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by

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Abstract

Previous literature regarding anxiety and its impacts on memory has been murky and contradictory. Where some studies have found associations of anxiety with working memory and long-term memory, many other studies have not. To understand the role of anxiety on memory performance, it may be necessary to examine both trait anxiety and anxiety in the moment (state anxiety). The current study seeks to determine whether the interaction of state anxiety on trait anxiety has a larger impact on long-term memory than trait anxiety alone. Two groups of participants – low trait anxiety and high trait anxiety – were divided in half into a state anxiety or control group. The state anxiety groups had anxiety induced by the Paced Auditory Serial Addition Test, before taking the Rey Auditory Verbal Learning Test, while the control groups took the RAVLT after completing basic math problems. It was hypothesized that the high trait anxiety/high state anxiety group (the "high-high" group) would not only report higher levels of state anxiety throughout the study, as compared to the other three groups, but also that the high-high group would have significantly lower delayed recall scores on the RAVLT caused by the high state anxiety, in comparison to the other three groups. Results indicated that although the high-high group did indeed have lower recall scores, as compared to the high-low group, the results were not significant. However, the low-high group demonstrated significantly higher recall scores than the low-low group, suggesting an influence of state anxiety manipulation and low trait anxiety on free recall. While the high trait anxiety group results seem to align with central hypotheses from the Attentional Control Theory, the low trait anxiety group results may demonstrate the Yerkes-Dodson Law, with moderate anxiety promoting better memory recall.

Keywords: anxiety, trait anxiety, PASAT-C, paced auditory serial addition test - computerized, memory, long-term memory, RAVLT, rey auditory verbal learning test

Examining Trait and State Anxiety Effects on Memory

The history of research on anxiety and its impact on memory has been lengthy in comparison to other psychological topics, spanning over 70 years. However, despite a long history, consensus on whether anxiety affects memory has not been reached. While some studies have found an impact of anxiety on memory such that anxiety results in a decrease in memory storage (Moldawsky & Moldawsky, 1952), other studies have found little to no impact of anxiety on memory (Banks et. al, 2015; Summers, 2020). Others have found that specific aspects of anxiety may drive findings. For example, one study found that worry had stronger associations with memory – in comparison to other anxiety or depressive symptoms (de Vito et. al, 2019). Therefore, anxiety as a whole may not necessarily cause memory impairments, but its symptoms do. The conflicting nature of previous literature has left much to be researched regarding anxiety and the effect it has on memory.

Attentional Control Theory

In order to understand the basis of how anxiety is theorized to affect memory, it is important to understand the attentional control theory (ACT) proposed by Eysenck et. al (2007). An update to the previous processing efficiency theory (Eysenck & Calvo, 1992), ACT proposes that anxiety disrupts the balance between the two attentional control systems in the central executive, the goal-directed system and the stimulus-driven system, which were suggested by Corbetta and Shulman (2002). The goal-directed system is primarily influenced by expectation, knowledge, and current goals, and can be referred to as “top-down” control. The stimulus-driven system, on the other hand, is influenced by detection of behaviorally-relevant sensory events, especially when those events are salient and unattended, and it can be referred to as “bottom-up” control. When anxiety is present, attentional control is reduced, causing an increased influence of the stimulus-driven system, and a decreased influence of the goal-directed system.

The central executive has three basic control functions: inhibition (of automatic responses), shifting (between tasks), and updating working memory (Miyake et. al, 2000). With the reduction of attentional control, the probability that attentional resources will be diverted from task-relevant stimuli to task-irrelevant stimuli on tasks requiring inhibition or shifting is increased. Specifically, inhibition is impaired when task demands on the central executive are high. This disruption of the central executive greatly affects working memory, as the central executive helps in regulating working memory (Baddeley, 1986).

Working memory, which can be defined as “memory as it is used to plan and carry out behavior” (Cowan, 2008), essentially replaced Atkinson and Shiffrin’s (1968) short-term memory, which only included the ability to hold a small amount of information for a short time. Working memory, on the other hand, is comprised of memory, attention, and executive functions, and it communicates directly with the central executive system (McCalla, 2021). It can manipulate information through the central executive, which can pull information from the visuospatial sketchpad, phonological loop, and episodic buffer, before sending the information to long-term memory. Thus, as anxiety affects working memory through a disruption of the central executive’s attentional control systems, as suggested by the ACT, it is inferable that anxiety also affects long-term memory. The manipulation of initial memories by working memory can cause a biased or incomplete representation to be committed to long-term memory, especially when under an anxious state where a bias for emotional stimuli occurs, which could affect the accuracy of long-term memory further on (Barg et. al, 2020). In addition, as anxiety has been suggested to decrease capacity of working memory (Ward et. al, 2020), it is possible that the long-term storage for episodic memories stored in an anxious state could be comprised of not only less information than episodic memories stored in a non-anxious state, but also more biased information.

Trait Anxiety and Working Memory

Trait anxiety can be defined as the individual differences in anxiety proneness, or the disposition to perceive a wide array of circumstances as threatening (Spielberger et al., 1970, as cited by Bucky & Spielberger, 1972). Previous literature has found a link between trait anxiety and poor executive functioning. Executive functioning, which controls a variety of tasks in the mind such as awareness, goal setting, self-inhibition, etc., also plays a role in working memory (McCalla, 2021). One study analyzed how trait anxiety affected memory in preschoolers (Cheie & Vesu-Petra, 2012). Results found that preschoolers ranking higher in trait anxiety demonstrated less accuracy in immediate verbal recall tasks, showing an influence of trait anxiety on working memory. This influence can further be seen in a similar study that saw impaired executive functioning attributed to trait anxiety in at-risk children (Ursache & Raver, 2014). When administered tasks to assess executive functioning, at-risk children performed poorer when they had higher levels of trait anxiety.

