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The Influence of Arousal and Expectation on Eyewitness Memory in a Virtual Environment

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Abstract

This study aimed to examine the effects of arousal and expectation on eyewitness memory. We exposed 97 participants to an immersive eyewitness experience by creating four virtual reality stimulus environments. The participants were randomly assigned to one of four conditions: arousing and expected, arousing and unexpected, nonarousing and expected, and nonarousing and unexpected. The results revealed that memory performance for an arousing encounter was significantly lower than that for a nonarousing encounter, and that memory performance for an unexpected environment was significantly lower compared with an expected one. In addition, memory performance was lowest in the condition that was both arousing and unexpected. No interaction between arousal and expectation was found.

Introduction

THE IMPORTANCE OF EYEWITNESS MEMORY (EM) in the criminal justice system cannot be emphasized enough. Unfortunately, there is no guarantee that the memory of such a witness is reliable. There are countless variables that can negatively affect the memory of a witness, during either the encoding or the retrieval process. Many of these variables have been identified through laboratory research and field studies, and categorized into system variables and estimator variables.[1]

One of the controversial estimator variables is the level of stress experienced by the witness at the time of the incident. Stress, or emotional arousal, leads to automatic physical and emotional changes that occur during the fight-or-flight response to danger or threats.[2,3] Previous research on the effects of emotional arousal on EM has yielded mixed results. Research claiming a negative effect of arousal on memory, such as attentional narrowing based on Easterbrook's cue-utilization hypothesis,[4] states that increased arousal leads to focused attention on central details, which in turn decreases memory for peripheral details.[5] An example of such attentional narrowing is the weapon focus effect.[6] However, other research has shown that arousal can have positive effects on memory. For example, participants who saw a slide show with an emotionally arousing narration recalled significantly more details compared with participants who saw the same slides with a neutral narration.[7] Another example is ''flashbulb memory,''[8,9] which is when witnesses report vivid memories of a highly arousing incident. These mixed results could also be explained by another theory on the different time course of response to stress hormones, in particular catecholamine and glucocorticoid.[10] According to this theory, depending on the timing of the stress exposure, stress can impair or improve the memory process. That is, stress immediately before learning enhanced memory 24 hours later, whereas stress 30 minutes prior to learning reduced the recall performance.

As with almost all laboratory-based eyewitness research, studies on the effects of arousal on EM have been limited particularly to the amount of arousal actually being experienced by the participants. Additionally, field studies have been limited to the reliability of any cause–effect relationships that may be revealed.[11] This may be one reason why previous research on arousal and EM has yielded conflicting results. Laboratory studies on EM have the critical limitation of not being able to expose participants to an actual crime. To minimize the effects of this limitation, we implemented virtual reality (VR)—an extension of three-dimensional computer graphics that replicates a functionally realistic environment through multisensory channels.[12] The use of VR in clinical psychology has become more widespread,[13,14] and in most clinical applications, a key characteristic of a virtual environment (VE) is the high level of interaction between the user and the tool, as well as an enriched experience for the user.[15] Presenting an eyewitness event using VR not only provides a more realistic real-time experience, but also increases the ecological validity of the experiment by exposing participants to a stimulus closer to reality than that obtained using a two-dimensional screen.

Another variable that has been known to affect EM is expectation.[11] People today are continuously being exposed to large amounts of crime through the news, television,

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movies, and video games. Therefore, a crime, as unexpected as it may be, may not be considered an unexpected event in our minds if the situation was similar to a stereotypical crime that fits our schema[16] of how that particular crime should have proceeded. However, if a certain aspect of a crime were highly irregular—for instance, a butcher committing a crime in a school classroom—witnesses would most likely consider it to be an unexpected crime.

As with arousal, the effects of expectation on EM have yielded mixed findings. Some studies have shown that expectation can have a positive effect on memory state. Specifically, when an event is predictable, expectations initiate the rapid encoding and recall of a memory,[17] and when longer processing is possible, expectations increase the attention paid to unexpected details, which can lead to enhanced memory for these details.[18,19] Conversely, other studies have shown that expectation can have a negative effect on the memory state. In these cases, the accurate recall of expected information can be accompanied by false memories of expected information that was not actually experienced.[20,21] Furthermore, expectations may bias an observer, such that they fail to notice details that seem irrelevant or fail to match their encoding scheme.[22]

As mentioned above, previous studies on unexpected stimuli have generally focused on memory for certain unexpected objects within a scene. The present study aims not only to measure memory performance for the unexpected stimulus—in this case a butcher—but also for the overall eyewitness event, including the details of the characters and surroundings. The purpose of this study is to investigate the effects of arousal and expectation on EM and possibly shed some light on the mixed findings from previous studies regarding these estimator variables. We exposed participants to a virtual environment to increase immersion and presence, which should lead to a more realistic arousal response. We believe that by inducing a realistic level of emotional arousal, we will be able to measure participant response that is closer to reality than that obtained in previous studies. Another purpose is to investigate the effects of expectation during a realistic eyewitness event. The final purpose is to investigate any possible interactions between arousal and expectation as variables in EM.

