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Visual Attention, Mental Stress and Gender: A Study Using Physiological Signals

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ABSTRACT The relationship between visual attention and stress is a long-standing question in cognitive science. There are few studies which indicate improvement in visual attention under stress while few other studies suggest that stress affect visual attention negatively. Even though the mental stress is a critical issue in the modern age, only a few studies investigate the impact of mental stress on visual attention. Several studies on stress suggest that stress response could differ based on gender difference. However, none of the investigations compared the male vs female visual attention under mental stress. Additionally, although there are two broad class of visual attention, namely focused and selective attention, most of the studies investigated either the focused or selective visual attention. Moreover, the stress inducer used in most of the studies could generate pain and discomfort as well. The generated pain and discomfort may affect visual attention differently than just mental stress. This incompleteness and contradiction in previous research motivated us to carry out a full spectrum analysis of visual attention (focused and selective) under mental stress. To the best of our knowledge, we are the first time investigating the gender-wise visual attention (both focused and selective) performance under mental stress. We have used Rapid Serial Visual Processing (RSVP) to study the focused visual attention and Stroop task to study selective attention. We induced mental stress using the Montreal Imaging Stress Test (MIST). We also have used Electrodermal Activity Signal (EDA) and photoplethysmogram (PPG), a more robust method to study emotion, to study the participants' mental stress condition. We observed that focused attention gets better after mental stress induction ($Median = 82.94$ and $std = 13.19$) than before the stress ($Median = 71.26$ and $std = 16.72$), t $(30) = 3.02889$ and $\rho = .00183$. Selective visual attention too improves significantly after stress induction ($Median = 1682.54$ and $std = 286.91$) than before stress ($Median = 2100.58$ and $std = 397.40$), t$(30) = 4.67151$ and $\rho = <.00001$. Furthermore, for both focused and selective visual attention, we observed that male and female both gender group had performed significantly well after stress induction than before stress. However, the gender difference does not show any statistically significant result in visual attention (both focused and selective) performance after stress induction.

INDEX TERMS Attentional blink (AB), electrodermal activity (EDA), focused visual attention, incongruent task, Montreal imaging stress task (MIST), mental stress, photoplethysmogram (PPG), rapid serial visual processing (RSVP), Stroop task, selective visual attention.

I. INTRODUCTION

Attention and stress are two indivisible cognitive processes of human life. While attention helps us to perceive and process the continual information surrounding us, mental stress becomes an integral part due to different factors associated with modern life [1]. In cognitive science as well as brain science, both of the cognitive processes has its own identity and significance. Though we frequently assume that attention is concomitant with emotion, the nexus between these two complex cognitive processes is more of implicit rather than explicit [2] assumption in cognitive science theory.

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Consequently, the relationship between attention and emotion, especially mental stress, is a fascinating topic for further investigation. We have used visual attention and attention alternatively in the rest of the article as we are mainly focusing on visual attention.

Although we used the term ''attention'' very frequently in our daily life but perhaps it is one of the most complex mechanisms of the human cognitive system. Visual Attention not only depends on prominent features of the event or object but also gets affected by our goals, knowledge, expectation and motivation [3]–[10]. Presence of this many factors in the attentional process make it a multidimensional process. Due to the multidimensionality of the visual attentional process, researchers have divided it into further sub-categories such as focused attention and selective attention [3], [6], [11]. Recently, Beck and Kastner [6] has given a detailed description of different types of attention and their mechanism. There are many available methods to study visual attentional process in a lab environment. Among all, Rapid Serial Visual Processing (RSVP) [12] is one of the effective tools to understand the visual attention phenomena of human. A classical RSVP task is instrumental in understanding the focused attentional process, whereas the variation of the RSVP task could help us to understand the selective and divided attention.

In a classical RSVP, the participants get exposed to a stream of stimuli while participants required to identify and report targets T1 and T2 where T1 represent the first target and T2 represent the second target. The limited amount of cognitive processing resources sometimes barred the participants from detecting the second target (T2) if it comes very soon after the first target (T1; less than 500ms) [12]–[14]. This limitation to detect T2, when the time interval between T1 and T2 is very less) also known as Attentional Blink (AB). The limited amount of attentional resources get busy to process T1, and therefore when T2 appears, it gets less or no attentional resource [15], [16]. Many pioneering works on AB have discussed different aspects of AB phenomena in detail [12]–[15]. However, to understand the sub-categories (i.e. selective and divided attention) in-depth, some other methods such as Stroop task [11] as well as other variation of classical RSVP task [15], [16] was used to get insight on the human attentional process. Stroop task [11] is widely in use to study selective attention in a lab environment. John Ridley Stroop first showed the Stroop effect in his thesis [17]. Later, MacLeod [18] summarize different aspects of the Stroop effect. In a Stroop task [11], the participant asked to report the color of the stimulus (word; the name of some color). In general, a Stroop task comprises two parts, namely congruent and incongruent. Congruent, where the word (stimulus) and color of the stimulus belong to the same color e.g. if the word is RED, then the stimulus color is also RED. In incongruent part, the color of the stimulus is different from word for example if the word is RED, then the stimulus color could be anything but RED. The response time (RT), which also reflects the processing time of the stimulus, of the participant help investigator to study the attentional process of the participants (for the detailed procedure the pioneering work of [11], [19] could be referred; we have also discussed the task detailing in material section). Performance in the congruent part reflects the focused attention ability, whereas performance in the incongruent task reflects the selective attention ability of the participants. Nevertheless, both focused and selective attention could be influenced by other cognitive function, especially emotion [3]–[10] due to the limited amount of cognitive processing resources.

Emotion is not a single state of mind. It is somewhat a cumulative term we use to describe different mental state such as fear, disgust, happy, stress [1], [2], [20]–[25]. Emotion, an amalgamated cognitive process of daily human life, is a very complex yet significant cognitive process of the human mind. Like other cognitive function, emotion also uses cognitive resources to get process by the human mind. But as mentioned earlier, we have a limited amount of cognitive resource, thus we can process only a limited amount of cognitive function. However, as emotion (especially stress) is an integral part of modern human life [26], [27] and indivisibility of this cognitive process act as an impetus for the scientist to study and analyze the various mechanism of emotion in great detail. Selye [26], in his book, first coined the term stress. Generally, stress response explained as ''fight - or flight'' response, but studies also indicate that male and female shows different behavioral pattern under stress response [28]. Furthermore, under the same stress condition, male and female show different hormonal and neurophysiological pattern [29]–[31]. Traditionally, stress categorized into two broad categories, i.e. mental stress and physical stress [22] based on stress generation factors. Recent studies on stress also reveal that impact of mental and physical stress on human activity and perception is also different [22], [32], [33]. After arduous studies of years, researchers have successfully outlined different facet of emotion, its measurement techniques and its importance in human life [1], [2], [20]–[25]. Healey and Picard [25] used a combination of EDA, electromyogram (EMG) and electrocardiogram (EKG) to study driver stress during the real-world driving condition. In another pioneering work, Setz *et al.* [23] also used EDA signal to study mental stress during MIST task. However, Sloan *et al.* [34] showed the importance of cardiac function during mental stress. Considering all these pioneering work [23], [25], [34], we have used EDA and PPG (cardio activity could be monitored from PPG [35], [36]) both for our study to make the study more robust and more accurate. Studies reveal that due to the limitation in the cognitive processing unit, stress affects higher cognitive function such as intelligence [37], creativity [38].

Similarly, the impact of stress on learning, memory [39] and attention [9], [19] is a matter of discussion for a while now. The effect of stress on learning and memory has been studied and scripted in-depth [39]. However, the relationship between attentional process and stress is still not so clear yet. The multidimensionality of stress and the attentional process has made the relationship more complicated.