State Anxiety and Working Memory

State anxiety, which describes the anxiety a person feels in the moment, has also been found to impact executive functioning and memory. For example, while a state of anxiety decreases neural representation for large amounts of information in working memory, it does not affect filtering of distracters (Ward et. al, 2020). Therefore, this suggests that state anxiety affects not only mental load, but also the ability to discern important information from non-important information. This is backed up by a study in which intuition was tested under a state of anxiety

(Remmers & Zander, 2018). When under an anxious state, participants showed impaired intuitive performance on the semantic coherence task.

Furthermore, anxiety is suggested to be unique from other negative affective states, and, as such, may impair executive functioning more so than other affective states. A study completed by Shields et. al (2016) assessed whether anxiety or anger impaired executive functioning, as the two negative affective states have often been mixed up. The results of this study found that anxiety, but not anger, impaired executive functioning.

Despite numerous studies finding an impact of anxiety on executive functioning, several other studies have shown no impact of state anxiety on executive functioning. One particular finding was that state anxiety did not cause working memory impairment; however, it did cause an increase in mind wandering (Banks et. al, 2015). In a study on subjects with no history of neurological or psychiatric impairments, states of anxiety did not have a lasting impact on neuropsychological measures, such as the Rey Auditory Verbal Learning Test, that were taken on rest days (Hoffman & al' Absi, 2004). These two studies may suggest that a state of anxiety provides distraction which impacts the efficiency of working memory, rather than the accuracy or capacity of working memory. This aligns with one of the hypotheses of the ACT, which suggests that anxiety impairs processing efficiency more so than performance effectiveness (Eysenck, 2007).

Anxiety and Memory

Further literature has studied the impact of anxiety on working memory, specifically – differing from previously mentioned literature that also assessed other executive functions. One such study compared high trait anxiety and low trait anxiety groups on their performance on an n-back task. Results showed that, despite the high trait anxiety group reporting higher levels of anxiety during the task, there was not an impairment in the working memory task (Patel et. al, 2017). Another study had similar findings, with anxiety and depression symptoms having few influences on working memory or other cognitive abilities (Salthouse, 2012). And, despite focusing on long-term memory instead of working memory, this trend of results can be seen in a third study, in which high and low anxiety groups showed no difference in delayed recall scores in the Rey Auditory Verbal Learning Test (Summers, 2020). However, trait anxiety levels did significantly impact self-reported measures of anxiety and state anxiety scores.

A possible explanation for these differing results in previous literature could possibly be explained through the comorbidity of anxiety and depression. In a study done by Kizilbash et al. (2002), participants with depressive symptoms (with no anxiety), anxiety symptoms (with no depression), or both depressive and anxious symptoms completed the California Verbal Learning Test and the Minnesota Multiphasic Personality Inventory. Results showed that depression alone caused adverse effects on immediate recall of information, but anxiety did not cause any memory impairments. The combination of depression and anxiety, however, caused not only adverse effects on immediate recall of information, but also the retrieval of any newly learned information. Thus, anxiety did not cause memory issues, but it exacerbated issues caused by depression.

Current Study

The combination of literature showing either a significant impact of anxiety on memory (Moldawsky & Moldawsky, 1952; Cheie & Visu-Petra, 2012) or no impact of anxiety on memory (Banks et. al, 2015; Hoffman & al' Absi, 2004) has left much to be researched on the topic. However, as many studies have strengthened the ACT's hypothesis that anxiety affects working memory, it is inferable that anxiety also affects long-term memory. In Spalding et. al

(2021), trait anxiety predicted poorer accuracy in shape and memory binding tasks in a task requiring divided attention for simultaneously presented stimuli. This poorer accuracy only occurred when participants reported high state anxiety – a result which supports the ACT. Further findings of lower working memory capacity in states of anxiety (Ward et. al, 2020) suggests that long-term memory should be impacted when participants undergo a memory task while in a state of anxiety. Thus, the current study sought to establish if trait anxiety affects long-term memory when state anxiety is high. The hypotheses for the long-term memory part of the study were as follows: 1) The high trait anxiety/high state anxiety group (high/high) would have significantly lower scores on the delayed recall portion of the Rey Auditory Verbal Learning Test, in comparison to the low trait anxiety groups and the high trait anxiety/low state anxiety group (high/low), and 2) The high trait anxiety/high state anxiety group would report higher and longer-lasting state anxiety scores than the low trait anxiety groups and the high trait anxiety/low state anxiety group, and this state of anxiety would affect long-term memory recall on the RAVLT. In addition, it was hypothesized that the high trait anxiety/high state anxiety group would have significantly lower scores on the Foster Shortened Operation Span task, in comparison to the other three groups. These hypotheses followed previous findings of lower memory scores or executive functioning due to trait anxiety (Spalding et. al, 2021; Shields et. al, 2016), as well as higher state anxiety scores in those with high trait anxiety (Patel et. al, 2017; Summers, 2020).

Materials and Methods

Participants

One-hundred participants were recruited from the Louisiana State University SONA system, which allows students to sign up for research studies in exchange for course credit.

Exclusion criteria included a history of ADHD to avoid concentration issues, as well as a history of heart conditions to avoid overstimulation caused by anxiety. In addition, all participants were asked to refrain from the consumption of caffeine or other stimulants that could affect their results.