Methods

Subjects

A total of 97 university students between the ages of 18 and 32 years ($M = 22.05$, $SD = 3.14$; 51.5% female) participated in the experiment. All participants were physically and psychologically healthy, and their state of health was checked by an interview. They read and signed a written consent form indicating their agreement to participate in the experiment, and received monetary compensation for participating.

Materials

Experimental stimuli. The two following VEs were created using the NeuroVR v.1.5 VR software: a classroom (unexpected: UE) and a meat market (expected: E). The classroom environment was provided within the software, and the meat market was created by adding raw and packaged meat products to an existing supermarket.

The two following 19-second scenarios were filmed at a blue screen studio: a threatening encounter (threat: T) and a friendly conversation (nonthreat: NT) between a male butcher (target) and a woman (female). The target wore a long bloody apron, a white sleeveless shirt, khaki cotton pants, and brown dress shoes, and he carried an extra-large kitchen knife (Fig. 1). Four experimental conditions were created by embedding either the T or NT scenario into either the E or UE environment. The first condition (E-T) was the target threatening the female at the meat market. The second condition (UE-T) was the target threatening the female in the classroom. The third condition (UE-NT) was the target having a friendly conversation with the female in the classroom. The fourth condition (E-NT) was the target having a friendly conversation with the female at the meat market.

Manipulation checks. (a) The State–Trait Anxiety Inventory (STAI): The STAI-trait and -state questionnaires[23] both have 20 items, each with a 4-point (1 = ''not at all''; 4 = ''very much so'') scale. The STAI-trait measures trait anxiety, which are more general forms of anxiety, and the STAI-state measures state anxiety, which are more momentary conditions of anxiety. (b) Threat and arousal indices: We conducted two self-reported questionnaires as manipulation checks to measure the perceived threat and arousal experienced by the participants. Each item was rated on a 7-point scale (1 = ''not at all''; 7 = ''very much so'') for both indices. Of the 12-item threat index (Cronbach's $\alpha = 0.97$), five items measured threat expressed by the target, five measured threat experienced by the female, and two measured threat felt by the participants. The 13-item arousal index (Cronbach's $\alpha = 0.90$) had seven items to measure psychological characteristics and six items to measure physical characteristics of arousal.

FIG. 1. Captured screen images of the expected nonthreat (left) and unexpected threat (right) virtual environments.

Memory test. To test memory performance, we administered a 31-item, open-ended memory questionnaire. The items measured memory for the environment, the situation, external characteristics of the female, external characteristics of the target, and objects the characters were carrying.

Virtual reality equipment. An eMagine Z800 head-mounted display (HMD), a Logitech Cordless-RumblePad™ 2 gamepad, and a desktop computer with an NVIDIA GeForce® 9800-GTX graphics card were used to present and navigate through the VEs.

Procedure

Upon arriving, the participants read and signed the consent form, and completed the STAI-trait questionnaire. They then practiced navigating through a virtual office, and once they were comfortable navigating, they put on the HMD and practiced navigating again until they could navigate without difficulty. They were then randomly placed into one of the four conditions and told to navigate around the environment and that approaching people would allow them to hear ongoing conversations. The virtual experience lasted approximately 2–3 minutes. After the VR exposure, the participants completed the threat and arousal questionnaires and the STAI-state questionnaire, followed by the memory test. Upon completion, the participants were thanked and debriefed.

Design and analysis

To compare the effects of threat and expectation on EM, we used a 2×2 (Expectation: Expected vs. Unexpected×Threat: Threat vs. Nonthreat) analysis of variance (ANOVA). SPSS Statistics for Windows v17.0 (SPSS, Inc., Chicago, IL) was used for all statistical analyses.

Results

Table 1 shows the means and standard deviations for all measurements within each condition. There were no significant differences in age or sex between the four conditions.

