THE IMPACT OF STRESS ON FALSE MEMORY: DOES AROUSAL TIMING AFFECT INDIVIDUAL SUSCEPTIBILITY TO MISINFORMATION?

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by
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Abstract

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The misinformation effect, or the idea that information introduced after an event can change the memory for that event, has been studied for many decades. Despite this long history, only recently have researchers begun to examine how emotion and arousal impact the effect. While there are several studies that have looked at how arousal impacts this misinformation effect, the studies vary in the timing in which arousal is introduced to the misinformation paradigm, leading to inconsistencies in the results. The purpose of the current study was to investigate whether arousal introduced during the reconsolidation period has a different effect than arousal introduced just prior to retrieval. The study followed a typical misinformation procedure where participants were shown a series of slide show images documenting an event followed by a written narrative about the event that contains misinformation and finally a memory test 24 hours later. At different intervals in this procedure, I induced arousal through a timed arithmetic stress task: one-third of the participants will perform the stress task immediately after the introduction of misinformation; one third will perform the stress task just before the memory test; the final third will not perform the stress task. While few statistically significant effects were found, participants in both stress conditions were more susceptible to misinformation than the control group, and participants were more likely to choose the misinformation than the novel foil. Due to high attrition rates, strong conclusions could not be drawn.

Keywords: Misinformation Effect, Arousal, Timing, Stress

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Imagine you have just witnessed a crime. While attempting to process all of the events, another witness approaches you and asks if you saw the perpetrator's red shirt. Later, the police question you and ask for a description of what the man was wearing. You think for a second and confidently say a red shirt. This is the general idea behind the misinformation effect. First studied by Loftus et al. (1978), the misinformation effect refers to a phenomenon in which information introduced after the original event can affect the memory for that event. In the original Loftus et al. (1978) paradigm, participants looked at slides that depicted the events leading up to a car crash. Following the presentation, they were given information about the scene, specifically the street signs, that was either consistent or inconsistent with the original slides. They found that the introduction of misinformation led to less accurate responses on the recognition test. Additionally, this misinformation had a greater effect when introduced before the final memory test, rather than immediately following the initial event (Loftus et al., 1978).

Many studies have followed Loftus et al.'s original paradigm in order to determine the boundary conditions of the misinformation effect. As in the Loftus et al. (1978) study, several of these studies show that the timing of elements during the experimental procedures can influence the results. One such example is that of Greene et al. (1982), in which it was found that a warning that misinformation may occur beforehand increased the time participants attended to the misinformation, and therefore slightly decreased suggestibility to the false information. However, when that same warning was given after the misinformation had been presented, participants showed little change in suggestibility to this misleading information. Additionally, other researchers have found that looking at differences between the original event and misinformation can lead to a decrease in the misinformation effect, and consequently improve memory for the original event (Putnam et al., 2017). Pena et al. (2017) looked at the effects of introducing high (80%), medium (50%), and low (20%) amounts of misinformation to the original event. There was a significant difference between the level of misinformation and correct answers, and participants tended to overestimate the number of questions they got correct. From these results, it was posited that higher levels of cognitive load increased the participants' susceptibility to misinformation.

While many of the classic misinformation paradigms utilize neutral stimuli or events, this is not indicative of all real-world situations. Thus, some researchers began to examine how emotion might influence susceptibility to misinformation. Emotion is a state of feeling that results in a physiological (arousal) and psychological (valence) change that can affect an individual's thoughts and behavior. In studies of false memory phenomena like the misinformation effect, emotion has been incorporated either through the content of the stimulus (for example, showing a car crash that kills a pedestrian as part of the original event), or the context of a mood induction (for example, having participants watch an emotionally arousing video that is not part of the to-be-remembered stimulus; Bookbinder & Brainerd, 2016). One example of the latter is a study done by Kensinger (2007), in which Red Sox and Yankees fans were asked to remember a World Series game in which the Red Socks beat the Yankees. They found that Red Socks fans, who had a more favorable outcome and were presumably happier, had more memory inconsistencies than that of the Yankees fans, who had a negative outcome and were presumably less happy. However, the Red Socks fans were more confident in their memories than were the Yankee fans. This article is consistent with the idea reviewed by

Bookbinder and Brainerd (2016) that false memory is intensified for negative content, but is reduced for a negative context (mood). Meaning that while the baseball game itself was not inherently emotional, the negative feeling from the outcome of the game may have made the memories of the Yankee fans more accurate.

In line with this research, both content and context have been shown to impact the misinformation effect. In one study examining how content impacted the misinformation effect, participants were asked to view two images, one positive and one negative. They then answered three questions about each image, one of which either contained or did not contain misinformation about the original photo. After either a week or a month, participants were asked to come back and answer 15 open-ended questions about the original images. Researchers found that negative content in the initial event was associated with the long-term greater incorporation of misinformation into events. This is known as the paradoxical negative emotion hypothesis, or the theory that while negative content is remembered better over time, it also increases the susceptibility to misinformation (Porter et al. 2010).

In contrast, when looking at the effect of the valence of the context, rather than the event itself, the effects look different. For example, one study was done where participants viewed one of two photos of a positive or a negative scene. They were then asked to write personal narratives to induce a positive, negative, or neutral mood, followed immediately by the introduction of misinformation in the form of questions about the scenes. Researchers found that negatively valenced mood, or a negative context, was associated with fewer false alarms than positively valenced mood, or a positive context, indicating that negative mood aided participants in reduced susceptibility to misinformation (Forgas et al., 2005). Therefore, while negative content has been shown to increase the rate of false alarms, a negative context, or mood, has the opposite effect.

One limitation in drawing strong conclusions about the impact of emotional context on the misinformation effect is that many of these studies manipulate valence while not controlling for arousal. This is a problem because arousal, or the physiological aspect of emotion, has been found to impact memory at each stage of the memory process (encoding, consolidation, and retrieval). In particular, arousal appears to be beneficial for encoding and consolidation, but disruptive when it occurs at retrieval. For example, studies have found that the level of arousal evoked by the stimulus content influences its memorability (LaBar & Phelps). That is, several studies have shown that highly arousing items are better remembered than lower arousing items (LaBar & Phelps, 1998; Ochsner, 2000). The mechanism for this effect may be due to the physiological impact of stress on memory encoding and consolidation. One study has shown that exposure to emotionally arousing content produces an increased level of epinephrine and increases heart rate. This secretion of epinephrine during this emotional event impacts the existing norepinephrine in the amygdala and facilitates memory consolidation, or the process of transforming recent experiences into long-term memory, by directly acting on the amygdala (McIntyre et al., 2011).

