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Stress and Retrieval-Enhanced Suggestibility

Amanda Capriglione
amanda.capriglione@student.shu.edu

STRESS AND RETRIEVAL-ENHANCED SUGGESTIBILITY

by

Amanda R. Capriglione

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THESIS COMMITTEE

(please sign and date beside your name)

Mentor:

Marianne Lloyd, PhD:____

Committee Member:

Amy Hunter, PhD:____

Committee Member:

Leamarie Gordon, PhD:____

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Abstract

Research has demonstrated that when witnesses are immediately questioned following an event, they can become even more susceptible to later presented misinformation and false memory production. This test-enhanced memory impairment is known as retrieval-enhanced suggestibility (RES; Chan, Thomas, & Bulevich, 2009). Research has also demonstrated that the experience of stress produces a reduced misinformation effect and better ability to discriminate accurate from inaccurate information (Nitschke et al., 2019). The primary goal of the current study was to explore the effects of stress and repeated testing on misinformation susceptibility in the RES paradigm. Participants engaged in an eyewitness memory paradigm in which half were tested immediately following witnessing an original event and prior to receiving a post-event narrative that contained misinformation. Following narrative presentation, half of the participants completed a mental arithmetic test under time pressure with negative feedback. All participants then completed a final memory test assessing their memory for details of the original event. Contrary to my original hypothesis, I did not find an interaction between stress and repeated testing on accurate recall or misinformation production on the final memory test. However, I replicated the RES effect in that participants who took an immediate memory test were much more likely to report misleading details from the narrative compared to single test participants on the final memory test. Additionally, I found that post-event narrative sentences containing misinformation took significantly longer to process than control sentences. Importantly, this effect was larger for repeated compared to single testing. The results suggest that attention to misleading post-event details is an important factor moderating the RES effect. Future research should aim to employ a more stressful task or examine individual differences in stress levels in order to determine whether stress negates the effects of repeated testing in the RES paradigm.

Keywords: eyewitness memory, stress, RES, misinformation effect

Introduction

Stress, which is a common experience, may affect memory in unexpected ways. People may experience stress when they have an important deadline coming up or when giving an impromptu speech in front of their colleagues. Researchers study stress and how it can make memory both more accurate and less so. For instance, acute stress improves later recall of a list of words when induced after a reminder of those words (Bos et al., 2014), but impairs memory for emotionally-valenced items when applied prior to retrieval (Kuhlmann, Piel, & Wolf, 2005).

Eyewitnesses of a crime are often presented with suggestive details of the event during police interrogation. The exposure to such misinformation can leave eyewitness memory particularly susceptible to distortion. Furthermore, recalling the details of a traumatic event is often accompanied by the experience of stress. In the context of eyewitness memory, witnesses are often asked to recall the details of a crime many times. This act of retrieval can leave memory even more susceptible to distortion. Thus, the goal of the present study was to explore the effects of stress on misinformation susceptibility in the context of eyewitness memory and the role of repeated testing in these effects.

Stress and Memory

Previous research has suggested that acute stress has a critical impact on memory performance. However, the effects of acute stress on memory are mixed and depend largely on the type of memory process affected (for a review, see Vogel & Schwabe, 2016). For example, mild acute stress induced after reconsolidation of a list of words enhances later declarative recall (Bos et al., 2014). Bos et al. (2014) presented participants with a series of negative, neutral, or positive words. Participants were then given a subsequent free recall task in which they were instructed to retrieve as many words as they could remember. Twenty-four hours later, participants received a reminder of the word list and were then exposed to an acute stressor or a control task. The following day, memory performance was assessed with a free recall task and a recognition test. The results demonstrated that when stress is induced after being reminded of a previously studied list of words, participants show better memory for the words compared to non-stressed participants.

In a recent meta-analysis, Shields et al. (2017) found that stress induced prior to or during retrieval impairs memory for emotionally-valenced items compared to neutral items. Similarly, Kuhlmann et al. (2005) demonstrated that stress significantly impairs memory retrieval for a list of positive and negative words. In this study, participants were instructed to learn a word list containing positive, neutral, and negative words. On the following day, participants either experienced acute psychosocial stress or a control task. Later, all participants completed a free recall test in which they were prompted to recall the words they had learned on the previous day. Kuhlmann and colleagues found that stressed participants recalled significantly fewer negative and positive words compared to neutral words. This finding suggests that emotionally arousing material is particularly sensitive to the effects of stress (Kuhlmann et al., 2005). In contrast, another study found that mild acute stress experienced during consolidation of highly arousing negative images has no effect on subsequent emotional recognition memory performance (Corbett, Weinberg, & Duarte, 2017). Although the consequences of stress on memory are not entirely understood, other memory findings have consistently produced robust effects.

The Beneficial Effects of Testing

Prior research has consistently demonstrated that repeated testing promotes enhanced long-term retention of material and facilitates performance on a subsequent test compared to repeated study (for a review, see Rowland, 2014). This phenomenon, known as the "testing effect," refers to substantial gains in long-term retention of material resulting from engaging in active retrieval of information during learning (Roediger & Karpicke, 2006). For instance, Roediger & Karpicke (2006) had participants study a prose passage. Participants in the repeated study condition restudied the passage, while participants in the test condition took a free recall test in which they were instructed to write down as much of the material as they could remember. Then, all participants took a final free recall test either after a 5-minute, 2-day, or 1-week retention interval. Roediger & Karpicke (2006) found that participants who had restudied the passage recalled more information after 5 minutes compared to participants who only studied the passage once. However, participants who studied the passage once and who had retrieval practice recalled significantly more after one week compared to participants who simply restudied the passage. That is, engaging in retrieval practice immediately after reading a prose passage enables participants to recall a higher percentage of material after a one-week delay compared to repeatedly studying the passage (Roediger & Karpicke, 2006; Bae et al., 2019).

Testing also appears to facilitate accurate recall of information that was present on the test but not actively retrieved (Carpenter, Pashler, & Vul, 2006). For example, Carpenter et al. (2006) presented participants with a series of weakly associated cue-target pairs. After a study phase, participants either restudied the pair (A + B) or took a cued recall test (A→?) immediately followed by another brief study phase of the pair (A + B). The following day, all participants either completed a cued recall test in the same (A→?) or opposite (? →B) direction relative to the original cued recall test, or engaged in free recall of only the cues (A) or only the targets (B). Carpenter and colleagues found that a cued recall test followed by subsequent presentation of the word pair significantly enhanced retention compared to repeated study. This occurred regardless of whether retention was tested with cued recall for the targets or cues, as well as for free recall of either targets or cues. This study demonstrates that the testing effect is not specific to the items for which retrieval is required on the initial test or to the type of information recalled on the final test (Carpenter et al., 2006).

Immediate testing of prior material has also been shown to facilitate learning of new material (Wissman, Rawson, & Pyc, 2011). For instance, Wissman et al. (2011) demonstrated that immediate testing in between learning episodes facilitated learning of prose material that was related to previously tested material. Specifically, participants were instructed to recall each section of an expository text before moving on to study the next section or were prompted to recall only after the final section. Wissman and colleagues found that recall for the final section was greater if prior sections were tested on compared to when prior sections were not tested on. One proposed explanation for these beneficial effects of testing is that testing may encourage participants to develop more effective encoding strategies during subsequent learning episodes (Wissman et al., 2011). That is, immediate testing may result in test-enhanced learning in that it may lead participants to prioritize rehearsal of subsequently related material.

