The effect of anxiety on memory accuracy, response time, and confidence

by

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Author’s Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Anxiety is an emotional state that has been associated with negative outcomes on cognitive tasks, as well as low confidence in responses, specifically in the domain of long-term memory. The following series of experiments explored the effect of anxiety on long-term memory performance as well as on memory confidence, the accuracy-confidence relation, and response times. The purpose was to determine how realistic anxious participants are when making confidence judgments compared to low anxious peers and to attempt to improve the memory accuracy and confidence of highly anxious individuals. In Experiment 1, participants encoded words presented visually, followed by an anxiety induction. Those with higher anxiety scores had poorer memory accuracy for target words as well as less confidence in their memory overall, consistent with much of the literature. Response time (RTs) was slower in the high- relative to low-anxious group when making confidence assessments but not memory judgments, suggesting that rather than slowing cognitive processing, high anxiety individuals may be doubting their memory ability, resulting in more time spent appraising their performance. In Experiment 2, I tested my hypothesis that high-anxious participants are particularly slowed only when asked to critically examine and evaluate their memory decisions. The same procedure as in Experiment 1 was used except that I allowed participants an opportunity to switch their memory responses immediately after making an initial classification. Highly anxious participants made more switches in their memory judgments and this decreased their overall memory accuracy. Interestingly, in this experiment, highly anxious participants did not have lower memory confidence than their low-anxious peers, nor longer RTs when making confidence judgments. They did however take longer when deciding whether to switch an answer. Results are in line with the suggestion that high-anxious individuals defer worry until after a memorial decision is made, and that it is in the post-mnemonic stage that high-anxious individuals differ from low-anxious ones. In Experiment 3, I examined anxiety without induction to determine whether differences in memory accuracy and in response time would remain. I also included a manipulation of encoding duration to determine whether longer encoding time would improve highly anxious participant's memory accuracy and confidence relative to the low-anxious group. Participants encoded words for either 750 or 4000 ms. High-anxious individuals had poorer accuracy and lower confidence compared to low-anxious individuals: specifically for correct memory responses. Longer encoding duration benefited both accuracy and confidence, and there was no differential benefit across groups. RTs to make memory classifications again did not differ between groups yet, as in Experiment 1, high-anxious participants were slower to make confidence judgments, though only for incorrect responses. Results suggest that high-anxious individuals have unrealistically low confidence in their memory, especially when correct, and that allowing additional encoding time does not alleviate the effect. Taken together, this series of experiments shows that individuals with high levels of anxiety take longer to evaluate their memorial decisions, suggesting that they engage in more post-mnemonic evaluation than their low-anxious peers.

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1. General Introduction

Anxiety is a negative emotion or state in which worry occurs and there are feelings of uneasiness, tension, and nervousness (Liebert & Morries, 1967, Eysenck, 1979). Researchers distinguish two types of anxiety. The first is state anxiety, which is a transient emotion that interacts with situational threat, and the second is trait anxiety, which is a semi-permanent susceptibility to experience state anxiety (Eysenck, 1979**)**. Anxiety has been studied extensively with respect to its effects on long term memory accuracy and confidence in both clinical (Hermans et al., 2008; McNally & Kohlbeck, 1992; Tuna et al. 2003) and non-clinical (Cheie & Visu-Petra, 2012; Dobson & Markham, 2001; Glover & Cravens, 1974; Kizilbash et al., 2002; Nolan & Markham, 1998; Ridley & Clifford, 2006; Salthouse, 2012; Taylor, 1958; Valentine & Mesout, 2009) populations. In this thesis, I examined how individual differences in anxiety affect memory in the non-clinical population. Specifically, I measured long-term memory accuracy and confidence for lists of words, as well as the relation between those variables in university undergraduates who had no past history of anxiety disorder, but who had varying levels of state and trait anxiety.

My motivation for studying the effect of anxiety on memory accuracy and confidence was to better understand the wide range of different findings in the literature. When anxiety is either experimentally induced or measured as an individual difference, some studies report significant memory deficits (Cheie & Visu-Petra, 2012; Dobson & Markham, 2001; Glover & Cravens, 1974; Salthouse, 2012; Valentine & Mesout, 2009), some null effects (Nolan & Markham, 1998; Kizilbash et al., 2002; Taylor, 1958), and some even show memory enhancement in the anxious group (Ridley & Clifford, 2006). The effect of anxiety on memory confidence, is much clearer however, with studies showing that induced or trait anxiety leads to lower confidence in memorial responses (Nolan & Markham, 1998; Ridley & Clifford, 2006; Valentine & Mesout 2009).

The relation between these variables is also poorly understood. There is disagreement in the literature as to whether the low confidence observed in highly anxious (HA) participants is a more realistic appraisal of their memory than is the high confidence usually found in low-anxiety (LA) groups. Given that lower confidence has been found in all studies that examined both memory accuracy and confidence together, researchers have speculated about whether HA participants are actually displaying greater insight into their performance and therefore are more realistically appraising their responses compared to the LA participants (Nolan & Markham, 1998). In the normal population, overconfidence is very common (Adams & Adams, 1960; Chua et al., 2012, Fichhoff et al., 1977) so lower confidence overall might be a more realistic evaluation of one's memory. This view is opposed by Ridley and Clifford (2006) who found near-ceiling performance in their HA group but very low confidence. Instead of seeming more self-aware, they argued that the HA participants were unrealistically under-confident.