The positive impact of arousal on memory encoding and consolidation is further supported by research showing that both pre-and post-encoding stress can enhance memory consolidation processes. Specifically, studies have indicated that when the adrenergic system is activated after learning, memory consolidation is enhanced (McGaugh, 2018). In one study looking at the timing of arousal, researchers conducted two separate experiments to examine the effects of post-encoding arousal and post-encoding distinctiveness on memory accuracy and consolidation (Anderson et al., 2006). Participants were shown a series of 12 neutral images each followed either by a positively valenced arousing image, a negatively valenced arousing image, or a neutrally valenced arousing image. Memory was tested through a recognition test and participants were also asked to rate how memorable the original image was and how intensely the arousing image made them feel. Researchers found that memory for the original images was enhanced by the increased emotional arousal following the encoding of the original event, in a phenomenon they described as retrograde memory enhancement (Anderson et al., 2006).

Schwarze et al. (2012) aimed to look at the effects of arousal on memory while excluding elaborate encoding and other cognitive processes. This was accomplished through the use of an electric shock following a neutral image at randomized interstimulus intervals. Participants were asked to rate the intensity of each shock and performed a recognition test either 5 minutes or 24 hours following the encoding and arousal tasks. These researchers found that memory was enhanced for scenes that were followed by the shock when participants' memory was tested 24 hours later. Additionally, MRI imaging suggested that successful encoding for scenes with and without the shock was mediated by the right parahippocampal cortex (Schwarze, et al. 2012).

While post-encoding arousal appears to have benefits for memory consolidation, the timing of the post-encoding arousal matters. For example, Wang and Bukan (2015) found that negative emotion elicited five minutes following a series of stimuli enhanced memory for the original learning while negative emotion elicited 30-45 minutes later had no enhancement effect, and the 30-minute delay actually reduced memory consolidation for the original event. Similarly, Nielson and Powless (2007) found that regardless of the valence, arousal induced up to 30 minutes later significantly increased participants' memory for word lists. Additionally, other researchers have found a carry-over effect in which when feelings of arousal carry over to the encoding condition, memory for the event is enhanced prospectively. This carry-over effect was shown to last for 9 to 33 minutes after the introduction to an arousing stimulus (Tambini, et al.

2017). These results indicate that the timing at which arousal is introduced has a variety of effects on memory consolidation for an event. These studies suggest that arousal introduced within 30 minutes of a stimulus should enhance consolidation.

It should be noted that post-encoding arousal may differentially enhance certain kinds of information, though the literature on this question is decidedly mixed. For example, a study done by Pardilla-Delgado et al. (2015) found that when stress is introduced after the learning of semantically related words, the false recognition for related words increased but true memory decreased. The authors interpret this finding as indicating that stress can enhance memory consolidation for gist information, but impairs memory for detail. In contrast, another study, in which a cold pressor task was utilized to mimic the physical symptoms of stress found that stressor timing influenced effects for both associative and item memory for an event. More specifically, it was found that arousal induced after encoding improved item memory, but not associative memory (Goldfarb, et al., 2019).

While arousal appears to be beneficial for consolidation, its impact on the related process of reconsolidation is less clear. Reconsolidation is the brain's mechanism for updating an existing memory and is particularly important for understanding the misinformation effect. Whenever a memory is retrieved, it becomes susceptible to the misinformation effect through the reconsolidation process (Akirav & Maroun, 2013). The exact effect of arousal on reconsolidation depends on many factors such as the type and duration of a stressor, as well as when the stressor is experienced (Akirav & Maroun, 2013). For example, heterotypic and homotypic stressors have different effects on memory consolidation processes. A homotypic stressor can occur daily such as a stressful job or stress in a relationship, versus a heterotypic stressor which is a novel stimulus. While homotypic stressors are linked to depression, repeated exposure can lead to habituation effects. Therefore, there is a difference in memory consolidation based on whether the context of the stress is homotypic or heterotypic (Akirav & Maroun, 2013).

Finally, research also shows that stress during memory retrieval can result in decreased performance (Wolf, 2009). For example, Wolf (2009) found that high stress and cortisol levels, independent of valence, blocked memory retrieval for a short time. This is relevant for the misinformation effect in two ways: besides being important for the final memory test, retrieval of the initial memory is also necessary for reconsolidation to happen during the introduction of misinformation.

While the literature suggests that arousal and its timing seem to have an impact on the memory for an event, many of the studies that have looked at emotion and the misinformation effect have failed to take this into account, leading to inconsistencies in the results (Bookbinder & Brainerd, 2016). For example, in a study done by Hoscheidt et al. (2014), researchers introduced the Trier Social Stress Task before the presentation of neutrally valenced images (the initial encoding of the slide show). While they found that the stress group had an overall better memory for the original images, they did not find a significant difference between groups in susceptibility to misinformation. In this case, the arousal carried through to the initial encoding condition leading to enhancement of this memory. This is in line with the research done by Tambini et al. (2017) in which a carry-over effect of arousal can enhance memory prospectively, and with the other research reviewed above.

In a more recent study by Nitschke et al. (2019), researchers introduced emotional arousal using a Trier Social Stress Test, as well as used cortisol to assess participants' level of arousal. Both studies used verbal misinformation and introduced the initial encoding images in the form of a slide show. However, unlike Hoscheidt et al. (2014), Nitschke et al. (2019)

introduced the stress test 10 minutes after the misinformation narrative was presented, during the reconsolidation phase. The results showed that individuals in the stress condition were less susceptible to misinformation than those in the control condition. The researchers interpreted these results by stating that the stress task disrupted the participants' reconsolidation process, leading to participants better remembering the original images over the narrative. However, this explanation contradicts many of the studies previously mentioned in this paper, which suggest that arousal benefits consolidation. One difficulty in drawing conclusions from the Nitschke et al. (2019) study is that for the stress group, their cortisol levels were high during both reconsolidation and during the final memory test. It is important to be able to make the distinction between whether the observed decrease in susceptibility to misinformation resulted from an interruption of the reconsolidation process or instead was due to the carryover of arousal into retrieval. While Nitschke et al. (2019) argued that the latter was not the case, previous literature suggests that arousal can disrupt the retrieval process (Wolf, 2009), and disruption in retrieval may have had more impact on the narrative than the slide show because the narrative was more recently encoded. Therefore, the inability to separate reconsolidation from retrieval in the Nitschke study is a significant limitation.

The purpose of the current study was to better understand the inconsistencies in the previous literature by manipulating the timing of arousal, so as to separate its effects on reconsolidation from those on retrieval. This was accomplished through a replication and extension of the study done by Nitschke et al. (2019), which separates the reconsolidation and retrieval phases by 24 hours. Participants self-selected into three separate conditions in which they performed an arousal task either during the reconsolidation period of the misinformation narrative (Day 1), before the retrieval of the information (Day 2), or not at all (control). In order to measure participants' sensitivity to misinformation, I used a d’ (d-prime) score. This score represents the ability to discriminate between a correct response (true information) and incorrect responses (misinformation). From this data, it would be concluded that higher scores on d’ indicate less susceptibility to misinformation, while lower scores indicate more susceptibility (Nitschke et al., 2019; Macmillan and Creelman, 2004).

