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The Impairing Role of Stress on Autobiographical Memory Reconsolidation

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Abstract

***Background*:** Despite some studies indicating improving role of stress on memory consolidation, very few animal and human studies show that stress impairs reconsolidation of memories. This study aimed to determine the effect of stress on autobiographical memory reconsolidation.

***Materials and Methods*:** The present study was done with an experimental method (Solomon Four-Group design). The statistical society of this study was all undergraduate female students in 2009-2010 academic year at Tabriz University. Forty students were selected using random cluster sampling, and we ensure about their physical and mental health by GHQ-28 and interview. Tools for this study were cueing autobiographical memory test, SECPT (for raising blood pressure and stress induction), autobiographical memory test, PANAS and general health questionnaire (GHQ-28). MANOVA was used for data analysis by SPSS-17.

***Results*:** The results show that stress after activation of memory impairs memory for neutral events ($p<0.001$), while there was no such effect on the memory for emotional events ($p>0.05$). None of stress and memory activation alone had effect on memory performance ($p>0.05$).

***Conclusion*:** These findings indicate that stress impairs autobiographical memory reconsolidation, which is opposite to its effects on memory consolidation, so it supports the view that consolidation and reconsolidation are separate process.

Introduction

Autobiographical memory is a type of memory that consists of a rich knowledge based on personal experiences. Many factors may play a role in changing or improving memory [1]. For example, emotional events are recalled easily which this has been attributed to effects of stress hormones such as glucocorticoids (cortisol in human) and catecholamines (adrenalin and noradrenaline) in memory consolidation. Studies have shown that that stress and its hormones, enhance memory performance shortly after learning [2], especially these effects is stronger for emotional information, so activation of the amygdala is necessary for the effect of stress on memory consolidation [3]. The view that memory consolidation is not a unique process, first described over 40 years ago, and has got stronger in the past decade [2].

Various animal and human studies have shown that consolidated memories, when reactivated, they become again unstable and therefore there is a need to another period of consolidation, called reconsolidation. Is reconsolidation like memory consolidation influenced by stress and glucocorticoids? Animal studies for the first time showed that stress after the reactivation of memory reduces later memory [4-6]. For example, Maroun and Akirav study has shown that stress impairs object recognition memory in the mouse consolidation and this effect is reversed by injection of glucocorticoids receptor antagonist injected into amygdala, [5]. Schwabe and Wolf in study of effect of stress on human memory consolidation demonstrated that the effect of stress on memory consolidation is opposite to its effects on consolidation process and found that the consolidation and reconsolidation are separate processes. Also, in their study only reconsolidation of neutral memories was impaired by stress [2]. The study of Zhao et al. also sound the impairing role of psychological stress on reconsolidation of neutral and emotional drug-related words in people addicted to heroin [7].

Due to the lack of adequate research in this area, the present study examines whether reconsolidation of autobiographical memories is affected by stress or not. Based on animal data and findings of Schwabe and Wolf, and Zhao et al., it can be assumed that stress impairs the memory reconsolidation.

Materials and Methods

Using a random multi-stage cluster sampling (based on faculty, major, and the year of entering to university), 40 undergraduate students of Tabriz University were selected to participate in the study (mean age= 20.4 years, SD= 0.6) and were asked not to eat the food and beverages containing caffeine, and not to do intense physical exercise 2 hours before the test. To ensure the physical and mental health of the subjects, the General Health Questionnaire was administered to participants and the

diagnostic interview was done in this area. One of ethical considerations of this study was to give some information about the test to participants. Also participants had this right not to accept to participate in the test and whenever they wanted they could go out of the study.

Four groups of participants (ten females per group) participated in this study. Solomon four-group design was used in this study, and replacement of participants in groups was random. In phase 1, after recalling past memories (reactivation of autobiographical memories), participants of first group exposed to a stressor-which was induced by the SECPT (socially evaluated cold pressor test)-and second group was exposed to control conditions (non-stressful). The third group of participants was exposed to stress without reactivation of memories, in order to control the effects of stress on memory regardless of the reactivation of memory. Finally, the fourth group of subjects was neither exposed to the stress nor was asked to recall the memory. Seven days later, in phase 2, autobiographical memory test was administered which its process was entirely similar in the four groups.