The Misinformation Effect

Numerous studies have investigated eyewitness memory in the context of the misinformation paradigm (Higham, Blank, & Luna, 2017; Hoscheidt et al., 2014; Loftus, Miller, & Burns, 1978; Nitschke et al., 2019; Otgaar et al., 2017; Polczyk, 2017; Schmidt et al., 2014). In a typical misinformation experiment, participants witness an original event by watching a video clip depicting a fictionalized crime taking place. Later, they are exposed to misleading information about the event they had just witnessed. The misinformation is often presented in the form of a written or audio narrative synopsis of the event containing details consistent and inconsistent with the video clip. Following the misinformation phase, participants are tested on their memory for details of the original event. The typical finding is that exposure to misleading post-event information impairs memory accuracy for the original event (for a review, see Frenda, Nichols, & Loftus, 2011). That is, participants who are exposed to misinformation after witnessing an event are less likely to report correct details on a final memory test, and more likely to produce misleading details as compared to participants not exposed to misinformation.

In one of the earliest studies to reveal the deleterious effects of exposure to misleading information on eyewitness memory, Loftus, Miller, & Burns (1978) presented participants with a series of slides depicting an auto-pedestrian accident. Half of the participants saw a red Datsun stop at an intersection with a stop sign, while the other half saw the red Datsun stop at a yield sign. Afterwards, a recall questionnaire was administered in which half of the participants were asked, “Did another car pass the red Datsun while it was stopped at the stop sign?” while the remaining participants were asked if another vehicle passed the red Datsun while it was stopped at the yield sign. That is, half of the participants were exposed to a question that provided information consistent with what they witnessed in the slides, while the other half was exposed to a question containing misinformation. Following the misinformation phase, a forced-choice recognition test was administered in which participants were asked to select the slide that they had seen earlier. Loftus et al. (1978) found that participants who had seen a stop sign but were later misinformed that it was a yield sign were more likely to report this misinformation on the final memory test. In other words, exposure to misinformation following witnessing an original event increased eyewitness memory suggestibility in that participants were less likely to recall correct details from the event and more likely to report the misinformation.

Several theories have been proposed to explain why participants are more likely to produce misinformation (for a review, see Ayers & Reder, 1998). One interpretation is that the original memory trace is altered or overwritten by the subsequently presented misinformation, also known as the trace alteration account (Loftus et al., 1978). This account assumes that once the misleading information is encoded, the original memory trace is replaced and is thus no longer accessible in memory. For example, the red Datsun stopped at a stop sign represents the original memory trace. When participants are asked a misleading question suggesting that the car was stopped a yield sign, the original memory trace for the stop sign is overwritten by a new memory trace for the yield sign. Thus, when participants are asked to recall the details of the original event on a final memory test, the original information about the stop sign is no longer available in memory, so participants use the only available trace containing the misinformation to answer the question.

An alternative explanation for the misinformation effect is the blocking hypothesis, which assumes that exposure to misleading post-event information impairs access to the original, correct information (Bowers & Bekerian, 1984). Contrary to the trace alteration account presented above, the blocking hypothesis assumes that traces for both the original and misleading information exist in memory. However, when asked to recall the details of the original event, the most recent trace containing the misinformation blocks access to the original trace containing the correct details. This prevents participants from recalling the correct information from the originally encoded event and thus results in the reporting of misinformation on a final memory test.

Few studies have examined the effects of stress on subsequent memory performance in the misinformation paradigm. Recent research has consistently demonstrated that acute stress during narrative encoding reduces misinformation endorsement on a subsequent memory test (Hoscheidt et al., 2014; Schmidt et al., 2014; Nitschke et al., 2019). For instance, acute psychosocial stress induced immediately following narrative presentation produces a decrease in misinformation production and better ability to recall original, correct details on a final memory test (Nitschke et al., 2019). Similarly, inducing stress immediately prior to encoding the details of a negative event improves recall for the most aversive parts of the event and reduces the misinformation effect (Hoscheidt et al., 2014; Schmidt et al., 2014). These results have important implications for eyewitness memory in that stress enhances memory by limiting intrusions into an encoded event. Thus, the most emotional aspects of the event are accurately remembered and subsequently more resistant to misinformation.

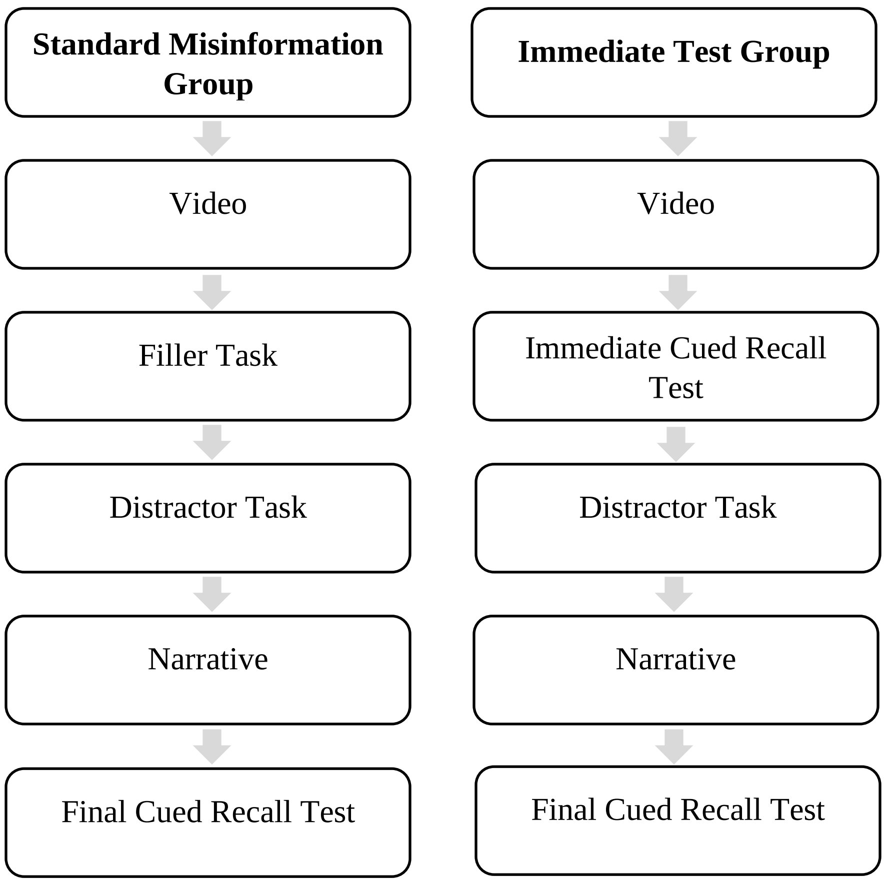
Retrieval-Enhanced Suggestibility

Engaging in a memory test over previously learned material has consistently demonstrated a robust testing effect in educationally relevant contexts (Roediger & Karpicke, 2006). However, immediate testing in the misinformation paradigm appears to conflict with the beneficial effects of testing that are typically observed on memory performance. Research has demonstrated that when witnesses are immediately questioned following an event, they can become even more susceptible to later presented misinformation and false memory production. This test-enhanced memory impairment is known as retrieval-enhanced suggestibility (RES) (Chan, Thomas, & Bulevich, 2009).

In the RES paradigm, participants typically watch a video clip depicting a fictionalized crime taking place. Immediately after witnessing the event, participants are tested on their memory for details presented in the video. Later, they are exposed to either a written or audio narrative synopsis of the event containing details consistent and inconsistent with details from the video. Following the misinformation phase, participants are instructed to recall the details of the originally witnessed event. Figure 1 displays the general procedure implemented to demonstrate RES in participants.