Most of the prior studies revolve around RSVP or modified version of the RSVP mechanism. In RSVP, the temporal difference between the two stimuli is also known as inter-stimulus Interval (ISIs). Bocanegra and Zeelenberg [40], modulated this ISIs and opined that emotional stimulus might hold the available attentional resources for a longer time than usual and may take a longer time to process. Due to this Longer processing time, participants may fail to identify the closely (short interval; temporally 50ms and 500ms apart) appearing stimulus. However, when attentional processing resources get released, it may increase the identification and perception accuracy for neutral stimulus, which is temporally ''far'' (more than 1000ms) distanced. Bocanegra and Zeelenberg [40] used emotional (negative) ''words'' and neutral ''words'' as their stimulus. The stimulus presentation gets varied temporally. They extend their study for the auditory stimulus as well and find similar effects [41] and explained their findings as to the twofold effect of emotional stimulus over the attentional process. Many other researchers studied the effect of emotion on perception [42], [43]. Empirical results from prior studies show that emotional stimulus may force us to identify and register some stimulus quickly. However, emotional stimulus holds the attentional recourse for a prolonged period and may bar another stimulus to acquire the required attentional resources to get processed. In result, information from the other stimulus fails to register any response. This phenomenon is also known as ''emotional induced blindness''. More recently, Ciesielski *et al.* [44] carried out a more thorough study to investigate the effects of different emotion (fear, disgust and erotic) using modified version of RSVP and further outlined effect of different emotion on attention [44]. They carried out their experiment with 50 participants. Their study is one of the pioneering works in the domain of emotion-induced blindness. However, most of these studies were based on negative emotion (fear, disgust, erotic) and revolved around the time difference between two subsequent stimuli. More interestingly impact of stress on attention was less discussed in these works. Though few studies do focus on stress, their findings were inconsistent and contradictory. Putman *et al.* [45] and Roefls *et al.* [46] observed inclination in attention after stress induction while some other studies [47], [48] report no significant impact of stress on attention. Callaway and Thompson [49] first observed that stress could increase the focused attention. However, the participants set was very few for their experiment. Most recently, Schwabe *et al.* [50] reported a detailed description of the effects of stress on attention. They chose 36 male non-smoker college students for their study. They used socially evaluated cold pressor test (SECPT) [detailed in [51]] to induce stress and Attentional Blink mechanism [12], [14], [15] to test the effect of stress on attention. They find out that stress improves the detection of the second target (T2). Although, the findings are pivotal and leading the path to understand the effect of stress on focused attention but lack few points. The SECPT, which requires specific physical activity, could induce physical pain and physical stress as well as mental stress. So, the effect of mental stress on attention cannot be inferred from this study. Furthermore, while recent studies show the importance of sex difference in stress (for detail review, please refer [29]–[31]) mechanism and Schwabe and Wolf [50] does not consider the sex difference factor. On selective attention, Chajut and Algom [19] reported that stress positively affects selective attention. They used the mental stressor used by Keinan *et al.* [51] and a modified version of the Stroop task [11] to study the impact of stress on selective attention. Although Chajut and Algom [19] discussed selective attention under mental stress condition, their study does not show if male and female participants show any difference in attentional performance under mental stress.

In this study, we are investigating the full spectrum of the attentional process (both focused and selective attention) under mental stress condition. To the best of our knowledge, this study first time we are studying the male and female participants (sex difference factor under stress response [29], [51]) attentional work performance under mental stress condition. We mainly trying to find answers for three main questions: a) How focused visual attention get affected under mental stress condition in other words if both the stimuli (T1 and T2) are emotionally neutral then can mental stress influence the detection of T2? b) How selective visual attention gets affected under mental stress condition? c) How sex hormones effects on stress response matters for visual attention (both selective and focused)?

II. METHOD

A. PARTICIPANT

We carried out two different experiments with 60 nonsmoking male and female participants (age M = 18.52 years and *std* = 0.89 years) from first year University student. We conducted to different experiment for focused attention and selective attention, respectively. Each participant has normal or corrected to normal vision. We divided these 60 participants into two equal groups (each group comprises15 males and 15 females; please refer Table 1 for statistical information on age). One group has participated in a focused attention task (Attentional blink) while another group has participated in selective attention task (Stroop task). Each participant has performed either focused attention or selective attention task. All the participants and experimenter have signed a written consent form. The consent form clearly states that participants' personal information will be kept hidden and will not be disclosed in any condition. The collected data will be used for research purpose only. The consent also includes that if the participants feel uncomfortable during the experiment, then they are free to walk out of the test. However, it will be worthwhile to mention here that no participants walked out of the experiment. Just to maintain the uniformity during the experiment, only one experimenter has handled the whole data collection part of the entire experiment.

Each participant has completed the entire task in two sessions. Each participant has performed the focused attention

TABLE 1. Dataset information.

Experiment	Total Participant		Attentional Blink (Focused Attention)		Stroop Task (Selective Attention)	
Gender	Male	Female	Male	Female	Male	Female
Number of Participants	30	30	15	15	15	15
Mean	18.63	18.4	18.6	18.47	18.66	18.33
Standard Deviation(std)	0.89	0.89	0.99	1.06	0.82	0.72

or selective attention under normal condition (non-arousal condition) first and then after a gap of 2 weeks participant has performed the focused attention or selective attention task under mental stress condition. The 2 weeks gap between the two-session kept as wash out period. The participants were explicitly instructed not to practice the task during this wash out period.

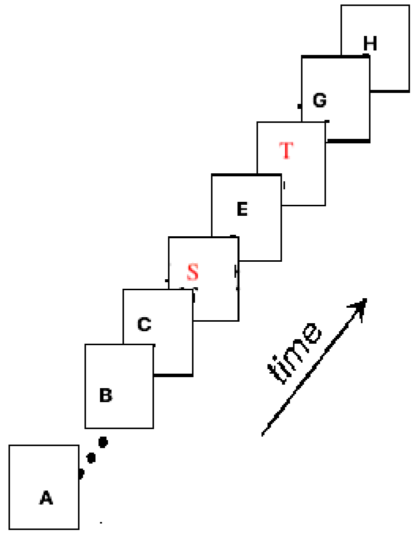

FIGURE 1. Block diagram of RSVP task (Attentional BLink).

B. STIMULI

As mentioned earlier, we conducted two separate experiments in this study. In experiment 1, we have studied the focused attention using The Attentional Blink mechanism while in experiment 2, selective attention has been studied using the Stroop task. We will briefly discuss the stimuli used for both of the experiment in below few paragraphs.

1) EXPERIMENT 1 (FOCUSED ATTENTION)

As discussed earlier, to calculate the Attentional Blink, we use RSVP [12]–[14] task mechanism. A sequence of stimulus presented to the participants. The task is to identify and report the target stimulus. We have developed the RSVP task interface using python and stimulus presented using a 17-inch color monitor. Here, we have used neutral alphabets (A to Z) as the stimulus. The volunteer was required to identify and report target alphabets S (first target; T1) and T (second target; T2) written in red color. Each trial comprises 18 alphabet sequence, 16 neutral alphabets written in black, 2 target alphabets (S and T) written in red, at the center of a white screen. Each alphabet presented for 110ms without any break in-between. The participants instructed to report their using mouse observation after each trial.

In the RSVP, we presented 1, 2, 3, 4, 5 and 6 alphabets between target T1 and target T2. So, the time difference between target T1 and target T2 were 110ms, 220ms, 330ms, 440ms, 550ms and 660ms, respectively. Technically, we used a six temporal lags (each lag corresponds to 110ms) [12]–[14] based measurement for this study. There were total 108 trails (18 trial for each of 6 (lag)) in the experiment and participants took 6 minutes to complete the task. Figure 1 shows the block diagram of the RSVP.

2) EXPERIMENT 2 (SELECTIVE ATTENTION)

In a classical Stroop task, the incongruent task response time is generally longer than congruent task response time [11], [17]–[19], [52]. According to the earlier research, the congruent task, where the word (color name) and the ink color is same, primarily influenced by the unintentional visual encoding [17], [18], [52] therefore may not be useful enough to understand the focused visual mechanism. However, the incongruent task, where the word (color name) and the ink color is different, effectiveness to understand selective attention mechanism, is well established now [11], [19], [52], [53]. Additionally, recent studies suggest that more than 6 trails per color could leave an adverse effect of Stroop task. Therefore, more than 6 trails per color are not advisable if the intended goal is to study the selective attention [52].

We developed the Stroop task interface using python and the stimulus presented using a 17-inch color monitor. Four color used as stimulus namely "Red", "Green", "Blue" and "Yellow". The stimulus appears at the centre of a black screen (Figure 2 and Figure 3). The experiment has two parts/section, congruent and incongruent, respectively, in each session. There were no gaps between the section. Each color appears 5 times in a random order per section; thus effectively there were 20 (5 trails × 4 colors) trails per section. We instructed the participant to use the mouse to submit the response. The next stimulus appears on the screen

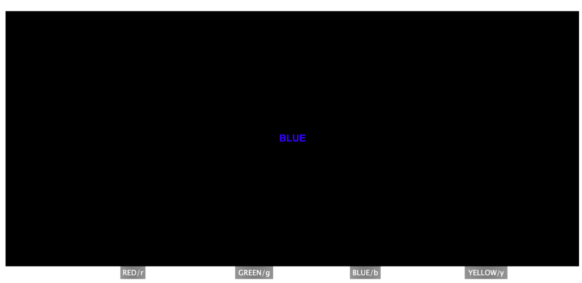

FIGURE 2. Stroop task - congruent task (Same word and ink color).