Based on the previous literature, I tested two hypotheses. First, consistent with the conclusions of Nitschke et al. (2019) that arousal impairs the reconsolidation process, I expected that the group that receives the stressor during the reconsolidation period (Day 1) will be less susceptible to the misinformation than the group that receives the stressor at retrieval (Day 2). However, if instead, the authors were incorrect in their conclusions, and the carryover of arousal to the memory test affected participants’ susceptibility, I expect that the group that receives the stressor before the retrieval of the original information (Day 2) will be less susceptible to misinformation than the group that received the stressor during reconsolidation (Day 1).

Method

Due to the COVID-19 pandemic, I encountered many setbacks in creating and conducting this experiment. First, because I had switched to an online format, I was unable to use a Trier Social Stress Test as the arousal task, as it requires in-person testing with three individuals in the same room. Therefore, I opted for a similar arousal task that is more suited for an online format (see description below). Additionally, due to the nature of SONA, our online participant recruitment platform, I was unable to randomly assign participants to groups. Instead, I created three identical SONA postings and had participants self-select into conditions. This unfortunately led to unequal distribution of participants into those groups, a limitation that I discuss later on. Finally, due to high attrition rates, and a two week break in data collection due to a fire at the host server of Psychopy, I was unable to meet the power requirements specified below. I will instead discuss the data, as it stands so far with the expectation that I will continue more data collection in the Fall of 2021.

Participants

A statistical power analysis (Faul et al., 2007) indicated that a sample of at least 159 would be required to detect the main effects found in previous research (f = .25, α = .05, β = .2). Due to high attrition rates, of the 33 participants who completed the first day of the experiment, only 23 participants completed the memory test on day two. Dropout rates were equivalent across conditions, $\chi^2(2, N = 39) = 0.287$, $p = .886$. A 3 (Condition: Control vs. Recall vs. Reconsolidation) x 2 (Dropout: Stayed in vs. Dropped out) ANOVA was conducted to determine whether participants' stress levels (STAI scores on the first day) by condition affected the attrition rates. There were no significant main effects of group $F(2, 33)$= .540, p= .588, $\eta 2$ = .023, nor was there a significant interaction between group and dropout, $F(2, 33)$= 2.43, p=.103, $\eta 2$ =.106. There was a significant main effect of dropout, $F(1, 33)$= 7.20, p=.011, $\eta 2$ =.156, with higher STAI scores in the people who dropped out (M = 42.56, SD = 12.48) than in the people who completed the study (M = 34.87, SD = 13.80). Post hoc tests did not reveal any significant differences between conditions or dropout.

Of the remaining 23 participants, 20 identified as female, 18 identified as caucasian, 3 identified as Hispanic, and 2 identified as having two or more ethnicities. Participants were recruited through introductory psychology classes and received course credit for their participation. All participation was voluntary, and participants were assured that their decision to participate (or not participate) would in no way affect their academic, social, or professional standing at the school.

An IRB review found this study to be Exempt, indicating that this study poses minimal risk to participants (See Appendix A).

Apparatus and Materials

Software

The experiment was programmed and run through Psychopy, a Python based software program used to run and share psychological experiments online (Peirce et al., 2019). Each participant completed the experiment online via their own personal computer.

Slideshow

A total of 50 images were used in this study, all selected from Hess et al. (2012), and all images were shot at NC State. The slides depicted a scenario in which a man breaks into an office and steals money from the owner's purse. Once the man leaves, the office owner returns and discovers that her money is missing.

Misinformation Narrative

The misinformation narrative was based on the slide show described above. Each sentence depicted one slide, totaling in 50 narrative sentences, some of which contained misinformation. Thirty-six of the narrative sentences contained correct information from the original photos, while 14 sentences contained incorrect information, aka misinformation. Each sentence was written to describe the actions of the individual seen on camera, and small details were changed, such as the color of a jacket or type of flowers on the desk, in the misinformation sentences. All sentences were rated by naive undergraduate research assistants to assess the believability of the sentences (see Appendix B for the narrative sentences).

Distractor Tasks

At Time 1, participants were asked to complete multiple distractor tasks totalling in about 45 minutes. For the first set of tasks, participants were asked to complete a series of spatial reasoning tasks. These reasoning tasks lasted approximately 35 min. For the second set of tasks, participants completed two questionnaires. The first of which was a demographic questionnaire that asked participants about their age, gender, ethnicity, and educational background. The second questionnaire was the Short Form-36 Health Questionnaire (SF-36). This questionnaire assesses eight health concepts related to quality of life, such as general mental health, limitations in physical and social activity, and general health perceptions (Ware & Sherbourne, 1992). Each questionnaire lasted approximately five minutes, totaling in 10 minutes overall.

Arousal Task

Arousal was manipulated through a variation of the Montreal Imaging Stress Task (Dedovic et al., 2005). This task has been shown to significantly increase the secretion of cortisol compared to control groups, as well as shown similar levels of cortisol secretion when compared to other mental arithmetic stress tasks. When compared to the Trier Social Stress Task, however, the MIST showed a modest change in cortisol levels. Researchers explained this difference in magnitude between the two tests as a difference in the tests themselves, aka public speaking versus mental arithmetic (Dedovic et al., 2005).

This computerized test presented participants with a timed mental arithmetic task at varying levels of difficulty. Participants were asked to choose an answer ranging from 0 to 9 that can be selected using the numbered keys on the keyboard for each problem. Participants were then given text-based feedback after each question. Additionally, they saw a countdown timer of 20 seconds for each question at all times. Each individual run lasted approximately 2 to 7 minutes. On the days in which participants did not receive the stress condition, a similar, but easier set of questions was administered. For this test, participants had as much time as they needed to complete the questions and did not see a countdown timer. All math questions, for both conditions, were chosen from a free to use test website (Mathtests.com) and were rated by undergraduate research assistants for their level of difficulty (see Appendix C for test questions).

Manipulation Check

Manipulation checks of arousal were conducted using the State-Trait Anxiety Inventory (STAI-state), which was used by Hoscheidt et al. (2014), (Spielberger et al., 2004). This questionnaire consisted of 20 questions assessing participants' state level of anxiety. Some of the STAI State questions included items such as "I feel tense," or "I feel calm." Participants were asked to rate each item on a 4-point Likert scale, with responses ranging from from almost never to almost always. The measure has been shown to have high internal consistency, with coefficients ranging from .85 to .95, as well as high test-retest reliability, with a coefficient of .75 (Spielberger et al., 2004). Participants' total STAI scores were calculated for both days by adding up the responses for each participant, making sure to reverse score nine of the items.

Memory test

The memory test consisted of 14 multiple-choice questions about the original photos. Each question had three responses, one of which was correct (from the original event), while the other two choices were incorrect (either from the misinformation narrative, or a novel foil). See Appendix C for the memory test questions. Finally, to examine the idea that post-encoding arousal enhances item memory but not source memory, participants were asked to determine the source from which they remembered the information; from the picture only, narrative only, both, or guessed (Wang & Bukan, 2015).