Manipulation checks

Threat index. A significant main effect on the threat index was found for threat, $F(3, 93) = 356.37$, $p < 0.01$, $\eta^2 = 0.80$ [95% CI 35.88, 44.31], but not for expectation. As expected, the participants from the E-T condition and the UE-T condition both reported that the threatening conditions were in fact threatening, whereas the E-NT condition and the UE-NT condition were not, $F(3, 93) = 2.27$, ns.

Arousal index. A significant main effect on the arousal index was found for threat, $F(3, 93) = 23.13$, $p < 0.01$, $\eta^2 = 0.20$ [95% CI 6.66, 16.01], but not for expectation. As expected, the participants from the E-T condition and the UE-T condition both reported feeling more aroused compared with those from the E-NT condition and the UE-NT condition, $F(3, 93) = 1.13$, ns.

STAI-trait. No significant main effects or interactions were found in the STAI-trait, suggesting that the participants from any of the conditions did not originally have higher anxiety levels.

STAI-state. A significant main effect on STAI-state was found for threat, $F(3, 93) = 5.91$, $p < 0.05$, $\eta^2 = 0.06$ [95% CI –4.00, 3.04], but not for expectation. As expected, the participants from the E-T condition and the UE-T condition both reported significantly higher levels of anxiety after the VR exposure compared with those from the E-NT condition and the UE-NT condition, $F(3, 93) = 0.02$, ns.

Memory performance

The memory questionnaire was scored by comparing the participants' answers to a predesignated answer sheet. Because the answers were open-ended, we designated what answers would be accepted as correct answers prior to scoring the questionnaires.

A significant main effect on memory was found for threat, $F(3, 93) = 7.71$, $p < 0.01$, $\eta^2 = 0.08$ [95% CI 0.39, 2.37], as well as a significant main effect for expectation, $F(3, 93) = 5.26$, $p < 0.05$, $\eta^2 = 0.05$ [95% CI 0.15, 2.13]). As predicted, the participants from the E-T condition and the UE-NT condition scored lower than those from the E-NT condition, and the participants from the UE-T condition scored lower than those from the conditions with only threat or unexpectedness (Fig. 2). Compared with the participants in the control condition, all of the participants in the other conditions showed decreased performance, and the condition with both threat and unexpectedness showed the greatest decrease. Additionally, as predicted, no significant interactions were found, $F(3, 93) = 0.19$, ns.

We further analyzed the memory test scores by dividing the total memory score into the four following categories of memory: environment, situation, female, and target. In summary, participant memory for environmental details was

Table 1. Means (*SD*) of the Dependent Variables in Each Experimental Condition

	Expected		*Unexpected*	
	Threat (n = *26*)	*Nonthreat* (n = *23*)	*Threat* (n = *24*)	*Nonthreat* (n = *24*)
Threat Index	71.81 (8.50)	34.91 (14.62)	71.17 (7.99)	27.88 (9.70)
Arousal Index	55.65 (9.47)	46.83 (12.21)	53.83 (13.00)	40.00 (11.58)
STAI-state	45.12 (10.27)	41.05 (8.7)	45.83 (8.55)	41.29 (7.30)
STAI-trait	42.38 (7.51)	43.70 (9.28)	40.88 (7.38)	43.50 (7.86)
Memory Test Score	20.88 (2.69)	22.48 (2.00)	19.96 (2.51)	21.13 (2.49)

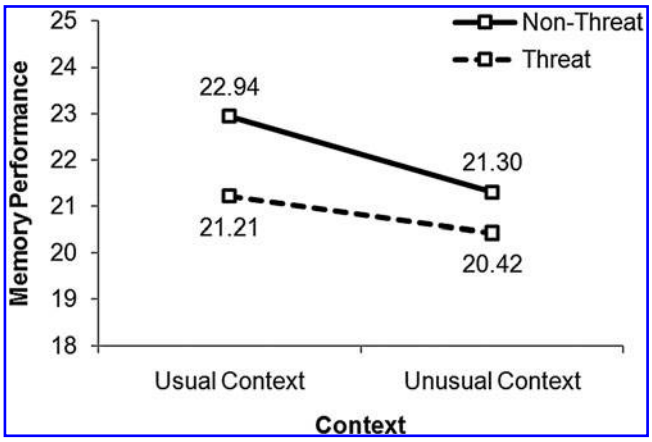

FIG. 2. Mean memory performance scores for each experimental condition.

significantly lower in the unexpected conditions compared with the expected conditions, $F(3, 93) = 51.11$, $p < 0.01$, $\eta^2 = 0.36$ [95% CI 0.75, 1.33], but no difference was found between the threat and nonthreat conditions, $F(3, 93) = 2.87$, ns. Participant memory for situational details and target details were significantly lower in the threat conditions compared with the nonthreat conditions, $F(3, 93) = 12.17$, $p < 0.01$, $\eta^2 = 0.12$ [95% CI –0.08, 0.370, but no difference was found between the expected and unexpected conditions, $F(3, 93) = 0.16$, ns. No significant interactions were found, $F(3, 93) = 0.04$, ns.

