Stress Induction and Visual Working Memory Performance: The Effects of Emotional and Non-Emotional Stimuli

Zahra Khayyer,1,* Vahid Nejati,2 and Jalil Fathabadi3
1Department of Educational Sciences and Psychology, University of Isfahan, Isfahan, IR Iran
2Head of Brain and Cognitive Science Research Group, Shahid Beheshti University, Tehran, IR Iran
3Department of Psychology and Educational Sciences, Shahid Beheshti University, Tehran, Iran
*Corresponding author: Zahra Khayyer, University of Isfahan, Isfahan, IR Iran. Tel: +98-9380171218, Fax: +98-312613693, E-mail: z.khayer62@yahoo.com

Abstract

Background: Some studies have shown working memory impairment following stressful situations. Also, researchers have found that working memory performance depends on many different factors such as emotional load of stimuli and gender.

Objectives: The present study aimed to determine the effects of stress induction on visual working memory (VWM) performance among female and male university students.

Methods: This quasi-experimental research employed a posttest with only control group design (within-group study). A total of 62 university students (32 males and 30 females) were randomly selected and allocated to experimental and control groups (mean age of 23.73). Using cold presser test (CPT), stress was induced and then, an n-back task was implemented to evaluate visual working memory function (such as the number of true items, time reactions, and the number of wrong items through emotional and non-emotional pictures). 100 pictures were selected from the international affective picture system (IASP) with different valences.

Results: Results showed that stress impaired different visual working memory functions (P < 0.002 for true scores, P < 0.001 for reaction time, and P < 0.002 for wrong items).

Conclusions: In general, stress significantly decreases the VWM performances. On the one hand, females were strongly impressed by stress more than males and on the other hand, the VWM performance was better for emotional stimuli than non-emotional stimuli.

Keywords: Stress, Working Memory, Visual Memory, Emotional Stimuli, Neutral Stimuli, Gender

1. Background

One of the mental actions, which play a major role in all daily activities, is memory. Memory is a mechanism by which previously stored experiences and information are recovered for use in the present (1). Working memory is one of the most important executive functions, which allow people to combine the old and new information (2). According to Baddeley and Hitch model, working memory consists of 4 components: phonological loop, visual-spatial sketchpad, central executive, and episodic buffer.

The previous studies have consistently shown that psychological pressure is one of the factors affecting memory processes such as recovery process. Stress is a response that a person expresses as a mental or physical behavior to adapt to a different external status from normal status (3). One of the promising justifications on the impact of stress on cognitive functions is in specific stress hormone, cortisol, that activates the hypothalamus-pituitary-adrenal axis after understanding the threat through the brain and disturbance of the balance of body's internal homeostasis so that physical resources of the organism’s body would have the necessary defense power to deal with stressful stimuli (2).

On the advantages of visual-spatial sketchpad, Baddeley (4) offered several suggestions: spatial system is important in determining geographical orientation and acquiring knowledge of the appearance of objects and planning spatial tasks.

Although an optimal level of stress increases the ability to learn, too much stress can lead to problems for physical and mental health (5-7) and decrease of self-confidence (8, 9).

The personal interpretation of stress requires attention to the fact that which stimulus is required to be in short-term memory and which one should be ignored. Also, information processing requires the structures of long-term memory, i.e. the cognitive context that allows people to assess some stimuli as pleasant and some others as unpleasant (10). From the physiological point of view, stressful events cause hormones to release from the adrenal cortex that easily pass the blood-brain barrier (BBB). Some areas of the brain (hippocampus, frontal cortex, and amygdala), which are important areas of memory, include glucocorticoid receptors (11) and the perfor-
performance of these areas is affected by the release of this hormone. Studies have shown that the attention system in anxious people has bias towards negative stimuli in a way that these people are more sensitive to stressful and threatening stimuli (12).

Glucocorticoids have an inverted U-shaped relationship with learning and memory. Its small amount increases recall, while large amounts cause impairment in the recalling process (13-16).

The effects of stress on working memory have been more ambiguous in studies. Some studies have reported the inhibition of working memory performance after stress (17-22), while some have shown the improvement or lack of influence of working memory after stress (23-26). The difference in the results of previous studies can be related to various factors including: type of memory (long-term memory against short-term memory), memory stage (encoding, storage, and retrieval), testing time (morning versus evening), emotional value of learned information (27, 28), gender of subjects (29, 30), and other factors such as age of subjects (31), one’s ability to control the stressful situation (32), intensity (low, medium, or high) and the duration of exposure to the stress (33), source of stress (internal versus external), type of learning (implicit versus explicit), certain psychological properties (34), mood (35, 36), personality (37), and type of individual cognitive assessment (38).

