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No effect of stress on false recognition

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Abstract

Background: The present study aimed to analyze the effect of acute stress on false recognition in the Deese/Roediger-McDermott (DRM) paradigm. In this paradigm, lists of words associated with a non-presented critical lure are studied and, in a subsequent memory test, critical lures are often falsely remembered. **Method:** In two experiments, participants were randomly assigned to either the stress group (Trier Social Stress Test) or the no-stress control group. Because we sought to control the level-of-processing at encoding, in Experiment 1, participants created a visual mental image for each presented word (deep encoding). In Experiment 2, participants performed a shallow encoding (to respond whether each word contained the letter "o"). **Results:** The results indicated that, in both experiments, as predicted, heart rate and STAI-S scores increased only in the stress group. However, false recognition did not differ across stress and no-stress groups. **Conclusions:** Results suggest that, although psychosocial stress was successfully induced, it does not enhance the vulnerability of individuals with acute stress to DRM false recognition, regardless of the level of processing.

Keywords: False memory, false recognition, stress, DRM paradigm.

Resumen

Ausencia de efecto del estrés sobre el reconocimiento falso. **Antecedentes:** en este estudio se analiza el efecto del estrés agudo sobre el reconocimiento falso empleando el paradigma Deese/Roediger-McDermott (DRM). En este paradigma se estudian listas de palabras asociadas a una palabra crítica no presentada, palabras a menudo falsamente recordadas en una posterior prueba de memoria. **Método:** se realizaron dos experimentos en los que los participantes se distribuían aleatoriamente en dos grupos: grupo estrés (Trier Social Stress Test) y grupo control no-estrés. En los dos experimentos se controló el nivel de procesamiento empleado durante la codificación. En el Experimento 1, los participantes debían crear una imagen visual mental para cada palabra estudiada (codificación profunda). En el Experimento 2, los participantes realizaban una codificación superficial (responder si cada palabra contenía la letra "o"). **Resultados:** los resultados indicaban que, en ambos experimentos, como se predecía, la tasa cardiaca y las puntuaciones en el STAI-E aumentaban solo en el grupo estrés. En cambio, el reconocimiento falso no difería entre los grupos. **Conclusiones:** los datos sugieren que, aunque se consiguió inducir adecuadamente estrés psicosocial, no se incrementó la vulnerabilidad de los individuos sometidos a estrés al reconocimiento falso, con independencia del nivel de procesamiento que se hubiera empleado.

Palabras clave: memoria falsa, reconocimiento falso, estrés, paradigma DRM.

In recent years, there has been a great amount of research on false memory based on the Deese/Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995). In this paradigm, one of the most frequently used procedures to produce false memory, participants are typically presented with lists of words (e.g., *bed*, *rest*, *awake*, *tired*, *dream, wake*, *snooze, blanket, doze,* etc.) that are highly associated with a non-presented critical lure (e.g., SLEEP) according to free association norms. Subsequently, high levels of false recall and/or false recognition are observed.

Several theoretical approaches have been proposed to account for DRM false memories. According to the activation-monitoring framework (e.g., McDermott & Watson, 2001; Roediger, Watson, McDermott, & Gallo, 2001), on the one hand, presentation of the study lists may arouse an implicit associative response of related words (critical lures). Thus, spreading activation through associative-semantic networks may be responsible, in part, for the false memory effect. On the other hand, monitoring processes allow determining whether each word that comes to mind was on the study list. From this perspective, the accuracy of memory depends heavily on the effectiveness of these latter processes. When monitoring effectiveness is poor and a source-monitoring error occurs, there is a greater probability of increasing false memories. In addition, according to the fuzzy-trace theory (e.g., Brainerd & Reyna, 1990; Reyna & Brainerd, 1995), memory judgments are based on two independent memory traces, verbatim and gist traces. Verbatim traces include item-specific details and surface structure, whereas gist traces contain the general meaning or theme of the study list. In a DRM list, a different verbatim trace is created by each presented word, but each presented word also activates the same gist trace. True memory is often mediated by verbatim traces, false memory, however, is predominantly based on gist traces. Every time a list of words is presented gist traces are strengthened and so is, therefore, the probability that words

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semantically related with the "theme" (i.e., critical lures) will be erroneously accepted as 'studied' words.