FIGURE 3. Stroop task - incongruent task (different word and ink color).

only after a successful response submission. A clock starts ticking as soon as the stimulus appears on the screen and stops immediately as the participants make a response. We recorded this time as Response Time for that specific stimulus. At the end of the session (congruent and incongruent), we calculated the average response time for each session. Basically, $AverageResponseTime(per\ session) = (1^{st} stimulusRT + .. + 20^{th} stimulusRT)/20$

C. MANIPULATION OF STRESS

We have used the Montreal Imaging Stress Task (MIST), as described by Dedovic *et al.* [54], to induce mental stress. The MIST task inspired by the Mental Challenge Test series. We have used the Inquisit lab[1] interface (trial version) for this. Dedovic *et al.* [54] have reported the MIST task in their work. Nevertheless, We are describing the experimental set up very briefly. The problems, in MIST task, are arithmetic problems ranging from simple to challenging. The arithmetic problems consist of number (between 0 to 99) and operands (addition, subtraction, multiplication and division). The results are always a single-digit number. Traditionally, the MIST graphical interface contains a problem box and answer dial (a rotary dial). The participants can rotate the highlighted number to left and right using the left and right mouse button, respectively. Once they reach the correct answer, they can submit the answer using the middle mouse button (Figure 4). After response submission, a popup notification ("correct" and "incorrect") appears which notify the participants if their answer is "correct" or "incorrect".

The MIST mainly divided parts, i.e. rest, tanning and experiment session, respectively. In the rest condition, participants stare at the screen and do nothing. However, for our experiment, we have collected the rest condition physiological data separately. In the training session, the mental calculation speed of the participant gets evaluated based on their average response time. The training session also helps the participants to get familiar with the overall experimental setup. In the experiment session, a clock and a performance bar appear on the screen. The performance bar continuously shows the performance of the participants compared to other participants performance while the clock indicates the remaining time for an individual problem. Previous results

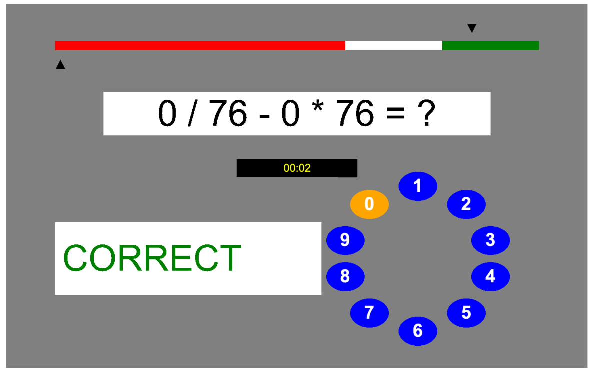

FIGURE 4. Graphical user interface of Montreal imaging stress task (MIST).

from fMRI data show that the time bar and the clock act as a stressor for the candidates [54].

D. PHYSIOLOGICAL MONITORING: EDA AND PPG SIGNAL RECORDING

In literature, many methods and devices such as saliva [31], fMRI [54], EEG, fNRIS [24] are available to study and analysis the human stress. However, these tools are either very complicated or sensitive towards noise; therefore, a bit tricky to use in a real-world environment. Physiologically, any emotional may state triggers the Sympathetic Nervous System (SNS) [53]. The aroused SNS also excite the eccrine gland and cause sweating. The sweating changes the skin conductance level (SCL) of human skin. Electrodermal Activity (EDA) measure this SCL changes [53] caused by the excitation of the eccrine gland [53]. Some recent studies on emotion recognition using EDA shows that EDA signal could be used for different emotion recognition [55]. This also imply that there is a correlation between emotion and EDA signal.

Furthermore, recent studies with cardiovascular signals also show that stress affects the heart activity [34]. These physiological signals are easy to collect, easy to analyze and most importantly, portable hence perfect for real-world use. The strong correlation between physiological signals and emotion, motivated researchers to carry out studies on emotion with physiological signals (EDA, PPG, HR). In recent years, studies with Electrodermal Activity (EDA), photoplethysmogram (PPG) and other physiological signals further demonstrate the effectiveness and accuracy of these signals in human affective state condition analysis [23], [25], [34], [56]–[58].

For our studies, we have recorded EDA and PPG signal from the participants using shimmers gsr3 kit[2] during MIST task. EDA signal collected from index finger and middle finger and PPG was collected from Ring Finger of the left hand. The device is a wearable device and data transmitted to the computer via Bluetooth. We have collected the signals at a

[1] https://www.millisecond.com/download/library/montrealstresstest/

[2] https://www.shimmersensing.com/products/shimmer3-wireless-gsr-sensor

frequency rate of 1024hz (both EDA and PPG signals) using ConsensysPRO[3] software. However, due to the Bluetooth transmission, we lost 30% data loss. The lost data corrected during signal analysis.

E. SURVEY DATA

We asked the participants to fill a questionnaire after each session, and it follows the same protocol used in the NASA task load index [59] experiment. The self-report helps us to understand a participant's assessment of the below questions

- Mental stress participants experienced during MIST task.
- The difficulty they have faced to spot 2nd target in AB task (before and after stress)
- The difficulty they have faced to respond in the incongruent task (before and after stress).

In a way, the self-report further validates the result obtained by the experiments. A snapshot of the questionnaire could be found in Table 2.

TABLE 2. Self-report questionnaire.

Questions	Likart Scale
Experiment 1 (Attentional Blink Task)	
Difficulty to spot and identify the Second Target (Before MIST)	$1\cdots3\cdots5$
Level of Mental Stress during the MIST	$1\cdots3\cdots5$
Difficulty to spot and identify the Second Target (after MIST)	$1\cdots3\cdots5$
Experiment 2 (Stroop Task)	
Difficulty faced to response during Incongruent task (Before MIST)	$1\cdots3\cdots5$
Level of Mental Stress during the MIST	$1\cdots3\cdots5$
Difficulty faced to response during Incongruent task (Before MIST)	$1\cdots3\cdots5$

F. PROCEDURE

The lab temperature was set to 25 degree Celsius (normal for sub-continent region) for the entire data collection phase. We maintained a good lighting condition for all the participant. A computer with 8 GB RAM, 17″ LCD monitor (resolution set to 1600 × 900) was used for the experiment. Both the experiment conducted in 2 sessions and there was a 2 weeks gap (washout period) between session 1 and session 2. Session 1 was without the stress task while in session 2, the participant performs MIST (stress) task before the attentional task. We assigned the participant randomly for session 1 and assigned a participant id. In session 2, The participant id was used to assign the participant to a specific experiment. Figure 5 and Figure 6 is a pictorial representation (flow chart of the experimental setup) of the procedure for both the experiment.

[3]https://www.shimmersensing.com/products/consensys

1) SESSION 1

We randomly assigned the participants (maintaining the male-female ratio) to each test (a flow chart for the experimental procedure given in Figure 5 and Figure 6). After entering into the room, the experimenter handed out the consent form to the participant. The experimenter also provides a short introduction describing the purpose of the experiment. After the brief introduction and signing of the consent form, we gave a 30 minutes relaxation time window to the participants. This relaxation time helps the participants to get accustomed to the room environment. During this time, the participant was the only person present in the room. The experimenter entered the room only after the relaxation time and explained the experiment related instruction to the participant. As presence of other person may influence the cognitive state of the participant, The experimenter asked the participant to start the task and left the room. During the experiment, the participant was all alone and monitored by the experimenter from a remote location. The participant fills out the survey form after completing the experiment. The experimenter also asked the participant not to discuss the experiment with other participants and not to practice the experiment during the 2-week wash out period between the experiment.

Session 2: Procedure wise, session 1 and session 2 are pretty similar except the MIST task (for both the experiment; Figure 5 and Figure 6). The participant completed the MIST task between the relaxation and the actual attention experiment. The participant id helped us to assign participant according to session 1. The participant signed a consent form before the MIST task. The physiological signal was collected during the MIST task, while the rest condition signal was collected just before the MIST task starting. The participant left alone in a room to complete the MIST task and subsequent experiment. However, the experimenter monitored the session from a remote place. There was a survey form at the end of the session.