Materials and Methods

1. Autobiographical Memory Cueing Test: This test which was designed by Williams and Broadbent in 1986 is a way to reactivate autobiographical memories. Therefore, two positive traits, two neutral traits, and two negative traits were presented to each participant in a random arrangement and participants should recall as much as details they can for an event of their past (e.g., specific time, location, feeling, events before and after, people, objects and their characteristics including color, etc., and the weather) [2].

2. SECPT: This test is designed by Schwabe, Haddad and Schachinger in 2008 to induce stress in which participants will be asked to put their right hands to the wrist in ice water (0-2°C) for 3 minutes and look at a camera in the room during this period. The participants are said to their face expressions are captured by a camera for research purposes. This increases cortisol and autonomous system activity significantly [8].

3. Positive and Negative Affect Schedule (PANAS): This scale which has 20 items is designed by Watson, Clark and Tellegen (1988) to measure two dimensions of mood: negative and positive affect. Each subscale has 10 items on a 5 Likert scale. This instrument has good reliability and validity. In Iran, in the study of Bakhshipour and Dejkam, the internal consistency of both subscales has been reported about 0.87 [9].

4. The general health questionnaire (GHQ): The questionnaire which has 28 items was designed by Goldberg in 1978 and measures four subscales: somatic symptoms, anxiety and insomnia, social dysfunction and depression. Each of subscales is measured in four-point Likert scale based on seven questions for each subscale. Total score varies from 0 to 84. In Iran, the reliability coefficient of this questionnaire with three different methods is reported about 0.70, 0.93 and 0.90. The concurrent validity of the questionnaire with Middlesex questionnaire was reported 0.55. Correlation coefficients between subscales of this test with total score have ranged from 0.72 to 0.87 [10]. This test was used in present study to control mental health of participants.

To control the effects of mood congruent memory, participants completed the PANAS scales in the beginning of the test phases. In phase 1, two positive traits, two negative traits and two neutral traits were randomly presented to first and second groups to recall a special event of the past with details (for example a specific time and location) for each trait. For example, for the trait "angry", one of the participants said: "Last week, I was sitting behind my computer typing my homework, my computer shut down and I had not saved the content I typed, it all became clear. Then my father came and blamed me because I had taken the car without his permission. I was very angry ... ". To control the age of activated memories, participants were asked to recall the events that occurred at least 24 hours to 3 weeks ago (in 4 minutes). After that, participants were asked to identify the time of occurrence of events, and write a title for each memory in order to use to refer to the events in phase 2.

About 10 minutes after autobiographical memories activation, participants in firs group were exposed to stress (by SECPT method previously described). Participants in the second group were asked to immerse their right wrist in warm water (35-37°C) and were not under the control of the camera (non-stressful or control condition). The third group of participants was exposed to stress without memory activation. 4th group of subjects was neither exposed to stress nor were asked to recall a memory. To assess the success of inducing stress, blood pressure was measured immediately before, during and immediately after SECPT or control condition.

One week after the first phase of experiment, the titles of autobiographical events which participants of group 1 and 2 had recalled before, were presented to them. They were asked to remember as many details as they can from those events. Participants of the third and fourth groups completed autobiographical memory cueing test that other groups have performed on phase 1, but they were told to remember the events that occurred at least 1 week and up to 3 weeks before. Again, there was a 4 minute time limit for each event.

Autobiographical memories were evaluated by two evaluators. For any details remembered, a point was given (i.e., for every person, place, time, feel, etc. that was mentioned). Agreement between the two evaluators was very high (reliability between evaluators: r =0.91). First points for each event were summed and then mean score for positive, negative and neutral events was calculated.