The Effect of Anxiety on Memory

Whether researchers induced anxiety in their studies seems to have influenced the pattern of memory performance. For example, Dobson and Markham (2001) found a decrease in memory for a sequence of events depicting a crime in an HA relative to LA group of participants, but only when anxiety was manipulated (by way of ego threat) at both encoding and retrieval. Notably, however, the difference in memory performance was not due to decreased performance in the HA group, but instead to an increase in the LA group. Such a finding suggests that the researcher's manipulation had a selective motivating effect on the LA group rather than a detrimental effect in the HA group. Another study by Nolan and Markham (1998) found no differences in memory performance following anxiety induction at retrieval. Similarly, Taylor (1958) found that under low stress, without induction, HA participants recalled more nonsense syllables than LA. However, after an anxiety induction of ego threat however, the HA and LA groups showed a similar rate of decrease in performance. This suggests that some anxiety manipulations may be motivating rather than detrimental to both HA and LA groups.

While these studies did not find significant memory deficits in HA participants following anxiety induction, others (Deffenbacher et al., 2004, Valentine & Mesout, 2009) have reported a negative association between heightened anxiety and memory. Deffenbacher and colleagues' (2004) meta-analysis of eyewitness studies showed that induced anxiety led to poorer memory performance, especially when anxiety was accompanied by high levels of physiological arousal. However, the experiments that they reviewed did not separate participants based on individual differences in trait anxiety, and even the authors state that since HA and LA participants may respond differentially to stress, they should be assessed separately (Deffenbacher et al., 2004). While this meta-analysis emphasized the importance of arousal, Eysenck and Calvo (1992) found that impaired performance can be found in a HA group even without supporting arousal data. Not all experiments collect physiological data, though one that did (Valentine & Mesout, 2009) sorted their participants into HA and LA groups based on self-reported state anxiety. Physiological data were collected as a manipulation check and were found to account for a significant portion of variance in state anxiety scores. The researchers found that the HA group was significantly worse at identifying a confederate that had frightened them while walking through an environment designed to elevate anxiety by the presentation of frightening stimuli. Overall, these experiments showed that an induction that is designed to elevate anxiety may also be motivating for LA participants, complicating conclusions about the effect of anxiety on memory. In addition, anxiety inductions appear to produce more anxiety in those who are high in trait anxiety than those who are not, suggesting that it is critical to consider individual differences in susceptibility to anxiety when examining how this manipulation affects memory.

There have also been studies that focused more exclusively on individual differences in anxiety without induction. It can be argued that the experiments that manipulated anxiety were merely exaggerating underlying differences in trait anxiety, effects which may remain without induction. Two such studies were carried out. One was by Salthouse (2012) with volunteers recruited from the community and another was by Kizilbash and colleagues (2002) with Vietnam-era veterans. Salthouse found that trait anxiety was negatively associated with memory performance on a variety of tasks including word recall and paired associates in his regression analysis. Depression symptoms, age, gender, and health were all controlled for and there was a highly varied sample of people tested (e.g., age range of 18-97, various careers, levels of education, etc.). In contrast, Kizilbash and colleagues (2002) did not find an effect of trait anxiety levels in a large sample of Vietnam-era veterans on memory. However, they did find that those with co-morbid anxiety and depression had significantly reduced performance. Unfortunately, this study had relatively few participants who were only trait anxious ($n = 47$) and far more participants with comorbid anxiety and depression ($n = 416$) which means that there may not have been enough participants to make the effect of trait anxiety alone significant. Thus, overall, the literature is divided as to whether elevated state or trait anxiety produces deficits or null effects on memory performance.

In the three experiments that form this Master’s thesis, sub-clinically anxious individuals were classified by their self-reported state and trait anxiety which was collected using the State-Trait Anxiety Inventory (STAI) (Exp. 1 and 2) and the State-Trait Inventory of Cognitive and

Somatic Anxiety (STICSA) (Exp. 3). Participants were either separated into groups using the average from normative data as a cut-off point (Exp. 1 and 2) or by conducting a median split (Exp. 3). There was not a distinction made between state and trait anxiety because in all experiments both were highly correlated. In Experiment 1, it was also attempted to better quantify the level of anxiety experienced by participants by collecting skin conductance data. Skin conductance is a well-established method of measuring physiological responses, such as arousal, that has been used since the 1930's (Bitterman & Holtzman, 1952). However, arousal does not always indicate higher levels of anxiety as other factors can also increase skin conductance such as motivation. It was hoped that the HA and LA groups would have different levels of physiological arousal and that would provide additional evidence of the anxiety manipulation affecting the HA group more than the LA.

Processing Efficiency Theory

One theory that aims to account for the divergent findings with respect to effects of high state or trait anxiety on memory is the processing efficiency theory (PET; Eysenck & Calvo, 1992). Consistent with the earlier 'drive theory' (derived from Hullian theory; Taylor, 1956), PET states that HA persons have a greater desire to perform well and therefore under normal conditions will tend to outscore LA participants (Eysenck, 1979). Under stressful conditions, however, PET posits that those with high trait anxiety are more likely to experience state anxiety which leads to worry (Eysenck & Calvo, 1992). In turn, worry is thought to tax working memory by dividing capacity between task relevant activities and task irrelevant worry. The load of worry on working memory is assumed to create more barriers for speed and efficiency of processing than for performance effectiveness. Thus, HA participants should still exhibit a strong desire to succeed (as in drive theory), however this drive may not be able to compensate for their increased working memory load. As such, PET predicts that under low stress conditions, HA participants should either outperform or perform at the same level as LA participants. However, when stress in introduced, HA participants should experience a decrease in performance and slowed processing speed (Eysenck & Calvo, 1992).