III. RESULTS

The primary motivation of the study was to find the impact of mental stress on visual attention (focused and selective visual attention). So, it is imperative to understand the effect of MIST (stress modulation task) on participants. We have used the same stress task for both the experiment and collected physiological signals (EDA and PPG signal) and survey report during the stress task. We will start the result section with physiological signal analysis during stress condition, and then we will discuss the result of experiment 1, experiment 2 and survey data respectively. We have used two-tail T test statistics to analysis the data

A. EDA AND PPG DATA ANALYSIS

As discussed earlier, physiological signal and emotion have a significant correlation. Several studies have used EDA, PPG or combination of both them to successfully investigate the

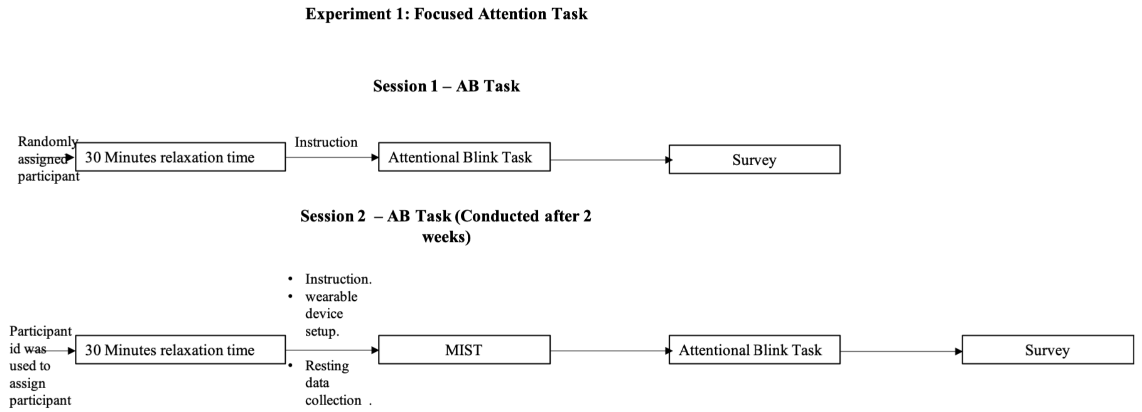

FIGURE 5. Experimental procedure for experiment 1 (Attentional Blink: focused attention).

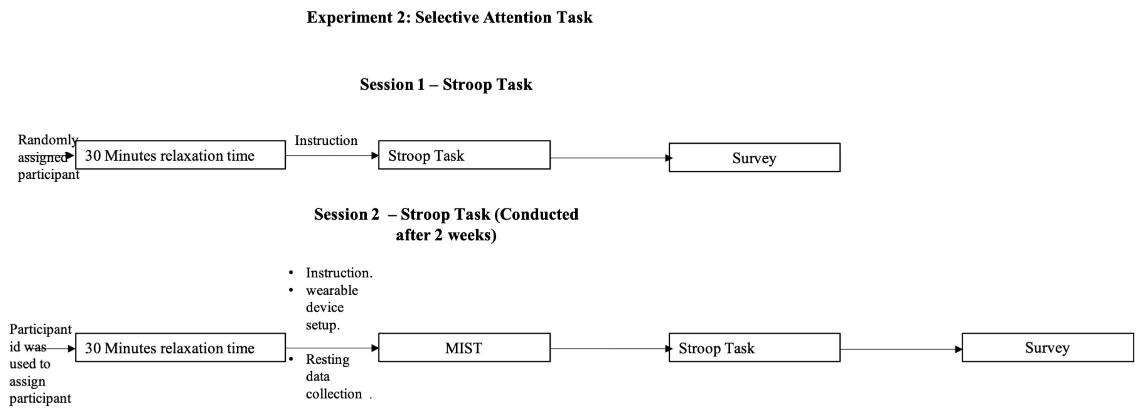

FIGURE 6. Experimental procedure for experiment 2 (Stroop task: selective attention).

emotional state of human [23], [25], [34], [53]. Figure 7 and Figure 8 represent a sample of EDA signal and PPG signal respectively, collected during MIST task.

1) EDA SIGNAL ANALYSIS

Setz *et al.* [23] and Healey and Picard [25] used features such as number of peaks, number of the peak above a certain threshold height, average peak height, standard deviation (std) of peak height to analyze EDA signal during human stress condition. We have used the neurokit2 python module for the feature extraction propose [60]. We have used the Skin Conductance Response component for the analysis purpose, as research [23], [25], [57] shows that SCR is suitable for emotional state investigation. In the rest of the paper, we have used EDA to actually refer SCR. We have cleaned the EDA signal using Healey and Picard [25] method, i.e. normalizing the SCR by subtracting the baseline minimum and dividing by the baseline range, to remove any unwanted artifacts from the signal. After cleaning the signal, we have extracted the number of peaks above a certain threshold height, average peak height and standard deviation (std) of peak height as features from the cleaned EDA signal.

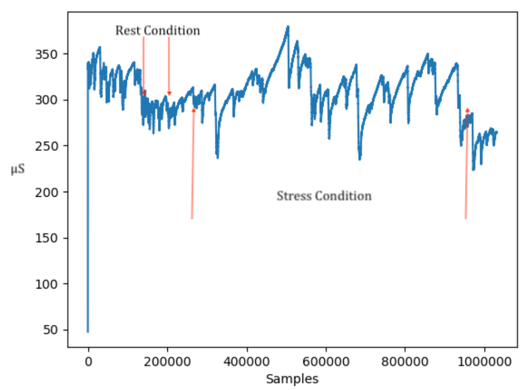

FIGURE 7. Sample EDA signal (rest and stress condition marked).

We have set the threshold to 75 % of the highest peak [60]. In other words, we have considered the peaks whose heights are 75 % of the highest peak. We observed that for total population (male and female combined) the standard deviation (std) of EDA peak height during stress (*Median* = 57.57, *std* = 77.31) is significantly greater than rest condition (*Median* = 13.97, *std* = 28.34), $t(60) = 4.11544$, $\rho = .00003$.

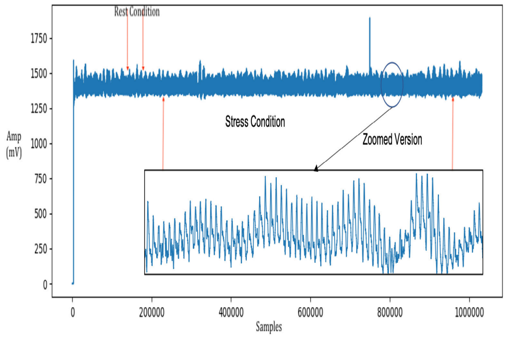

FIGURE 8. Sample PPG signal (rest and stress condition marked).

Similarly, the number of peak above threshold (where threshold set to the 75% of the highest peak) during stress condition (*Median* = 9.41, *std* = 9) is also significantly higher than rest condition (*Median* = 0.43, *std* = 0.78), t (60) = 4.15666, ρ =.00010. Furthermore, the average peak amplitude (above the threshold height) is also significantly high for stress condition (*Median* = 27.25 and *std* = 43.13) compared to rest condition (*Median* = 3.77, *std* = 8.25), t(60) =7.74621 and ρ =.00010.

Furthermore, for male group, we observed that standard deviation of peak height is significantly high for stress condition (*Median* = 61.64, *std* = 89.42) than rest condition (*Median* = 10.63, *std* = 14.25), t (30) = 3.08611, ρ =.00310. For the other two features (the number of peaks above the threshold and average peak height above the threshold), we observed a similar pattern for the male group (refer Figure 9, Table 3 and Table 4). The same trend was observed in the female group for these three features as well (for detail result refer to Figure 9, Table 3 and Table 4). Even the self-report data shows that the participants have rated the MIST task very high (*Mean* = 4.20 and *std* = 0.63; refer Table 12 and Figure 14).