Figure 1

General Procedure Used to Demonstrate RES

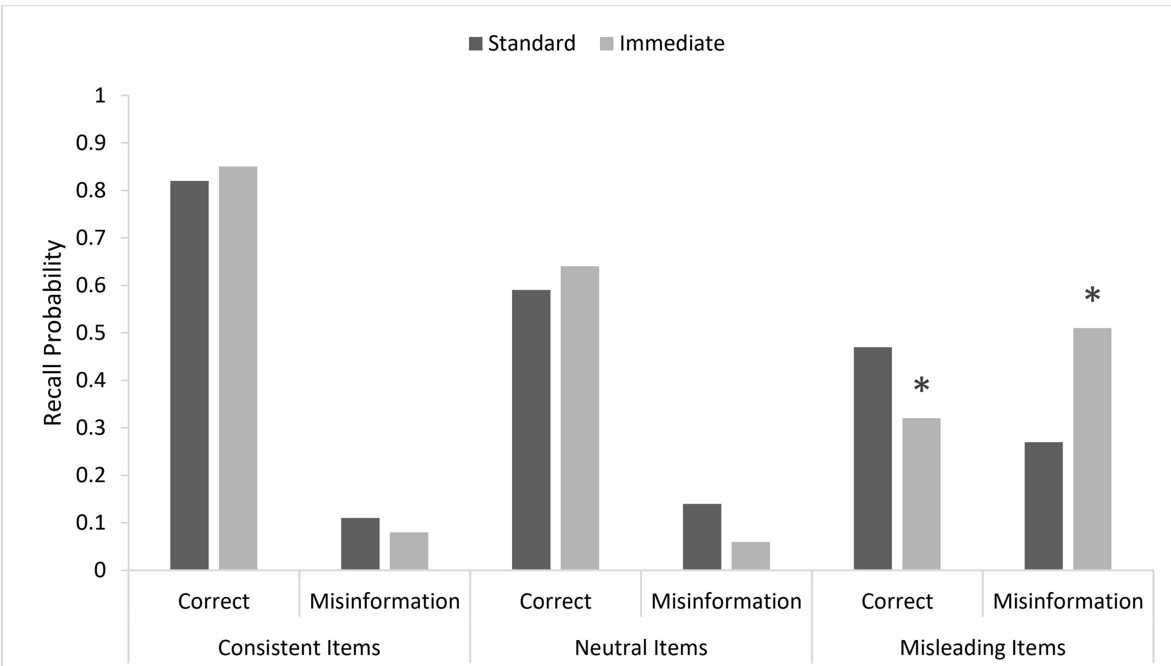


Note. Figure adapted from Gordon, Thomas, & Bulevich (2015).

The typical finding is that immediate retrieval of details following an event causes participants to become more susceptible to later presented misinformation. As shown in Figure 2, compared to standard misinformation participants, participants who take a repeated memory test are more likely to produce misleading information from the narrative on a final memory test and less likely to report accurate information from the originally witnessed event on misleading trials (for a review, see Chan, Manley, & Lang, 2017).

Figure 2

Typical Results of RES Experiments



Note. In typical RES experiments, participants who take an immediate test prior to receiving misinformation are less likely to report correct details from the original event and more likely to report misinformation presented in the narrative on misleading trials, as represented by the asterisks (*). Figure adapted from Chan, Thomas, & Bulevich (2009).

The first study to reveal the detrimental effects of immediate testing prior to receiving misleading information was conducted by Chan, Thomas, & Bulevich (2009). Chan et al. (2009) argued that immediate testing in the misinformation paradigm would reduce eyewitness memory susceptibility to later presented misinformation in that retrieval practice should enhance retention of original event details. To test this hypothesis, Chan and colleagues presented participants with a video depicting a fictionalized crime taking place. Participants in the testing condition then took an immediate cued recall test assessing their memory for original event details. Later, all participants listened to an audio narrative summarizing the event in which some details were changed. Following the narrative presentation, all participants took a final cued recall test in which they were instructed to recall details from the original event. Importantly, Chan et al. (2009) found that participants who had retrieval practice were much more likely to recall misinformation from the narrative on the final memory test compared to participants who did not have retrieval practice. That is, immediate testing in the misinformation paradigm greatly increased the misinformation effect.

A series of recent studies have indicated that immediate testing in the misinformation paradigm may influence how the post-event narrative is learned (Gordon & Thomas, 2014; Gordon et al., 2015; Gordon & Thomas, 2017; Gordon et al., 2019; Wissman et al., 2011). For instance, immediate testing appears to influence attention allocation to details in a post-event narrative, resulting in increased reading times during narrative presentation on misleading trials and increased production of misinformation on a subsequent memory test (Gordon & Thomas, 2014; Gordon et al., 2015). In other words, participants who take an immediate test spend more time processing conflicting information in the post-event narrative and may spend more time reading sentences in the narrative that contain information useful for answering initial test questions (Gordon et al., 2015).

Immediate testing may also enhance eyewitness memory suggestibility in that testing results in elaborative processing of subsequently presented material (Gordon & Thomas, 2017;

Gordon et al., 2019). That is, disrupting narrative encoding with a secondary distractor task prevents further elaboration of critical narrative details (Gordon & Thomas, 2017; Gordon et al., 2019), resulting in a reduced misinformation effect and better ability to recall accurate information from the original event. However, immediate testing in the misinformation paradigm does not appear to disrupt accessibility to original event details (Gordon & Thomas, 2014; Rindal et al., 2016). In other words, when instructed to recall information from both the video and post-event narrative on a final memory test, participants who take an immediate test demonstrate better memory for the original event and post-event narrative compared to standard misinformation participants, suggesting that immediate testing may help segregate memory for each source (Gordon et al., 2014).

The literature has described many instances in which eyewitnesses may or may not be susceptible to misinformation. For example, participants who detect discrepancies between the original event and the post-event narrative are more resistant to subsequently presented misinformation than those who fail to detect discrepancies (Butler & Loftus, 2018). However, when exposed to misleading versions of their own memory reports, participants fail to detect the discrepancies (Cochran et al., 2016), resulting in an increased misinformation effect. In addition, participants are less likely to produce misinformation if given warnings about final test items for which misinformation was presented earlier (Higham, Blank, & Luna, 2017). Furthermore, RES can be demonstrated when the misinformation reinstates contextual details of the originally witnessed event but disrupting narrative coherence by randomizing the order of contextual details eliminates it (LaPaglia & Chan, 2019). Finally, children and adults appear to be equally susceptible to RES (Brackmann et al., 2016; Otgaar et al., 2018).

Although previous research has investigated the relationship between stress and memory susceptibility in the misinformation paradigm, no existing studies have explicitly examined the effects of stress and repeated testing on eyewitness memory. In real-life situations, eyewitnesses are often asked to recall the details of an event multiple times during the investigation process. Research has consistently demonstrated that this act of retrieval can leave memory susceptible to distortion when later presented with misleading or suggestive details about the event (Chan et al., 2009; Gordon & Thomas, 2014; Gordon et al., 2015). However, typical RES studies exclude a critical component of eyewitness memory: the experience of stress. Recalling the details of an emotional experience, as well as being presented with conflicting misinformation, is often accompanied by high levels of stress. Thus, the current study examined the effects of stress and repeated testing on eyewitness memory performance.