Discussion

The present study investigated the effects of arousal and expectation on EM, and whether an interaction exists between the two. Although we did not observe an interaction effect, we were able to demonstrate that both arousal and expectation independently influence EM performance. We also revealed that the independent effects of the two variables led to a greater memory deficit when they were both presented together at the same time. In other words, EM performance decreased when the situation was threatening, regardless of whether it was expected,[4,8,9,10] and performance also decreased when the situation was unexpected, regardless of whether it was threatening.[17] Unlike past research that presented threats symbolically or indirectly, the present study provided a more direct and realistic representation of the threat to the participants through a VE that was relatively closer to the emotional arousal response that might be experienced in a real life eyewitness situation. Additionally, to our knowledge, this study is the first to assess the effects of expectation on EM directly.

Contrary to the mixed findings of past research,[24] the present study was able to demonstrate that when emotional arousal is provided through a realistic and immersive experience, overall EM performance for the event is negatively affected. These results provide empirical support for previous studies that have shown a negative effect of emotional arousal on EM.[6,25] These results, however, cannot be generalized to instances in which the victim is also the eyewitness, in which case many other variables would come into play, such as viewing distances and durations.

Because our memory questionnaire was categorized into four main groups—specifically, environment, situation, female, and target—we further analyzed the memory test results by differentiating each category as an individual dependent variable. When we analyzed only the items related to environment, we found a main effect for expectation but not for threat. We believe this may have been because it was the environment that gave the event its relative expectedness or unexpectedness, in that the target was either at a place where he belonged or did not belong. Therefore, regardless of whether the situation was threatening, when the participants realized the event was unexpected, additional attentional resources were spent on the unexpectedness of the butcher, which would have led to decreased memory for environmental details. These results are consistent with previous studies that have shown a negative effect of an unexpected event on EM.[18,19,26,27]

The present study has some limitations. First, we measured emotional arousal using self-reporting measures. Although the self-report measure is an obvious index of emotional arousal, determining changes in other forms of autonomic responses, such as skin conductance, are also important in measuring emotional arousal. Second, we hypothesized that when enough arousal is induced, the effects of arousal would overcome the effects of expectation. Our results, however, did not reveal a statistically significant interaction between these factors. We believe that a possibility as to why an interaction between threat and expectation was not observed was due to a flaw in the design of the memory questionnaire. Specifically, we may have had enough items in the questionnaire to observe the independent effects of the two variables, but we may not have used enough items to detect an interaction between them. Third, although we found that there were significant main effects on memory for threat and expectation, effect sizes in our results were on the small side. Thus, we provided confidence intervals to support our results. Finally, we could not investigate how emotional arousal and expectation influenced EM. Further research is needed, as well as a more elaborate and detailed memory test and other new technologies for estimating the influence of attention on memory, such as eye trackers.

VR research is very important in criminal psychology studies, since for ethical reasons experimental participants cannot be subjected to the same stress that a victim of crime may experience. Future research on EM using VR should focus on improving the VEs by designing and filming more realistic scenarios, improving computer graphics, introducing the latest VR technology, and expanding sensory input channels beyond sight and sound to include smell, touch, and motion. As the level of realism is enhanced, the VEs should further increase the level of induced emotional arousal, which will allow for a more accurate measurement of stress-induced responses.

Based on the results of this study, judgment of the reliability of EM and eyewitness testimonies should include an evaluation of how threatening an event was perceived to be, as well as how unexpected the situation may have been. Eyewitness' self-reported accounts of the level of threat conveyed by the perpetrator, the level of emotional arousal experienced from the overall event, and how expected or unexpected the event was perceived to be should also be

considered for their potential in alerting us to the negative effects of arousal and expectation on EM. In doing so, we should be able to increase the reliability of EM, which will in turn, enhance the accuracy of information gathered from eyewitnesses.

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Author Disclosure Statement

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