Anxiety (low, moderate and high) and Eye Parameters during the performance of varying task complexity.
2. To determine whether increasing task-complexity has an effect on visualization behaviour.
3. To see whether there is any difference in the attentional focus towards relevant and irrelevant information in a given task.
4. To see if there exists any relationship between perceived cognitive load and performance markers.

METHODOLOGY

After the screening, the study recruited 31 students (11 female and 20 male) aged 21 to 35 years (mean 28.02, standard deviation 0.62). Exclusion criteria included individuals with visual impairments without substance abuse and no history of neurological disorders. All participants provided informed consent before participation. STAI-Y2 was used to categorize participants into low, moderate, and high (N = 9, N = 10, and N= 12).

Experimental Design

Following the acquisition of informed consent, the subjects proceeded to undertake the State-Trait Anxiety Inventory - Form Y2 (STAI-Y2). The eye movements of the participants were calibrated and recorded using a Tobii

Pro x3-120 eye- tracker, which was positioned on the screen. Concurrently, the audio and video of the subjects were captured for subsequent analysis. The participants are positioned at a distance of 60 cm from the exhibition within a sound proof chamber that is enclosed by a door.

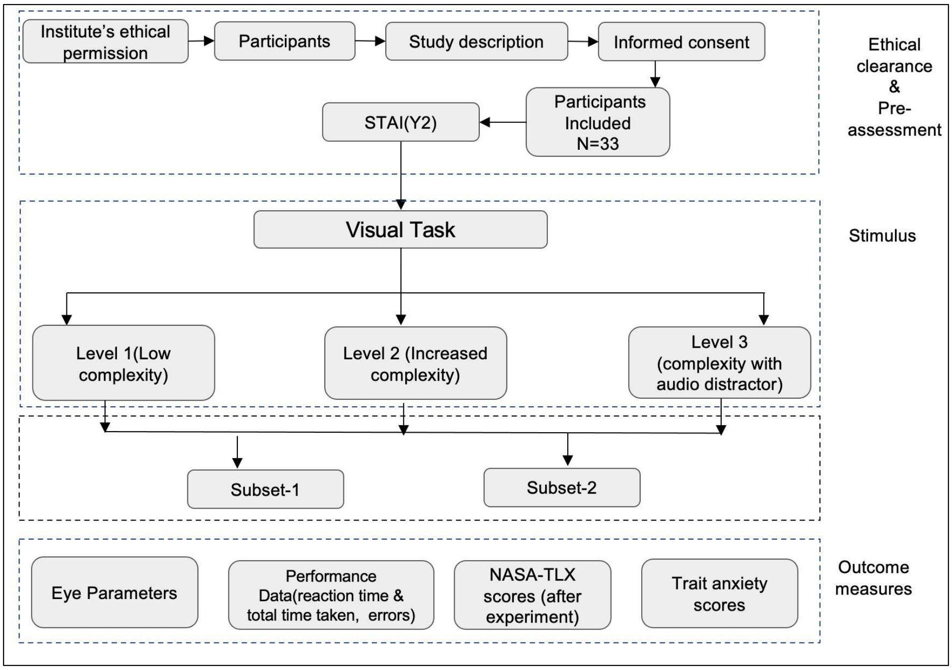

Figure 1: Flow of study.

The experimental design encompassed three progressively complex levels of visual tasks, each consisting of two subsets. Within each subset, participants were presented with six arithmetic equations comprising numerical values, alphabetical characters, and spatial symbols (e.g., >, <) as you can see in Figure 1. Participants were instructed to sum all numerical values on the left-hand side of the equation, disregarding alphabetical characters, and then compare the resulting sum with the right-hand side to determine its veracity by indicating "true" or "false" using a computer mouse key. The first subset of each level required participants to provide synchronous responses, utilizing their right index finger for "true" and their left index finger for "false." In contrast, the second subset necessitated asynchronous responses, with participants using their left index finger for "true" and their right index finger for "false."