The Current Study

The primary goal of the current study was to better understand the effects of stress and repeated testing on subsequent memory performance in an eyewitness memory paradigm. Several studies have demonstrated that participants who take an immediate memory test after witnessing a video of a crime taking place were less accurate on a subsequent memory test and were more likely to report misleading details about the video than participants who did not take an immediate memory test (Chan et al., 2009; Gordon & Thomas, 2014; Gordon et al., 2015). However, these studies do not investigate the effects of stress and immediate testing on subsequent memory performance in an eyewitness memory paradigm. Some studies suggest that inducing acute stress following narrative presentation produces a reduced misinformation effect and better ability to discriminate accurate from inaccurate information (Nitschke et al., 2019). Thus, the current study aimed to examine how inducing acute stress immediately following misinformation exposure will affect subsequent memory performance in the RES paradigm. Specifically, I predicted that the stress manipulation will result in a reduced RES effect and better memory accuracy for details of the originally encoded event.

A secondary goal of this study was to investigate the effects of repeated testing on the processing of misleading narrative details. Reading time has commonly been used as a proxy for measuring attention, with longer reading times corresponding to increased attention allocation. Previous research suggests that repeated testing in the misinformation paradigm influences attention allocation to details in a post-event narrative, resulting in increased reading times during narrative presentation on misleading trials and increased production of misinformation on a subsequent memory test (Gordon & Thomas, 2014; Gordon et al., 2015). Thus, the current study aimed to investigate the effects of repeated testing on attention allocation to misleading post-event details in the RES paradigm. Specifically, I predicted that taking an immediate cued recall test will result in increased attention allocation to sentences in the post-event narrative containing misinformation, thereby resulting in increased misinformation production on a final memory test.

Method

Design

The current study employed a 2 (Testing Condition: repeated, single) x 2 (Emotional Condition: stress, no stress) x 2 (Item Type: control, misleading) mixed experimental design. Testing and emotional conditions were manipulated between subjects, while item type was manipulated within subjects. The dependent variables were the proportion of misleading and correct details produced on the final memory test and reading time (in milliseconds).

Participants

A sample size estimation was calculated using G*Power Version 3.1.9.7 software. The analysis revealed that a minimum sample size of 128 would be necessary to detect an interaction with a small-to-medium effect (effect size = 0.25) and a power level = 0.80. However, based on previous RES studies (Gordon & Thomas, 2017), a sample size of approximately 240 participants would be needed to detect the interaction between stress and immediate testing on a final memory test. A total of 257 undergraduates from Seton Hall University participated and were compensated with credit towards a course research requirement for participating in this study. Participants were students enrolled in psychology courses at Seton Hall University. Students enrolled in the study through SONA, an online sign-up system. Four participants were excluded after completion of the experiment for failure to complete the stress manipulation check (n = 1) and for failure to attend to experimenter instructions (n = 3). Participants were drawn from a sample that consisted of 24% of individuals who identified as male, 75% of individuals who identified as female, and 1% of individuals who identified as non-binary or chose not to provide this information. Participants were mostly Caucasian (52%) and sophomores in college (46%). All participants were above the age of 18 years. Table 1 contains further demographic information for participants in this study.

Table 1

Demographic Characteristics of Study Sample

Characteristic	Repeated				Single				Full Sample	
	Stress		No Stress		Stress		No Stress			
	N	%	*N*	%	*N*	%	*N*	%	*N*	%
Gender Identity										
Female	49	80	48	77	45	68	47	73	189	75
Male	12	20	14	23	19	29	17	27	62	24
Non-binary	0	0	0	0	1	2	0	0	1	0.4
N/A	0	0	0	0	1	2	0	0	1	0.4
Ethnicity/Race										
Caucasian	34	56	34	55	27	41	37	58	132	52
Asian	7	11	9	15	17	26	8	13	41	16
Black/African American	8	13	10	16	8	12	4	6	30	12
Multi-racial	2	3	2	3	3	5	1	2	8	3
Hispanic	10	16	6	10	9	14	11	17	36	14
Middle Eastern	0	0	1	2	1	2	3	5	5	2
Pacific Islander	0	0	0	0	1	2	0	0	1	0.4
Year in School										
First-year	29	48	22	35	31	47	23	36	105	41
Sophomore	28	46	28	45	25	38	36	56	117	46

Characteristic	Repeated				Single				Full Sample	
	Stress		No Stress		Stress		No Stress			
	N	%	*N*	%	*N*	%	*N*	%	*N*	%
Junior	3	5	7	11	8	12	4	6	22	9
Senior [a]	1	2	5	8	2	3	1	2	9	4

[a] Senior class year also includes students in their fifth year of study.

Materials and Procedure

This study was conducted entirely online. Participants used their personal computers to complete the experiment under the supervision of a research assistant. All participants first watched a 5-minute video clip of a young girls' occupational therapy session. Participants were instructed to make sure that their computer sound was on and that they could hear the video. Participants were also told that they would later be asked to report on what they saw and heard in the video clip.

Following the video presentation, participants were randomly assigned to the repeated or single testing condition. Participants in the repeated test group took an immediate cued recall test to assess their memory for details presented in the video clip. Twenty-four questions were used as immediate test stimuli (see Appendix A). Each question targeted critical details that were later manipulated in the upcoming narrative (e.g., *What is the color of the patient's shirt?*) and were presented in the same order as information presented in the video. Participants viewed each question one at a time on their computer screen and had as much time as they needed to type in their response. Participants were encouraged to provide an answer to each question but were able to withhold responses. Instead of taking an immediate cued recall test, the single test group completed a filler task for the same amount of time (5 minutes). The filler task consisted of several questions in which participants were instructed to count how many shapes of a particular kind they saw. Participants in both groups then completed a distractor task that consisted of a brief demographic questionnaire and several unscrambling and categorization questions (e.g., *Match the country to the corresponding continent.*) The responses on the distractor task were not recorded for use in any analysis. Next, all participants read a narrative summary of the occupational therapy video. Each narrative sentence was presented on the computer screen sentence by sentence to collect reading time data. Participants pressed the enter key on their keyboard to advance to the next sentence when they were ready. Importantly, the narrative included twenty-four sentences containing critical details from the video clip. These sentences introduced neutral or misleading information about the video (twelve details each), in addition to filler sentences that were not tested on during the immediate or final test phases. Control sentences contained an ambiguous detail from the video, but not manipulated in the narrative (e.g., *Exercises that incorporate reaching across the midline are important.*) Misleading sentences contained details from the video that were manipulated in the narrative (e.g., *The patient reaches over her head for a toy turtle.*) Sentences serving as control or misleading were counterbalanced across participants.

Based on the findings from Nitschke et al. (2019), stress induced immediately following narrative presentation produces a reliable decrease in misinformation production and better ability to recall correct details on a final memory test. Thus, in the current study, participants were randomly assigned to an emotional condition (stress vs. no stress) following narrative presentation. Participants in the stress group completed a mental arithmetic task under time pressure with negative feedback for five minutes (Al-Shargie et al., 2016). Participants were given sixty mental arithmetic problems with 5 seconds to complete each one. Each problem appeared one at a time on the computer screen. Participants were instructed to answer each problem as quickly as possible and to use their mouse to select from an array of answer choices. Participants were also instructed to not use a calculator. If participants got the problem incorrect, a negative feedback screen appeared (e.g., *Your answer is… Incorrect!!!!*) and participants were also able to see how long they took to answer the problem. Similarly, participants received positive feedback if they got the answer correct (e.g., *Your answer is… Correct*) and a time out screen appeared if they took longer than 5 seconds to answer the problem. Participants in the control condition completed a filler task for the same amount of time. The filler task consisted of several questions in which participants had to count the number of shapes of a particular kind they saw. These questions were different from those in the filler task that single test participants completed.

