PHYSICAL AND EMOTIONAL AROUSAL AND THEIR EFFECTS ON RETROACTIVE MEMORY ENHANCEMENT: GENDER MATTERS

by

Edgar Alexander Petras

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Approved: ______________________________
Steven B. Most, Ph. D.
Professor in charge of thesis on behalf of the Advisory Committee

Approved: ______________________________
Richard W. Hass, Ph. D.
Committee member from the Department of Psychology

Approved: ______________________________
Christine Ohannessian, Ph. D.
Committee member from the Board of Senior Thesis Readers

Approved: ______________________________
Michael Arnold, Ph.D.
Director, University Honors Program

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ABSTRACT

There is evidence that emotional events hold a special place in memory and may affect consolidation of neutral events that surround it. This effect has shown to be both an inhibiting factor for neutral events that precede emotional ones, and, more recently, an enhancing factor for those events. This effect has been coined retroactive memory enhancement (RME). In addition, it has been shown that physical arousal also plays a similar part in memory. In order to try to mesh these findings, the current study examined the effect that physical arousal has on memories formed prior to exercise by having subjects associate names with shapes and undergo moderate exercise. Memory was assessed after a 24 hour delay. Though no main effects were seen, a significant correlation between change in heart rate during exercise and scores on the memory test arose. In a follow up experiment studying the effect of emotional stimuli on RME, the same gender differences arose, with females appearing to be more susceptible to the effects of emotional manipulation.

Chapter 1

INTRODUCTION

Anyone who has had a child, suffered the loss of parent, or even heard major national news such as the assassination of John F. Kennedy or the September 11th attacks can attest that emotional events have strong consequences on one's memory. It is clear that memory for the actual emotional event will be heightened, but less is known about the mundane and neutral events that surround emotional ones. Though memory for the event is heightened, the reverse has been true for surrounding facts and details. Previous work indicates that emotional arousal demands attentional resources and hinder memory for neutral items surrounding the event (Schmidt, 2002; Bornstein, Liebel, & Scarberry, 1998).

Recently, contradictory evidence has been found pertaining to these surrounding events. Anderson, et al. (2006) found, while conducting experiments on how post-encoding arousal affects memory, an effect they coined retroactive memory enhancement (RME). Participants were presented with neutral stimuli followed by either self-reported emotionally arousing or neutral stimuli. One week later they were tested on whether or not they recognized images from the first phase of testing. Participants demonstrated stronger memories for neutral test events that had been followed by emotional stimuli, but only when that emotional stimuli were presented at a delay onset of 4 seconds and not 9 seconds. These findings indicate that some biological process induced by emotional arousal positively affects memory consolidation immediately after a stimuli is learned.

Knight and Mather (2009) replicated findings of RME, and found that level of arousal or activation played an important role in determining whether emotional events or stimuli would enhance or inhibit memory for neutral items surrounding the event. Researchers inserted an emotionally-variable (oddball) item into a list of everyday items, and manipulated attentional weight, or the amount of primary attention that a particular stimulus is given, by having one group of participants freely recall each list of items immediately after it appeared. They concluded that the items recalled must have been given higher attentional resources than other members of the list, and found a stronger enhancement of these items a week later. Many other studies have linked emotion to memory as well (Nielseon, et. al., 1996; Nielson, et. al., 2005; Nielson & Powless, 2007).

Strong emotional arousal can be witnessed in a number of different physiological ways, such as skin conductance, heart rate, and pupillary changes (Bradley, Miccoli, Escrig, & Lang, 2008). Some of these same physiological responses, among others, are also observed while participants take part in physical exercise as well. Memory and physical exercise have long been linked, with several different studies demonstrating the ability for exercise to affect what one can recall (e.g. Schmidt-Kassow, et. al., 2010). A study conducted with college age and elderly adults had participants squeeze a hand dynamometer during consolidation and initial recall of material. All subject groups, except for one, showed significant enhancement on a long-term recognition test for trials in which they were squeezing the dynamometer (Neilson & Jensen, 1994). This effect was not seen for elderly participants who were taking beta-adrenergic blockers for medical reasons, indicating that adrenaline and other stress hormones play a critical role in the consolidation of long-term memories.