2) PPG SIGNAL ANALYSIS

Sloan *et al.* [34] used cardio activity to analyze mental stress. They used an ECG multivariate analysis to show the individual difference during mental stress. They used heart period variability (HPV), RR peak interval analysis of ECG data during mental stress. However, Van Gent *et al.* [35], [36] showed that similar effective features could be calculated from the PPG signal. Moreover, PPG device is wearable and easy to operate. We recorded the PPG signal during the MIST task as well. We calculated beats per minute (BPM), interbeat interval (IBI), standard deviation if intervals between adjacent beats (SDNN), root mean square of successive differences between adjacent R-R intervals (RMSSD), the proportion of differences between R-R intervals greater than 20ms, 50ms (pNN20 and pNN50 respectively) and breathing rate (moving window of 10sec) [35], [36] to analyze the PPG signal. Van Gent *et al.* [35], [36] have discussed the technical details in their work. We observed that bpm feature is significantly high during stress condition (*Median* = 108.57, *std* = 28.41) than rest condition (*Median* = 76.55, *std* = 18.7), t (60) = 7.29231, ρ = <.00001, for the overall participants (male and female combined). The analysis also showed that for the total population (male and female combined), all other features,

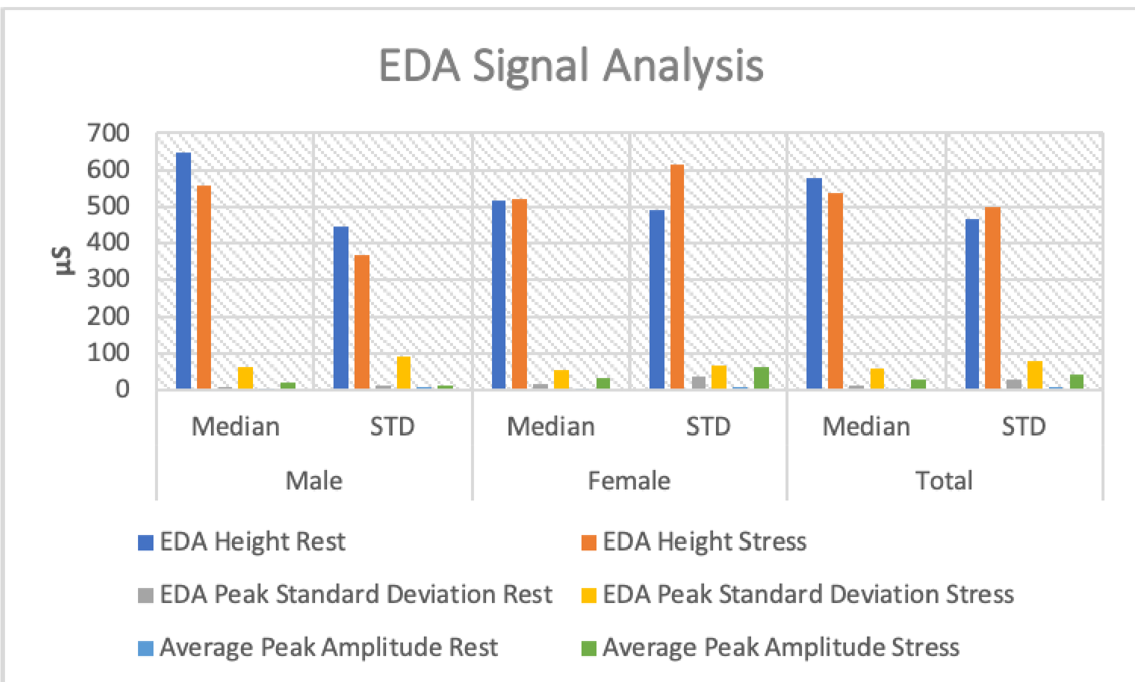

FIGURE 9. Descriptive statistics of EDA signal features.

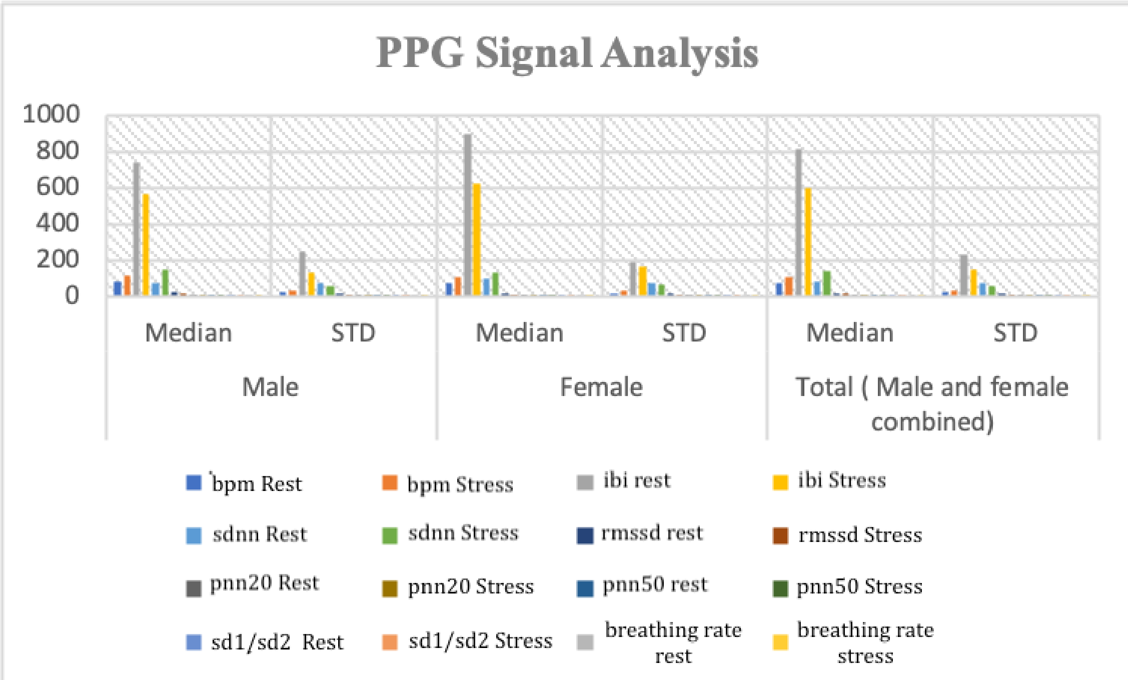

FIGURE 10. Descriptive statistics of PPG signal features.

TABLE 3. EDA data analysis during rest and stress condition.

Group	Statistics	Average EDA Height (μS)		EDA Peak Std (Above threshold)		Number of peak (Above Threshold)		Average Peak Amplitude(Above threshold) (μS)	
		Rest	Stress	Rest	Stress	Rest	Stress	Rest	Stress
Male	Median	648.75	555.23	10.63	61.64	0.50	10.13	3.47	21.79
	std	446.28	367.80	14.25	89.42	0.86	10.23	8.41	14.25
Female	Median	514.91	521.26	17.70	54.75	0.33	8.87	3.41	32.74
	std	491.48	613.50	37.78	65.55	0.71	7.81	7.53	60.38
Total Participant	Median	578.29	534.59	13.97	57.57	0.43	9.41	3.77	27.25
	std	467.18	498.40	28.34	77.31	0.78	9.00	8.25	43.13

TABLE 4. T-test analysis of collected features from EDA signal.

Group	EDA Peak Std (Above threshold)		Number of peak (Above Threshold)		Average Peak Amplitude(Above threshold)	
	t	ρ	t	ρ	t	ρ
Male	3.08611	.00310	5.13752	.00010	6.06391	.00010
Female	2.68195	.00475	5.95895	.00010	4.26182	.00010
Total	4.11544	.00003	4.15666	.00010	7.74621	.00010
Male vs Female	0.80121	.21314	0.49320	.31184	0.90161	.18542

except pnn20 feature, possess a significant difference during stress condition than rest stress (please see the Table 5 for details). Individually, for the female group, we observed a significant difference in bpm, ibi, sdnn, sd1/sd2 and breathing rate values during stress condition compared to rest condition (Refer to Table 5 and Figure 10 for details). For female group, the bpm is significantly high for stress condition ($Median = 104.86$, $std = 28.81$) than rest condition($Median = 70.92$, $std = 12.69$), t (30) = 5.90400, $\rho = .00010$. The other features, ibi, sdnn, sd1/sd2 and breathing rate, is also significantly different during stress condition compared to rest condition (Refer to table 5 and Table 6 for details). The Male participant group also showed a significant difference in bpm, ibi, sdnn, rmssd, sd1/sd2 and breathing rate values during the stress condition in comparison to the rest condition(Refer Table 5 and Table 6 for details).

B. EXPERIMENT 1: FOCUSED ATTENTION ANALYSIS

As discussed in the earlier section, the participants find it difficult to spot and identify target T2. Moreover, the accuracy of identification of target T2 is very less in the smaller lags (less than lag 4) scenario. We have performed the analysis in three parts, i.e. firstly, overall participant (combining male and female) analysis, secondly, male and female within-group analysis and lastly, male vs female between the group analysis.