Following the stress manipulation, all participants then completed the State-Trait Inventory for Cognitive and Somatic Anxiety (STICSA; Ree, French, MacLeod, & Locke, 2008) as a manipulation check. All participants then took a final cued recall test that was identical to the immediate test that the repeated test group took. Participants were instructed to respond only with original information they remembered from the video clip. All participants were then thanked for their participation and debriefed on the purpose of the experiment. See Figure 3 for a complete depiction of the materials and procedure used in the current study.

Data Analysis

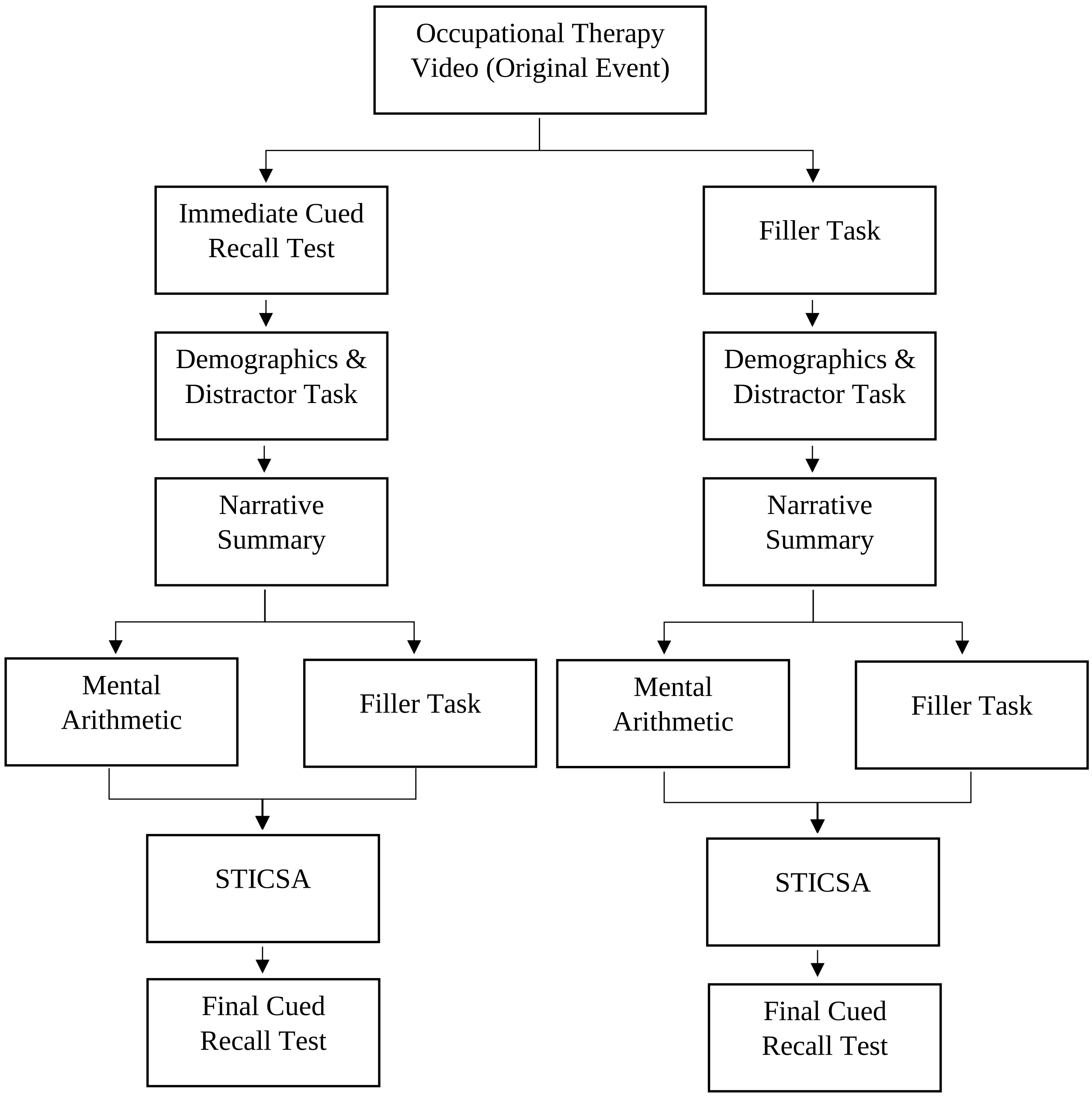
All analyses were conducted using Jamovi version 2.2.5. A Student's independent samples *t*-test revealed that participants who completed the mental arithmetic test (*M* = 37.93, *SD* = 9.67) did not significantly differ from participants who did not complete it (*M* = 36.01, *SD* =

9.86), suggesting that the stress manipulation was unsuccessful, $t(251) = 1.56$, $p = .119$. In order to continue to examine the effects of stress, a median split was conducted to separate participants into thirds based on reported stress levels. Because a median split puts individuals with similar stress scores in different groups, I only included participants who were sorted into the top (high stress: 39 repeated, 42 single) and bottom (low stress: 39 repeated, 37 single) thirds. Thus, data from only 157 participants were included in the analyses on memory performance. Participants in the low stress condition had a reported stress score of 30 or below, whereas those in the high stress condition had a reported stress score of 40 or above. A Welch's independent samples *t*-test revealed that low ($M = 27.01$, $SD = 2.87$) and high ($M = 48.67$, $SD = 6.98$) stress participants significantly differed from each other, $t(107.8) = 25.7$, $p < .001$, $d = 4.06$. I thus performed a 2 (Testing Condition: repeated, single) x 2 (Reported Stress: high, low) x 2 (Item Type: control, misleading) mixed factorial analysis of variance (ANOVA) on proportions of accurate and misleading details produced on the final memory test with reported stress levels serving as a quasi-independent variable in each analysis.

The reading time analysis included data from all 253 participants and was performed on a subset of the data. Only reading times for critical narrative sentences that included control or misleading details were included. Reading times faster than 300 milliseconds (ms) and those corresponding to the first critical narrative sentence were excluded for each participant. Given that stress was not experienced until after narrative presentation, I did not include reported stress levels in the reading time analysis. I thus performed a 2 (Testing Condition: repeated, single) x 2 (Item Type: control, misleading) mixed factorial analysis of variance (ANOVA) on median reading times. The measure of effect size used in the current study was eta-squared (η^2), which is a simple way to measure how big the overall effect is for any particular term. Specifically, it is a measure of the proportion of variance in the outcome variable that can be accounted for by the main effect of each factor in the model. It is therefore a number that ranges from 0 (no effect at all) to 1 (accounts for *all* of the variability in the outcome). The following are general rules of thumb used to interpret values for eta-squared: .01 (a small effect size), .06 (a medium effect size), and .14 or larger (a large effect size).