Personality Inventory for DSM-5 – Negative Affect Domain and Depressivity Subscale

The Personality Inventory for DSM-5 (PID-5) is a 220-item questionnaire that assesses five different personality trait domains – negative affect, detachment, antagonism, disinhibition, and psychoticism (Krueger et. al, 2012). Each domain can be divided into separate facets. For example, negative affect can be divided into emotional liability, anxiousness, and separation insecurity.

Participants are asked to complete this questionnaire by answering each statement in accordance to which response best describes them on a scale of 0 to 3 (0 = "Very false or often false," 1 = "Sometimes or somewhat false," 2 = "Sometimes or somewhat true," 3 = "Very true or often true"). These responses are then added up according to the separate facets, which are then averaged out to calculate domain scores.

For the purpose of this study, the anxiousness subscale (from the negative affect domain) and the depressivity subscale were assessed. The negative affect domain, which consists of the 9-item anxiousness subscale, the 7-item emotional liability subscale, and the 7-item separation insecurity subscale, was given in its entirety to participants to lengthen the questionnaire and to prevent participants' awareness of which subscale was being assessed. The depressivity subscale, which is related to both the negative affect and detachment domains, consists of 14 items, and was used to assess if there is an influence of depression on the results of the study. The use of the anxiousness subscale helped determine trait anxiety scores. The highest score achievable for each domain or facet is 3.00. For the purpose of this study, participants were split between the high trait anxiety and low trait anxiety group based on a median split within the study.

Tests for validity and reliability have produced high correlation values. The internal consistency value for the negative affect domain has been calculated as α = .93 (Al-Dajani et. al, 2016), and the test-retest coefficient has been calculated at .95 (Dhillon & Bagby, 2015, as cited in Al-Dajani et. al, 2016). Construct validity for negative affect has been assessed to be .81 when compared to the Revised NEO Personality Inventory trait neuroticism.

Positive and Negative Affect Schedule – Negative Affect Scale

The Positive and Negative Affect Schedule (PANAS) is a 20-item scale used to assess positive and negative affect (Watson et. al, 1988). Participants are presented with 20 separate words and are asked to rate each word on a scale of 1 to 5 (1 = very slightly or not at all, 2 = a little, 3 = moderately, 4 = quite a bit, 5 = extremely) based on how they feel/felt during the specific time period chosen by the administrator. For the purpose of this study, only the negative affect scale will be examined; however, participants will be asked to complete the entire PANAS each time, and rate each word based on how they are feeling in the moment. As a note, state negative affect is considered a proxy for state anxiety, but this measure also assesses other negative affect traits such as aggression or guilt.

This scale has indicated high reliability and validity. Internal consistency ranged from .84 to .87 for the negative affect scale, and convergent validity was assessed to range between .89 and .95 (Watson et. al, 1988).

The PASAT-C

The Paced Auditory Serial Addition Task – Computerized is an updated version of the Paced Auditory Serial Addition Task specifically designed to induce anxiety (Lejuez et. al, 2003). The task involves presenting a series of digits (1-9) to participants. Participants are then asked to add pairs of numbers so that the number being presented is added to the one preceding it. The test is comprised of 3 levels – Level 1, Level 2, and Level 3 – with Level 1 being the easiest level, and Level 3 being the most difficult.

Differing from the original PASAT, where numbers are presented orally, the PASAT-C presents stimuli in a 70-point bold font in the upper middle of the computer screen. In addition, participants provide their answers by clicking on a keypad provided in the lower middle part of the computer screen – another deviation from the original PASAT. Furthermore, a participant's score can continuously be seen on the computer screen at any point during the trial.

The three levels differ in latency time between the presentation of each number. Level 1 (low difficulty) provides 3 seconds between each number, Level 2 (medium difficulty) provides 1.5 seconds between each number, and Level 3 (high difficulty) provides 1 second between each number. Level 1 lasts for three minutes before transitioning into Level 2 with no warning. Level 2 lasts for five minutes, and is then followed by a two-minute break, which allows for any desired assessment data to be collected. Fifteen seconds before Level 3 begins, a warning sign is used to alert the participant to the next level. Level 3 can last up to 10 minutes, and participants are given a "QUIT" option below the answer keypad, which would allow immediate termination of the task. Participants are informed of the option to quit before exposure to the task.

Reliability for the PASAT-C is decent, with an r value of .74 (Overstreet, 2015). Internal consistency was calculated to be $\alpha = .81$, and, when compared to other distress intolerance measures (such as the Mirror-Tracing Persistence Task, or the MTPT-C), the PASAT-C demonstrated decent validity (McHugh et. al, 2011).

The Rey Auditory Verbal Learning Test

The Rey Auditory Verbal Learning Test is a measure used to assess verbal memory through free-recall. A participant will hear a list of 15 nouns before being asked to recall as many as possible (Rey, 1958). This list is repeated and recalled four more times, after which an interference list (List B) is presented and recalled. Following the interference list, participants are asked to recall the initial list (List A) immediately, followed by a 30-minute delayed free-recall.

Test-retest reliability for this measure is high, with a correlation of .88 for the delayed recall score (Calamia et. al, 2013). The RAVLT also has been shown to correlate moderately well with similar tests, such as the Wechsler Memory Scale – Revised, the California Verbal Learning Test, and Visual Reproduction subtests (Strauss et. al, 2006).