1) **Overall participant (combining male and female) analysis:** The analysis of AB data reveals that all the participant's performance in identifying the target T2 is better after stress task ($Median = 82.94$ and $std = 13.19$) than before the stress task ($Median = 71.26$ and $std = 16.72$), t(30) = 3.02889 and $\rho = .00183$. We also observed that all the participants have performed better in identifying target T1 after stress induction than before stress induction (if we compare the *Median* of final accuracy (final identification accuracy) for after and before stress; refer Table 7, Figure 11). However, the result was not statistically significant for

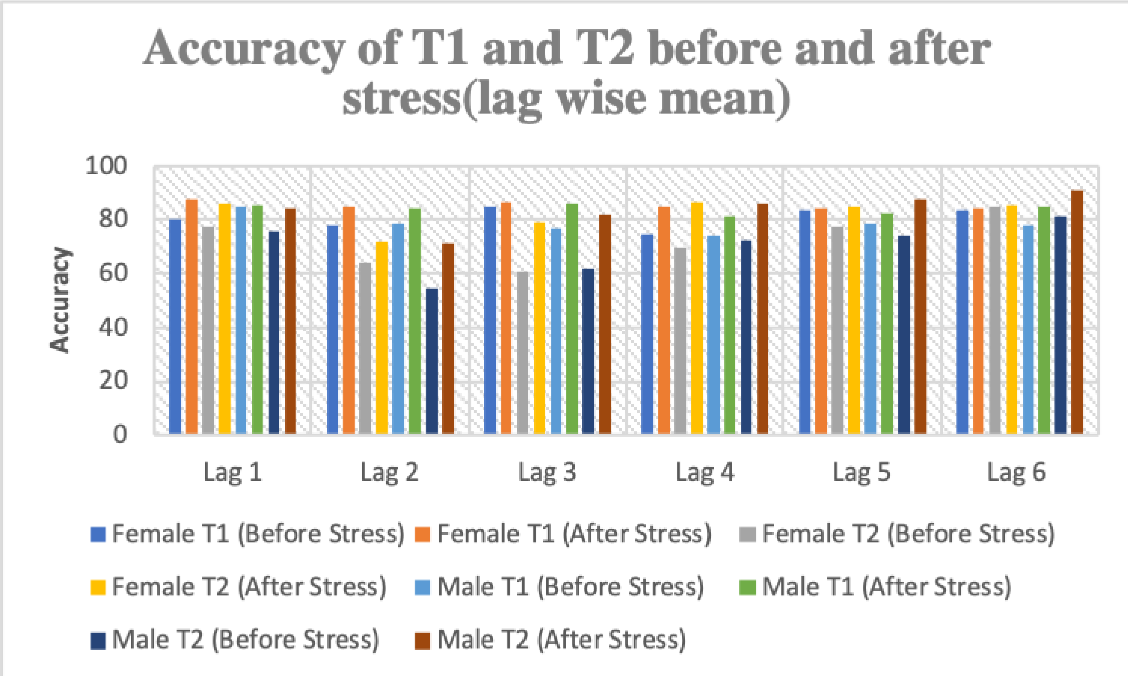

FIGURE 11. Attentional Blink performance lag wise comparison (before and after stress).

TABLE 5. Descriptive statistics of PPG signal.

Features	Condition	Male		Female		Total (Male and female combined)	
		Median	std	Median	std	Median	std
bpm	Rest	82.19	22.01	70.92	12.69	76.55	18.70
	Stress	112.28	27.99	104.86	28.81	108.57	28.41
ibi	Rest	735.33	246.33	898.97	185.22	817.15	231.29
	Stress	564.56	128.23	621.68	166.47	593.12	150.17
sdnn	Rest	70.59	69.70	98.89	71.50	84.74	71.45
	Stress	146.80	52.88	132.58	61.09	139.69	58.39
rmssd	Rest	19.70	10.99	15.67	11.98	17.69	11.57
	Stress	10.99	5.08	9.25	9.13	11.03	8.30
pnn20	Rest	0.94	0.16	0.85	0.20	0.89	0.18
	Stress	0.87	0.19	0.82	0.17	0.84	0.20
pnn50	Rest	0.86	0.30	0.74	0.35	0.80	0.33
	Stress	0.75	0.31	0.64	0.30	0.69	0.32
sd1/sd2	Rest	0.59	1.64	0.56	0.64	0.40	0.59
	Stress	0.97	0.66	1.04	0.70	1.01	0.68
breathing rate	Rest	0.08	0.15	0.17	0.16	0.12	0.16
	Stress	0.44	0.27	0.25	0.25	0.35	0.27

target T1 (refer to Table 8). Nevertheless, to get more insight, we carried out a lag wise comparison for the total participant. The lag wise comparison reveals that for target T2, the overall participant have performed better in lag 1 after stress induction ($Median = 85$ and $std = 11.67$) than before stress task ($Median = 76.67$ and $std = 23.48$), $t(30) = 1.72872$ and $\rho = .04459$. Likewise, we observed similar statistically significant results for target T2 in lag2, lag3, lag4 and lag5(Table 9). Although the performance increased at detecting target T1 (Table 7 and Table 9), the T-test result was insignificant for all the lags except for lag4.

2) **Male and Female within the group analysis:** For male participants, we observed a rise in accuracy (median and mean accuracy; Table 7 and Figure 13) for final accuracy (both T1 and T2 detection) after

TABLE 6. PPG signal analysis (T-test statistics).

Group/Feature	Female		Male		Male vs Female		Total (Male and female combined)	
	t	ρ	t	ρ	t	ρ	t	ρ
bpm	5.90461	.00010	4.62934	.00001	.66482	.25443	7.29231	<.00001
ibi	6.09673	<.00010	3.36812	.00060	2.02575	.02370	6.29277	<.00001
sdnn	1.92941	.02920	4.77093	<.00001	1.88152	.03240	0.00004	.00004
rmssd	1.56933	.06100	4.14721	.00005	1.42774	.05130	3.62021	.00021
pnn20	0.61831	.26930	1.50700	.06860	0.97562	.16660	1.44972	.07489
pnn50	1.20761	.11600	1.37824	.08670	0.06623	.47370	1.80718	.03664
sd1/sd2	2.74522	.00400	4.78183	<.00001	1.07643	.14300	5.15902	<.00001
breathing rate	1.90262	.03100	6.40546	<.00001	3.24621	.00090	5.68527	<.00001

TABLE 7. Lag wise performance during the AB task (descriptive statistics of AB task).

lags	Stats	Female				Male				Total (Overall Male and Female)			
		Before Stress		After Stress		Before Stress		After Stress		Before Stress		After Stress	
		T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
Lag1	**Median**	80.00	77.33	87.33	86.00	84.67	76.00	85.33	84.00	82.33	76.67	86.33	85.00
	std	10.00	22.51	13.87	11.83	18.46	25.58	15.52	18.83	14.78	23.48	14.49	11.67
Lag2	**Median**	78.00	64.00	84.67	72.00	78.67	54.67	84.00	71.33	78.33	59.33	84.33	71.67
	std	16.56	18.82	14.07	15.68	15.98	24.75	17.64	22.32	15.99	22.11	15.69	18.95
Lag3	**Median**	84.67	60.67	86.67	79.33	76.67	62.00	86.00	82.00	88.67	61.33	86.33	80.67
	std	12.46	23.44	10.47	20.17	25.54	25.41	16.39	16.56	20.16	24.03	13.51	18.18
Lag4	**Median**	74.67	69.33	84.67	86.67	86.00	72.67	81.33	86.00	74.33	71.00	83.00	86.33
	std	13.02	23.14	14.57	16.33	27.20	28.65	17.27	12.98	20.96	25.64	15.78	14.49
Lag5	**Median**	83.33	77.33	84.00	84.67	62.00	74.00	82.67	87.33	81.00	75.67	83.33	86.00
	std	12.90	19.44	16.81	14.07	19.59	24.44	15.33	17.51	16.47	21.77	15.83	15.67
Lag6	**Median**	83.33	84.67	84.00	85.33	82.00	81.33	84.67	90.67	80.67	83.00	84.33	88.00
	std	13.97	17.26	14.04	15.06	17.40	15.98	25.59	16.24	17.74	16.43	20.29	15.62
Final identification Accuracy	**Median**	80.67	72.22	88.38	82.33	78.44	70.11	84.00	83.56	79.56	71.26	84.61	82.94
	std	8.94	15.35	8.83	12.72	18.01	18.47	14.57	14.07	14.02	16.72	11.86	13.19

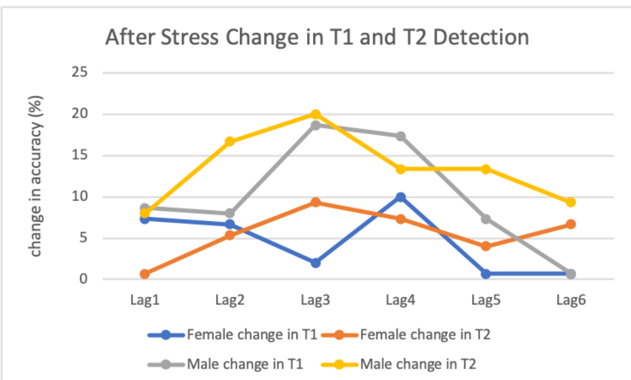

FIGURE 12. Lag wise performance increment (male vs female).