Figure 3

Procedure Implemented in the Present Study



Results

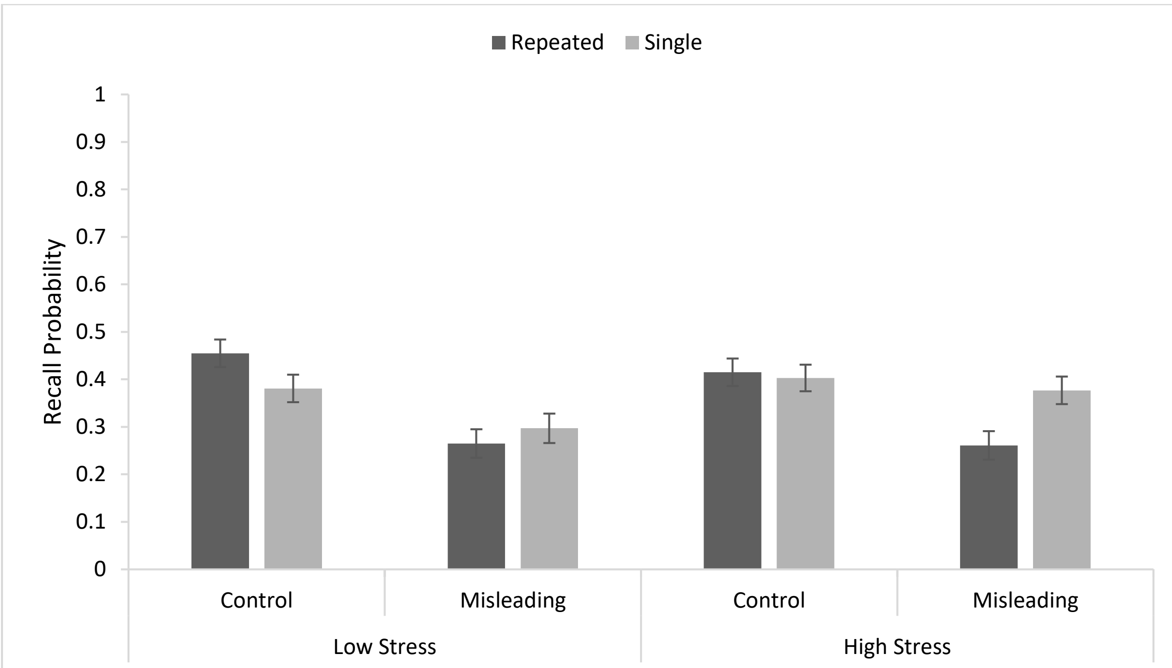
Memory Performance

Accurate recall was calculated by dividing the total number of trials in which participants produced the correct video detail out of the total number of trials for that given item type. During the immediate cued recall test, .52 of participants' responses were accurate and .07 spontaneously produced misinformation.

Accurate video recall on final test. Figure 4 and Table 2 present the accurate recall probabilities on the final cued recall test. A 2 (Testing Condition: repeated, single) x 2 (Reported Stress: high, low) x 2 (Item Type: control, misleading) mixed analysis of variance (ANOVA) examined accurate video detail recall on the final memory test. The analysis revealed a main effect of Item Type, F (1, 153) = 42.52, $p < .001$, $\eta^2 = 0.04$. Participants were more accurate on control trials (M = .41) as compared to misleading trials (M = .30).

Figure 4

Mean Accurate Recall Probabilities as a Function of Item Type, Stress, and Testing Condition



Note. Error bars represent mean standard errors.

Table 2

Means and Standard Errors for Accurate Recall Probabilities on the Final Memory Test

Condition	Item Type	
	Control	Misleading
High Stress		
Repeated	.42 (.03)	.26 (.03)
Single	.40 (.03)	.38 (.03)
Low Stress		

Condition	Item Type	
	Control	Misleading
Repeated	.46 (.03)	.27 (.03)
Single	.38 (.03)	.30 (.03)

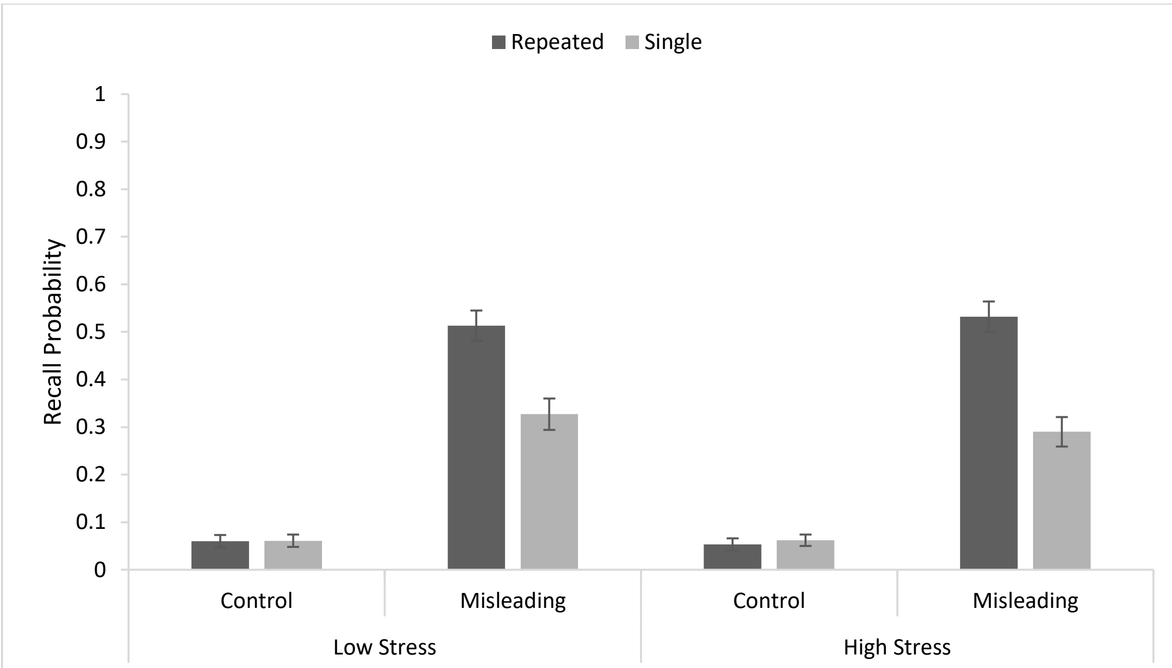
Note. Standard errors are in parentheses.

The ANOVA on accurate video detail recall also revealed an Item Type x Testing Condition interaction, F (1, 153) = 11.42, p < .001, η^2 = 0.01. A post hoc Tukey test indicated that repeated testing did not have an impact on correct detail recall on control trials (p > .05). However, repeated testing led to a marginally significant decrease in correct detail recall on misleading trials (p = .068). Neither the main effect of Testing Condition, F (1, 153) = 0.44, p > .05, nor the main effect of Reported Stress, F (1, 153) = 0.36, p > .05, was significant. Additionally, the Item Type x Reported Stress interaction, F (1, 153) = 1.82, p > .05, the Testing Condition x Reported Stress interaction, F (1, 153) = 2.41, p > .05, and the three-way interaction, F (1, 153) = 0.09, p > .05, were all non-significant.

Misinformation production on final test. Figure 5 and Table 3 present the probabilities of reporting misinformation on the final cued recall test. Misinformation production was calculated by dividing the total number of trials in which participants produced the misleading detail out of the total number of trials for each item type. A 2 (Testing Condition: repeated, single) x 2 (Reported Stress: high, low) x 2 (Item Type: control, misleading) mixed analysis of variance (ANOVA) examined misinformation production on the final memory test. The analysis revealed a main effect of Item Type, F (1, 153) = 379.67, p < .001, η^2 = 0.39. Overall, participants were more likely to report misinformation on misleading trials (*M* = .42) as compared to control trials (*M* = .06), establishing a standard misinformation effect.

Figure 5

Mean Misled Probabilities as a Function of Item Type, Stress, and Testing Condition



Note. Error bars represent mean standard errors.