Furthermore, complexity increased not only within each level but also between levels. In Level 1, equations demanded a minimal number of operations with only six characters. In Level 2, participants were tasked with summing only odd numbers on the left-hand side before comparison, with equations now comprising eight characters. Finally, Level 3 mirrored Level 2 instructions but introduced an auditory distractor to further enhance task complexity.

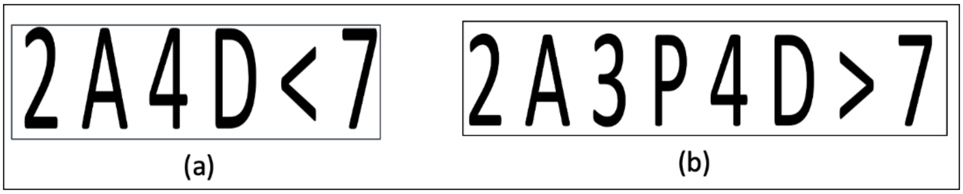

Figure 2: Illustrates multiple types of equations frequently used for tasks as a stimulus. Images(a) signify the type of equation used in level 1. In level 2 and 3, a different form of equation (b) is used as the complexity of operations and stimulus increases.

In the current investigation, the researchers regarded numbers and spatial symbols as pertinent data for problem-solving, while seeing alphabets as inconsequential or irrelevant. Performance scores were computed based on the parameters of response time, accuracy of responses, and frequency of errors. No specific time constraint was established for responding to the questions. Participants were asked to solve the problems as quickly as they could. The study was approved by the Institute's Ethics Committee (IIT/SRIC/DEAN/2023).

Tools

STAI: The State-Trait Anxiety Inventory (STAI) is a commonly used tool to assess trait and state anxiety. The forms Y-1 (state) and Y-2 (trait) measure the state and trait apprehension, respectively. The internal consistency coefficient of the scale ranges from 0.86 to 0.95, and the reliability coefficient of the two-month test-retest ranges from 0.65 to 0.75. A large amount of evidence supports the concept and simultaneously validity of scales. The present study uses STAI-Y2 (T).

Eye Tracking: An eye-tracking device was utilized in this study to objectively and precisely capture and assess visual behavior. Eye tracking enables researchers to see how participant's eyes move while engaging in various Cognitive activities. Eye tracking is a sensor system that can detect a person's presence and monitor their gaze in real-time. The technology converts eye movements into a stream of data that provides information about pupil disposition, gaze vector for each eye, and fixation point. Fundamentally, the automation interprets eye movements and converts them into insights that can be used in various applications or as a supplementary input process.

NASA-TLX: It is a validated subjective tool (questionnaire) to measure and analyze the cognitive load of a task or system, the NASA-TLX (NASA Task Load Index) is frequently used. It assesses six sub- aspects—mental demand, physical demand, temporal demand, own assessment of performance, effort, and frustration—it evaluates the user's mental, physical, and emotional needs. NASA-TLX entails asking the person to rate the mental, bodily, and temporal demands of a task and their level of frustration and performance (Zagermann et al., 2016).

Data Acquisition: STAI-Y2 was scored according to Spielberger's (1983) scoring protocol, which categorized trait anxiety levels as low, moderate, and high. The cognitive load of each of the three levels of the visual task was examined using NASA-TLX scores. Eye marker analysis involved feature extraction and AOI (Area of Interest) notation. This study aimed to determine whether there are statistically significant differences between the performance parameters (reaction time, correct response, and error), eye parameters (First Fixation Duration, Time to First Fixation, Total Visit Duration and Total Fixation Duration), and trait anxiety scores. Individuals from the high, moderate, and low anxiety groups were subjected to Analysis of Variance-One Way to determine whether there were statistically significant differences in their visualization patterns.