Unfortunately, PET has not been extensively examined or tested using long term memory paradigms. Researchers have primarily focused on working memory and various other cognitive tasks. Previous research (Cheie & Visu-Petra, 2012; Dobson & Markham, 2001; Glover & Cravens, 1974; Kizilbash *et al*., 2002; Nolan and Markham, 1998; Ridley & Clifford, 2006; Salthouse, 2012; Taylor, 1958; Valentine & Mesout, 2009) did not analyze response time which is vital to test predictions from PET, given that the main distinguishing feature is slowed processing before a decrease in performance is observed. If PET is an accurate representation of the effect of anxiety on memory, it would be expected that every experiment that showed a deficit in memory accuracy would have an accompanying response time difference between the LA and HA groups. As well, in experiments that did not find an accuracy deficit, a response time slowing would be predicted in the HA group.

Factors Influencing Memory Confidence

Memory confidence is another way of assessing the quality of one's memory. Many factors affect memory and confidence in different ways which is why in this thesis both accuracy and confidence were examined. As discussed in the previous section, anxiety occasionally affects memory confidence and accuracy in the same way but this is not always true. Other factors such as familiarity (Chua et al., 2012; Fischhoff et al., 1977) and repeated questioning (Shaw & McClure, 1996) have divergent effects on memory and confidence in the literature. Familiarity can increase confidence but not accuracy for general knowledge (Fischhoff et al. 1977) if a well-known association is misleading. For example, participants in Fischhoff and colleagues' (1977) experiment were quite certain that potatoes originated from Ireland as that association is very common in our culture, despite potatoes actually originating from Peru. Researchers stated that this experiment shows the reconstructive and deceptive nature of memory for facts as participants recalled hearing or learning the incorrect information. Such research shows divergent influences on memory confidence and accuracy. As for repeated questioning, a manipulation used in this thesis, Shaw and McClure (1996) had participants view a staged event in class and then questioned them about it five times over five consecutive weeks. The memory test began with a few questions and each week it increased in size while maintaining the earlier questions. It was found that by the last test, confidence had increased significantly for the items that had been tested five times; importantly, however, accuracy remained constant.

In contrast, other studies have shown that experimental manipulations can affect memory accuracy and confidence in very similar ways. For example, when testing memory in a forced-choice paradigm, deliberate reasoning will either increase or decrease both confidence and accuracy together (Chua et al., 2012). Deliberate reasoning is described as the ability of a participant to make a memory decision based on logic rather than a strong memory. For example, if the participants had to pick out memorized words from two options, if the original list had only contained words related to furniture and the lures were all bird names, the participants would have very high accuracy and confidence. Response fluency, how quickly a person brings a memory to mind and responds, also increases accuracy and confidence concurrently (Robinson et al., 1997, Shaw et al., 2001).

As discussed above, some manipulations can affect memory and confidence in divergent ways and anxiety occasionally has divergent effects on these variables. Some researchers have found that both memory accuracy and confidence decreased in a group of HA individuals (Dodson & Markham, 2001; Valentine & Mesout, 2009) while others have found that accuracy was not affected, though confidence was very low (Nolan & Markham, 1998; Ridley & Cifford, 2006). Because confidence has been found to be consistently low in HA participants I introduced two manipulations in my thesis: the ability to change responses, a form of repeated questioning, and longer encoding durations in an attempt to increase confidence in this group. These manipulations will be discussed in greater detail in Experiments 2 and 3.

The Relation between Memory Accuracy and Confidence

Given that lower confidence has been found in HA participants in all studies that examined both memory and confidence together, researchers have speculated about whether HA participants are actually displaying greater insight into their performance and therefore are more realistically appraising their memory performance compared to LA participants. Overconfidence has been found in many studies and it has been suggested that in general, people are often overly-confident that they are correct (Adams & Adams, 1960; Chua et al., 2012; Fichhoff et al., 1977).

In a study by Nolan and Markham (1998), the HA group showed a significant correlation between accuracy and confidence at 0.60, whereas there was no significant correlation in the LA group. This led to the conclusion that HA participants may be more self-aware and have improved insight into their performance compared to LA participants. Such findings are in contrast to those of Ridley and Clifford (2006), who found that despite memory for the contents of a video portraying a crime being near ceiling in a group of HA participants, they reported low confidence in their memory judgments compared to the LA participants who achieved lower memory scores. Ridley and Clifford’s memory test was made up of sentences that described either veridical details or false information from the video participants had just watched. While the accuracy-confidence correlation was not tested statistically in that study, the authors argued that since the HA group had highly accurate memories, their low confidence was unrealistic.

The difference in the strength of the association between accuracy and confidence, across these two studies, may be methodological. Nolan and Markham (1998) induced anxiety prior to encoding; Ridley and Clifford (2006), on the other hand, simply assessed levels of state and trait anxiety in their participants without manipulation. According to PET, high state anxiety produces excessive worry or thoughts of task evaluation (Eysenck & Calvo, 1992). The anxiety manipulation in Nolan and Markham's study likely further increased focus on appraisals of performance, leading to more realistic confidence judgments. Yet, given that worry is also thought to slow processing (Eysenck & Calvo, 1992), it is possible that HA individuals perceived tasks as more difficult than LA participants and therefore reported lower confidence overall, as in the Ridley and Clifford (2006) study.