Results

Table 1 shows the descriptive findings on blood pressure and numbers of remembered details for the neutral, positive and negative events in different phases of the experiment. In the phase 1 of the experiment, participants of first and second groups remembered average 13.85 (standard deviation: 0.87) details in each event. Age of

Table 1. The mean and standard deviation of blood pressure and numbers of details remembered

Variables		group 1	group 2	group 3	group 4
Systolic pressure	pre-experiment	119.1±5.3	13.9±4.0	120.4±1.4	-
	during experiment	134.8±4.6*	13.9±4.8	137.7±2.7*	-
	post-experiment	119.8±4.4	13.9±4.0	120.2±1.5	-
Diastolic pressure	pre-experiment	70.7±4.0	13.9±2.3	72.1±3.4	-
	during experiment	77.8±3.4*	13.9±6.4	85.7±2.8*	-
	post-experiment	69.8±4.4	13.9±5.6	72.6±3.7	-
Positive memories	phase 1	13.9±1.1	14.4±0.5	-	-
	phase 2	13.2±1.2	12.3±0.6	14.6±0.8	14.1±0.5
Negative memories	phase 1	13.8±1.1	13.1±0.7	-	-
	phase 2	13.5±1.0	12.3±0.6	15.1±0.5	14.6±0.5
Neutral memories	phase 1	14.2±1.0	13.5±0.5	-	-
	phase 2	8.4±0.8**	13.2±0.7	14.8±0.9	15.4±0.6

* Significantly different from the second group (post hoc LSD test, $p<0.05$)
** Significantly different from the other groups (post hoc LSD test, $p<0.05$)

Table 2. Summary of MANOVA for the effect of group on recalling emotional memories

Source of variance	Dependent variable		SS	df	MS	*F*	*p*
Group	Systolic blood pressure	pre-experiment	88.338	1	88.338	2.961	0.069
		during experiment	775.01	1	775.01	34.918	0.000
		post-experiment	11.10	1	11.10	0.613	0.444
	Diastolic blood pressure	pre-experiment	4.418	1	4.418	0.409	0.53
		during experiment	291.848	1	291.848	12.79	0.002
		post-experiment	91.032	1	91.032	2.74	0.063
	Details remembered in phase 1	positive	1.25	1	1.25	1.47	0.241
		negative	2.45	1	2.45	2.67	0.119
		neutral	2.45	1	2.45	3.64	0.072
	Details remembered in phase 2	positive	4.05	1	4.05	4.11	0.057
		negative	2.2	1	2.2	3.87	0.068
		neutral	115.20	1	115.20	172.80	0.000

memories did not differ between groups ($p>0.05$). In the phase 2, the average age of the memories was 15.8 days (standard deviation: 0.6). In addition, the comparison of scores of groups in the subscales of PANAS showed that there was no mood difference between two groups in phases 1 and 2, so mood states cannot affect the results.

Based on table 1 and the results of MANOVA presented in table 2, groups had no significant difference in systolic and diastolic blood pressure during the experiment, so changes in blood pressure confirmed the successful induction of stress. LSD test results showed that blood pressure was significantly increased by SECPT (both $F>33.5$, $p<0.001$), whereas there was no such increase in response to the control condition ($p>0.05$) and the participants of the first and third groups had higher blood pressure than those in the second group in response to SECPT ($p<0.05$). The blood pressure of two groups which were under stress induction (groups I and III) did not differ significantly in response to SECPT (both $F<1$, $p>0.05$).

MANOVA results showed that in phase 1, memory performance of two groups was similar, and was not influenced by emotionality of memories (according to table 2, in all cases $p>0.72$). MANOVA test in phase 2, showed that the groups only have significant differences in recalling neutral memories ($p<0.001$).

LSD post hoc tests showed that participants in the first group which were exposed to stress after autobiographical memory activation in comparison with other groups, remembered less details from neutral events ($F=23.8$, $p<0.001$), and other groups had no difference, but memory for positive and negative events was not influenced by stress (both $p>0.05$); so stress just impaired reconsolidation of neutral autobiographical memories.