This same effect was also found when physical exercise occurred during learning (Schmidt-Kassow, et. al., 2010). German participants were tasked with learning French vocabulary words through headphones. Groups were divided into exercise and inactive groups, and for 9 sessions spanning 3 weeks listened to the German-French word pairings while either exercising on a spin bike, or sitting at a table. Active participants performed better than their inactive counterparts on each of the 3 vocabulary tests that were administered. In addition, Winter et. al. (2007) provided evidence that participants that took part in high-intensity sprints prior to vocabulary learning performed better than low-intensity or sedentary participants. This vocabulary retention effect was seen on both a 1-week delay and after 8 or more months.

There is also strong evidence for a link between the adrenal catecholamine system, a biological system that secrets epinephrine and norepinephrine and responds to both physical and emotional arousal, and consolidation of memory. In addition to the beta-blocker effects demonstrated in the hand-dynamometer study, Hurlemann et al. (2005) also demonstrated a link between the pharmaceutical manipulation of the norepinephrine system and memory. Their study supported a link between retrograde enhancement and ß-adrenergic receptors, but only with emotionally positive targets. Participants given ß-adrenergic reuptake inhibitors, thereby increasing the amount of adrenaline other adrenergic chemicals in the brain, scored better on recall experiments, but only for neutral stimuli immediately preceding positive oddball images.

It is easy to see the evidence that both emotional and physical arousal, while fundamentally different, can produce some of the same physiological and behavioral effects on participants. With these links relatively well established, we believe it is important to investigate RME, a phenomenon that has been produced solely in the realm of emotional arousal, with physical arousal. Further research with this physical arousal-RME link, and exercise and memory in general, could have an important impact on education, specifically on recess and physical education in primary schooling.

Chapter 2

EXPERIMENT 1

Participants

Seventy-two University of Delaware undergraduates (31 male and 41 female) at the University of Delaware participated in the experiment for class credit. All participants provided informed consent and the experiment was approved by the University of Delaware Human Subjects Review Board.

Materials and Methods

Participants were run through the experiment twice, once on each condition, with testing phases separated by one week. Demographic data, including age, gender, and ethnicity were collected, as well as whether or not English was the participants' first language. After reading instructions detailing the experiment, all participants viewed a short video showing 15 unique black shapes on a white background, paired with a common male name. Each shape measured 250 pixels square and was presented on a 19-in CRT monitor with a resolution of 1040 x 768 pixels, making each shape 3.375 inches square. Each shape appeared with a male name (i.e. Mark, Stephen, John) directly below it, written in 48 pt. font. For learning, each shape-name combination was presented 5 times for 4 seconds each in a random order. Two groups of ten different shape-name combinations were used, with one group shown to every participant during their week 1 visit, and the other group shown on week 2 visits. Shapes were randomly assigned to week 1 or week 2 groups, and shape-name pairs were also randomized at the start of the experiment, and held constant for each participant.

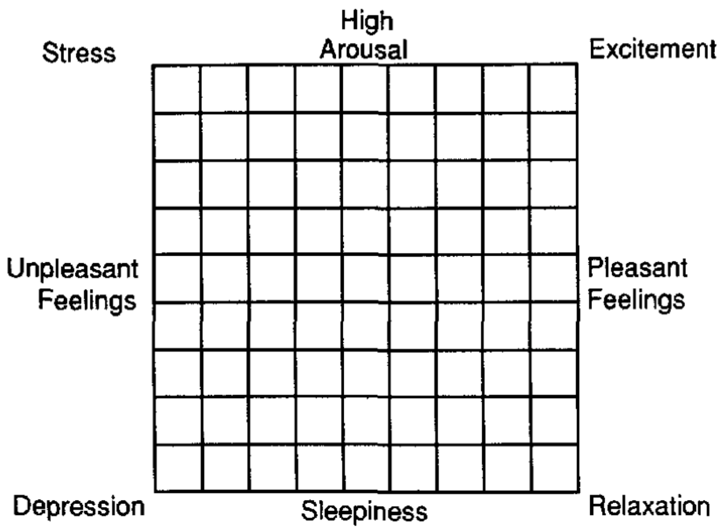

Figure 1 The Affect Grid, developed by Russell et al. (1989) and meant to be a one-shot measure of one's current arousal (y-axis) and valence (x-axis).