Procedure

On Day one of this two-day experiment, participants self-selected into three groups; a reconsolidation arousal group (Day1), a retrieval arousal group (Day 2), and a control group through three SONA studies. Although participants self-selected into the groups, each of the three postings were labeled the same. The postings were labeled as The Impact of Stress on Memory, and had a .1, .2, or .3 at the end so that participants did not know which group they had selected into. Additionally, each experiment was presented in a different random order to participants each time they logged in, and the experiments were set up so that participants could only sign up for one of the three.

On the first day, after consenting to participation, all participants were asked to view and closely attend to the initial slide show. Each photo appeared for 3500 ms, one after another. Following a 35-minute distractor task, consistent with the procedure of Nitschke et al. (2019), participants were then asked to read through a narrative that describes the events shown in the initial photo presentation. Consistent with the methodology of Nischke et al. (2019), the narrative was presented in the form of 50 sentences, each shown individually for 20 s. Following another 10 minute period, after the narrative sentences were presented, the reconsolidation arousal group was given the arousal task while the remaining two groups completed an untimed but simpler math test that took approximately the same amount of time. Participants were then informed to return 24 h later for a memory test.

On the second day, participants returned to the experiment. The retrieval arousal group was then given the arousal task, while the reconsolidation arousal and control groups took a simpler test in place of this task. Finally, all groups were given the memory test for the original photos.

Planned Statistical Analysis

For this analysis, I used d' (from signal detection theory) to calculate participants' sensitivity to misinformation. In order to do this, I computed the raw scores from the memory test into two proportions; the proportion of how often participants answered the question correctly or based on the original images (hit rate), and the proportion of how often participants answered the question incorrectly or based off of the misinformation narrative (false alarm rate). These proportions were then converted into Z scores for each participant and subtracted from one another. The formula goes as follows, d'=Z(hit rate) - Z(false alarm rate). Based on signal detection theory literature, higher d' scores indicate a greater ability to discriminate between true information and misinformation (Nitschke et al., 2019). Once d' scores were calculated, I used one-way ANOVA to determine the effect of arousal timing and susceptibility to misinformation (d' scores). Additionally, I ran follow-up tests to determine if there were significant differences in susceptibility to misinformation among the three groups.

It is important to note that although my calculation of d' was based on Nitschke et al. (2019), it is not a true measure of d-prime. This is because I did not include misses or correct rejections in the multiple choice test. Additionally, and consistent with Nitschke et al. (2019), I counted all false alarms (including the novel foil) in the calculation of d'. Therefore, I also calculated the d' score for just the misinformation responses as well. This was done so that I would be able to compare between the two scores to determine if the false alarms are a result of misinformation or the novel foil.

Results

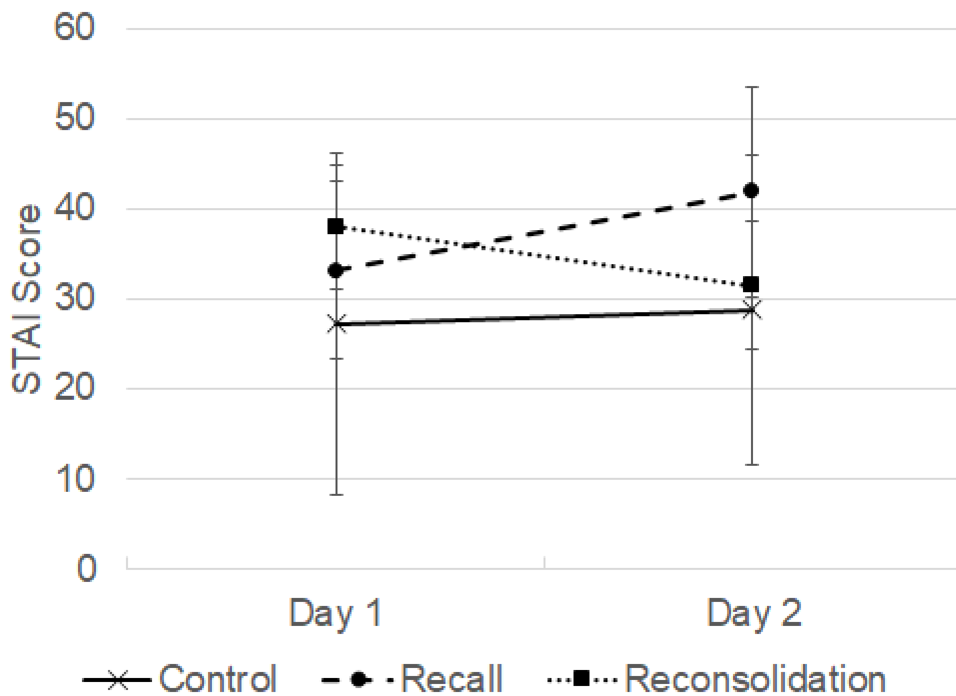
Manipulation Check

In order to determine if the arousal task was effective, participants in each group took the State-Trait Anxiety Inventory (STAI) twice; once following the arousal task and second following the no-arousal task on the other day. It was expected that at Time 1, the reconsolidation group would have been more stressed than the other two groups, while at Time 2, the retrieval group should have been more stressed than the other two groups.

The mean STAI scores for each condition and time point are presented in Figure 1; this graph depicts only those who completed the entire study. A 2 (Time Point: Day 1 vs. Day 2) x 3 (Condition: Reconsolidation vs. Retrieval vs. Control) mixed ANOVA was run on the STAI scores. The ANOVA indicated that there was no significant main effect of Time Point, $F(1, 20)= 0.142$, $p = .710$, $\eta^2 = .002$ or of Condition, $F(2, 20) = 0.743$, $p = .488$, $\eta^2 = .05$, indicating that in general stress did not differ between time points or among the groups. Most importantly, there was a trend toward the expected Time Point x Condition interaction, $F(2, 20) = 2.621$, $p =.098$, $\eta^2 = .056$.

Figure 1

Mean scores on the State-Trait Anxiety Inventory across both days. Error bars are 95% Confidence Intervals.



Follow-up planned directional t-tests were then conducted to compare STAI scores for (1) The Reconsolidation condition to the combined Control & Recall conditions on Day 1 and (2) The Recall condition to the combined Control & Reconsolidation conditions on Day 2. On day 1, the Reconsolidation group ($M = 38$, $SD = 12.69$) had higher STAI scores than other two groups combined ($M = 30.8$, $SD = 14.77$), though the result did not reach statistical significance, $t(21) = 1.257$, $p = .111$, $d = .529$. On Day 2, the Recall group had higher STAI scores than the other two groups combined, though again the result did not reach statistical significance, $t(21) = 1.664$, $p = .056$, $d = .79$.

To summarize, the results from the manipulation check, the data trended in the directions that were expected and participants seemed to be stressed on the appropriate days.