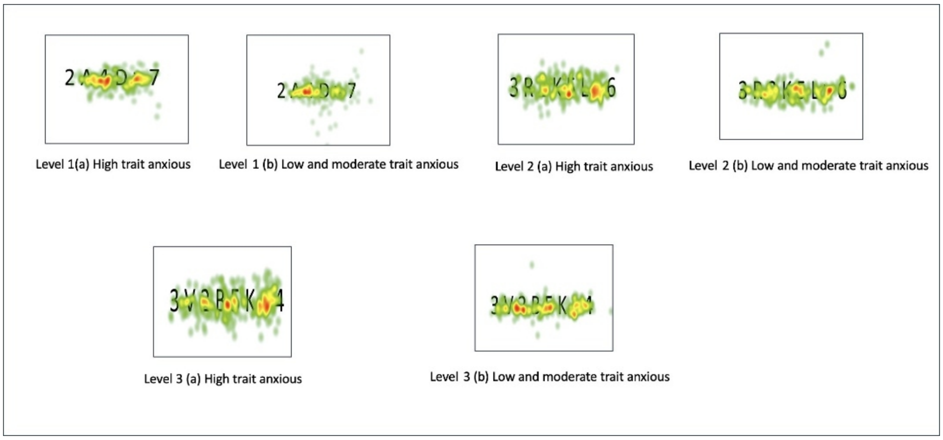

Figure 3: Heat-map plot for high trait anxiety and moderate and low trait anxiety people.

Feature Extraction

The following eye parameters were computed by the Area of Interest (AOI) technique using various studies (Nasreen et al., 2022). a. First Fixation Duration (FFD): The time involved in the first fixation in an AOI. b. Time to First Fixation (TTFF): The time taken for the first fixation to occur in an AOI. c. Total Visit Duration (TVD): Sum of all visit duration in an AOI. d. Total Fixation Duration (TFD): Total amount of time taken for all fixations in an AOI (Nasreen et al., 2022).

RESULT AND DISCUSSION

Cognitive Load and Performance Data

In the context of a bi-variate correlation analysis, the study investigated the relationship between performance data and trait anxiety across three different levels of visual tasks and cognitive load. The results revealed a statistically significant correlation between cognitive load and levels 2 and 3 ($p < 0.01$), indicating that as participants progressed to higher task levels, they encountered increased complexity, necessitating a greater allocation of cognitive resources to solve the problems. In contrast, no significant association was observed between cognitive load and level 1. These findings suggest that participants perceived the tasks as progressively more challenging, requiring an escalation in their cognitive efforts as they advanced through the levels. This aligns with previous research indicating that assessing cognitive load provides a more comprehensive understanding of performance, encompassing factors such as mental, physical, and temporal demands, as well as self-evaluation of effort and frustration necessary for task completion (Zagermann et al., 2016).

Table 1. The data were analyzed using analysis of variance (ANOVA). The group was divided into three categories based on trait anxiety level (low, moderate, high) to determine the distinction between trait anxiety, task performance, and eye parameter. Significant differences were found among eye parameters & trait anxiety in task performance in levels 1, 2 & 3 (95% CL * & 99% CL**).

Eye Parameters & Anxiety	Mean	SD	F Ratio	Significant
	6.46	4.03		
TVD Irrelevant Information (Level 2)	6.03	3.37	7.13	0.003**
	12.01	4.76		
	7.25	3.92		
TFD Irrelevant information (Level 2)	6.59	3.49	6.1	0.006**
	12.32	4.87		
	25.04	10.17		
TTFF Irrelevant information (Level 3)	29.13	12.53	3.36	0.049*
	40.00	16.81		
	3.27	1.6		
FFD Irrelevant Information (Level 3)	3.14	1.3	7.43	0.003**
	5.37	1.58		
	6.04	3.11		
TFD irrelevant information (level 3)	5.87	2.59	10.3	0.00**
	13.33	6.05		
	6.49	3.28		
TVD Irrelevant information (Level 3)	6.19	2.64	9.75	0.001**
	13.65	6.15		

Trait Anxiety and Eye Movement Markers

In this study, all participants successfully completed the three levels of visual tasks. Table 1 presents the results, indicating that individuals with high trait anxiety tended to engage in meticulous examination or validation of irrelevant information before responding to specific questions, particularly evident in the more complex task levels. Conversely, those in the low and moderate anxiety groups displayed superior ability to concentrate on pertinent information. This trend is evident in the mean values of various eye metrics for levels 2 and 3, as depicted in Table 1.