According to the related literature, emotional factors are among the factors affecting the variability of information processing (39), because many cognitive processes are affected by emotional states. A study has indicated that variability in emotional factors predicts change in response time to a task of working memory both in adults and adolescents (40). In another study by Segal et al. (41), the researchers found that inefficient cognitive bias as inhibition of positive emotional information and slower processing of information and faster removing of their attention from them is a major factor of stability in their anxiety problems because it prevents the entry of positive feedback to the working memory system of people with high anxiety. Since the capacity of working memory is limited, updating of selective information is highly important in emotional regulation and psychological well-being (42).

Also, the results of studies (43) showed that perceived stress threshold in women is lower than that in men, i.e. the level of cortisol in women increases more in comparison with that in men and as a result, their limbic system becomes more active (30) and the cortisol response to stress is different between women and men (44-46). A study (47) showed that stress was associated with the improvement of memory performance for negative stimuli. In another study, the effect of social stress on various aspects of human memory (neutral materials for explicit and active memory and emotional stimuli for implicit memory) was investigated and the results showed that the impairment of verbal working memory is related to dealing with stress, while no functional difference was seen between experimental and control groups in the verbal explicit memory and explicit memory of non-emotional stimuli. In addition, stress has led to an increase in classic conditioning for negative stimuli. Moreover, stress improved spatial working memory (19).

In addition, research on the cognitive differences between men and women indicates that women’s performance is better than men’s performance in verbal tasks such as word recalling and recognition (48) and visual recognition memory (49), while men have better performance in spatial memory tasks. In the study by Schoofs (50), it was found that stress has caused impairment in the performance of women’s working memory through increasing the response time to tasks, while it led to an improvement in men’s performance.

2. Objectives

In terms of the experimental framework, the present study was done with the aim of investigating the effect of stress on cognitive performance (visual working memory) in both genders using different stimuli. The research questions include:

1- Does stress lead to change in physiological indices in both genders in a different way?

2- Is the stress induction effective on the working memory performance (accuracy score) of visual emotional stimuli (positive and negative) in students?

3- Is the stress induction effective on the working memory performance (accuracy score) of visual non-emotional stimuli (neutral) in male and female students?

4- Is the stress induction effective on the working memory performance (speed score) of visual emotional stimuli (positive and negative) in male and female students?

5- Is the stress induction effective on the working memory performance (speed score) of visual non-emotional stimuli (neutral) in male and female students?

6- Is the stress induction effective on the visual working memory performance (total error score) in male and female students?

3. Methods

3.1. Procedure and Sample:

The current study was a quasi-experimental study, which is a type of quantitative methods, designed based
on a posttest only control group and conducted through mixed repeated measures ANOVA 2.2.3. In this study, we defined gender and group variables each at two levels and emotional materials at three levels consisting of positive, negative and neutral stimuli. Replacement of subjects, selection of control and experimental groups, and determination of the type of experiment were randomly conducted while the first choice of sample group was done using convenience sampling because of the study conditions (Figure 1).

**Figure 1. Research Design**

The study population comprised students of Shahid Beheshti University during 2013 - 14 academic year (N = 13000). Although 100 students were selected using convenience sampling, finally 62 participants including 30 females and 32 males (at least 15 subjects are suggested for experimental studies according to research methodology resources) with an average age of 23.73 were enrolled. The participants were given a written description of the trial and were offered participation in the study if they met the following criteria: 1) age of 19 - 30 years; 2) not meeting DSM-5 criteria for psychosis, mania, depression, current substance abuse, and dependency; 3) no other psychological treatments for the duration of the study and; 4) no medical disease. The adequacy of the sample size was determined according to eta power. The test power was $1 - \beta \geq 0.83$ and therefore sufficient according to Cohen.

**3.2. Ethical Considerations**

All participants gave informed consent based on the ethics committee approval form of Shahid Beheshti University. Their participation was voluntary and they were free to withdraw at any time during the experiment without giving a reason. The researchers ensured the confidentiality and anonymity of all information. Also, they assured that there was not any potential risk during the experiment.