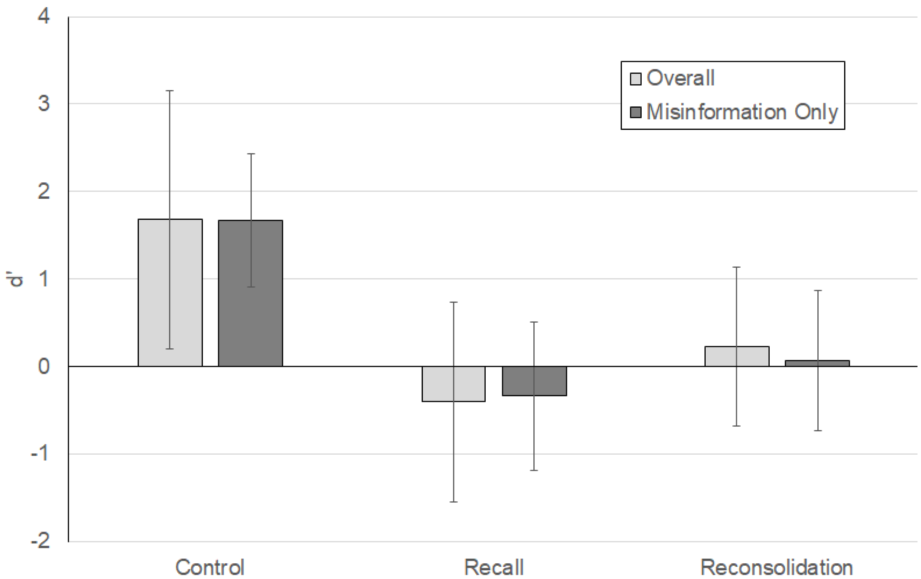
Memory Performance

To test the hypothesis that either the retrieval or reconsolidation groups would be more susceptible to misinformation than the control group, participants' d' scores were calculated using the hits and false alarms from the memory test. D-prime was calculated by subtracting the z-scores of the proportion of how often participants answered the questions correctly or based on the original images (hit rate), from the proportion of how often participants answered the question incorrectly or based on the misinformation narrative (false alarm rate). Two d' scores were calculated, an overall score that included the novel foil response as a false alarm, and a misinformation score that only included the misinformation answer as a false alarm. The former method was used by Nitschke et al. (2019), and was included to allow for direct comparisons to that study.

The mean d' scores for each type of calculation are presented in Figure 2. Two One-way ANOVAs were then conducted to compare differences d' scores among the retrieval, reconsolidation, and control conditions. Because of the small sample size, I followed each ANOVA with Bonferroni-corrected post-hoc tests comparing the conditions individually regardless of the overall ANOVA result.

Figure 2

Overall and Misinformation d' scores across all three groups. Error bars are 95% Confidence Intervals.



For the overall d', the ANOVA showed that the effect of the group did not reach statistical significance, $F(2, 20) = 2.104$, $p = .148$, $\eta 2 = .174$. The control group had higher d' scores than either the Recall, $t(18) = 3.03$, $p_{\text{bonf}} = .167$, or Reconsolidation groups, $t(9) = 5.90$, $p_{\text{bonf}} = .382$, but the differences were not statistically significant; nor was the difference between the Recall and Reconsolidation group, $t(18) = -.813$, $p_{\text{bonf}} = 1.00$.

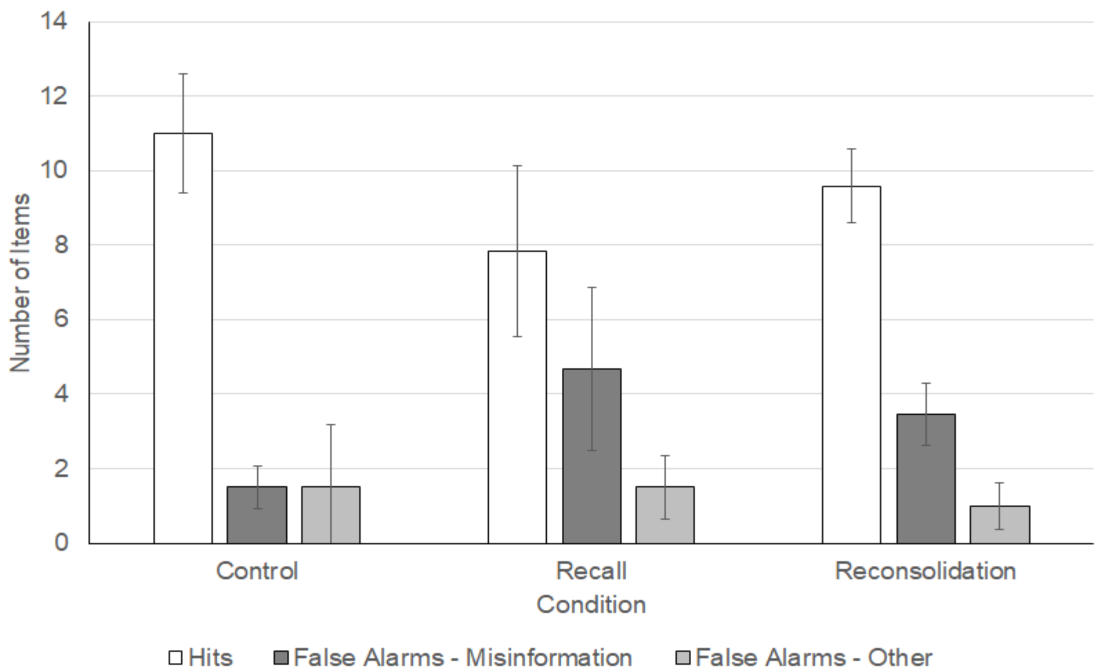
Another One-way ANOVA was then conducted for the d' misinformation score. The ANOVA also indicated that the effect of the group did not reach statistical significance, $F(2, 20) = 3.188$, $p = .063$, $\eta 2 = .242$. As before, the Control group had higher d' scores than either the Recall, $t(18) = 2.416$, $p_{\text{bonf}} = .076$, or Reconsolidation groups, $t(9) = 2.176$,

$p_{bonf} = .125$, but the differences were not statistically significant; nor was the difference between the Recall and Reconsolidation group, $t(18) = -.639$, $p_{bonf} = 1.00$.

To further illustrate the results of the memory test, I also examined the raw data. Figure 3 presents the number of hits, false alarms to misinformation and false alarms to the unpresented foils by each group. Next, I conducted a 3 (Response Type: Hit vs. FA-Misinform vs. FA-Other) x 3 (Group: Control vs. Recall vs. Reconsolidation) ANOVA on memory test responses. Because the sphericity assumption was violated, I used a Greenhouse-Geisser correction for the ANOVA. The ANOVA indicated a significant effect of Response Type, $F(1.545, 30.891) = 70.895$, $p < .001$, $\eta 2 = .736$, and a marginal Response Type x Condition interaction, $F(3.089, 30.89) = 2.721$, $p = .06$, $\eta 2 = .056$. Looking at the condition effects separately for each of the response types, there was a significant effect of Condition for False Alarms to misinformation, $F(2, 20) = 3.565$, $p = .047$, $\eta 2 = .263$; A marginal effect of Condition for Hits, $F(2, 20) = 2.856$, $p = .081$, $\eta 2 = .222$; and no effect of Condition for False alarms to unpresented foils, $F(2, 20) = 0.463$, $p = .636$, $\eta 2 = .044$. For the False Alarms to misinformation, the Control group significantly differed from the recall group, $t(9) = 2.669$, $p_{bonf} = .044$, but no other comparisons reached statistical significance ($p_{bonf} > .230$). For Hits, The difference between the Control and the Recall group was marginally significant, $t(9) = 2.338$, $p_{bonf} = .090$, but no other comparisons were statistically significant ($p_{bonf} > .346$).