After this learning phase, participants were presented with an Affect Grid, a single item measure developed to quickly assess two different dimension of current affect: pleasure-displeasure and arousal-sleepiness (Russell et al. 1989). The affect grid has shown to be a good measure of mood, and in the past has been used as a manipulation check in multiple mood-induction experiments. The measure presented is a 9 x 9 grid on which each participant is to place a single mark indicating his or her current score on each of these indexes separately. See Figure 1 for an example of an Affect Grid. Detailed instructions for the grid were included before the learning phase.

A finger pulse-oximeter was used to obtain each participants heart rate following the affect grid and before they participated in one of two conditions.

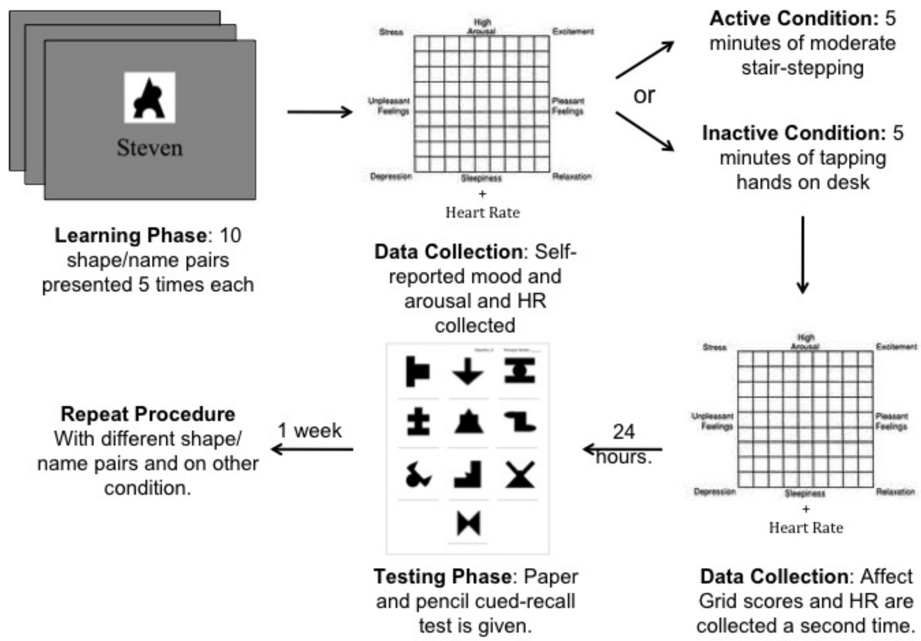

Figure 2	A flow chart of experiment 1. Please note that participants took part in both conditions, separated by a delay of 1 week. Which condition was completed first was randomized

The active condition participants were brought to a small back room with a desk, chair, and a 6-inch high stair-stepper and instructed to step on and off the stair-stepper for 5 minutes. They were not instructed to count their steps, but were told to go fast enough to “get your heart-rate up.” Following the five-minutes of stair stepping, participants heart rate and affect grid ratings were collected again, and the participant was dismissed. 24 hours later, participants returned and were presented with a paper and pencil quiz, asking them to fill in the names recalled when presented with the shapes from the previous day. See Figure 2 for a graphical representation of the procedure.

The passive control condition was identical in every way, but instead of stair stepping for 5 minutes, participants were brought to the same room, and instructed to sit at the desk and tap their hands back and forth on the desk for 5 minutes. Which condition each participant did during their week 1 visit was randomized.

Results

Due to the high number of visits required, a total of 15 males and 10 females did not complete all 4 days of experimentation. Only those that had complete data were analyzed, leaving a total of 16 males and 31 females.

By using self-reported changes in valence and arousal as well as change in heart rate during the assigned task, we were able to collect manipulation check data that supported our dependant variable. The mean change in self-reported arousal for the stepping condition was 2.28 ($SD = 1.81$) while the same measure for the tapping condition was -0.11 ($SD = 1.81$, $t(46) = -6.22$, $p < 0.001$). Furthermore, average change in heart rate for the stepping condition was 38.12 beats per minute ($SD = 20.1$), and the same measure for the tapping condition was 5.49 beats per minute ($SD = 15.3$, $t(46) = 9.128$, $p < 0.001$).