Automated Operation Span Task

The Automated Operation Span Task (AOSPAN) is a measure utilized to assess working memory capacity. Depending on the version of the AOSPAN, participants are presented with a distracting task (reading sentences, solving math problems, etc.), followed by items to be remembered (letters, digits, words, etc.) (Unsworth et. al, 2005). For this study, participants were given the Foster Shortened OSPAN task, which utilized simple algebraic expressions to distract from a series of letters that needed to be remembered. To ensure that participants were paying attention to both the math section of the task and the memory section of the task, any participants with a math accuracy score under 85% were removed from the working memory data. After a certain number of letters had been presented, participants were asked to recall as many items as possible.

Test-retest reliability for this task is high, with a correlation of .83, and internal consistency has proven to be good (.78) (Unsworth et. al, 2005). The AOSPAN task correlates well with other working memory tasks, including the Raven Progressive Matrices and the original OSPAN task (Unsworth et. al, 2005).

Methods

Before undergoing the PASAT and RAVLT, participants were asked to complete the PID-5 scales. Participants were divided into two conditions based on a median split on the anxiousness subscale in the study (M = 1.49), with forty-six participants being marked as having high trait anxiety and fifty-four participants being marked as having low trait anxiety. After taking the PID-5 – anxiousness subscale, participants were asked to complete the PANAS to assess state anxiety before the study began.

Once both of these inventories had been completed, participants in the state anxiety groups (n = 50) took the PASAT-C. Participants in the control groups (n = 50) completed a variety of basic math problems. After ten minutes of completing either task (equivalent to completing the first two levels of the PASAT-C), participants were asked once again to complete the PANAS to assess state anxiety during each presented task. This helped ensure that the PASAT-C induced an anxious or negative state in the state anxiety groups, and the basic math problems were not inducing an anxious or negative state in the control groups. After completing either the PASAT-C or basic math problems, participants were asked a third time to complete the PANAS to assess state anxiety after the PASAT. This ensured that the PASAT-C induced an anxious or negative state in the state anxiety groups, and the basic math problems did not induce anxiety in the control groups.

Finally, participants took the Rey Auditory Verbal Learning Test. For the purpose of avoiding ceiling effects (Uttl, 2005), only three repetition phases for List A were done before doing the interference list (List B), instead of the usual five. In addition, a 20-minute delayed free recall was used instead of a 30-minute delayed free recall. During the 20-minute delay, participants completed the Foster Shortened OSPAN task. This analyzed working memory capacity across the groups. The approximate total time between the end of the anxiety induction and the delayed free recall was 25 minutes.

After completion of the study, participants completed the PANAS one more time. This was done to assess if feelings of anxiety lasted throughout the study. Levels of state anxiety and number of words recalled were compared between the two groups to see if trait or state anxiety affected long-term memory.

Analysis

Descriptive statistics for the sample of 100 participants are presented in Table 1. For the Foster Shortened OSPAN task, five datapoints were removed due to the participants' math accuracy being below 85%. Descriptive statistics for the Foster Shortened OSPAN task are listed in Table 2.

Table 1

Descriptive Statistics

		High-High	High-Low	Low-High	Low-Low
N		25	21	25	29
Negative Affect 1	Mean	23.04	21.95	15.52	15.62
	SD	8.47	6.90	3.82	4.69
	SE	1.69	1.50	0.76	0.87
Depressivity Scores	Mean	0.63	0.76	0.30	0.20
	SD	0.61	0.74	0.30	0.22
	SE	0.12	0.16	0.06	0.04
Negative Affect 2	Mean	21.16	16.81	17.04	12.17
	SD	7.81	5.72	5.36	2.32
	SE	1.56	1.25	1.07	0.43
RAVLT A1	Mean	6.20	6.90	6.48	5.97
	SD	1.94	1.95	1.23	1.82
	SE	0.39	0.42	0.25	0.39
RAVLT A2	Mean	8.88	9.86	9.44	8.66
	SD	2.16	2.41	2.10	2.38

	SE	0.43	0.53	0.42	0.44
RAVLT A3	Mean	10.36	11.05	11.48	9.86
	SD	2.66	2.46	1.98	2.49
	SE	0.53	0.54	0.40	0.46
Total Words Learned	Mean	25.44	27.81	27.40	24.48
	SD	5.72	6.08	4.27	5.85
	SE	1.14	1.33	0.85	1.09
RAVLT B	Mean	4.72	5.43	5.16	4.55
	SD	1.06	1.96	1.55	1.59
	SE	0.21	0.43	0.31	0.30
RAVLT A4	Mean	8.52	9.43	9.00	7.86
	SD	2.20	3.08	2.20	2.42
	SE	0.44	0.67	0.44	0.45
RAVLT A5/Delay	Mean	7.60	8.71	8.36	7.00
	SD	2.24	3.38	2.36	2.41
	SE	0.45	0.74	0.47	0.45
RAVLT Recognition	Mean	11.60	12.62	12.36	12.24
	SD	2.18	2.01	3.12	2.15
	SE	0.44	0.44	0.62	0.40
RAVLT Recognition False Positives	Mean	3.52	3.19	3.04	3.38
	SD	4.00	3.86	3.86	4.08
	SE	0.80	0.84	0.77	0.76
Negative Affect 3	Mean	18.52	16.00	13.24	12.55
	SD	7.86	5.98	3.26	2.93
	SE	1.57	1.31	0.65	0.54

Note. The first “high” or “low” corresponds to trait anxiety. The second “high” or “low” corresponds to state anxiety. The “Total Words Learned” category represents the means of the sums of words recalled from A1, A2, and A3 for each of the four trait-state groups.