Figure 3:

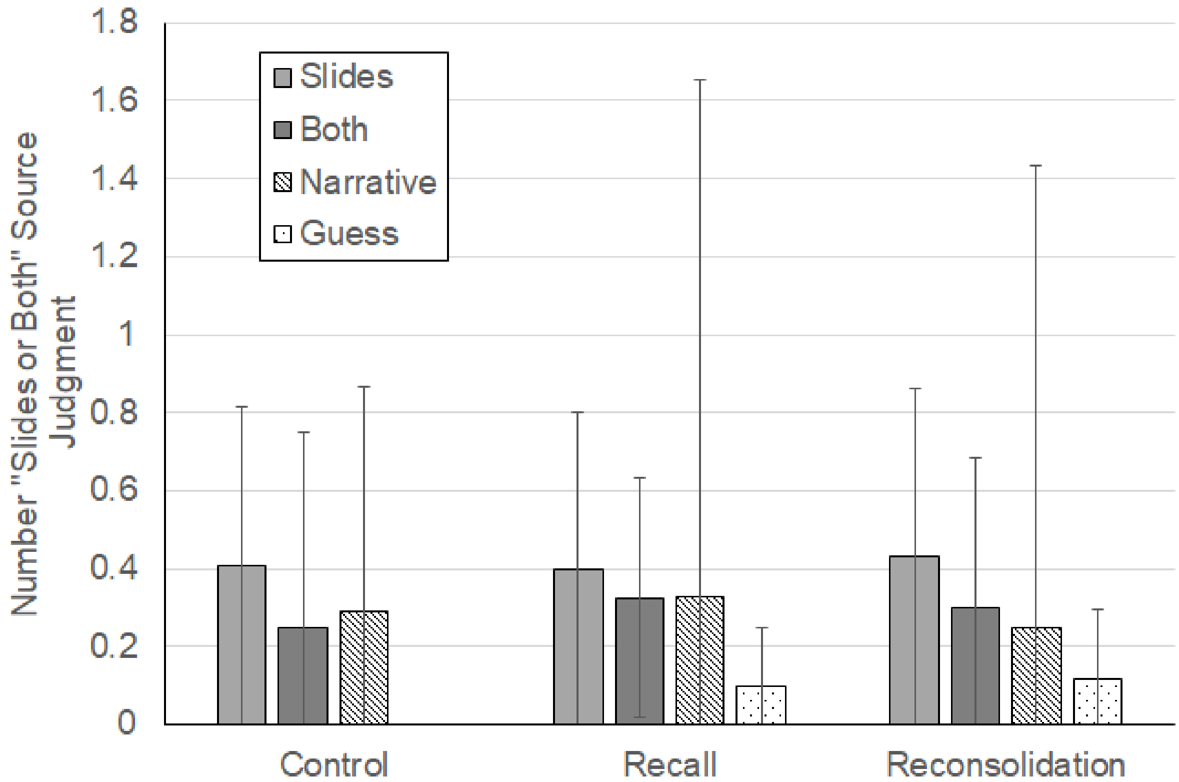
Descriptive plot for error type across the three experimental groups. Error bars are 95% Confidence Intervals.



Finally, Figure 4 shows the proportion of each type of source judgment as a proportion of participants' false alarms to misinformation. (That is - when a participant made a false alarm endorsing misinformation, what source did they indicate the information coming from). There do not appear to be any differences between groups in their source judgments for false alarms to misinformation.

Figure 4

Descriptive plot for source monitoring judgements across all three groups. Error bars are 95% Confidence Intervals



Discussion

In the present study, I attempted to replicate and extend the study done by Nitschke et al. (2019), focusing on arousal timing. To do this, a standard misinformation effect paradigm was used and an arousal task was added. Participants were separated into three groups where they performed an arousal task either during the reconsolidation period of the misinformation narrative (Day 1), before the retrieval of the information (Day 2), or not at all (control). Two competing hypotheses were tested in this experiment. Consistent with Nitschke et al. (2019)'s thesis that stress at reconsolidation reduces the misinformation effect, Hypothesis One predicted that the group that receives the stressor during the reconsolidation period (Day 1) should be less susceptible to the misinformation than the group that receives the stressor at retrieval (Day 2). Conversely, it was possible that Nitschke et al. (2019) were incorrect in their conclusions, and the carryover of arousal to the memory test affected participants' susceptibility to misinformation. Therefore, Hypothesis Two predicted that the group that receives the stressor before the retrieval of the original information (Day 2) should be less susceptible to misinformation than the group that received the stressor during reconsolidation (Day 1). Because of the unexpectedly small sample size, I was unable to adequately test between these two hypotheses. What is clear, however, was that I was not able to replicate the findings of Nitschke et al. (2019): participants in both of the stress conditions were more susceptible to misinformation than participants in the control condition.

Within the analyses, there was only one statistically significant effect. The repeated measures ANOVA examining whether response type differed among the groups indicated that there was a significant main effect of response type, such that hits were more common than false alarms of either type, and false alarms to misinformation were more common than false alarms to the unpresented foil. . While the rest of the analyses did not reveal any statistically significant effects, I did not meet the power requirements laid out at the beginning of the experiment. Therefore, I will be talking about the trends of the data so far with the expectation that further data collection will be conducted in the fall semester of 2021.

Both of the ANOVAs run on d' scores trend in the direction of the first hypothesis, indicating that those who received the arousal task during reconsolidation may be less susceptible to misinformation than those who received the task at retrieval. Even if this effect were to become statistically significant with more data collection, it is a relatively small effect (i.e., Cohen's d = 0.30 for the misinformation-only d'). However, and inconsistent with the Nitschke et al. (2019) findings, both groups that received the arousal task were more susceptible to misinformation than the control group (see Figure 2), with a much larger effect size (Cohen's *d* = 1.18 for control vs. reconsolidation, d = 2.10 for control vs. recall; for the misinformation-only d').

As mentioned earlier, many studies have indicated that the presence of arousal can enhance memory performance when introduced during consolidation but decrease memory performance when introduced at retrieval (Akirav & Maroun, 2013; Wolf, 2009). However, the results of Nitschke et al. (2019) seemed to contradict this. After introducing arousal ten minutes after the misinformation narrative was presented (during the reconsolidation phase) the memory test showed that individuals in the stress condition were less susceptible to the misinformation than those in the control condition. Based on these results, the authors suggested that the arousal task interrupted the reconsolidation process for the narrative sentences, meaning that participants' memories for the original images were enhanced thus leading to less susceptibility to the misinformation. The current study, however, seems to align better with past research, indicating that stress introduced after misinformation is presented increases the susceptibility to the misinformation, whether that stress was introduced during reconsolidation or retrieval.