In my thesis, I sought to clarify the accuracy-confidence relation by computing Gamma correlations for HA versus LA individuals, instead a Pearson correlation coefficient (Bornstein & Zickafoose, 1999). A Gamma correlation is derived from the chi squared statistic and is a nonparametric correlation measure. It is considered best measure of resolution, how effectively confidence corresponds to correct and incorrect recognitions, as it takes into account all responses and not overall performance (Krug, 2007). Confidence is correlated positively with accuracy if confidence is greater for correct than incorrect responses (Nelson, 1984). In this way, higher Gamma correlations are taken as evidence of better meta-memory insight. This statistic is particularly suited for examining differences between HA and LA participants as it distinguishes individual item performance (unlike point biserial correlations), and not a person's overall confidence level (Nelson, 1984). Since it has been shown that HA individuals have lower confidence in general (Nolan & Markham, 1998; Ridley & Clifford, 2006; Valentine & Mesout, 2009) it is beneficial in this group to look at the relative difference between accurate and inaccurate responses instead of overall confidence. Other measures of the accuracy-confidence relation, such as calibration, do not consider confidence separately for correct and incorrect classifications, but simply plot confidence and percentage accuracy on a given memory test (Krug, 2007). Gamma correlations are also suggested when using a scale to measure confidence (1 to 6 in my experiments) rather than a percentage score (0%-100% confident) (Krug, 2007).

The literature is divided as to what the effect of anxiety is on long-term memory accuracy, confidence, and the relation between them. Therefore in this thesis, I sought to elucidate findings such as the possibility of a processing speed deficit in HA individuals and expand on others, specifically the relation between confidence and accuracy in HA compared to LA participants. I also endeavoured to produce conditions in which HA participants would not have deficits in memory or confidence, by allowing participants to change their memory classification (Experiment 2), and by allowing a longer encoding time (Experiment 3). In each experiment, memory confidence, accuracy, response time, and the accuracy-confidence relation were examined to provide a clear picture of how memory is affected by anxiety. By collecting data for each of these variables simultaneously, predictions from PET were tested directly. It was also explored whether the lower level of confidence found in HA participants, represents a more realistic judgment of one's memory accuracy. This question is important to clarify as it has not yet been established if lower confidence in HA individuals is actually a realistic or unrealistic evaluation of their memory. Overall, this thesis endevoured to provide a wealth of data demonstrating the differences between HA and LA participants and to determine whether there exist any conditions which could make the HA group appear more similar to their LA peers.

2. Experiment 1: Effect of Anxiety Induction on Long Term Memory

The purpose of the first experiment was to establish whether deficits to memory accuracy and confidence could be demonstrated in an HA group in my paradigm given that findings are not consistent in the literature. The methods used that were close to those of Dodson and Markham (2001) in that anxiety was manipulated specifically after encoding and also used a recognition test to assess memory. Because memory performance has been varied in HA participants in the literature, as discussed in the general introduction, in order to determine whether memory accuracy as well as confidence would be impaired when using these methods.

In this experiment, memory performance and confidence were assessed in HA and LA participants following an anxiety induction. In addition, the relation between memory accuracy and confidence was also examined. Response time was also recorded and analyzed to determine whether memory and confidence decisions take longer in HA than LA participants to test the assumptions of PET. That is, if HA participants would experience a processing efficiency deficit (increased RTs) before or simultaneously with a decrement in processes effectiveness (memory accuracy). In Experiment 1 (as well as Experiment 2), an anxiety manipulation was administered to all participants and groups were formed based on each participant's self-reported level of state anxiety during the experiment. (While state anxiety was used in Experiments 1 and 2 to group participants, group membership would have remained the same even if they were created based on trait anxiety scores due to the high degree of correlation between state and trait anxiety). In Experiment 1, physiological data was collected using skin conductance which measured arousal. It was hoped that skin conductance would provide further evidence of differences in anxiety between the HA and LA group as anxiety is often associated with heightened arousal (Bitterman & Holtzman, 1952). It was thought that skin conductance would be higher overall in the HA group based on the findings of Valentine and Mesout (2009), but be particularly elevated during the anxiety induction.

In Experiment 1, anxiety was manipulated by having participants engage in one of two challenging cognitive tasks to be completed under time pressure, which has been found to be stressful for anxious participants (Mattarella-Micke et al. 2011). The Raven's Progressive Matrices (Raven et al., 1983) was used which is a standardized IQ test and a mathematics test that was composed of questions involving carrying, which math anxious individuals in particular find specifically anxiety-inducing (Mattarella-Micke et al. 2011). Two different inductions were used because it was thought that there would be a different level of anxiety induced by each one. It was hypothesized that the math test might be more anxiety-inducing in the population tested, which had a high level of math anxiety as well as general trait anxiety, than the Raven's Matrices, which are pattern- rather than number-based.

To better characterize the influence of anxiety on memory and confidence ratings, a recognition test was administered in which different types of memory responses could be examined: correct (hits and correct rejections) and incorrect (false alarms and misses). In so doing, I hoped to provide converging evidence that anxiety is linked to decreased memory confidence and accuracy, and to test PET (Eysenck & Calvo, 1992) by comparing response times between HA and LA participants.

2.1 Method

Participants. 60 undergraduate participants from the University of Waterloo took part in the experiment. The participants were separated into groups based on their scores of state anxiety on the STAI (Speilberger et al., 1983). Participants were split into high (n = 30) and low (n = 30) anxiety groups based on normative data (Speilberger et al., 1983) for each gender of college students. Females scoring 39 and higher and males scoring 37 and higher were included in the HA group (6 male, mean Age = 19.73, *sd* = 2.28, mean Years of Education = 14.17, *sd* = 1.05) and all participants scoring below were included in the LA group (10 male, mean Age = 20.83, *sd* = 3.48, mean Years of Education = 14.87, *sd* = 1.11). Data from 11 other participants were excluded from analyses: 4 participants scored zero on the memory test, suggesting they did not follow instructions, and 7 participants were excluded due to experimental equipment failure. All participants had never been diagnosed, been treated for, or currently had depression or clinical anxiety disorders.