Table 2

Foster Shortened OSPAN Descriptive Statistics

		High-High	High-Low	Low-High	Low-Low
N		22	20	25	28
Foster Shortened OSPAN	Mean	51.23	59.15	58.08	59.93
	SD	18.23	10.94	12.25	9.50
	SE	3.89	2.45	2.45	1.80

Note. The first “high” or “low” corresponds to trait anxiety. The second “high” or “low” corresponds to state anxiety.

To analyze the results from each of the three given negative affect scales, which were used as a measure of state anxiety, a 2 x 2 Type III ANOVA was conducted, with trait anxiety and state anxiety manipulation being the independent variables and negative affect scores being the dependent variable. Post-hoc tests were conducted using simple effects analyses, and effect sizes were reported using partial eta-squared to reduce bias within the sample. Similarly, a 2 x 2 Type III ANOVA was used to analyze the results for each RAVLT free recall, as well as the RAVLT recognition task.

Between the fourth free recall of List A and the fifth (delayed) free recall of List A on the RAVLT, participants completed the Foster Shortened OSPAN task as a measure of working memory. Prior to analysis, one data point within the High-Low group was winsorized to be within three standard deviations of the mean. Like the analyses for the negative affect scales (state anxiety measure) and the RAVLT, the analysis for the Foster Shortened OSPAN task was done using a 2 x 2 Type III ANOVA, with effect sizes being reported using partial eta-squared.

Finally, a 2 (high or low trait anxiety) x 2 (high or low state anxiety) x 2 (high or low depressivity) Type III ANOVA was run on the delayed free recall RAVLT results to see if depressivity scores affected free recall results. Participants were split into high or low depressivity categories based on a median split in the sample (M = 0.45). Additionally, a 2 x 2 x 2 Type III ANOVA was run on each negative affect scale (state anxiety measure) to see if depressivity scores affected reported state anxiety.

Results

Reported state anxiety analyses – PANAS negative affect scale

For the first negative affect scale, a main effect of trait anxiety was identified, indicating higher negative affect scores in the high trait anxiety group ($\bar{x}$ = 22.50, SD = 7.73), as compared to the low trait anxiety group ($\bar{x}$ = 15.57, SD = 4.27), $F(1, 96) = 31.19$, $\eta_p^2 = 0.25$, $p < .05$. No main effect of state anxiety was found, $F(1, 96) = 0.16$, n.s., and trait anxiety did not interact with state anxiety in a way that impacted negative affect scores, $F(1, 96) = 0.23$, n.s.

However, for the second negative affect scale, which was given after participants had either completed the control task or the PASAT-C, a main effect for state anxiety was identified, with the high state anxiety groups ($\bar{x}$ = 19.10, SD = 6.95) reporting higher negative affect scores than the low state anxiety groups ($\bar{x}$ = 14.49, SD = 4.67), $F(1, 96) = 17.00$, $\eta_p^2 = 0.15$, $p < .05$. Additionally, a main effect for trait anxiety was identified, again showing higher reported negative affect scores in the high trait anxiety groups ($\bar{x}$ = 18.99, SD = 7.21), as compared to the low trait anxiety groups ($\bar{x}$ = 14.61, SD = 4.67), $F(1, 96) = 15.34$, $\eta_p^2 = 0.14$, $p < .05$. No interaction effect was found for the second negative affect scale, $F(1, 96) = 0.05$, n.s.

Finally, for the third negative affect scale, which was given at the end of the experiment, a main effect for trait anxiety was identified, and the high trait anxiety groups ($\bar{x}$ = 17.26, SD = 7.73) once again reported higher negative affect scores than the low trait anxiety groups ($\bar{x}$ = 12.90, SD = 4.27), $F(1, 96) = 16.75$, $\eta_p^2 = 0.15$, $p < .05$. No main effect of state anxiety was found, $F(1, 96) = 2.26$, n.s., and trait anxiety did not interact with state anxiety in a way that impacted negative affect scores, $F(1, 96) = 0.74$, n.s.

RAVLT analysis

For the first List A recall, no main effect for trait anxiety, F(1, 96) = 0.87, n.s., state anxiety, F(1, 96) = 0.07, n.s., or an interaction between trait anxiety and state anxiety was identified, F(1, 96) = 2.98, n.s. Similarly, for the second List A recall, no main effect for trait anxiety, F(1, 96) = 0.49, n.s., state anxiety, F(1, 96) = 0.83, n.s., or an interaction between trait anxiety and state anxiety was found, F(1, 96) = 3.72, n.s. However, for the third List A recall, an interaction between trait anxiety and state anxiety that affected the number of words recalled was identified, F(1, 96) = 5.64, η_p^2 = 0.06, p < .05. A simple effects analysis found that the low-high group ($\bar{x}$ = 11.48, SD = 1.98) remembered more words than the low-low group ($\bar{x}$ = 9.86, SD = 2.49), F(1, 53) = 6.83, η^2 = 0.12, p < .05. No additional groups were found to differ from each other. No main effect for trait anxiety, F(1, 96) = 0.005, n.s., or state anxiety, F(1, 96) = 0.92, n.s., was identified.

Additionally, when assessing the sums of total words learned across the first, second, and third List A free recalls, an interaction between trait and state anxiety was identified, F(1, 96) = 5.67, η_p^2 = 0.06, p < .05. A simple effects analysis revealed a difference between the low trait anxiety groups, F(1, 96) = 4.25, η^2 = 0.08, p < .05, with the low-high group recalling more words across the three free recall trials than the low-low group. Furthermore, a slight difference between the high state anxiety groups was found, F(1, 96) = 3.81, η^2 = 0.07, p < .1, where the low-high group recalled more words than the high-high group. No main effect for trait anxiety, F(1, 96) = 0.38, n.s., or state anxiety, F(1, 96) = 0.06, n.s., was identified.