Table 3

Means and Standard Errors for Misled Probabilities on the Final Memory Test

Condition	Item Type	
	Control	Misleading
High Stress		
Repeated	.05 (.01)	.53 (.03)

Condition	Item Type	
	Control	Misleading
Single	.06 (.01)	.29 (.03)
Low Stress		
Repeated	.06 (.01)	.51 (.03)
Single	.06 (.01)	.33 (.03)

Note. Standard errors are in parentheses.

The ANOVA on misinformation production on the final memory test also revealed a main effect of Testing Condition, *F* (1, 153) = 41.6, $p < .001$, $\eta^2 = 0.03$. Consistent with the RES literature, repeated test participants (*M* = .29) produced more misinformation on the final memory test as compared to single test participants (*M* = .19). The analysis also revealed a significant Item Type x Testing Condition interaction, *F* (1, 153) = 35.79, $p < .001$, $\eta^2 = 0.04$. A post hoc Tukey test indicated that repeated test participants (*M* = .05) did not differ from single test participants (*M* = .06) in proportion of misleading details reported on control trials ($p > .05$). However, more importantly, repeated test participants (*M* = .51) were much more likely to report misleading details compared to single test participants (*M* = .32) on misleading trials ($p < .001$). The main effect of Reported Stress was not significant, *F* (1, 153) = 0.13, $p > .05$. Additionally, the Item Type x Reported Stress interaction, *F* (1, 153) = 0.03, $p > .05$, the Testing Condition x Reported Stress interaction, *F* (1, 153) = 0.57, $p > .05$, and the three-way interaction, *F* (1, 153) = 0.75, $p > .05$, were all non-significant.

Reading Time Analysis

Table 4 presents the average reading times associated with narrative presentation. A 2 (Testing Condition: repeated, single) x 2 (Item Type: control, misleading) mixed analysis of variance (ANOVA) was performed on median reading times. The analysis revealed a main effect of Item Type, F (1, 251) = 137.34, p < .001, η^2 = 0.049. Sentences that included misinformation (M = 3,051 ms) took longer to process than did control sentences (M = 2,508 ms). The analysis also revealed a main effect of Testing Condition, F (1, 251) = 6.12, p = .014, η^2 = 0.02. Slower reading times were associated with repeated testing (M = 2,954 ms) than with single testing (M = 2,605 ms). The ANOVA on median reading times also revealed a significant Item Type x Testing Condition interaction, F (1, 251) = 14.74, p < .001, η^2 = 0.005. A Welch's independent samples t-test revealed that although participants in the repeated and single test groups took longer to process sentences containing misinformation, the effect was larger for repeated (M = 834 ms) compared to single (M = 504 ms) testing, t(206.53) = 4.12, p < .001, d = 0.52.

Table 4

Mean Reading Times in Milliseconds as a Function of Item Type and Testing Condition

Testing Condition	Item Type	
	Control	Misleading
Repeated	2,593 (92)	3,314 (119)
Single	2,422 (90)	2,787 (116)

Note. Standard errors are in parentheses.

Discussion

Several studies have demonstrated that participants who take an immediate memory test after witnessing a video of a crime taking place are less accurate on a subsequent memory test and more likely to report misleading details about the video than participants who do not take an immediate memory test (Chan et al., 2009; Gordon & Thomas, 2014; Gordon et al., 2015). However, these studies do not investigate the effects of stress and repeated testing on subsequent memory performance in an eyewitness memory paradigm. Previous research examining the effects of stress on eyewitness memory susceptibility in the misinformation paradigm has suggested that inducing acute stress following narrative presentation produces a reduced misinformation effect and better ability to discriminate accurate from inaccurate information (Nitschke et al., 2019). Thus, the primary goal of the current study was to explore the interaction between stress and repeated testing on subsequent memory performance in an eyewitness memory paradigm. Specifically, I predicted that the stress manipulation will result in a reduced RES effect and better memory accuracy for details of the originally encoded event. Contrary to my original hypothesis, I did not find an interaction between stress and repeated testing on accurate recall or misinformation production on the final memory test. However, consistent with the RES literature, I found that participants who took an immediate memory test were significantly more likely to report misinformation on the final memory test compared to participants who did not take an immediate memory test. More importantly, I found that participants who took a repeated memory test were much more likely to report misleading details on misleading trials compared to single test participants.

Previous research has suggested that increased attention allocation to misleading narrative details moderates the RES effect (Gordon & Thomas, 2014; Gordon et al., 2015). That is, repeated testing in the misinformation paradigm influences attention allocation to details in a post-event narrative, resulting in increased reading times during narrative presentation on misleading trials and increased production of misinformation on a subsequent memory test. Reading time has commonly been used as a proxy for measuring attention, with longer reading times corresponding to increased attention allocation. Thus, a secondary goal of the current study was to investigate the effects of repeated testing on the processing of misleading narrative details. Specifically, I hypothesized that taking an immediate cued recall test will result in increased attention allocation to sentences in the post-event narrative containing misinformation, thereby resulting in increased misinformation production on a final memory test. In line with previous research, I found that sentences containing misinformation took significantly longer to process compared to control sentences. Furthermore, and more importantly, this effect was larger for repeated test participants than for single test participants. That is, repeated testing led to much slower reading times for sentences in the narrative containing misinformation compared to single testing.

Previous research has shown that attempts made to retrieve original information may enhance learning of subsequently presented information through a general error correction process (Carrier & Pashler, 1992; Kang et al., 2011; McClelland & Rumelhart, 1985). In other words, when participants produce a response that is contradicted by later presented information, the discrepancy may produce an error signal, activating a general error correction mechanism. This mechanism may encourage participants to develop new encoding strategies to better learn subsequent material (Carpenter, 2012; Pyc & Rawson, 2012). The reading time data in the present study support the conclusion that discrepancies in originally retrieved information and post-event misinformation may influence attention allocation to misleading narrative details and thus encoding of those details. That is, because repeated test participants spent much more time reading misleading narrative sentences than single test participants, it is possible that a more efficient encoding process was engaged during these trials.

A second possible explanation for the finding that testing previously learned information results in slower reading times for sentences in the narrative containing misinformation is that immediate test questions may serve as endogenous search cues, which guide processing and learning of information during subsequent study episodes (Gordon et al., 2015). In the present study, repeated testing led participants to spend more time reading narrative sentences that contained information useful for answering initial test questions. In contrast, less attention was directed toward sentences in the narrative containing uninformative information (i.e., control sentences). These findings are in support of those from Wissman and colleagues' (2011) experiment. Wissman et al. (2011) found that immediate testing in between learning episodes facilitated learning of prose material that was related to previously tested material (Wissman et al., 2011). Specifically, participants were instructed to recall each section of an expository text before moving on to study the next section or were prompted to recall only after the final section. Wissman and colleagues (2011) found that recall for the final section was greater if prior sections were tested on compared to when prior sections were not tested on (Wissman et al., 2011). That is, immediate testing may encourage participants to develop more effective encoding strategies during subsequent learning episodes (Wissman et al., 2011). Taken together, these findings suggest that repeated testing may result in test-enhanced learning in that it fundamentally changes the way in which subsequently related material is learned and may lead participants to prioritize rehearsal of that material.