The average score on our test following the physical arousal condition was 9.1 ($SD = 4.0$), while the control (tapping) score average was 8.9 ($SD = 4.2$, t(46) = 0.342, $p = 0.734$). There is no main effect for gender, as has been seen in the past with arousal experiments and memory. Men (Tapping: $M = 9.68$, $SD = 4.08$; Stepping: $M = 9.125$, $SD = 4.15$, $t(15) = -0.712$, p = 0.49) and women (Tapping: $M = 8.55$, $SD = 4.25$; Stepping: $M = 9.10$, $SD = 3.92$, $t(30) = 0.867$, p = 0.39) showed no significant differences in scores. Pearson correlations were run between the change in heart rate during the stepping condition and score on the test. These showed a small, yet statistically not significant correlation ($r = 0 .22$, $p = 0.13$). Looking between genders however, an interesting trend is seen. Men's correlation between change in heart rate and score on the test after the stepping condition ($r = -0.058$, $p = 0.83$) and tapping and tapping condition (r = -0.054, $p = 0.84$) are not existent. Meanwhile, females scores on both the stepping ($r = 0.34$, $p = 0.06$) and tapping ($r = 0.23$, $p = 0.21$) show moderate, yet insignificant trends. Including four females who did not complete the study, but did fully complete the stepping condition, we do see a significant correlation between their score following the stepping exercise and the change in heart rate during the exercise ($n = 35$, $r = 0.34$, $p = 0.049$). Also, when running the same correlation on only females who completed the study, and including scores and heart rate changes from both experimental conditions another significant trend arose ($n = 62$, $r = 0.26$, $p = 0.041$). In order to be confident that all tests ran were valid, a Shapiro-Wilk test of normality was run, and results indicated that our distribution of both scores after stepping and change in heart rate during the stepping exercise were normally distributed.

Identical evaluations were run between males' and females' scores and their self-reported change in arousal and valence scores on the affect grid. Neither males nor females showed a significant correlation between their scores in the stepping condition and their self-reported change in arousal (Males: $r = 0.17$, $p = 0.54$, Females: $r = 0.18$, $p = 0.33$). More disparate statistics were seen in correlations between scores during the tapping condition and self-reported change in valence, or mood (Males: $r = -0.12$, $p = 0.67$, Females: $r = .27$, $p = 0.15$). Change in heart rate and self-reported change in arousal across both conditions were moderately and significantly correlated (Males: $r = 0.49$, $p < 0.005$; Females: $r = 0.47$, $p < 0.001$). Change in self-reported valence measures and scores, both within and across conditions proved to insignificant as well.

Discussion

Participants showed significant arousal in physiological measures through heart rate and through the self-report affect grid. Though no main effects for differences between the two conditions arose, there are several correlations that are promising for further research.

First, it is important to note that the affect grid proved to be an accurate measure of participants' arousal, as the changes in self-reported arousal and changes in heart rate were correlated to each other. In addition, my manipulation checks also returned positively, as the differences in means between both conditions were significant and trended in a way such that the active condition increased heart rate and self-reported arousal, and the inactive control condition did not increase nor decrease either measure.

Though there were no exhibited group differences between our active and inactive condition, it does appear that change in heart rate, both during the stepping task and during the inactive sitting task, correlates with better scores on the cued-recall test after a 24 hour delay, but only for female participants. This finding is consistent with what Kilpatrick et al. (2006) and others regarding the difference in amygdala form and function differences between the sexes. It appears that there is a lateral difference between men and women and amygdala activation, which deals with emotion, and subsequently memory consolidation. This effect has been shown in several emotion-manipulation studies, but rarely, if ever, in a physical arousal and memory study.

Additionally, it has been shown that females have higher and more sensitive responses to other physiological measures of emotional data, such as startle reflex, heart rate deceleration, and certain ERP measures (Bianchin & Angrilli, 2012). Though this has not been shown as physiological side effects to physical exercise, it is important to note that there are many behavioral and biological gender differences that could account for the difference observed, but more work is needed to tease out exactly which mechanisms are involved.

One possible explanations for our lack of correlations regarding males, and also the lack of mean differences between groups could the inability for us to manipulate or measure the level of attentional resources given to each face-name combination. It is evident in prior research (Knight & Mather, 2009) that only those stimuli that are given higher attentional weight, as indicated by immediate recalling the list items, are subject to retroactive enhancement.