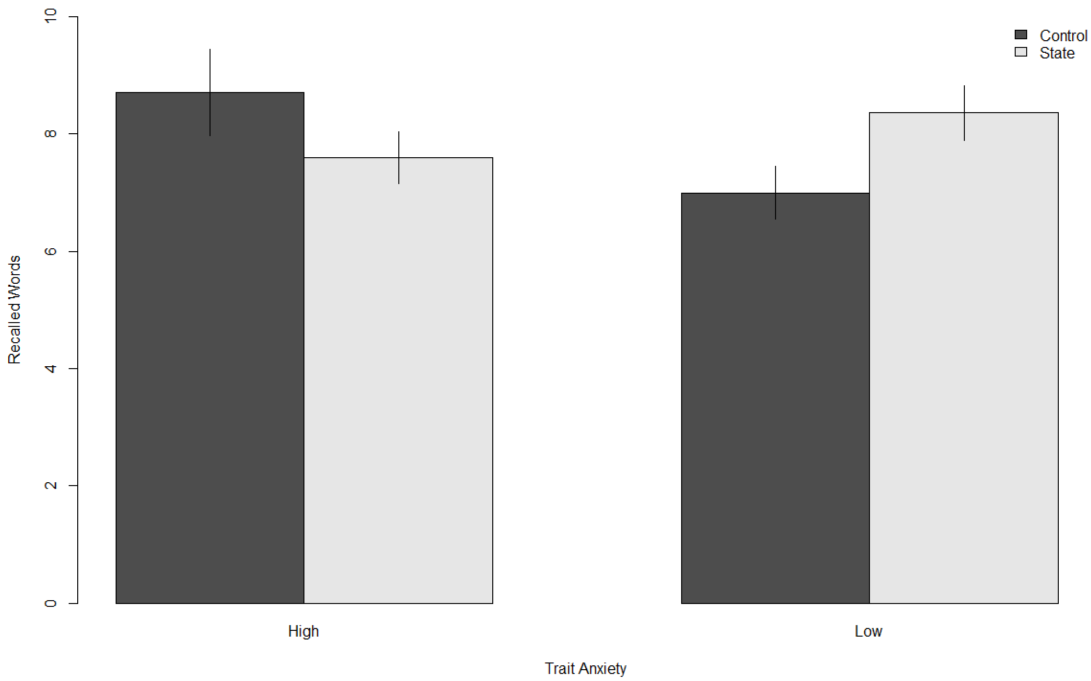
Following the third List A free recall, participants were asked to do a free recall for List B. For the List B free recall, an interaction between trait anxiety and state anxiety that affected the number of List B words recalled was identified, F(1, 96) = 4.41, η_p^2 = 0.04, p < .05. A simple effects analysis found that the high-low group ($\bar{x}$ = 5.43, SD = 1.96) recalled more words than the low-low group ($\bar{x}$ = 4.55, SD = 1.59), $F(1, 49) = 3.03$, $\eta^2 = 0.06$, $p < .1$. No main effect for trait anxiety, $F(1, 96) = 0.49$, n.s., or state anxiety, $F(1, 96) = 0.03$, n.s., was identified.

After the List B free recall, participants recalled List A for a fourth time. On this recall, an interaction between trait anxiety and state anxiety that affected the number of List A words recalled was identified, $F(1, 96) = 4.24$, $\eta_p^2 = 0.04$, $p < .05$. A simple effects analysis revealed higher recall scores in the high-low group ($\bar{x}$ = 9.43, SD = 3.08) than the low-low group ($\bar{x}$ = 7.86, SD = 2.42), $F(1, 49) = 4.07$, $\eta^2 = 0.08$, $p < .05$. Additionally, the low-high group ($\bar{x}$ = 9.00, SD = 2.20) recalled marginally more words than the low-low group ($\bar{x}$ = 7.86, SD = 2.42), $F(1, 53) = 3.24$, $\eta^2 = 0.06$, $p < .1$. No main effect for trait anxiety, $F(1, 96) = 1.20$, n.s., or state anxiety, $F(1, 96) = 0.05$, n.s., was found.

Following the Foster Shortened OSPAN task, participants recalled List A for a fifth time. On this delayed recall, an interaction between trait anxiety and state anxiety that affected the number of List A words recalled was identified, $F(1, 96) = 5.63$, $\eta_p^2 = 0.06$, $p < .05$. A simple effects analysis revealed that the low-high group ($\bar{x}$ = 8.36, SD = 2.36) recalled more words on the delayed recall than the low-low group ($\bar{x}$ = 7.00, SD = 2.41), $F(1, 53) = 4.37$, $\eta^2 = 0.08$, $p < .05$. Another simple effects analysis showed that the high-low group ($\bar{x}$ = 8.71, SD = 3.38) recalled more words on the delayed recall than the low-low group ($\bar{x}$ = 7.00, SD = 2.41), $F(1, 49) = 4.40$, $\eta^2 = 0.08$, $p < .05$. These results are shown in Figure 1. No main effect for trait anxiety, $F(1, 96) = 0.84$, n.s., or state anxiety, $F(1, 96) = 0.06$, n.s., was identified.