For instance, examining the Total Visit Duration (TVD) for irrelevant information at level 2, mean values for the low, moderate, and high anxiety groups were 6.46, 6.03, and 12.01, respectively. Similarly, at level 3, mean values for TVD on irrelevant information were 6.49, 6.19, and 13.65 for the low, moderate, and high anxiety groups, respectively. Total Fixation Duration (TFD) followed a similar pattern, with mean values at level 2 of 7.25, 6.59, and 12.32 for the low, moderate, and high anxiety groups, and at level 3 of 6.49, 6.19, and 13.65, respectively. These results suggest that individuals in the low and moderate anxiety groups demonstrated greater adaptability to task complexity and maintained focus on pertinent information despite increased complexity.

These findings are consistent with the Attentional Control Theory (ACT), which suggests that highly anxious individuals encounter challenges in attentional control during task execution. Previous research also supports these findings, indicating that individuals with higher levels of math anxiety tend to allocate attention to both task-relevant and task-irrelevant distractions, leading to diminished task performance (Nasreen et al., 2022). At Level 1, representing a low-complexity task, no significant differences were observed in the expression of eye metrics across the three anxiety groups regarding relevant and irrelevant information. However, at Level 2, which entails higher task complexity, results showed significant differentiation in Total Visit Duration (TVD) and Total Fixation Duration (TFD) among the three trait anxiety groups concerning irrelevant information, but no significant differences were found for eye metrics related to relevant information. In Level 3, where task complexity was further increased by introducing an auditory distractor, significant differences emerged in all four eye parameters (Time to First Fixation, First Fixation Duration, Total Fixation Duration, and Total Visit Duration) among the three anxiety groups regarding irrelevant information in the visual tasks. This suggests that individuals with high trait anxiety spent more time on irrelevant information and encountered difficulty concentrating on important information, especially in tasks with heightened complexity.

These findings corroborate previous research indicating a link between anxiety and attentional control difficulties, wherein high trait anxiety may lead to heightened vigilance for potential threats, diverting attention from goal-oriented processes (Li et al., 2022; Stout et al., 2015). This can impair processing efficiency, consume attentional resources, and impact concentration and performance (Eysenck et al., 2007). The objective eye tracking (ET) markers employed in this study provide empirical validation of the association between anxiety and eye metrics, including initial fixation, first fixation gaze, and proportion of viewing duration. The study's outcomes underscore that individuals with high trait anxiety are prone to spending more time on irrelevant information and experiencing difficulty in focusing on relevant information, particularly in tasks with elevated complexity (Basanovic et al., 2023). These findings align with existing research on anxiety and attentional control, reinforcing the relationship between anxiety and attention-related challenges (Mills et al., 2016). The ET markers objectively validate prior research findings, indicating a strong correlation between anxiety and eye metrics, including initial fixation, first fixation gaze, and proportion of viewing duration (Oar et al., 2022).

CONCLUSION AND IMPLICATIONS

Our results provide evidence in favor of the notion that individuals with high trait anxiety may find it challenging to maintain concentration on visual tasks due to the interference of irrelevant information. This highlights the importance of considering the impact of irrelevant information on the performance of individuals with high trait anxiety. Moreover, the significant eye markers effectively distinguish between low, moderate, and high trait anxiety groups. This suggests that eye tracking has the potential to be a valuable tool for future studies focusing on anxiety disorders. It can offer valuable insights into how individuals with anxiety perceive challenges in visual tasks and the underlying factors contributing to declines in their performance.

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