**3.3. Instruments**

We used n-back and CPT tests in the current study.

### 3.4. Computer Based N-Back Test

In this test, numbers of visual stimuli are successively provided by computer monitor and based on 1-back task, subjects should press key number 1 of the computer if each stimulus is similar to the previous stimulus and key number 2 in case of the lack of similarity. In this test, 100 images (using international affective picture system, IAPS) were used. The reliability measures of n-back task ranged between $r = 0.54$ and $r = 0.84$ and it has strong face validity and widespread use as a measure of working memory in clinical and experimental settings (51).

### 3.5. Social Cold Presser Test (SCPT)

Participants in the experimental group were asked to place their non-dominant hand in cold presser containing 0 - 2 degrees Celsius water for 3 minutes (along with videotaping) and participants in the control group were also asked to place their hand in cold presser containing 35 - 37 degrees Celsius water (without videotaping). To investigate stress-induced changes, heart rate and blood pressure were measured before and after the test (39). SCPT is a reliable and effective international paradigm to induce high levels of social-evaluative threat in the laboratory settings. It significantly blunted cortisol responses in different psychophysiological studies (52).

### 3.6. Measures/Manipulations

This study was performed on the subjects individually. After signing a consent statement and filling a demographic sheet, the subjects were allocated to either experimental or control groups based on random assignment (tossing a coin). The basic blood pressure and heart rate of the subjects were recorded and after the implementation of the relevant phase (stress induction or lack of stress induction), blood pressure and heart rate of the subjects were again recorded. Visual working memory test began with the time interval of 5 minutes. Finally, in order to determine the time of the second stage of the experiment, with a time interval of maximum 10 days, the necessary arrangements were done. For data analysis, two-way ANOVA was run.

### 4. Results

The subjects were at the age range of 18 - 56 years old with the mean age of 23.73 years and standard deviation of 4.3 and the frequency percentage of 48.4% for female group and 51.6% for male group.

In this part, the mean differences of the indicators of physiological and visual working memory performance including accuracy score, reaction time score, and error
score in both genders are reported and then, one can see the results of t-test and two-way ANOVA. According to mean differences of physiological indicators, there is a small increase in heart rate (females: $9.8 \pm 2.2$, males: $9.6 \pm 2.2$) and blood pressure (females: $15.07 \pm 5.5$, males: $10.2 \pm 5.3$) in the phase of stress. To determine the effect of stress induction on the abovementioned parameters, the paired t-test was used. There was a significant difference in the scores of heart rate ($M = 9.6$, $SD = 8.7$, $t (61) = 8.1$, $P = 0.001$) as well as blood pressure ($M = 12.7$, $SD = 21.7$, $t (61) = 5.8$, $P = 0.001$), which suggests the correct stress induction process.

4.1. Analysis of the Indicators of Visual Working Memory Performance

The scores of visual working memory performance of students were analyzed through a two-way mixed ANOVA with two levels of gender as a between-subjects variable and control/experimental group as a within-subjects factor.

4.1.1. Visual Accuracy Indicators

These indicators include scores of correct answers of the subjects to the target stimuli (Table 1).

### Table 1. Two-Way ANOVA for Accuracy Index of Visual Working Memory

<table>
<thead>
<tr>
<th>Source</th>
<th>Df</th>
<th>Ms</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position</td>
<td>1</td>
<td>0.08</td>
<td>0.12</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>0.04</td>
<td>0.02</td>
</tr>
<tr>
<td>Error</td>
<td>57</td>
<td>0.00</td>
<td>-</td>
</tr>
<tr>
<td>Accuracy score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position</td>
<td>1</td>
<td>7.96</td>
<td>8.05a</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>0.09</td>
<td>0.06</td>
</tr>
<tr>
<td>Error</td>
<td>57</td>
<td>0.09</td>
<td>-</td>
</tr>
<tr>
<td>Accuracy score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position</td>
<td>1</td>
<td>20.26</td>
<td>26.47a</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>0.21</td>
<td>0.42</td>
</tr>
<tr>
<td>Error</td>
<td>57</td>
<td>0.6</td>
<td>-</td>
</tr>
</tbody>
</table>

*P < 0.01.