There is an interest in the literature in studying factors that affect the production of false memories (e.g., Beato, Boldini, Cadavid, 2012; Beato & Díez, 2011; Cadavid, Beato, & Fernández, 2012; Sanford & Fisk, 2009; Unsworth & Brewer, 2010). Stress is one of the variables of interest. In fact, although it is well known that stress affects episodic memory in general (for a review, see Wolf, 2009), knowledge about the effects of induced psychosocial stress on false memories is sparse (Payne, Nadel, Allen, Thomas, & Jacobs, 2002; Smeets, Jelicic, & Merckelbach, 2006; Smeets, Otgaar, Candel, & Wolf, 2008).

Payne et al. (2002) explored for the first time the impact of psychosocial stress, as induced by the Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993), on false memory. In their study, participants were first exposed either to the TSST or to the non-stressful filler task, and then, they had to listen to DRM word lists, each followed by an immediate recognition memory test. Results indicated that, compared to control group, stress group showed elevated rates of false recognition. From these data, Payne et al. (2002) concluded that moderate psychological stress renders subjects unable to distinguish between true and false memories in the DRM paradigm. This conclusion implies that individuals under stressful situations are more vulnerable to specific memory distortions (associative illusions of memory, in this case).

In contrast, Smeets et al. (2006) observed that exposure to TSST before the study phase was insufficient to increase false memories (both false recall and false recognition) in the DRM paradigm. In Study 1, participants were assigned to either a stress (TSST) or a control group (filling out some questionnaires and playing a computer card game or minesweeper). Subsequently, they performed the memory tasks, a free-recall test after each word list and a final recognition test. The main results indicated that stress and control groups did not differ in their false recall and false recognition rates. In a later paper, Smeets et al. (2008) took into consideration the timing of stress in order to analyze its effect on DRM memory task. In particular, the authors assessed the effects of stress induced at encoding, consolidation, and retrieval phase on the DRM paradigm in a delayed stem-cued recall test. Participants were explicitly told to pay close attention to all words because they would be tested the next day. Twenty-four hours later, participants had to perform the memory test. Stress was induced, also before the study phase, using the Cold Pressor Stress (CPS, Lovallo, 1975). In this research, Smeets et al. (2008) also failed to find higher false recall in the three stress-induced groups under consideration (i.e., encoding stress, consolidation stress, and retrieval stress groups) than in the control group.

Therefore, while Payne et al. (2002) observed a negative effect of stress on false memories, Smeets et al. (2006, 2008) concluded that stress does not increase memory distortions. Thus, the only three available studies that, so far, analyzed the relationship between stress and false memory on DRM paradigm have failed so far to provide a clear picture and consistent results.

In sum, after reviewing previous literature, it can be observed that, at present, there are very few published studies on the effect of stress on false memories and some of these studies reach different conclusions. So, and as pointed out by Gallo (2006), we are convinced that more research is needed to clarify the potential role of stress on false memories. In this vein, the main goal of the present study was to analyze the effect of stress on DRM false recognition, trying to provide data to shed light on this question since, there is no general agreement in the previous literature on this topic. Specifically, participants were exposed either to a stress condition (acute psychosocial stress before the study phase induced by the TSST), or a no-stress control condition in two experiments. We verified the effectiveness of the stress induction method with physiological (heart rate) and subjective measures (STAI-S, Spielberger, Gorsuch, & Lushene, 1997).

In previous studies, participants were asked to recall or recognize lists of words for a subsequent memory test without encoding instructions during the study phase. Instead, we wanted to control the level-of-processing at study giving participants a specific encoding task. So, in Experiment 1, participants had to create a mental image for each presented word (deep encoding), while in Experiment 2, participants had to respond whether or not the word contained the letter "o" (shallow encoding).