Figure 1

Recalled Words from the Delayed Free Recall of List A



Note. The error bars correspond to standard error.

Finally, after the delayed List A recall, participants completed the RAVLT recognition task. There was no main effect for trait anxiety, F(1, 96) = 0.15, n.s., or state anxiety, F(1, 96) = 0.86, n.s., found for correct recognition hits. There was also no interaction between trait anxiety and state anxiety identified for correct recognition hits, F(1, 96) = 1.37, n.s. Participants in each group also did not differ significantly in the number of false positives on the recognition test. No main effect for trait anxiety on false positives, F(1, 96) = 0.03, n.s., or state anxiety on false positives, F(1, 96) = 0.00, n.s. was identified, and no interaction between trait anxiety and state anxiety on false positives was found, F(1, 96) = 0.17, n.s.

Foster Shortened OSPAN Analysis

No significant interaction was found between trait anxiety and state anxiety, $F(1, 96) = 1.28$, n.s. Additionally, no main effect was found for trait anxiety, $F(1, 96) = 2.02$, n.s. A marginal difference between the state anxiety groupings were found, with the low state anxiety group having slightly higher partial OSPAN scores than the high state anxiety group, $F(1, 96) = 3.32$, $\eta_p^2 = 0.04$, $p < .1$.

Depressivity Analysis

No significant interaction was found between trait anxiety, state anxiety, and depressivity on delayed free recall scores, $F(1, 92) = 0.43$, n.s. Additionally, no main effect was found for trait anxiety, $F(1, 92) = 0.00$, n.s., and no main effect for state anxiety was found, $F(1, 92) = 0.06$, n.s. No main effect was found for depressivity, $F(1, 92) = 0.72$, n.s.

However, when assessing negative affect scores, main effects for trait anxiety and depressivity were found across all three negative affect scales, and a main effect for state anxiety was found on the second negative affect scale. No interaction effects were identified for any of the three negative affect scales. For the first negative affect scale, the main effect for depressivity was $F(1, 92) = 7.87$, $\eta_p^2 = 0.08$, $p < .05$, and participants who were classified as having high depression reported significantly higher negative affect scores. The main effect for trait anxiety was $F(1, 92) = 16.29$, $\eta_p^2 = 0.15$, $p < .05$, with the high trait anxiety groups reporting higher negative affect scores than the low trait anxiety groups.

For the second negative affect scale, the main effect for depressivity was $F(1, 92) = 7.10$, $\eta_p^2 = 0.07$, $p < .05$, again showing higher negative affect scores in high depressivity participants. The main effect for trait anxiety also continued to show higher negative affect scores in the high trait anxiety groups rather than the low trait anxiety groups, $F(1, 92) = 7.52$, $\eta_p^2 = 0.08$, $p < .05$.

In addition to a main effect for trait anxiety, a main effect of state anxiety found the high state anxiety groups reporting higher negative affect scores than the low state anxiety groups, F(1, 92) = 15.69, η_p^2 = 0.15, p < .05.

Finally, for the third negative affect scale, the main effect for depressivity was F(1, 92) = 6.19, η_p^2 = 0.06, p < .05, and the main effect for trait anxiety was F(1, 92) = 6.59, η_p^2 = 0.07, p < .05. Results for the third negative affect scale followed the trends of the first two scales, with high depressivity and high trait anxiety groups showing the highest negative affect scores, respectively.

The combination of the negative affect results suggest that not only did the high depressivity individuals report higher negative affect scores, but also that the trait-state grouping affected negative affect scores, with high trait anxiety participants reporting significantly higher negative affect scores throughout the study, and high state anxiety participants reporting higher negative affect scores after the anxiety induction. However, these differences in reported negative affect did not impact recall on the RAVLT. As the absence of an interaction between trait anxiety and state anxiety on delayed recall in this section contradicts the interaction previously mentioned in the RAVLT analysis section, it is important to note that the number of participants in each trait-state grouping and depression grouping differed vastly. Thus, although a Type III ANOVA was used to help offset differences caused by the uneven sample sizes, the robustness of the main effects for trait anxiety, state anxiety, and any interaction between the two is notably weaker than the robustness of the trait-state interactions mentioned in earlier sections. The low trait anxiety groupings in particular were affected the most. Sample sizes for the depression and trait-state groupings are listed in Table 3.

Table 3

N for Depressivity Analyses

	High Depression	Low Depression
High-High	11	14
High-Low	9	12
Low-High	3	22
Low-Low	3	26

Discussion

Previous studies on the effects of anxiety on memory have produced murky results, with some studies having found an impact of trait anxiety on memory (Cheie & Visu-Petra, 2012), some having found an impact of state anxiety on memory (Shields et al., 2016), and some finding no impact of anxiety on memory at all (Salthouse, 2012; Summers, 2020). However, few studies have examined the effects of the interaction between trait anxiety and state anxiety on memory. Thus, this study set out to identify if the interaction between trait anxiety and state anxiety affected verbal long-term memory and working memory. Applying the gathered results to the hypotheses for this experiment offered some interesting insight. The first hypothesis, which stated that the high-high group would have significantly worse recall scores than the other three groups, could not be supported by the obtained data. While the high-high group remained in the two lowest-scoring groups (accompanied by the low-low group) and followed a trend predicted by the hypothesis, as the high-high group had lower, though not significant, delayed recall scores than the high-low group, the weaker scores were not significantly different from any of the other groups.