What is especially interesting is that the retrieval group actually had a negative d' score. This means that those who received the stress task at retrieval were roughly equally likely to choose the wrong answer as they were to choose the correct response (See Figure 3). However, the reconsolidation group had more hits than false alarms. This could indicate that the reconsolidation group is recalling both true and false memories while the retrieval group is not remembering the true memories at all. That is, the reconsolidation group's false memories may be driven by a source memory error (recalling both slides and narratives, and not being able to discriminate between them), while the recall group's false memories may be driven by a more broad retrieval failure. If this result holds with more data collection, it could indicate the presence of different mechanisms at retrieval versus reconsolidation. One way of conceptualizing this is that someone who is stressed while studying but calm while taking a test would show a susceptibility to misinformation, as would someone who is calm while studying but stressed while taking the test. While the end result is the same (a misinformation error) it may come about through different mechanisms. Although the source memory test did not indicate significant differences between groups in their source judgments, future research could employ a more sensitive source test to investigate different possible mechanisms.

Along with the main analysis, manipulation checks were also conducted to determine if participants were sufficiently aroused on the appropriate days. I expected that those in the reconsolidation group would be more stressed on Day 1 than Day 2, the retrieval group would be more stressed on Day 2 than Day 1, and the control group would be equally stressed across both days. These manipulation checks were not significant, however, on average the data trended in the directions that were expected (see Figure 1 above). The relatively small effect of the stress manipulation, however, may explain why my results differed from Nitschke et al. (2019). As mentioned earlier, due to the COVID-19 pandemic, I was unable to use the Trier Social Stress Task (TSST) so I instead opted for a similar stress task more suited for an online format. The Montreal Imaging Stress Task (MIST), however, has been shown to have a moderately arousing effect when compared to the TSST. One analysis that Nitschke et al. (2019) ran was a correlation between participants' cortisol levels and their d' scores. What they observed was a curvilinear relationship between the two. What this means is that both at lower and higher levels of cortisol, participants' d' scores were fairly high meaning they were less susceptible to misinformation, while at moderate levels of cortisol participants' d' scores were lower. It is entirely possible that lower d' scores were seen because I used a moderately arousing test, such as the MIST, rather than a more stressful test such as the TSST.

Creating and conducting an experiment during a pandemic comes with a long list of setbacks, some of which have led to the limitations of this study. The first, and most obvious limitation is the high attrition rates. Due to the nature of an intensive two-day study, some attrition was expected, however, the number of people who did not complete the second day of the experiment was unexpected. This, along with a two-week break in data collection due to a host server fire at Psychopy, resulted in only having about 23 of the 159 participants needed to meet the power requirements set at the beginning of this experiment. Meaning this study is underpowered and conclusions are severely limited until a larger sample is collected. Although dropout did not differ across conditions, the people who dropped out had higher STAI scores than those who stayed in.

The next limitation that may have influenced the results of this study is the random assignment of participants, or more specifically lack thereof. When translating the experiment to an online format it was determined that random assignment to groups would be difficult to accomplish online. Therefore, I opted to have participants self-select into one of the three groups with three separate SONA experiments. All of the SONA postings were the same and excluded those who had already signed up for one of the other sections. Even though I attempted to minimize the confounds that arise with a non-random sample, this decision could have also contributed to the unequal distribution of participants into groups. While a lack of random assignment may compromise internal validity, there is little reason to believe it played a major role in the current findings. In particular, as both dropout and STAI scores did not differ across conditions, there does not appear to be major selection effects going on.

Even though most of the results failed to reach statistical significance, there are still real-world implications that can be discussed. The first of which is the pandemic itself. From the very beginning of the Covid-19 crisis, misinformation about the virus and its effects were rampant on social media websites such as Facebook, Twitter, and Instagram. While the misinformation effect has shown that people can be susceptible to misinformation, the research on how this effect is impacted by stress or arousal has been largely inconsistent. In a pandemic, where we all were a little stressed, it becomes important to understand how this arousal affects susceptibility to misinformation. From these preliminary results, it can be concluded that arousal produced by stress may increase susceptibility to misinformation. Knowing what those variable effects are, could help to inform people better on how they process information in times of stress. Studies have shown that when participants are aware that misinformation may be present, they are less susceptible to incorporating that misinformation into their memory (Greene et al., 1982). It is unclear from the current study if arousal confounds this effect, but just knowing how arousal affects this susceptibility may be able to help individuals to be aware of when they are learning information and how their stress levels may affect that learning.

It is also important to note that during a pandemic, participants may already have elevated stress levels on top of the arousal that was induced, which could influence the results much differently than other studies. One reason for this could be the different types of stressors participants are exposed to. Differences in stressors can have variable effects on individuals. For example a heterotypic, or a novel stressor, will affect an individual's memory differently than a homotypic stressor, or stress that occurs on a daily basis and can be habituated to (Akirav &

Maroun, 2013). The stress induced during this experiment and in studies such as Nitschke et al. (2019) is mostly likely a heterotypic stressor, as people do not usually take timed math tests on a daily basis. However, results may differ than previous studies because daily stress induced by a pandemic is more likely to be a homotypic stressor. Therefore, the combination of these two stressors may have novel effects on participants susceptibility to misinformation. Further data collection and research would be needed to determine if this is the case, but by comparing the d' scores from this study to that of Nitschke et al. (2019), a study in which participants presumably were not experiencing both types of stress at the same time, can give a rough idea of what this might mean. Nitschke et al. (2019) reported that their stress group had a mean d' score of 1.87. This, compared to the very low d' scores that were shown in both of the stress groups in this study, indicate that participants in the present study may be experiencing more than just the acute stress induced during the study. With data collection to be continued in the fall, this combination of stressors may not be present, as the pandemic has begun to wind down. It will be interesting to observe participants' stress levels and d' scores to determine if there are any differences from this pilot study.

Overall, while this study is underpowered and strong conclusions cannot be made until a larger sample is collected, there are a few main points that can be taken from this study. Most importantly, it was determined that the timing of when arousal is introduced might affect an individual's susceptibility to misinformation, such that if arousal is introduced after misinformation is presented (regardless of whether it is introduced at reconsolidation or retrieval) participants may be more susceptible to misinformation. This is important to further understand as it could suggest the presence of different memory mechanisms for reconsolidation and retrieval. Additionally, even though hypothesis one was tentatively supported, the results of

Nitschke et al. (2019) were not supported, in that the reconsolidation group was more susceptible to misinformation than the control group. In the future, further research will be conducted to look deeper into these phenomena.