Experiment 1

Method

Participants

The sample comprised 44 undergraduate students whose native language was Spanish (71% women). Participants' ages ranged from 19 to 26 years (*M*= 20.21, *SD*= 1.69). Participation was voluntary and rewarded with extra credit in a psychology course. A detailed signed informed consent was obtained.

Materials

A total of 10 ten-word lists were used, composed of the strongest forward associates to the critical lure (Alonso, Fernández, Díez, & Beato, 2004). The words were arranged in the lists in decreasing order of their associative strength with the critical lure and were digitalized with a male voice.

The answer booklet included the encoding task and the final recognition memory test with 60 words: 30 studied words, 10 critical lures, and 20 unrelated distractors. These words were randomly placed in six different orders following the criteria proposed by Graham (2007).

Additionally, two stress measures were employed, a physiological one (heart rate with Polar Pro-RS400 cardiotachometer) and a subjective one (Spanish adaptation of State-Trait Anxiety Inventory – State form, STAI-S; Spielberger et al., 1997). The control group was given a non-stressful task that consisted of filling out a questionnaire (Spanish adaptation of Vividness of Visual Imagery Questionnaire - Revised Version, VVIQRV, Beato, Díez, Pinho, & Simões, 2006).

Procedure

Participants were randomly assigned to either the stress or no-stress group and they were tested individually in a one-way mirror room (Gesell Dome). At the beginning of the experimental session, they were informed about the nature and procedure of the experiment and signed a consent form. A brief health survey was conducted, to exclude participants with cardiovascular problems or high blood pressure. Then, the cardiotachometer was connected.

The stress group was exposed to the TSST (Kirschbaum et al., 1993) before the study phase. Specifically, the induction procedure consisted of a 5 min preparation period (stress anticipation phase), and 5 min of free speech in front of a one-way mirror, followed by 5 min of performing a mental arithmetic task (serial subtractions of the number 13 from 1022) (induction phase) while being videotaped. Participants were told that, throughout the session, their verbal and nonverbal behavior would be observed and evaluated by a committee of experts located in the observation room behind the mirror. In addition, they were informed that their execution would be recorded on video and audio for further analysis. The no-stress group was given a filler task consisting in completing a neutral questionnaire (VVIQRV). The TSST and the filler task had a similar duration. Subsequently, participants completed the STAI-S and, finally, performed the memory task.

Ten 10-word lists were studied under semantic elaboration; participants were instructed to create a mental image for each presented word (one word every 2 s.) and to indicate in an answer booklet whether or not they were able to do so. The lists were presented in six different orders. After each list of words, participants were asked to carry out some simple arithmetic operations for 30 s. as a distractor task. Once the study phase finished, the final self-paced recognition test was completed. The standard free-recall task was not included after each study list to avoid its effect on the recognition task (e.g., Stadler, Roediger, & McDermott, 1999), a key issue when using lists as short as ours. Finally, participants were debriefed and thanked for their participation.

Data analysis

The results are presented as means of proportion of true recognition, false recognition, and intrusions, with their respective standard deviations (SD). A two-way analysis of variance (ANOVA) was used to determine the effect of induced psychosocial stress on heart rate throughout the experiments. Furthermore, unpaired Student's t-test was performed to determine differences in STAI-S scores in the experimental groups. The analyses of true and false recognition in experimental groups were carried out using repeated measures ANOVA. Subsequently, appropriate Scheffé post-hoc analysis was performed. A value of $p<.05$ was considered statistically significant. In the analysis, partial eta squared (η^2) indicates effect size.

Results and Discussion

Table 1 shows the mean proportion of true recognition, false recognition, and intrusions, as a function of Group in Experiment 1.

Manipulation check: Heart rate (HR) and STAI-S

A 2 (Group: Stress vs. no-stress) × 2 (Phase: Pre-induction vs. induction) two-way ANOVA, with Phase as repeated factor, was carried out on mean scores of HR.