However, some support could be found for the second hypothesis, which stated that the high-high group would have higher state anxiety scores that would affect free recall. For each of the negative affect scales, a main effect of trait anxiety was found, indicating that the high trait anxiety groups reported higher state anxiety than their low trait anxiety counterparts. Additionally, on the second negative affect scale, which took place after the anxiety induction, a main effect of state anxiety was found, with the high-high group reporting the highest state anxiety out of the four groups. When assessing the delayed recall scores, although the high-high group and the high-low group did not differ significantly, the high-high group had markedly reduced free recall scores as compared to the high-low group. This difference between the high trait anxiety groups can be seen as early as the first free recall test, and the difference only increased as free recall trials continued, which could suggest an effect of state anxiety on both short-term and long-term verbal free recall. The insignificant difference between the high trait anxiety groups could potentially be explained by the fact that there was no indication in the study as to when the anxiety induction wore off. If the anxiety induction wore off before the delayed recall, it is possible that free recall became easier for the high state anxiety groups than if the state anxiety from the anxiety induction had lasted longer or the recall task had been given earlier.

Notably, the trend in the low trait anxiety groups is quite the opposite from the high trait anxiety groups. In fact, as state anxiety increased in the low-high group, recall scores for all free recall trials also increased, culminating in an interaction on the third, fourth, and fifth List A free recall trials. The difference between how state anxiety affected the high trait anxiety group versus the low trait anxiety group seems to contradict one of the core hypotheses for the Attentional Control Theory (ACT). Where the ACT states that anxiety should diminish processing efficiency and effectiveness in working memory (Eysenck et al., 2007), which should logically affect long-term memory storage, the results of this study only support that hypothesis in the high trait anxiety groups. The low trait anxiety groups seem to be helped by a state of anxiety; however, this difference between the trait anxiety groups and their performance after the state anxiety manipulation could be explained through the Yerkes-Dodson Law. This law, although not proposed by Yerkes and Dodson themselves, was summarized in Teigen's (1994) paper, where the level of arousal corresponds in a curvilinear fashion to performance (Hebb, 1955, as cited by Teigen, 1994). At a certain level of arousal, performance peaks, and any further arousal contributes to a decline in performance. Thus, the trends exhibited in this study may follow that of the Yerkes-Dodson Law, where the low-high group was able to work more efficiently as a result of a moderate level of arousal. The high-high group, on the other hand, could have been pushed past that level of ideal arousal, with the increased state anxiety causing decreased recall scores.

For the third hypothesis, which suggested that high-high group would have significantly lower working memory scores on the Foster Shortened OSPAN task, results provided no support for the hypothesis. No significant differences were found between the working memory scores for any of the four groups, supporting previous suggestions that states of anxiety may not affect working memory capacity, but rather working memory efficiency (Hoffman & al'Absi, 2004; Banks et al., 2015). However, it is worth noting that the high-high group had the lowest scores out of the four groups, which, although not significant, may suggest some influence of states of anxiety on working memory capacity.

The results of this study did not support or only partially supported many previous findings. For example, whereas Summers (2020) did not find a significant difference in recall scores on the RAVLT between low trait anxiety and high trait anxiety individuals, the current study found a significant difference between the high-low and low-low groups, with the high-low group significantly outperforming the low-low group on the fourth List A free recall and the fifth (delayed) List A free recall. Furthermore, analyses investigating whether depressivity interacted with state and trait anxiety to influence recall scores resulted in no significant results, contradicting previous findings from Kizilbash et al. (2002).

Additionally, as stated previously, the results of this study seem to only partially support Eysenck et al.'s Attentional Control Theory (2007). Where state anxiety should have impaired processing efficiency and effectiveness for both high state anxiety groups, only the high trait anxiety groups seemed to follow the ACT's hypotheses. The low trait anxiety groups, on the other hand, seemed to be helped by a state of anxiety. One potential explanation for this interesting result could be that the adverse effects of state anxiety appear greater in threatening situations. In Bar-Haim et al. (2007), a meta-analysis revealed that high trait anxiety individuals were more likely to be distracted by perceived threats than low trait anxiety individuals, resulting in poorer scores on tasks such as the Stroop task. Thus, results in the current study could be due to threat detection in the high-high group, but not the low-high group; however, this still does not explain the significant increase in free recall scores in the low-high group, as compared to the low-low group. Further studies should be completed to investigate the effect of moderately anxiety-inducing situations on the performance of low trait anxiety individuals.

To conclude, although this study did not find support for the hypothesis that the high-high group would demonstrate significantly worse delayed recall on the RAVLT, interesting effects were still observed. Predominantly, it is worth noting that while the high trait anxiety groups seemed to follow the ACT's hypothesis regarding anxiety and memory impairment, the low trait anxiety groups did not. In fact, the low-high group had significantly better long-term memory on the delayed free recall portion of the RAVLT than the low-low group – results which contradict the ACT. Results such as these provide a jumping-off point for future studies to investigate how low trait anxiety individuals are affected by anxiety-inducing situations. Previous studies, such as those discussed in Bar-Haim et al. (2007), have shown little-to-no difference on memory or executive functioning performance – especially on the Stroop task – between low trait anxiety individuals placed in a control situation or anxiety-inducing situation. The results of this study, however, suggest that perhaps low trait anxiety individuals who are placed in high-anxiety situations may do better depending on the task they are asked to complete. Furthermore, the significant difference between the high-low group and the low-low group in this study suggests a potential effect of trait anxiety on overall memory that contradicts previous findings, such as those from Summers (2020). Overall, further investigation into the effects of anxiety on low trait anxiety individuals and the effects of trait anxiety on memory should be completed.

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