One possible explanation for the failure to detect an interaction between stress and repeated testing, and a limitation of the current study, is that the stress manipulation was not stressful enough. Recent work has demonstrated that participants who complete a mental arithmetic task under time pressure with negative feedback exhibit an increase in salivary alpha amylase levels, which have been proposed to be a physiological marker of stress, compared to control participants (Al-Shargie et al., 2016). Previous research examining the effects of stress on eyewitness memory in the misinformation paradigm has shown that experiencing acute stress during narrative encoding reduces misinformation endorsement on a subsequent memory test (Nitschke et al., 2019). For example, in Nitschke and colleagues' (2019) study, participants studied an event via a slideshow and were then exposed to a related narrative that contained misleading information about the event. Following the narrative presentation, participants were randomly assigned to either the Trier Social Stress Test (TSST) or a matched no-stress control task. The TSST involves a mock-job interview in which participants are given 10 minutes to prepare a speech to be given in front of a panel of expert judges. Following this anticipation period, participants perform a 5-minute speech task, followed by a 5-minute oral arithmetic task, in front of trained confederates. The TSST has been shown to reliably produce a significant increase in stress across a variety of markers (e.g., cortisol, ANS, and subjective stress). Once stress levels returned to baseline, participants completed a memory test for the slideshow that contained accurate and inaccurate information about the event. Nitschke and colleagues (2019) found that participants in the TSST condition demonstrated a reduced misinformation effect and better ability to discriminate accurate from inaccurate information on the final memory test compared to control participants, and that this effect lasted over a multiple day delay (Nitschke et al., 2019). Thus, future research should aim to use a more salient stress task, such as the TSST, or examine individual differences in stress levels prior to completing the study, to investigate the effects of stress and repeated testing on misinformation susceptibility in the RES paradigm.

An alternative explanation for the fact that I did not find an interaction between stress and repeated testing on eyewitness memory performance in the current study is that the materials used were not appropriate to measure stress in participants. In the current study, I used the State-Trait Inventory for Cognitive and Somatic Anxiety (STICSA) to measure overall stress levels in participants. The STICSA is a self-report questionnaire consisting of 42 items, with 10 items measuring cognitive anxiety and 11 measuring somatic components of anxiety at both the state and trait level (Ree et al., 2008). Items are rated on a 4-point Likert scale from 1 (*Almost never* or *Not at all*) to 4 (*Almost always* or *Very much so*) on the trait and state scales, respectively (Ree et al., 2008). Cognitive anxiety is specific to anxiety symptoms related to thought processes, such as worry and inability to concentrate, whereas somatic anxiety relates to physiological anxiety symptoms, such as hyperventilation, trembling, and palpitations (Ree et al., 2008). Items on the trait scale are asked in terms of "how often, in general, the statement is true of you," while state items (those used in the current study) are answered in terms of "how you feel right now, at this very moment" (Ree et al., 2008). In general, higher scores on the STICSA indicate higher levels of anxiety. However, the aim of the current study was not to measure anxiety in participants, but to measure physiological stress. Future research is thus needed to measure stress using physiological measures, such as measuring cortisol levels (e.g., Nitschke et al., 2019), salivary alpha amylase levels (e.g., Al-Shargie et al., 2016), or heart rate, to detect the potential interaction between stress and repeated testing on eyewitness memory. Future work should also consider using stress as a linear variable and running regression analyses to determine whether the interaction term has an effect on eyewitness memory in an RES paradigm.

Another limitation of the current study is that the stressor occurred shortly before participants took the final memory test. Previous research has suggested that the timing of stress in relation to learning or retrieval may be an important determinant of the effects of stress on memory (Schwabe & Wolf, 2014; Zoladz et al., 2011). For example, if stress acts in part through actions of cortisol, which is not expected to reach peak levels until approximately 20 minutes after stress is initiated, then the effects of stress on memory may depend upon the delay after the stressor. In addition, several theories have been proposed to account for the effects of stress on episodic memory. For example, one broad class of theories that has been useful in understanding the effects of stress on memory are consolidation theories (Cahill & McGaugh, 1998). According to these perspectives, recently encoded events are likely to be forgotten unless there is an active process of consolidation whereby the initial fragile memory traces formed by the encoding event are "stabilized" or "solidified" into long-term memories. If stress is experienced shortly after encoding, it will aid in consolidating memory for recent information (Shields et al., 2017). That is, stress should improve episodic memory when it is induced post-encoding because it facilitates consolidation of the original memory trace and slows forgetting. Furthermore, recent work examining the effects of post-encoding stress on eyewitness memory in the misinformation paradigm have found that inducing stress immediately prior to encoding the details of a negative event improves recall for the most aversive parts of the event and reduces the misinformation effect (Hoscheidt et al., 2014; Schmidt et al., 2014). Thus, future research should also investigate whether stress negates the effects of repeated testing if the stressor occurs following video presentation in the RES paradigm.

In conclusion, using brand new materials, the results of the current study are consistent with the RES literature in that participants who took an immediate memory test were less accurate on misleading trials and more likely to produce misinformation on a final memory test. Future work should consider running an item analysis to ensure that the items are quality items. Consistent with previous RES work, the results of the current study also suggest that increased attention allocation to sentences in a post-event narrative containing misinformation moderates the RES effect. Future research should aim to determine whether stress negates the effects of repeated testing in an eyewitness memory paradigm.

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Appendix A

Immediate and Final Test Questions

Instructions: Please answer the following questions with information from the occupational therapy video. You are encouraged to provide an answer to each question.

1. What is the patient's name?
2. How old is the patient?
3. What hairstyle did the patient have?
4. What color was the patient's shirt?
5. What was the patient's diagnosis?
6. What does the patient’s diagnosis mean?
7. Why were weights placed on the patient's ankles and wrists?
8. What color were the ankle and wrist weights?
9. What colors were the floor mats?
10. What animal were her pincers?
11. What was the purpose of the pincers?
12. What was the purpose of exercises that reach across the midline?
13. What was the purpose of having the patient play games on her stomach?
14. What color was the scooter board?
15. What was the purpose of placing the weighted vest on the patient?
16. What pattern was the weighted vest placed on the patient?
17. What was the purpose of the fishing rod exercise?
18. How were heavy work activities incorporated into the treatment?

19. What was the purpose of having the patient stand on the BOSU ball?

20. How many times did the patient throw a toy at the wooden board?

21. What toy animal was the patient reaching over her head for?

22. How are the sessions ended?

23. How many kids were sitting at the end?

24. What was the name of the hospital?

Appendix B

IRB Approval Form

SETON HALL UNIVERSITY

1856

07/26/2021

Amanda Capriglione

Seton Hall University

Re: 2021-238

Dear Amanda,

The Research Ethics Committee of the Seton Hall University Institutional Review Board reviewed and approved your research proposal entitled, "Stress and Retrieval-Enhanced Suggestibility" as resubmitted. This memo serves as official notice of the aforementioned study's approval as exempt. If your study has a consent form or letter of solicitation, they are included in this mailing for your use.

The Institutional Review Board approval of your research is valid for a one-year period from the date of this letter. During this time, any changes to the research protocol, informed consent form or study team must be reviewed and approved by the IRB prior to their implementation.

You will receive a communication from the Institutional Review Board at least 1 month prior to your expiration date requesting that you submit an Annual Progress Report to keep the study active, or a Final Review of Human Subjects Research form to close the study. In all future correspondence with the Institutional Review Board, please reference the ID# listed above.

Sincerely,

Mara Podvey

Mara C. Podvey, PhD, OTR
Associate Professor
Co-Chair, Institutional Review Board

Phyllis Hansell

Phyllis Hansell, EdD, RN, DNAP, FAAN
Professor
Co-Chair, Institutional Review Board

Office of the Institutional Review Board

Presidents Hall · 400 South Orange Avenue · South Orange, New Jersey 07079 · Tel: 973.275.4654 · Fax 973.275.2978 · *www.shu.edu*

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