Table 1
Mean proportion (SD) of true recognition, false recognition and intrusions with regard to group (stress vs. no-stress) in Experiment 1

	Stress group	**No-stress group**
True Recognition (studied words)	.89 (.10)	.89 (.07)
False Recognition (critical lures)	.68 (.23)	.66 (.20)
Intrusions (distractors)	.02 (.03)	.01 (.02)

The ANOVA yielded a significant main effect of Group, $F(1, 42)= 7.63$, $p<.01$, $\eta^2= .780$, and a significant main effect of Phase, $F(1, 42)= 18.26$, $p<.001$, $\eta^2= .994$. In addition, as expected, a significant Group × Phase interaction was obtained, $F(1, 42)= 53.48$, $p<.001$, $\eta^2= 1.00$. The two groups did not differ with respect to HR in pre-induction phase (90.37 vs. 94.89), $t(42)= -1.024$, $p>.05$, but there were significant differences in induction phase (87.28 vs. 106.65), $t(42)= -4.335$, $p<.001$.

Finally, stress group ($M= 24.59$, value above the 60th percentile) and no-stress group ($M= 11.86$, value below the 15th percentile) differed significantly in STAI-S[1] scores, $t(42)= -5.26$, $p<.001$. Therefore, both results of HR and STAI-S suggested that stress induction was effective.

True Recognition and False Recognition

A 2 (Group: Stress vs. no-stress) × 3 (Type of word: Studied words, Critical lures, Distractors) ANOVA, with Type of word as repeated factor, was performed. The analysis revealed no significant main effect of Group, $F(1, 42)= .068$, $p>.05$; $\eta^2= .057$. As expected, there was a significant main effect of Type of word, $F(2, 84)= 536.90$, $p<.001$; $\eta^2= 1.00$. Further, Scheffé post-hoc analysis indicated that true recognition ($M= .89$) was higher than false recognition ($M= .67$) and non-critical intrusions ($M= .016$) ($p<.001$). In addition, false recognition was higher than non-critical intrusions ($p<.001$), confirming that there was false recognition. Finally, no Group × Type of word interaction was obtained, $F(2, 84)= .048$, $p>.05$, $\eta^2= .057$.

The results of Experiment 1 replicated the standard effect obtained in previous DRM studies (e.g., Roediger & McDermott, 1995; Gallo, 2010). That is, participants falsely recognized critical lures. Furthermore, as expected, we obtained physiological (HR) and subjective (STAI-S) measures of stress that confirmed the effectiveness of the TSST as a stress induction method. Additionally, we did not find any evidence that the acute stress increased the vulnerability of individuals to false recognition.

Experiment 2

In Experiment 1, we instructed participants to create a mental image for each presented word to make sure they made a semantic processing. In the levels-of-processing literature, it is well established that semantic elaboration is associated with deep processing, which would enhance true recall and recognition of words (e.g., Craik & Tulving, 1975; Hyde & Jenkins, 1973). Looking closely at the high percentage of true recognition observed in Experiment 1 (89%), one may think that the memory task was particularly easy for both stress and no-stress groups, and that for this reason, it was not possible to find the expected detrimental effect of stress on true and false recognition. In contrast, with shallow processing less distinctive recollections would be expected. Therefore, we might think that with a shallow processing, one could impair true recognition, increase false memories —as it happens, for example, with divided attention tasks (e.g., Pérez-Mata, Read, & Diges, 2002)— and, perhaps so, find some stress effects on memories.

With this in mind, in Experiment 2, the encoding phase involved studying items with a shallow level-of-processing. In particular, participants were instructed to focus on surface features of studied words. This type of processing has clearly shown negative effect on recall and recognition (e.g., Craik & Tulving, 1975). If, as argued Payne et al. (2002), people under stressful circumstances are more vulnerable to specific memory distortions, with the change introduced in Experiment 2 we expected the memory task to be sufficiently demanding as to be able to observe the negative effect of stress on false recognition.