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Appendix A

IRB

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Psychology
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From: Nat Krancus, IRB Administrator
Date: 9/24/2020
RE: Notice of Exempt Research Determination

STUDY #: 21-0034
STUDY TITLE: Impact of Stress on Memory

Exemption Category: 3.Benign Behavioral Intervention

This study involves no more than minimal risks and meets the exemption category or categories cited above. In accordance with the 2018 federal regulations regarding research with human subjects [45 CFR 46.101(b)] and University policy and procedures, the research activities described in the study materials are exempt from IRB review. If this study was previously reviewed as non-exempt research under the pre-2018 federal regulations regarding research with human subjects, the Office of Research Protections staff reviewed the annual renewal and the initial application and determined that this research is now exempt from 45 CFR 46.101(b) and thus IRB review.

Appendix B

Misinformation Narrative Sentences

S1: A scene of an office, a vase of lilies sits on the desk next to the computer
S2: A woman with brown hair and a tan jacket opens the door to the office.
S3: The woman enters the office and closes the door behind her
S4: The woman walks past the blue box by the door towards the desk
S5: Once she reaches the desk, the woman places her coffee mug next to the keyboard
S6: She then opens the bottom right drawer of her desk
S7: The woman places her purse in the open desk drawer
S8: The woman begins to take off her jacket
S9: The woman then hangs her jacket on the back of the door
S10: Back at the desk, the woman pulls the chair out to sit down
S11: The woman then turns the computer on
S12: While sitting at her desk, she begins to write on a piece of paper
S13: She picks up her coffee mug
S14: The woman takes a drink from her red coffee mug
S15: After placing the mug back, the woman turns her attention to the computer
S16: She then picks up a file

S17: The woman begins to look through the file
S18: The woman picks up her phone to check the time
S19: After checking the time the woman picks up the manilla folder
S20: She then stands up and pushes her chair back into the desk
S21: The woman walks past the desk towards the door
S22: She opens the door
S23: The woman leaves the office
S24: The woman leaves the office door cracked open
S25: Once the woman has left, a man's head pokes through the open office door
S26: A man wearing a backpack enters the room and checks the hallway behind him
S27: He then closes the door behind him and looks around the room
S28: The man then begins to riffle through the woman's tan coat
S29: He looks in the pocket of the jacket but finds nothing.
S30: The man then grabs the calendar that is on the wall
S31: He then checks both the front and the back of what he is holding
S32: After finding nothing to steal man places what he is holding back on the wall
S33: The man then opens the top office drawer on the right and riffles through papers
S34: He opens the bottom office drawer and finds the woman's purse
S35: The man picks up the purse and places it on the table next to the desk
S36: The man begins to look through the contents of the purse
S37: He pulls out a wallet from the purse
S38: The man pulls out a few bills from the wallet
S39: He then places the wallet back into the purse
S40: The man leaves the purse behind and walks around the desk
S41: As he walks towards the door, the man puts the money in his back pocket
S42: The man continues walking towards the office door
S43: Before leaving the office, the man peaks his head out the door
S44: The man then closes the door behind him
S45:The woman walks back into her office carrying a briefcase
S46: The woman closes the door behind her and looks at her purse sitting out
S47: She grabs her wallet and looks inside with a shocked look on her face
S48: The woman looks through the other pockets of her wallet
S49: The woman flips the wallet upside down and a single dollar falls out
S50: Finally, she looks back into the empty wallet

Appendix C

Memory Test Questionnaire

Q1: What type of flowers were on the office desk?

a. Roses
b. Lilies
c. Sunflowers

Q2: What color was the box next to the door?

a. Orange
b. Blue
c. Green

Q3: Where did the woman hang her coat?

a. The coat hanger
b. The back of the door
c. The back of her chair

Q4: What was the color of the coffee mug the woman drank from?

a. White
b. Red
c. Blue

Q5: What did the woman use to check the time?

a. Her watch
b. Her cellphone
c. The computer screen

Q6: What did the man grab from the wall to look for money?

a. A picture frame
b. A wall calendar
c. A poster

Q7: After stealing the money, where did the man put the wallet?

a. On the desk
b. Back in the purse
c. In the file cabinet

Q8: What was the woman carrying when she returned to the office?

a. A manilla folder
b. A briefcase
c. Nothing

Q9: What does the man do with the object he takes from the wall?

a. Places it on the desk
b. Places it back on the wall
c. Takes it

Q10: Where did the man put the money that he stole?

a. In his front pocket
b. In his back pocket
c. In his own wallet

Q11: What falls out of the woman's wallet when she turns it over?

a. A business card
b. A single dollar
c. A photo

Q12: What task did the woman perform at her desk?

a. Used the computer
b. Wrote on a piece of paper
c. Answer her office phone

Q13: Where did the man place the purse before rummaging through it?

a. On the desk
b. On the table next to the desk
c. On top of the filing cabinet

Q14: How was the door left when the woman exited the office?

a. Closed shut
b. Cracked open
c. Wide-open

Appendix D

Math Questions

Arousal:

Question	Correct answer
1. If x=5, what is the value of (2x+8)/3	6
2. If 2x=12 What is the value of x?	6
3. 12-____= 5	7
4. If 3x-7=17 what is the value of x	8
5. Work out (7x5)-(8x4)=	3
6. If 7(x-2)=3x-2 what is the value of x	3
7. What is the mean of 13,7,8, and 4?	8
8. 4x7=30-___	2
9. Find 2/9 of 26	8
10. What is the remainder when 32 is divided by 7?	4
11. Find the mean of 6.1, 1.3, 2.5, and 2.1	3
12. 42/6=	7
13. What is ⅓ of 21?	7
14. What is the mean of 6, 7, and 2	5
15. 48/(15-9)	8
16. 56=50+___	6
17. How many groups of 3 make 15?	5
18. 18-15	3
19. What is ¼ of 20?	5

No Arousal

Question	Correct answer
1. 3+6	9
2. 8 - 5	3
3. 20 +___ =26	6
4. Half of 10	5
5. 6+___= 11	5
6. 13 - 4	9
7. What is ½ of 8	4
8. 5+7=10+___	2
9. 4+4+4+4+4=4x__	5
10. How many 3s make 12	4
11. Double 6=10+__	2
12. 100+70+__=179	9
13. 5+3=2x__	4
14. I have 12 socks, how many pairs can I make?	6
15. How many 50s make 200?	4
16. 10+6=8+__	8
17. 15-___=9	6
18. How many 5s make 40?	8
19. Find the difference between 2 fives and 3 threes	1

Vita

Celia Caroline Whisman was born in Norfolk VA, to Bobbi and Kevin Whisman. She graduated from South River High School in 2016. The following August, she entered the College of Charleston to study Psychology, and in May 2019 she was awarded a Bachelor of Science degree. In the fall of 2019, she accepted a research assistantship for Experimental Psychology and began study toward a Master of Arts degree. She will be awarded the M.A. in July 2021.

Celia has been a member of the Psychonomic Society since 2020 and plans to continue her career in Psychology as a research assistant in the fall.