TABLE 8. T-test statistics for final accuracy (Before and After stress Attentional Blink).

Participant Group	T1		T2	
	t	ρ	t	ρ
Female	1.40276	.08584	1.96439	.02974
Male	0.92884	.18045	2.24277	.01650
Total (Male and Female combined	1.50819	.06846	3.02889	.00183
Male vs Female	0.42616	.33662	0.78136	.22057

stress. Statistically, the final accuracy in target T2 detection was significantly better after stress induction (*Median* = 83.56 and *std* = 14.07) than before stress (*Median* = 70.11 and *std* = 18.47), t(15) = 2.24277 and ρ = .016505. However, The analysis of target T1 showed insignificant result for final accuracy. Furthermore, we carried out a lag wise analysis for the male group. For target T2, the lag wise analysis reveals that in lag 2, lag 3 and lag 5, the accuracy is significantly better after stress induction (Table 9). All the remaining lags were insignificant. However, for target T1, though there was a rise in target detection after stress induction (*Median* and mean accuracy; Table 7 and Figure 13), the statistical analysis reports an insignificant result. Similarly, the female participants' results show a prominent rise in performance for final accuracy (*Median* and mean accuracy; Table 7 and Figure 13) of target T1 and target T2 detection after stress induction. Additionally, there was a rise in accuracy (*Median*; Table 7) for almost all the lags. However, the analysis of the accuracy for detecting target T2 reveals that except lag 3 and lag 4, all the lags were statistically insignificant (Table 9). It further showed that all the lags were statistically insignificant, too, for target T1 (Table 9). Nevertheless, the analysis does tell us that the final accuracy was statistically better (Table 8) for target T2 after stress (for both female and male group). Figure 12 and Figure 13 shows

TABLE 9. T-test analysis for lag wise Attentional Blink comparison.

Group	T- Test Analysis Report											
Female	Target T1											
	Lag 1		Lag 2		Lag 3		Lag 4		Lag 5		Lag 6	
	t	ρ	t	ρ	t	ρ	t	ρ	t	ρ	t	ρ
	1.66101	.05391	1.18792	.12243	0.47601	.31883	1.98181	.02863	0.12174	.45192	0.13033	.44861
	Target T2											
	Lag 1		Lag 2		Lag 3		Lag 4		Lag 5		Lag 6	
	t	ρ	t	ρ	t	ρ	t	ρ	t	ρ	t	ρ
	0.78684	.21893	1.26491	.10814	2.33793	.01333	2.37063	.01242	1.18333	.12333	0.11271	.45555
Male	Target T1											
	Lag 1		Lag 2		Lag 3		Lag 4		Lag 5		Lag 6	
	t	ρ	t	ρ	t	ρ	t	ρ	t	ρ	t	ρ
	0.10701	.45777	0.86777	.19641	1.19111	.12171	0.88151	.19273	0.62266	.26922	0.83417	.20561
	Target T2											
	Lag 1		Lag 2		Lag 3		Lag 4		Lag 5		Lag 6	
	t	ρ	t	ρ	t	ρ	t	ρ	t	ρ	t	ρ
	1.09933	.14044	1.93707	.03144	2.55377	.00811	1.64166	.05599	1.71761	.04843	1.58662	.06191
Total	Target T1											
	Lag 1		Lag 2		Lag 3		Lag 4		Lag 5		Lag 6	
	t	ρ	t	ρ	t	ρ	t	ρ	t	ρ	t	ρ
	1.05817	.14713	1.46702	.07383	1.27888	.10300	1.80901	.03788	0.55941	.28901	0.78202	.21866
	Target T2											
	Lag 1		Lag 2		Lag 3		Lag 4		Lag 5		Lag 6	
	t	ρ	t	ρ	t	ρ	t	ρ	t	ρ	t	ρ
	1.72877	.04455	2.31923	.011963	3.51412	.00044	2.85091	.00300	2.11044	.01950	1.20777	.11601
Male vs Feamle	Target T1											
	Lag 1		Lag 2		Lag 3		Lag 4		Lag 5		Lag 6	
	t	ρ	t	ρ	t	ρ	t	ρ	t	ρ	t	ρ
	1.04251	.15300	0.20702	.41871	1.25821	.10934	0.42433	.33722	0.56711	.28753	0.84344	.20306
	Target T2											
	Lag 1		Lag 2		Lag 3		Lag 4		Lag 5		Lag 6	
	t	ρ	t	ρ	t	ρ	t	ρ	t	ρ	t	ρ
	0.08742	.46541	1.13833	.13236	0.18271	.42813	0.53754	.29751	0.75602	.22791	1.28276	.10501

improved mean (Target T2 detection) after stress for the male and female group.

3) **Male vs Female between the group analysis:** Finally, we carried out a between the group analysis to see if the female group has performed better than the male group or vice versa. We calculated the rise in performance (final and lag wise) for each group (for target T1 and T2). We found out that neither group have a clear edge over the other as all the report were statistically insignificant (Table 9).

C. EXPERIMENT 2: SELECTIVE ATTENTION ANALYSIS

Like the experiment 1, we investigate experiment 2 (Stroop task) result in three categories i.e. a. overall participants data analysis, b. male and female individual group analysis (within the group analysis) and c. male vs female between the group analysis.

1) **Overall participant data analysis:** The overall participant data analysis showed a significant improvement in response time (RT) in incongruent task after stress induction ($Median$ = 1682.54 and std = 286.91) than before stress ($Median$ = 2100.58 and std = 397.40), t(30) = 4.67154 and ρ = <.00001. Further, RT in congruent task also improved significantly after stress induction ($Median$ = 1455.06 and std = 315.19) than before stress $Median$ = 1750.89 and std 497.25), t(30) = 2.75223 and ρ =.00391 (Table 10, Table 11 and Figure 13 for detail anlayis).

2) **Male and Female individual group analysis:** How mental stress has affected each group (male and

TABLE 10. Descriptive statistics for Stroop task.

Participant Group	Stats	Congruent		Incongruent	
		Before Stress	After Stress	Before Stress	After Stress
Male	Median	1866.47	1404.67	2230.39	1763.39
	Std	603.97	385.59	442.19	349.37
Female	Median	1635.32	1505.45	1970.78	1601.69
	Std	344.64	227.33	309.02	185.59
Overall	Median	1750.89	1455.06	2100.58	1682.54
	Std	497.25	315.19	397.40	286.91

TABLE 11. Stroop task (T-test analysis).

Participant Group	Congruent		Incongruent	
	t	ρ	t	ρ
Female	1.21823	.11666	3.96563	.00021
Male	2.49601	.00931	3.20934	.00162
Total Participant	2.75223	.00393	4.67154	< .00001
Male vs Female	2.05777	.02452	0.87381	.19494

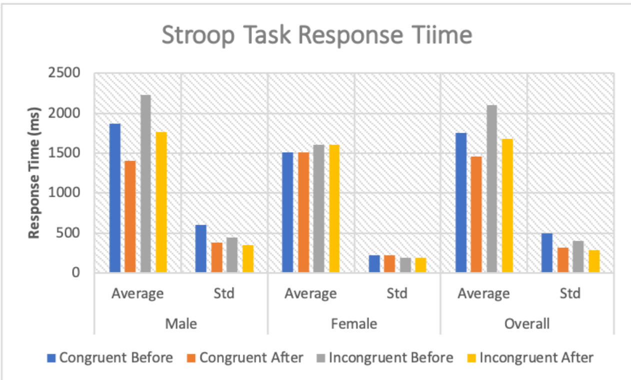

FIGURE 13. Stroop task performance (descriptive statistics).

female)? To examine the effect of mental stress on each group, we performed within the group analysis. The analysis showed that male group RT have improved significantly in incongruent task after stress induction (*Median* 1763.39 and *std* = 349.37) compared to before stress RT (*Median* = 2230.39 and *std* = 442.19), t(15) = 3.20934 and ρ = .00162. Furthermore, we observed a significant improvement in the congruent task's RT after stress than before stress (Table 10, Table 11 and Figure 13 for detail analysis). Similarly, we also investigate the female group. The female group also showed a significant improvement in incongruent task's RT after stress induction (*Median* = 1601.69 and *std* = 185.59) in comparison to before stress RT (*Median* = 1970.78 and *std* = 309.02), t (15) = 3.96563 and ρ = .00021. The RT in the congruent task was not statistically significant (For detail analysis, please refer to Table 10, Table 11 and Figure 13).