Discussion

Overall, regard to the findings of this study, stress can disrupt the reconsolidation of neutral autobiographical memories, but it had no effect on reconsolidation of emotionally positive and negative autobiographical memories. The results show that stress can have harmful effects on the autobiographical memory consolidation. This finding is in line with recent studies on the harmful effects of stress on memory re-consolidation in mice and humans [2, 4-6]. Stress alone (without reactivation of memories), had no effect on subsequent memory, so any unknown effects of the stressor cannot be accepted. In addition, if stress does not occur following reactivation of the memory, the memory performance will not change.

Although some studies indicate that stress may disrupt consolidation of memories for neutral events [11], the vast majority of studies show the effect of stress on memory consolidation [12-14]. This study in consistent with before animal studies and the study of Schwabe and Wolf show that the effect of stress in memory reconsolidation is different with its effect on memory consolidation which can imply that the process of reconsolidating memories is not similar to memory consolidation and these are two independent processes in memory.

Different brain circuits play a role in memory consolidation and reconsolidation [15]. In addition, mediating molecular mechanisms for consolidation and reconsolidation differ at least partly. Memory

consolidation is dependent on brain-derived neurotrophic factor (BDNF) but not on transcription factor zif268; while reconsolidation is dependent on zif268 but not on BDNF [16]. Moreover, reconsolidation, in contrast to consolidation, doesn't require expression of the transcription factor of EBPβ/C in the hippocampus. Stress and glucocorticoids have different effects on different brain regions and memory process related to transcription factor [2]. Understanding the difference between consolidation and reconsolidation that leads to different effects of stress on these two processes, is a challenge for future studies to clear the mechanisms of these two processes in memory.

In present study, stress impaired the neutral autobiographical memory consolidation. Since stress significantly enhances memory consolidation of emotional materials [2]; a possible explanation for no effect of stress on emotional memory consolidation, may be more consolidation of emotional memories which are less susceptible to damage. Studies have shown that pharmacological manipulations that lead to significant changes in the stress response systems, impairs further consolidation of memories related to trauma, drugs or fear (which are emotionally strong) [4, 6, 17].

So it seems unlikely that stress can not impair the reconsolidation of emotional memories. On the other hand, the study of Zhao et al., showed the impairing effects of psychological stress on reconsolidation of neutral and emotional drug-related words in people addicted to heroin [7], so one could argue that perhaps like the study of Schwabe and Wolf, stressors in present study was not strong enough to affect the emotional memory reconsolidation.

Recently, different approaches for the treatment of posttraumatic stress disorder (PTSD) have been developed which tried to mediate the memory consolidation processes by pharmacological manipulation of glucocorticoids. It has been shown in an animal model that when glucocorticoids receptors get inactive, fearful memories weakened [18]. Although this methods may seem contradictory at first glance, but are based on the idea that very low and very high concentrations of glucocorticoids would harm memory processes [19].

Future studies should evaluate whether the effects of pharmacological glucocorticoid elevations has such an effect like stress or not. If higher levels of glucocorticoids impair reconsolidation of emotional memories after memory reactivation, controlling and regulating glucocorticoids after memory retrieval can be a suitable therapeutic approach for PTSD and future research should study in this area.

It is useful to separate the details of semantic memory (e.g., recalling the city of birth) and details of episodic memory which are directly related to the described event (such as location, time and other details of an event) in future studies because such factors may help much to the understanding of the observed differences in the effects of stress on neutral and emotional memories. In summary, the present study showed that the stress after reactivation of memory impairs memory reconsolidation in human. Although reconsolidation process enables us to integrate new information into existing information, the impairing effect of stress on this adaptive updating mechanism can be useful because they can open another window to the treatment of psychological disorders, such as PTSD, which is characterized by strong emotional memories.

One of the Limitations of present study is its limited sample, so the generalizability of the results to other populations is difficult. Also assessment of the mental health and mood states by self-report instruments, could lead to biased or inaccurate responses in participants.

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Authors' Contributions

All authors had equal role in design, work, statistical analysis and manuscript writing.

Conflict of Interest

The authors declare no conflict of interest.

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