Chapter 3

EXPERIMENT 2

Introduction

In an effort to observe more broad RME effects in males and females under the conditions established in experiment 1 we chose to manipulate emotional arousal as opposed to physical arousal. This methodology is closer to previous work on emotional retroactive enhancement of memory (Cahill & McGaugh, 1995), and serves to establish that retroactive effects are present under our delayed cued recall test, and also further explore the gender differences seen in experiment 1.

In designing experiment 2, we decided to use both positive and negative mood inductions, since level of arousal, specifically physiological arousal, may be affected differently under the two different conditions. Hurlemann et al. (2005) found that memory for neutral stimuli preceding emotionally-negative oddball stimuli was worse than when preceding positive stimuli.

A study by Nielson and Powless (2007) administered word lists to be memorized by participants who then watched a video clip of a comedy or of surgery. Participants were assigned to various movie delay times, ranging from immediate to 45 minutes after learning concluded. Their results clearly showed that those participants who watched either emotional video clip, positive or negative, had better recall than control groups for delays up to 30 minutes. Negative images are often exclusively used in other emotional manipulation studies, but we felt that recent experiments offer significant evidence to support the use of both positive and negative emotional manipulation.

In addition to our emotional manipulation, experiment 2 uses faces as opposed to the simple black and white shapes that were the main stimuli in experiment 1. The special nature of faces is well documented (see Bruce & Young, 1986) and using faces in the place of shapes may make many trends and results more sensitive to manipulation.

The type of memory studied in experiment 1 could have also led to our lack of significant main effects, as we used a cued recall memory with a paired association task. In order to better understand memory type and its interaction with retroactive memory enhancement, experiment 2 uses recognition memory in addition to cued recall memory. We designed our test this way in order to understand how arousal may affect the two different memory systems.

Experiment 2 also aimed to increase attentional resources given to each stimuli by replacing shapes with faces and by testing participants immediately after the initial learning activity. It appears that the attentional weight, or the amount of attention subjects' pay to a particular stimulus, at the time of encoding is critical to seeing emotional effects. I've hypothesized that those names that are remembered immediately after the learning task are those that had high attentional weights for that subject, and are expecting only those names that are remembered immediately after the learning phase to be subject to memory enhancement.

Participants

120 (61 female and 59 male, Mean Age = 19.6) University of Delaware undergraduate students took part for class credit. All subjects provided consent, and the Human Subjects Review Board approved the study.

Materials and Methods

After given instructions, participants were led into a computer room with 19" CRT monitors. Upon the participants keystroke, a short movie showing 10 different faces measuring 3.5 inches by 4 inches obtained from the Karolinska Directed Emotional Faces (KDEF) database, paired with common male names (similar to Experiment 1) were shown 5 times each, for 4 seconds in a random order (See Figure #). Immediately following, participants were presented with an on-screen affect grid identical to the one used in Experiment 1, and used the mouse to select one square on the grid. Following a keystroke by the participant, one of three videos was then played.

The positive emotional condition movie was a 2:33 clip from the Movie *Stepbrothers* and was found to increase both arousal and valence in pilot testing out of a number of video clips. The neutral video was a 2:33 clip from Woody Allen's *Hannah and Her Sisters* and was found to be neither positively nor negatively arousing in the same pilot study, and was matched for time to the *Stepbrothers* clip. The negative (fear) condition was a 2:11 second clip from the movie *The Blair Witch Project*. Participants saw only one of the clips, and only took part in one condition.

Immediately following the movie clip, participants were again presented with an on-screen affect grid, then proceeded to the testing phase, which was also on the computer. During this phase, each participant was presented with a face, and instructed to hit the Y key if they recognized the face from the learning phase, or an N key if they did not. If the face was recognized, then they were instructed to type in the name associated with that face. A total of 20 faces were shown, 10 targets and 10 foils. Faces were presented in a randomly generated order.