A) Accuracy score of the positive stimuli of visual memory: not significant

B) Accuracy score of negative stimuli of visual memory: $F (1.57) = 8.05$, $P < 0.006$, $\eta^2 = 0.12$

C) Accuracy score of neutral stimuli of visual memory: $F (1.57) = 26.47$, $P < 0.001$, $\eta^2 = 0.32$

By comparing the means, it can be inferred that the mean of response accuracy of men's visual working memory was better than the women's and visual working memory performance of emotional stimuli was better than non-emotional one (the highest and lowest accuracy scores belonged to positive and neutral positive, respectively). Generally, 16% of variation can be explained by total accuracy score of visual stimuli. This part answers the questions number 2 and 3.

4.1.2. Visual Speed Index

These indices include the response time of subjects to the target stimuli.

A) Speed score of positive stimuli of visual memory: $F (1, 58) = 26.65$, $P < 0.001$, $\eta^2 = 0.32$

B) Speed score of negative stimuli of visual memory: $F (1, 58) = 51.87$, $P < 0.001$, $\eta^2 = 0.47$

C) Speed score of neutral stimuli of visual memory: $F (1, 58) = 3.71$, $P < 0.05$, $\eta^2 = 0.06$

The results presented in Table 2 show that there are significant differences between the speed scores of visual working memory for positive, negative, and neutral emotional stimuli in both experimental and control groups. Also, according to the calculation of the difference score, the results indicate that speed is affected by stress more than the accuracy index of visual working memory, while on the way of the two genders’ performance, better performance of men, especially for positive stimuli, can be mentioned. Generally, 36% of variation can be explained by total speed score of visual stimuli (reaction time score). This part answers the questions number 4 and 5.

### Table 2. Analysis of Two-Way ANOVA for the Indices of Visual Working Memory Speed

<table>
<thead>
<tr>
<th>Source</th>
<th>Df</th>
<th>Ms</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive speed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position</td>
<td>1</td>
<td>260.34</td>
<td>26.65a</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>376</td>
<td>0.82</td>
</tr>
<tr>
<td>Error</td>
<td>58</td>
<td>29.28</td>
<td>-</td>
</tr>
<tr>
<td>Positive speed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position</td>
<td>1</td>
<td>118.94</td>
<td>51.87a</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>8.39</td>
<td>1.14</td>
</tr>
<tr>
<td>Error</td>
<td>58</td>
<td>2.29</td>
<td>-</td>
</tr>
<tr>
<td>Positive speed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position</td>
<td>1</td>
<td>5.55</td>
<td>3.71b</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>5.59</td>
<td>1.74</td>
</tr>
<tr>
<td>Error</td>
<td>58</td>
<td>1.5</td>
<td>-</td>
</tr>
</tbody>
</table>

*P < 0.01*

4.1.3. Error Index

Based on Table 3, this index includes scores of the subjects in incorrect response to non-target stimuli (commission error) ($F (1.58) = 10.68$, $P < 0.01$, $\eta^2 = 0.15$).

4.1.4. Question Number 6

Is the stress induction effective on working memory performance (the total errors) of male and female students? In general, the error rate of omission was more...
in women, while the error rate of commission was higher in men. In addition, the errors in the control phase were higher for women (especially for neutral stimuli), whereas they were higher for men in the experimental phase of the study (especially for negative stimuli).

The comparison of the means showed that at the experimental phase, the error rate was more for men than women while in the control phase, the error rate was higher for women than men. A total of 15% of variation can be explained by the total index of visual working memory errors.

5. Discussion

In general, according to the results of this study, stress caused problems in various functions of visual working memory, which are consistent with the findings of other recent studies (21, 22).

From the results of this study, there was no difference between the experimental and control groups in terms of the number of correct responses to visual stimuli with positive emotional load; however, this difference can be considered statistically significant following stimuli with negative and neutral emotional load. In terms of the way of the performance of both genders, after induction of stress, women responded to more positive and neutral stimuli, while men responded to more negative stimuli. On the other hand, according to the mean total accuracy score of both phases of this study, we have: neutral more than positive and positive itself more than total number of correct responses to negative stimuli.

Our findings were in accordance with Zoladz’s study (39) where the induced stress led to the destruction of free recall of negative words immediately before learning. To explain these results, it was observed that emotional events can be remembered better than ordinary events (53).