Method

Participants

Fifty-four undergraduate students (80% women) with ages ranging from 19 to 33 years (*M*= 19.80, *SD*= 2.11) participated in this experiment. All participants received extra credit in a psychology course, and a detailed signed informed consent was obtained.

Materials

Materials used were the same as those described in Experiment 1.

Procedure

The procedure was similar to the one used in Experiment 1, we only changed the encoding instructions asking our participants to indicate on their answers booklet, and for each word, whether or not it contained the letter “o”.

Data analysis

Data analysis was the same as in Experiment 1.

Results and Discussion

Table 2 shows the mean proportion of true recognition, false recognition, and intrusions, as a function of Group in Experiment 2.

Manipulation check: Heart rate (HR) and STAI-S

A 2 (Group: Stress vs. no-stress) × 2 (Phase: Pre-induction vs. induction) two-way ANOVA, with Phase as repeated factor, was carried out on mean scores of HR. The ANOVA yielded a significant main effect of Group, $F(1, 52)= 10.90$, $p<.01$, $\eta^2= .918$, and a significant main effect of Phase, $F(1, 52)= 9.45$, $p<.01$, $\eta^2= .872$. Further, a significant Group × Phase interaction was obtained, $F(1, 52)= 45.787$, $p<.001$, $\eta^2= 1.00$. The experimental groups' HR did not differ in pre-induction phase (87.54 vs. 93.44), $t(52)= -1.316$, $p>.05$, but there were significant differences in induction phase (83.26 vs. 104.84), $t(52)= -5.201$, $p<.001$. Finally, stress group (*M*= 29.41, value above the 70th percentile) and no-stress group (*M*= 13.48, value below the 23rd percentile) differed significantly in STAI-S scores, $t(52)= -6.857$, $p<.001$.

Table 2
Mean proportion (SD) of true recognition, false recognition and intrusions with regard to group (stress vs. no-stress) in Experiment 2

	Stress group	**No-stress group**
True Recognition (studied words)	.71 (.14)	.72 (.13)
False Recognition (critical lures)	.63 (.15)	.62 (.21)
Intrusions (distractors)	.07 (.10)	.06 (.08)

Therefore, as in the Experiment 1, both results of HR and STAI-S suggested that the stress group experienced significantly more stress than the no-stress control group.

True recognition and False recognition

A 2 (Group: Stress vs. no-stress) × 3 (Type of word: Studied words, Critical lures, Distractors) ANOVA, with Type of word as repeated factor, was performed. The ANOVA revealed a significant main effect of Type of word, $F(2, 104)= 371.277$; $p<.001$, $\eta^2= 1.00$. Scheffé post-hoc analysis indicated that true recognition (*M*= .72) was higher than false recognition (*M*= .62) ($p<.01$) and non-critical false alarms (*M*= .06) ($p<.001$). Moreover, false recognition was higher than non-critical false alarms ($p<.001$), confirming that there was false recognition. However, there was neither a significant main effect of Group, $F(1, 52)= .018$, $p>.05$, $\eta^2= .052$, nor an interaction, $F(2, 104)= .196$, $p>.05$, $\eta^2= .079$.

These results replicated those of Experiment 1. In particular, we observed false recognition, confirmed the effectiveness of the TSST as a stress induction method and, again, observed a similar false recognition in the two experimental groups.

General Discussion

The objective of this research was to determine the effect of acute psychosocial stress on false recognition. To summarize the main findings, (1) false recognition was found, as in previous studies with similar DRM lists. (2) Both physiological (heart rate) and subjective (STAI-S) measures of stress verified the effectiveness of the TSST as a stress induction method. (3) Acute stress had no effect on true and false recognition in the two experiments. Therefore, the stress group was not more likely to commit false recognition than the no-stress group. That is, these results suggest that acute stress does not enhance vulnerability of individuals to associative illusions of memory. These results are consistent with previous findings obtained with the induction of acute psychosocial stress (Smeets et al., 2006, 2008) and, however, do not replicate Payne et al.'s (2002) study.