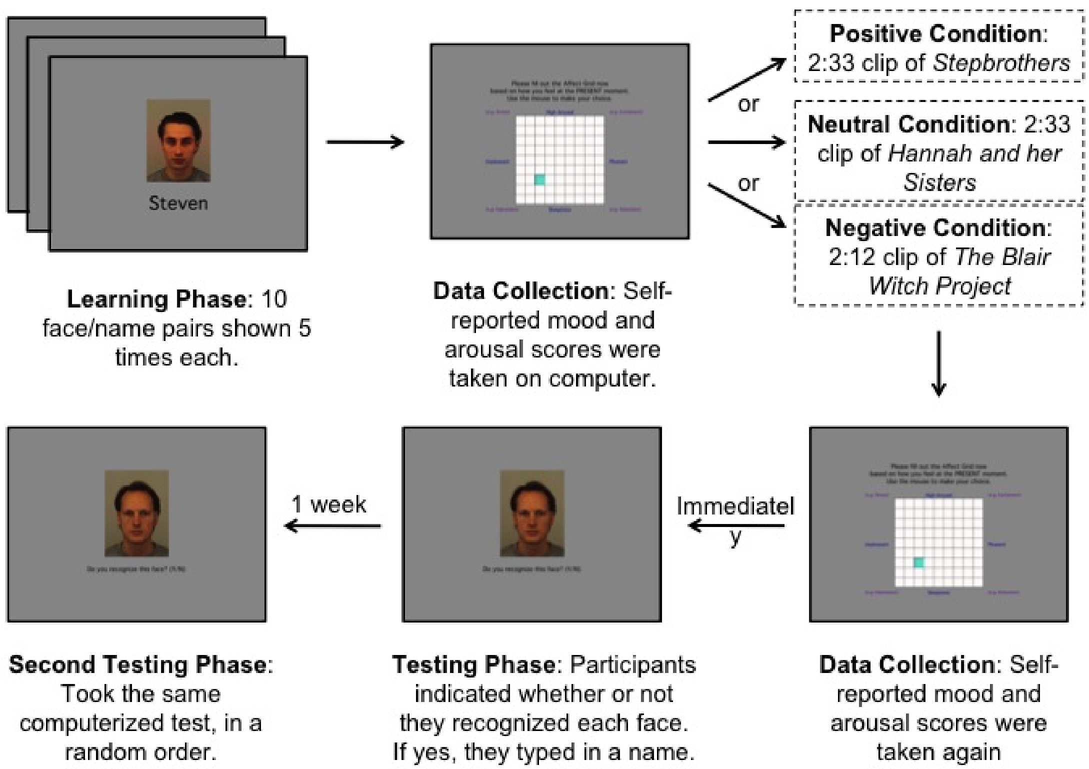

Figure 3 Flow chart representation of experiment 2. Participants only took part in one of three experimental conditions, and the order of presented faces in both tests was randomized.

Participants returned one week later and were given the same recognition and recall test that was given in week 1. After the short test, participants were asked if they were reminded of any experiments from their class work, debriefed, and dismissed. See Figure 3 for a graphical representation of the study design.

Results

Only data from participants that fully completed the experiment was analyzed, leaving 35 subjects (20 females and 15 males) in the positive condition, 30 subjects (16 females and 14 males) in the neutral condition, and 36 subjects (19 females and 17 males) in the negative condition. Again in experiment 2, manipulation checks proved significant. Changes in self-reported valence for the positive emotional condition (M = 2.19, SD = 2.54), neutral conditions (M = 0.105, SD = 1.45), and negative condition (M = -2.28, SD = 2.29) were subjected to a one-way ANOVA, which returned that the means were statistically significant ($F(2,98) = 29.196$, $p < 0.001$). Post hoc comparisons using Tukey HSD tests revealed that all 3 means for change in valence were significantly significant. This held true for arousal as well, with a one-way ANOVA returning significant results ($F(2.98) = 10.049$, $p < 0.001$). Post hoc Tukey HSD tests revealed, however that only differences between the negative condition (M = 2.19, SD = 2.47) and neutral condition (M = -0.13, SD = 1.72) as well as the difference between positive (M = 1.91, SD = 2.43) and neutral conditions were significant, and not the difference between the negative and positive conditions. In other words, both the positive and negative movies elicited significant positive changes in arousal from the neutral movie, but were not uniquely arousing from each other.