There was a significant difference between the experimental and control groups in terms of response speed to all kinds of positive, negative, and neutral stimuli; however, in terms of gender differences, the better performance of men for all stimuli was seen (female mean = 21.72 and male mean = 18.96). On the other hand, according to the mean total speed score for both phases of the present study, we have: neutral more than negative and negative itself more than total speed to positive stimuli.

The results of this study were inconsistent with those of a study investigating the effect of stress on 62 healthy women and men before learning that reported the increased free reminder in 1 hour and 24 hours for neutral stimuli and no effect for positive stimuli and increased remembering of negative stimuli due to more information processing in amygdala (the center of emotions in the brain). Hence, the difference of arousal level of the autonomic nervous system according to the type of test material (47) is consistent with the study by Schoofs (50). Better performance of the working memory is related to the greater involvement of the dorsolateral prefrontal cortex (DLPFC) and less involvement of the default mode network including Hippocampus, amygdala, ventromedial prefrontal cortex, and posterior cingulate cortex. In addition, stress leads to increased attention span which, in turn, results in the reduction of the processing time of stimuli and eventually the faster reaction to memory tasks.

From the current study outcomes (15), it can be interpreted that cortisol has a positive impact on memory consolidation leading to an optimal arousal level because of the inverted U-shaped relationship between cortisol and arousal level. If the emotional content of stimulus is more than the optimal level, it will have a destructive impact on memory function (16).

Gender differences are important in the effect of stress on cognitive functions. Cortisol response to stress is at lower levels in women than men, especially in women who take oral contraceptive pills (OCP) containing estrogen and progesterone hormones, because these hormones cause a slow response to HPA axis, minimizing the impact of stress hormones on memory (44, 45), as observed in the result section. Therefore, one can say that the cortisol response is affected by the phase of menstrual cycle in women. This response is increased in the luteal phase in which estrogen and progesterone hormones are at high levels compared to the follicular phase in which they are at the lower levels (46).

The results of this study are compatible with those of Luethi, Meier, and Sandi study (19). Their study suggests that stress affects the capabilities requiring deep consciousness and information processing and as a result, leads to reduced efficiencies of cognitive functions such as working memory.

Another significant difference between the experimental and control groups was in terms of the error numbers. The number of errors was more in the male group than the female group in the experimental phase (female mean
= 9.8 and male mean = 10.12), while in the control phase, the number of errors committed by women was more than that by men (female mean = 5.76 and male mean = 3.86). As studies have shown, anatomical position of working memory is in dorsolateral prefrontal cortex (DLPFC), which involves the emotion regulation of the learning processes and attentional control from visual cortex (38). Consequently, the presence of a female examiner during the experiment may be considered as a distraction for male participants and it may be a reason for their weaker performance and more errors (12).

Studies have shown that one of the important mediating factors in the effect of stress on memory is mood, which exerts its effect in two ways: 1) selecting information with different emotional loads to be brought to consciousness; 2) pleasant and unpleasant perception of information. The difference observed in remembering positive and negative stimuli can be resulted by the current one’s sustained emotion (mood) or transient emotion (affect) (36). Personality is the other factor that may account for the stress effects. People have different personality types and since they have various behavior patterns, they have different cognitive processes and cognitive procedures such as memory and perception. For instance, individuals with type A personality respond to stimuli more quickly and they could recall more words in the memory tests but their performance on the accuracy tests is not much perfect, while the results for individuals with type B personality who are less challenging and competitive are the other way round (37).

Lack of knowledge about the participants’ personality profile can be mentioned as a limitation for this study. Other limitations of the study were related to considering an intervening psychological concept and emotional intelligence, which indirectly affects the tendency of people to experience positive and negative emotions (34), and checking biological related markers. Studying age differences and applying other stress induction protocols can be suggested for further research.

In summary, the results reinforce the view that acute stress can be highly disruptive for working memory processing through decreasing the efficiency of the prefrontal cortex and increasing the ability of the amygdala for emotional processing.

Acknowledgments

The researchers thank the colleagues in the psychology lab of Shahid Beheshti University and all students who helped us achieve the objectives of this study with their sincere cooperation.

Footnote

Conflict of Interests: No potential conflict of interest was reported by the authors.

References

10. Mehdipour A. Comparing students copying styles with their personality traits among high schools in Kashan [In Persian]. ; 2004.


36. Beck AT, Clark DA. Anxiety and depression: An informa-