The groups had significantly different levels of state (the grouping variable) and trait anxiety. I instructed participants to report their feelings at the time of test (state anxiety) and how they felt in everyday life (trait anxiety). Contrasts showed that the HA group had significantly higher state (t (58) = 11.10, p < 0.001) and trait (t (58) = 5.38, p < 0.001) anxiety than the LA group. For means and standard deviations, see Table 1.

Table 1

Mean (and standard deviation) state and trait anxiety scores for the HA and LA groups

Group	State Anxiety	Trait Anxiety
Low Anxious	28.90 (*3.28)*	34.63 (*8.63)*
High Anxious	45.13 (*7.30)*	48.70 (*11.42)*

Design Overview. The dependent variables were memory accuracy and confidence ratings for recognition decisions. I compared accuracy and response times in the two groups of participants. Following an initial encoding phase for a word list, an anxiety-inducing mathematics test or the Raven's Progressive Matrices (Raven et al., 1983) was administered to all participants. Subsequently, the retrieval phase for the word memory task began. It was assumed that the influence of the anxiety manipulation would last for at least 2-3 minutes (Ononaiye et al., 2007). The success of the manipulation in increasing arousal was assessed skin conductance and a self-report questionnaire.

Memory Task. Two word lists were created for visual presentation on the computer. These were selected from the 'Affective Norms of English' (ANEW) database containing normative ratings of English words for valence, arousal, and dominance (the perceived degree of control expressed by the stimulus) rated on a 1-9 scale (Bradley & Lang, 1999), as well as word frequencies (Kucera & Francis, 1967). Two 30-word lists were created, equated based on ANEW ratings of valence, arousal, word frequency, letter length, and dominance. All words were concrete nouns of medium frequency and between four and seven letters in length. An additional 5-word list was created for study use in a practice phase, and another 5 words to be used as lures in practice, using the same criteria as in the experimental phase. All words were presented in a random order in 20-point Arial font in black on a white background, centered on a computer screen.

Skin Conductance . Skin conductance was measured using the Affectiva Q 1.0 sensor (Affectiva Inc., Santa Clara, CA). This device is similar in appearance and weight to a wrist watch and was placed snugly on the participant's non-dominate wrist. Two sensors sent a small electric current between each other measured conductance while in contact with the participants' skin. The skin conductance device was mounted on the participant's wrist following their informed consent.

Anxiety Induction. The anxiety-inducing tasks were both completed using a pencil and paper. I used two different tasks: a mathematics test and Raven's Progressive Matrices. The mathematics test consisted of 4 pages of basic mathematical problems that could all be solved without the use of a calculator. All questions involved either addition, subtraction, division, or multiplication, or combinations of these. The questions all involved carrying, multiple steps, or long division which have been shown to arouse mathematics anxiety (Mattarella-Micke et al. 2011). The four basic math operations were used in an effort to reduce boredom in those who did not find the task difficult. It was explained to participants before the test that if they forget how to perform a certain operation, for example long division that they should move on to the next section in an effort to reduce the possibility of participants giving up. Given the length of this task, participants were not expected to be able to complete it in the time given.

The Raven's Progressive Matrices (Raven et al. 1983) was also used as an anxiety induction. The Raven's involves viewing a 3 x 3 matrix with a specific pattern and choosing the piece out of 8 available options to complete the pattern. The pattern is different for each new matrix. Usually participants have a total of 40 minutes to complete as much of the two booklets as they can. IQ is calculated by subtracting incorrect and incomplete answers from correct ones. Unlike the mathematics test, questions in the Raven's do not require prerequisite knowledge; therefore participants were instructed not to skip any questions. The children's version of the RP was also included in case a participant finished the adult test and also made the task appear longer.

Procedure. Participants were tested individually in a quiet room. SC, used to measure physiological arousal, was averaged at four different 2-minute time intervals. The first interval was called 'Baseline SC' and occurred while the participant was resting comfortably awaiting task instructions. The second was called "Encoding SC" and occurred during the memory encoding phase of the experiment, starting concurrently with presentation of the first word on the study list. The third was called 'Arousal Induction SC' and occurred 2 minutes after the participant began the arousal induction test. The forth was called ‘Retrieval SC’ and began at the start of the recognition memory task.

Prior to commencing the experimental phase, participants completed a practice memory test consisting of 5 study words and 10 words on the recognition test (half old), to familiarize participants with stimulus presentation and timing. For the memory task, stimulus presentation and response recording was controlled using E-prime v.1.1 software (Psychology Software Tools Inc., Pittsburg, PA). A 17” computer monitor was used to present participants with word stimuli. Participants were required to make responses with their dominant hand using a standard keyboard. During encoding, words from list 1 were presented in a random order in 20 point Arial font, centered on the computer screen. Each was shown for 4 seconds in black lettering against a white background display, followed by a fixation cross for 1 second. List 2 words were used as lures on the recognition test. Word lists were counterbalanced across participants such that each list served as “study” for half of the participants in each anxiety group.

The participant then moved to a second desk where the anxiety induction took place. Half of the participants in each group were given the mathematics test and half the Raven’s Progressive Matricies. The participant had 10 minutes to work on the anxiety-inducing task, starting from the moment they acknowledged understanding the task. When the 10 minutes ended, the participant returned to the computer desk.