In assessing our outcomes, we first aimed to see whether any main effects for mood induction type and scores were visible. When an one-way independent-samples ANOVA for all three conditions, positive mood induction, negative mood induction, and control, was run, we found that overall recognition rates, out of 10, during the week 1 test were statistically equivalent for all 3 groups (F(2,98) = 0.924, $p = 0.400$). The paired association, and correct assignment, of names to their respective faces was also equivalent for both groups (F(2,98) = 0.100, $p = 0.905$). We took the number of names correctly assigned out of faces recognized to assess whether one group's paired association was stronger without regard for recognition of each face. The group means for this measure were not significantly different as well (F(2.98) = 0.211, $p = 0.810$).

In our one-week delayed recognition memory test, scored out of a possible 10, the positive emotional group (*M* = 8.7, *SD* = 0.15) and negative emotional group (*M* = 8.5, *SD* = 0.16) were statistically equivalent to both the control condition (*M* = 8.5, *SD* = 0.17) and to each other (F(2,98) = .176, $p = 0.84$). Name recall during week 2 testing was also not significant across all three groups in an ANOVA (F(2.98) = 0.444, $p = 0.643$). Furthermore, we computed a week 2-retention rate, consisting of the names correctly assigned in week 1, divided by those names that were retained for week 2. In this measure our control group (*M* = 48%, *SD* = 32%) out performed both the positive (*M* = 35%, *SD* = 26%) and negative (*M* =44%, *SD* = 27%) conditions, but not significantly (F(2,98) = 1.944, $p = 0.149$).

Without any significant main effects seen between means, we decided to explore correlations between scores on both tests and change in arousal, in both conditions and combined, as well as between genders.

Starting with our immediate test of recognition and cued recall, we looked a how change in arousal correlates with the number of faces recognized, the gross number of names correctly assigned, and the percentage of names assigned out of faces recognized. Across all conditions and including both genders, we see a correlation between the number of faces recognized and change in arousal such that those who reportedly were more aroused by their video recognized fewer faces (n = 101, $r = -0.21$, $p = 0.037$). This correlation holds true for the change in valence, or mood, as well ($r = -0.216$, $p = 0.030$). Paired-association recall scores were not correlated with arousal or valence (all $p > 0.05$).

When breaking down the data by gender, we find that there are no significant correlations between arousal and recognition scores for either gender. We do, however, see a negative correlation between pair-association recall and arousal again in females only ($r = -0.343$, $p = 0.01$). Looking at valence, we do continue to see a negative correlation with recognition scores, but only for females ($r = -0.296$, $p = 0.028$).

Taking a look at the data from our week-1 immediate testing and breaking down results by mood-induction condition (positive, neutral, or negative) and across both genders, we predictably see a negative correlation between arousal and name-pair associations for our positive ($r = -0.336$, $p = 0.048$) and negative ($r = -0.343$, $p = 0.041$) conditions, but not our neutral condition. No such correlations between valence and paired recall exist.

Switching focus to our one-week delayed test (week 2) statistics and looking at the change in arousal and how it correlates to number of faces recognized across all mood-induction conditions and genders, we again find a significant negative correlation ($r = -0.252$, $p = 0.011$). A correlation between change in arousal and the number of name-face pairs recalled was not significant in week 2. When splitting the results by gender, we also find no significant correlations between change in arousal and any measures. There were no across or between gender correlations with change in valence and any week 2 statistics, either.

Analyzing the data by mood-induction condition reveals only 1 significant correlation between week 2 outcomes and changes in arousal. For participants that underwent the negative mood induction condition, change in self-reported arousal scores and recognition rates were significantly correlated, such that those who expressed a higher change in arousal score correctly recognized fewer faces ($r = -0.418$, $p = 0.011$).

General Discussion

Throughout both experiments, it seems that there was no overall memory improvement for groups that underwent either physical or emotional arousal. In experiment 1, the act of exercising has little bearing on cued-recall memory for paired associations after a 24 hour delay. This conclusion held true for both men and women. It is clear that those females who took the 5 minutes of exercise to significantly raise their heart rates did see an increase in the amount of names they correctly matched with faces the next day. To mesh this correlation with the lack of main effect on females and exercise condition, it is possible that more focused instructions or higher intensity workouts for women could have lead to main effects across groups. Instructions as to the speed and intensity of stair stepping were vague, and the range of change in heart rates was large (the minimum change was only 9 bpm, while the upper bound was 105 bpm, with a mean of 39.8 and standard deviation of 21.5) and both these facts could have lowered the overall performance of the group.