With the aim of disclosing differences that could justify the inconsistency of the results found in stress and false memories literature, a detailed comparison was carried out between the current research and previous studies.

We would like to point out that, firstly, in our experiments the induction of stress was performed just before the study phase, as was the case in previous studies (Payne et al., 2002; Smeets et al., 2006).

Secondly, we used the same stress induction method (TSST) that Payne et al. (2002) and Smeets et al. (2006). One could hypothesize that the lack of effect of stress on false memory in the current work could be explained by a low stress level in both stress and no-stress groups. However, this explanation cannot be applied to our results because HR and STAI-S scores are significantly higher in stress group than no-stress group. Therefore, the absence of effect of stress on false memory has been found after confirming that psychosocial stress was successfully induced, and experimental groups differed significantly in the level of stress, as it happened also in Smeets et al. (2006, 2008). Unfortunately, Payne et al. (2002) did not include measures that allow us to determine the size of the effect of their manipulation of stress. Thus, the present results cannot be therefore explained by a failure in the induction of stress.

Thirdly, in Payne et al.'s (2002) study, participants were asked to listen carefully to the upcoming lists of words, and to remember as many words as possible for subsequent recognition test. This procedure does not allow us to know the encoding strategy employed by participants. In contrast, in our experiments, encoding strategies were controlled. In Experiment 1, participants had to create a mental image for each presented word, obtaining a deep processing, while in Experiment 2 they had to indicate whether the word contained a specific letter (shallow encoding). This last manipulation was intended to hinder the performance in the memory task. The levels-of-processing framework suggests that memory performance is a function of the shallow or deep level-of-processing by which items are encoded. Specifically, previous research has shown that true memory is better when words are semantically encoded (deep processing) than when they are studied focusing on perceptual or orthographic characteristics (shallow processing) (e.g., Craik & Tulving, 1975). Thereby, the deeper the level-of-processing of an event, the more robust its memory trace is. True recognition in Experiment 1 and Experiment 2 are consistent with this idea. In particular, the present results indicated that deep processing increased the probability of true recognition with respect to shallow processing both in stress and no-stress groups (89 vs. 71 and 89 vs. .72, respectively). Regarding the effect of level-of-processing on false memory, there was no effect on false recognition both in stress group (.68 vs. .63) and in no-stress group (.66 vs. .62) when comparing Experiment 1 and Experiment 2, respectively. These results replicate findings from other previous studies (e.g., Tussing & Greene, 1997; Wimmer & Howe, 2010).

Fourthly, regarding the memory test, it should be noticed that there are some procedural differences between Payne et al.'s (2002) work and the current study. The main difference was that we used a final recognition memory test, as it was done in other DRM studies (e.g., Gallo, Roediger, & McDermott, 2001), while Payne et al. (2002) used multiple recognition tests. Specifically, participants studied several DRM lists for immediate recognition memory tests administered after each list. In this regard, Smeets et al. (2006) applied a memory task (free recall) after each list and they found no effect of stress on false memory. It seems, therefore, that this procedural difference cannot justify the different results found in Payne et al. (2002) and the present experiments.

In summary, the purpose of the current research was to understand the effect of acute stress on false memories. The main contribution is that experimentally induced acute psychosocial stress alone might be insufficient to increase false recognition in a DRM paradigm. For the first time, it has been provided evidence that acute psychosocial stress has no effect on false recognition, regardless of the level-of-processing. More comprehensive research is needed in order to determine the mechanisms underlying the false memory phenomenon in acute stress conditions and to understand the divergent results reported in previous research. For example, it would be necessary to determine whether the same pattern of results would be obtained with other types of memory tests (e.g., free recall). Furthermore, there are not many previous studies about the effect of stress on false memories. This issue warrants further investigation, for example, exploring whether other types of anxiety (e.g., trace and state anxiety) affect false memories.

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Footnotes

In the Spanish adaptation of STAI-S (Spielberger et al., 1997) each item scored from 0 to 3 values and the test scores range from 0 to 60 values.

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