For the retrieval phase, participants were shown a list of words, half of which were from the study list. For each recognition memory trial, a word was presented on the screen for 3 seconds. Participants were asked to make an ‘old’ or ‘new’ decision about the word by pressing the appropriate key, the “n” key had a sticker labelled “Y” affixed to it, to indicate “yes had seen before/old”, and the “m” key had a sticker labelled “N”, to indicate “no had not seen before/new”. These keys were chosen as they are easy to reach with one hand. Next, a screen was presented for 3 seconds, asking participants to make a rating to indicate their confidence in their memory judgment. Confidence ratings were to be made on a 6 point scale: 1-2 indicating not very confident, 3-4 indicating moderately confident, and 5-6 indicating very confident. A fixation cross appeared for 500 milliseconds in between word recognition trials. After the memory test was completed, participants were asked to complete the STAI both state and trait.

2.2 Results

Memory Accuracy. A univariate ANOVA was conducted using d’ memory accuracy (Snodgrass & Corwin, 1988) as the dependent measure, with Anxiety Induction (mathematics test or Raven’s Progressive Matrices), List (1 and 2), and State Anxiety Group (HA and LA)) as between-participant factors. The effect of Group was approaching significance, F (1, 52) = 3.52, MSE = 0.85, $\eta_p^2 = 0.06$, $p = 0.07$ with the HA group scoring lower on the memory test (mean = 1.69, sd = 0.91) than the LA group (mean = 2.18, sd = 0.94). There was no effect of List ($F < 1$) or Anxiety Induction (F (1, 52) = 1.83, MSE = 0.85, $\eta_p^2 = 0.03$, $p = 0.18$) and no significant interactions.

Pearson correlations were also computed for memory performance and RTs. Memory performance was negatively correlated with state anxiety, r (58) = -0.39, $p < 0.01$. State anxiety and RT to make hits, false alarms, misses and correct rejections were uncorrelated. Therefore, it was demonstrated that with this paradigm, HA participants had worse performance on the memory task and higher anxiety was associated with poorer performance.

Memory Response Times. RTs to make memorial decisions were analyzed with a mixed ANOVA with Group (HA and LA) as a between participant factor and Response Type (hits, false alarms, misses, and correct rejections) as a within participants factor. There was a main effect of Response Type *F* (3, 156) = 26.08, *MSE* = 59371.07, $\eta_p^2 = 0.33$, $p < 0.001$, with hits having the fastest RTs, followed by correct rejections, misses, and then false alarms. There was no effect of Group ($F < 1$) and the interaction was not significant ($F < 1$). Therefore, HA participants did not have a processing speed deficit as predicted by PET but were able to make recognition decisions as quickly as their LA peers.

Memory Confidence. The analysis for confidence was done using the method commonly used in the field which includes comparing correct to incorrect responses (Migueles & Garcia-Bajos, 1999). Confidence was analyzed using a mixed ANOVA with Accuracy (correct and incorrect) as the within-participants factor and Group (HA and LA) as the between-participants factor. Correct responses were classified as hits and correct rejections and false alarms and misses were classified as incorrect responses. There was a main effect of Group, *F* (1, 55) = 11.53, *MSE* = 1.01, $\eta_p^2 = 0.17$, $p = 0.001$, with the HA group reporting lower confidence than the LA group. There was also a main effect of Accuracy, *F* (1, 55) = 77.84, *MSE* = 0.30, $\eta_p^2 = 0.59$, $p < 0.001$, such that correct responses were given higher confidence ratings than incorrect responses. There was not a significant interaction: Accuracy x Group *F* (1, 55) = 1.04, *MSE* = 1.01, $\eta_p^2 = 0.02$, $p = 0.31$. For means and standard deviations, see Table 2. HA participants reported lower confidence than their LA peers in their memorial responses which is consistent with the literature.

Table 2

Mean (and standard deviation in parentheses) confidence ratings in HA and LA participants for correct and incorrect responses

Group	Correct	Incorrect
Low Anxious	5.09 (*0.52*)	4.20 (*1.19*)
High Anxious	4.46 (*0.57*)	3.58 (*0.75*)

Confidence Response Times. RTs to make confidence ratings for each memory decision were analyzed in a mixed ANOVA as well, with Accuracy (correct and incorrect) as the within participants factor and Group (HA and LA) as the between participants factor. There was a main effect of Group, F (1, 57) = 7.25, MSE = 138544.05, $\eta_p^2 = 0.11$, $p = 0.009$, with the HA group taking significantly longer to respond. There was also a main effect of Accuracy, F (1, 57) = 21.75, MSE = 25101.97, $\eta_p^2 = 0.28$, $p < 0.001$. The interaction was not significant, F (1, 57) = 1.94, MSE = 25102.97, $\eta_p^2 = 0.03$, $p = 0.17$. Therefore, HA participants do have a processing speed deficit as predicted by PET but in this design it was found in confidence judgments rather than memorial decisions. For means and standard deviations, see Table 3.