The correlation between heart rate and memory is congruent with much of the current research on physical arousal and memory, though the reason this correlation is limited to women is more surprising. As mentioned earlier, the differences in amygdala activation bi-laterally in males and females may be implicated in these results. Though it's link to memory and physical arousal is unclear, studies have shown that emotional arousal activates the increased number of functional connections to the left amygdala in women and not in men (Kilpatrick et al. 2006).

Other studies have shown physiological reaction to emotional stimuli differences between men women as well, and these differences may be the reason we see some contrast between genders in both experiments 1 and 2. Bianchin and Anggrilli (2012) showed both men and women pleasant, neutral, and unpleasant pictures while recording their self-reported valence and arousal, heart rates, and skin conductance. They also measured their startle response and collected ERP data. This wide net of data sampling led to interesting results. Overall, it seems that females are more sensitive and react with greater amplitude to emotional stimuli, particularly unpleasant images. Women exhibited higher mean amplitudes across all 3 emotional conditions for startle reflex, a physiological measure including eye-blink response and facial EMG data (which records muscular movement in the face) that is meant to measure the amount each stimuli "startled" the participant. Furthermore, heart rate deceleration, which is an indication of attention orienting, was much greater for females than males in the pleasant condition, indicating that females directed more attention at these slides than men. The researchers point out that this could be an indication of dampened deceleration on the part of men for the pleasant slides, since half of them contained erotic material and males tended to show increased blood pressure for those slides, which would in turn correlate to higher heart rates.

The critical difference between Experiment 1 and Experiment 2 that needs to be addressed is why, in Experiment 1, higher levels of arousal (as measured by heart rate) correlated with higher scores, and in Experiment 2 higher levels of arousal correlated with lower scores, both in recall and recognition and throughout week 1 tests and week 2 tests. In order to try to reconcile these findings, I will go over each of the differences in methodologies between the two experiments, and what they may contribute towards our findings.

First, the obvious methodological difference is the main experimental manipulation made during each study, the main difference being physical vs. emotional arousal. As evidenced by Nielsen and Jensen (1994) memory consolidation and enhanced memories rely heavily on brain chemistry and underlying neurotransmitter and hormonal responses. In their study, there was a broad effect such that physical arousal in the form of squeezing a hand dynamometer enhanced memories across the board, except for those participants that were taking drugs that blocked the effects of the adrenal catecholamine system. In Experiment 1, through physical exercise, I believe that this system was activated for those participants that were part of the active condition, and not the inactive condition. The activation of these physiological systems could very well be responsible for increased memory.

However, these systems are also activated for those undergoing emotional arousal as well, and so this explanation does little to explain the differences seen between experiments 1 and 2. I propose that it was the inability for subjects in Experiment 2 to rehearse the information they just learned that accounts for the memory enhancement seen in females in experiment 1. It seems that arousal of any kind can lead to increased activation of certain brain pathways and processes that can then aid in the consolidation of learned material, but only if ample attentional resources are available. I would argue that in experiment 2, when participants were watching any of the 3 movies, those that are emotionally invested in the clip enough to report a positive change in arousal are giving more attentional weight and resources to that movie and away from the process of consolidation that could be happening at that time. This could explain the negative correlation between self-reported arousal and the number of faces recognized during week 1 testing in experiment 2.

We also see gender-based correlations in Experiment 2, such that women tested to correctly recall fewer names during the immediate (week 1) memory test. If it is true that females attend to emotional stimuli more than men as is implied by Bianchin & Angrilli (2012), then it naturally follows that women would be more inclined to focus more attentional resources to the videos they were watching, and in turn not have the mental capacity to rehearse information thoroughly, resulting in lower memory scores immediately after the movie-watching phase.

Another possible explanation for the gender differences seen in the results of experiment 2 could be the stimuli used. All faces and names presented were male, and it is very possible that memory for same sex faces could be higher than that of opposite sex faces. This effect could mediate the effects that higher arousal could have had on males. Further study with a more diverse set of faces and names is necessary in order to address this effect, and in order to gauge the nature of the differences between emotional reactivity and memory in males and females.

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