3) **Male vs Female between the group analysis:** In this analysis, we have calculated the changes in RT for each group (male and female). Further, we have analyzed the differences in performance (change in RT) statistically. The between the group analysis shows no significant improvement in incongruent task's performance for male/ female over female/male. However, for congruent task performance, the male group have performed significantly better than the female group of participants (For detail analysis, please refer to Table 10, Table 11 and Figure 13).

D. SURVEY DATA

As per earlier discussion, we mainly collect survey data to investigate participants assessment of 1. MIST task, 2. AB task, and 3. Stroop task.

1) **MIST task survey data:** We collected this survey to see the participant's assessment of the MIST task as mental stress inducer. The study showed that all the participants feel the MIST is beneficial to induce ethical mental stress (*Median* = 4.20 with *std* 0.63. Further, each group (male and female) have opined the same (*Median* of male group = 4.23 and *Median* of female group = 4.17). See Table 12 and Figure 14 for details.

2) **AB Task:** The overall participant ratings disclose that the after stress (*Median* = 2.63 and *std* = 0.80) AB task (spotting the target T2) was easier than before stress (*Median* = 3.73 and *std* = 0.73), t(30) = 5.49731 and ρ = <.00001. Individual group's (male and female) rating also followed a similar trend (Table 13 and Table 14 for details). However, when we check the between the group ratings (male vs female or vice versa), no significant result was found.

TABLE 12. Survey data for MIST.

	Median	Std
Male ratings for MIST	4.23	0.68
Female ratings for MIST	4.17	0.59
Overall Ratings	4.20	0.63

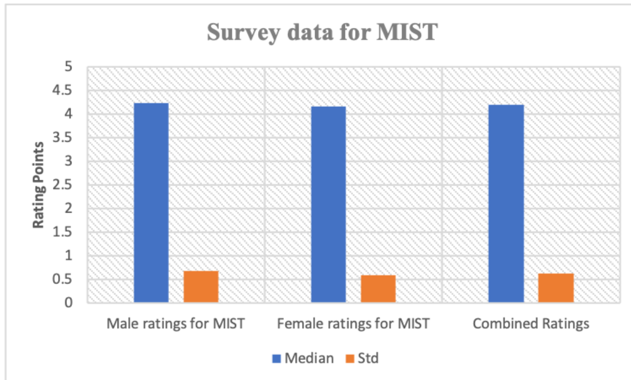

FIGURE 14. Survey data results.

TABLE 13. Survey data result for AB and Stroop task (descriptive statistics).

Group	Task	Median	Std
Female	AB Task (Before Stress)	3.26	0.70
	AB Task (After Stress)	2.26	0.88
	Stroop Task(Before Stress)	3.93	0.96
	Stroop Task(After Stress)	2.86	0.91
Male	AB Task (Before Stress)	4.20	0.4140
	AB Task (After Stress)	3.00	0.53
	Stroop Task(Before Stress)	3.53	1.06
	Stroop Task(After Stress)	2.60	0.91
Total	AB Task (Before Stress)	3.7333	0.7396
	AB Task (After Stress)	2.63	0.80
	Stroop Task(Before Stress)	3.73	1.01
	Stroop Task(After Stress)	2.73	0.90

TABLE 14. T-test result for survey data (AB and Stroop).

Group	Task	T-Test Analysis	
		t	ρ
Female	Attentional Blink	3.4283	.00094
	Stroop	3.11233	.00212
Male	Attentional Blink	6.8738	< .00001
	Stroop	2.58701	.00758
Total (Male and Female)	Attentional Blink	5.49731	< .00001
	Stroop	4.02381	0.00008

3) **Stroop Task:** Based on the Stroop task rating (only for incongruent task), we can conclude that the overall participant felt the incongruent task was easier after stress ($Median = 2.73$ and $std = 0.90$) compared to before stress ($Median = 3.73$ and $std = 1.01$), t(30) = 4.02381 and ρ =.00008. Male and Female group's rating was also significant for the Stroop task (Table 13 and Table 14). However, when we studied between the group ratings (male vs female or vice versa), no significant result was recorded.

IV. DISCUSSION AND CONCLUSION

As we observed from the physiological data of the result section, during MIST stress task, participants do get mentally stressed. The time pressure, the performance challenge and the task difficulty contributed significantly to induce stress during the MIST task. The self-assessment of participants also reflects that MIST does create ethical mental stress. The physiological monitoring observed during the MIST task is aligned with previous studies [23], [24], [34]. Furthermore, the physiological observation reflects that the male and female get affected differently during MIST task. The hormonal difference could have resulted in the differences in stress [29]. Anyway, the two things are clear from the results that MIST generates mental stress, and the impact of MIST task is different in male and female. These two claims are well in line with prior studies [23], [24], [29]–[31], [34], [53].

In the Attentional Blink (AB) task, we observed that the overall performance of the participant gets boosted after stress induction. Most importantly, we noted that in lag 1, lag 2 and lag 3, the participant's performance gets increased. In principle, the target T2 identification accuracy takes a dip for the short lags (generally under up to lag 3) due to the short temporal difference between the stimuli [12], [15]. However, we observed an improvement in target T2 identification for all the participants in final accuracy as well as in short lags after stress induction. Furthermore, we saw that both the male and female group individually performed better under stress. However, there was no significant result which could show that one group's performance was better than the other.

Nevertheless, the improvement in performance in short lags is well in support of Schwabe *et al.* [31] findings. They used emotional stimulus to investigate the focused visual attention and induced stress using SECPT. The used emotional stimulus may interfere with the affect of stress. However, we must mention that unlike Schwabe and Wolf [50] study, the current research conducted using neutral stimuli and mental stress. Thus our study is more concrete evident of how visual attention get affected after mental stress as the stimulus were neutral. Our observation strongly suggests that under mental stress, even for neutral stimuli, the focused attention gets boosted positively.

In the Stroop task also, we observed that overall the participant's response time (for both congruent task and incongruent task) considerably improves after stress task. However, prior studies have a different opinion on congruent task as focused attention [11], [15]–[18]. So we aren't considering the performance in the congruent task. Nevertheless, the incongruent task is well accepted as a selective task, and we observed a positive impact of stress on incongruent task performance. Additionally, though we see a considerable perforce for each group (male and female) when we study the performance of male over female or vice versa, there were no significant results. It implies that the male and female group individually performed better under stress, but there is no evidence that male/female group have performed better than female/male group. The analysis supports the claim of Chajut & Algom [19] and further enhanced their claim by studying the effect of sex difference factor.

In conclusion, this research presents a complete analytical study of focused and selective attention under mental stress. This study also finds that mental stress could improve the focused and selective attention for all gender (male and female). One possible reason for this enhanced performance could be due to the intact amygdala, which gets enhanced during stress [61], [62]. The intact amygdala helps to amplify the visual attention [61], [62]. However, as suggested by the earlier study on learning and memory [63], the learning and competition associated with MIST task must have influenced the attention [19]. The research also inspect the gender difference factor and found that though there are differences in stress (for the male and female group), there is no conclusive evidence if the male group has performed better/worse in the attention task than female or vice versa after mental stress induction. Although the earlier researchers expected that the gender difference could impact the attention and stress relationship, the current empirical evidence proves otherwise. Therefore, we hypothesized that mental stress, where learning and competition is an integral factor, may amplify the visual attention (both focused and selective) invariant of gender. We further support the conclusion of Beck and Luine [63]. From the behavioral aspect, stress may affect male and female differently. However, that might not be the case with the cognitive task which required neural information processing of a certain extent. Thus, we need to study the impact of the gonadal hormone on neural information processing [63]. However, as of now, there is no evidence of how gonadal hormones influence the shifting of neural activity in response to stress. So it needs further investigation [63]. We aim to study the neurophysiological reason behind it in future.

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