Table 3

Median (and Standard Deviation in parentheses) RTs to make confidence ratings in HA and LA Participants

Group	Correct	Incorrect
Low Anxious	777 (*243*)	953 (*327*)
High Anxious	1002 (*261*)	1097 (*304*)

Accuracy-Confidence Relation. To examine the relation between accuracy and confidence, I calculated Goodman-Kruskal (1954) Gamma coefficients for each person at each of the two durations. Responses in each of the 6 confidence bins were tabulated for correct and for incorrect memory responses for each participant, and these values were used to calculate Gamma which, like Pearson's r, gives a value between -1 to +1. A score of +1 would require all of a person's correct responses to be assigned very high confidence (6) and their incorrect responses to be assigned very low confidence (1) without variation. A negative Gamma value would result if a participant assigned confidence in the opposite manner, high for incorrect and low for correct. A

Gamma value close to 0 would result if one assigned the same confidence to all response types or assigned values randomly. The resulting Gamma correlations were analyzed using an independent t-test. There was no significant effect of Group, $t(58) = 0.54$, $p = 0.59$. The HA group had a mean gamma score of 0.44 (*0.26*) and the LA a mean of 0.49 (*0.38*). This means that both groups confidence is equally predictive of memory accuracy; neither group is more realistic than the other in their confidence ratings. Therefore, the HA groups is not more realistic in their confidence judgements despite reporting less confidence than the LA group.

Skin Conductance. I measured skin conductance in microSiemens (μS) during 4 recording blocks. Before any comparisons could be made between groups on skin conductance, data were converted to account for individual differences in baseline reactivity. The Rose's Range correction was used (Lykken et al. 1966):

$$\text{Converted value} = \frac{SC_{ix} - SC_{min}}{SC_{max} - SC_{min}}$$

where SC_{ix} is the value under examination, SC_{min} is the lowest value recorded by the participant being analyzed and SC_{max} is the highest recorded value.

A mixed ANOVA was also conducted to examine the results of skin conductance, with Group (HA and LA) and Anxiety Induction (mathamatics test and Raven's Progressive Matrices) as between-participants factors, and Recording Block (baseline, encoding, arousal induction, and recognition) as the within-participants factor. Mauchly's test of sphericity was significant for all of the following ANOVAs so the Greenhouse-Geisser correction was used for all F statistics. There was a main effect of Recording Block, $F\ (1.40, 100.35) = 9.83$, $MSE = 0.14$, $\eta_p^2 = 0.15$, $p < 0.001$, but no main effect of either Group ($F < 1$) or Anxiety Induction, $F\ (1, 56) = 1.57$, $MSE = 0.07$, $\eta_p^2 = 0.03$, $p = 0.21$. There were two significant interactions, Recording Block x Anxiety Induction, $F\ (1.79, 100.35) = 3.16$, $MSE = 0.14$, $\eta_p^2 = 0.05$, $p = 0.03$, and Group x Anxiety

Induction, F (1, 56) = 6.01, MSE = 0.07, η_p^2 = 0.02, p = 0.02. All other interactions were non-significant (Fs < 1).

To explore the Anxiety Induction interactions, I ran 2 separate repeated measures ANOVAs, one for each Anxiety Induction (mathematics test and Raven's Progressive Matrices) with Recording Block (baseline, encoding, arousal induction, and recognition) as the within participants factor and Group (HA and LA) as the between participants factor. For the mathematics test there was only a main effect of Block F (2.27, 63.50) = 13.03, MSE = 0.10, η_p^2 = 0.32, $p < 0.001$ but no main effect of Group or interaction. For Raven's Progressive Matrices there was no effect of Block or interaction but there was a main effect of Group F (1, 28) = 4.79, MSE = 0.07, η_p^2 = 0.04, p < 0.05. In Raven's, the LA Group had higher levels of arousal than the HA group. These results do not support the prediction that skin conductance would be higher in the HA than the LA group. There is also not a clear pattern across anxiety inductions.

2.3 Discussion

In the current study I considered the effect of anxiety on recognition memory and also examined the participants' confidence in their recognition judgments. My results provide converging evidence with past studies suggesting that confidence ratings of memories are reduced following anxiety-induction in anxious participants (Dobson & Markham, 2001; Nolan & Markham, 1998; Ridley & Clifford, 2006; Valentine & Mesout 2009). I provided converging evidence that anxiety can reduce memory performance (Cheie & Visu-Petra, 2012; Deffenbacher et al., 2004; Dobson & Markham, 2001; Glover & Cravens, 1974; Salthouse, 2012; Valentine & Mesout, 2009). Response times were found to be longer in the HA group, consistent with PET, but only for confidence judgments and not memorial classifications. I also found that the confidence and accuracy relation was not differentially predictive across the two groups.

Several of my results map well on to Eysenck and Calvo's (1992) PET, such as the decrease in memory confidence and accuracy, but the RT predictions found less support. The theory predicts that HA individuals experience more worry than their LA counterparts which in turn leads to slowing of their cognitive processes. I did not find that RTs were longer for the HA group on a binary memory decision, but I did find a nearly 200 ms delay in the HA group when making confidence judgments. At first glance, such a pattern may seem out of line with PET, but it could be that the HA group was deferring their task performance worry until the confidence rating stage. PET states that the worry experienced in HA participants is related to task concerns. Post-decisional processes, in this experiment confidence ratings, were more affected than the initial memorial decisions. This finding suggests an amendment to PET such that worry slows only post-decisional processes but not recognition decisions. Studies in the past that examined anxiety, confidence, and memory, did not report RTs (Dobson & Markham, 2001, Nolan & Markham, 1998, Ridley & Clifford, 2006) precluding comparison of my findings to others.

The correlations and comparisons between anxiety and memory accuracy, as well as confidence, are more in line with PET. Poorer memory was associated with higher levels of state anxiety. Unlike in the study by Dobson and Markham (2001), which instead of showing a detriment in the HA group showed improvement in the LA group, I can be reasonably certain that my manipulation decreased the performance of the HA group. Support comes from the significant negative correlation between state anxiety and memory accuracy. My results are in line with those of Valentine and Mesout (2009) who also found that state anxiety was associated with decreased memory, perhaps because I, like Valentine and Mesout (2009), had long-lasting anxiety manipulations that may have significantly elevated state anxiety in the HA group.

My results also support PET and replicate past findings showing lower memory confidence in HA compared to LA groups. Interestingly, even though the HA group was less confident in their memorial ability, their confidence was equally as predictive of accuracy as the LA group. Practically, this could be detrimental to HA individuals in everyday life as those who are less confident are seen as less reliable when reporting their memories (Deffencbacher et al., 2004). Indeed, Nolan and Markham (1998) found that the HA group was perceived by observers to be less confident, in line with what the group members report themselves. Also, given that HA participants took longer to make confidence decisions, HA individuals may require more time to complete school tests because they do not have enough confidence that their responses are correct.

Skin conductance was not found to be higher in the HA than the LA group and it also was not correlated with either measures of memory accuracy or confidence. While this may seem counter-intuitive, previous studies have reported similar findings to mine: the HA reporting high levels of anxiety while having similar physiological responses to those in the LA group (Holroyd *et al*., 1978). Eysenck and Calvo (1992) noted that physiological arousal appears to have a very minor role in mediating the relation between anxiety and performance. I was optimistic that the extended length of the anxiety manipulation would increase skin conductance but this was not found; given this, skin conductance was not recorded in Experiments 2 and 3.

As I found that the HA group took more time to make confidence judgments, I was interested in exploring what HA participants were doing with this extra time. In Experiment 2, participants were given an opportunity to change their responses as a way of determining whether anxious participants were critically analysing or “second-guessing” their responses prior to making confidence judgments, thereby accounting for those longer RTs.

3. Experiment 2: Anxiety and Response Switching

In Experiment 1, I found that HA participants were taking longer to make confidence decisions, but not memory decisions, relative to their LA peers. This led me to question what the HA participants were doing during that time. It is possible that they were critically analyzing their responses as Eysenck and Calvo (1992) suggest that anxious participant spend time engaged in worry which in the context of an experimental task could be task-focused. Given this assumption, I hypothesized that HA participants might benefit from a chance to alter their responses if they were indeed focused on the accuracy of their decisions.

Answer switching has been studied in the literature but mainly in the context of multiple choice tests. It has been consistently found that when participants make response changes they overwhelmingly improve test scores despite prevailing myths that answer switches are inadvisable (Welch & Leichner, 1988; Geiger, 1991; Kruger et al., 2005). Most studies in this area use data from real tests in university classes. One of these studies also examined confidence and found that though 70% of participants had in fact increased scores though switches, they felt confident that they had done worse on the test because of it (Geiger, 1991). Green (1981) examined individual differences in test anxiety among graduate students taking a first year statistics course. The researcher found that high test-anxious participants made more switches overall and also had slightly lower net test scores as they switched more often to incorrect responses. In the current experiment, I gave participants a chance to change their responses on the memory task.

I decided to discontinue use of the skin conductance recording device as my recordings did not detect a difference between the HA and LA group. To determine if the anxiety manipulation was indeed effective and to ensure that participants did not have elevated levels of anxiety before the anxiety induction, I administered the STAI for most of my participants, both before the experiment began and after it ended. I then examined these self-reported scores (for state only) to ensure that the HA group was increasing in anxiety after the manipulation rather than simply having a high baseline level.

I expected to replicate findings that the HA would make more answer switches than the LA group for two reasons. It had been found in the literature previously (Green, 1981) and because the HA spent more time making confidence judgments in Experiment 1 than the LA group, which may indicate a greater propensity to consider responses critically. As for confidence, two outcomes seemed reasonably possible. One was that, after switching, confidence would decrease as participants have been found previously to believe they would do worse after making change responses (Geiger, 1991; Kruger et al., 2005). The other possibility was that confidence would increase as one study observed that, in an eyewitness context, repeated questioning led to higher confidence over time (Shaw & McClure, 1996). I also expected that confidence would be lower in the HA group as it was in Experiment 1 and longer response times specifically for responses after the first memorial response. I predicted that the HA would have lower memory accuracy than the LA group before answer switching, as in the first experiment, but higher afterward based on the idea that they were realistically assessing their performance.

3.1 Method

Participants. Overall, 65 participants took part in this experiment and 59 were included in the final analysis. The 6 participants who were excluded scored below chance on the memory test suggesting that they were not following instructions. Participants were divided into HA (n = 24) and LA (n = 35) groups based on their STAI score from when it was administered after the experiment was completed (Speilberger et al., 1983) by the same criteria as Experiment 1. There were no significant differences in age (HA mean = 19.54 (*1.35*), LA mean = 19.57 (*1.53*)) or years of education (HA mean = 14.46 (*1.35*), LA mean = 14.37 (*1.45*) between groups.

There were significant differences in state anxiety between groups, which was recorded before and after the task for most participants (23 or ~1/3 participants did not complete the pre-test state anxiety scale), and trait anxiety recorded at the end of the experiment. State anxiety was recorded twice in two thirds of participants as I realized after starting data collection that without the skin confuctance recording, a manipulation check was required. The HA group reported higher state anxiety before test, $t(34) = 9.59$, $p = 0.001$, and after test, $t(57) = 17.82$, $p < 0.0001$, and higher trait anxiety, $t(57) = 13.17$, $p < 0.001$, than the LA group (see Table 4 for means and standard deviations), indicating that my manipulation was successful in elevating anxiety. Importantly, state anxiety increased after the task only for the HA ($t (15) = 2.34$, $p = 0.04$) and not for the LA ($t (21) = 0.48$, $p = 0.64$) group.

Table 4

Mean (and standard deviation) state and trait anxiety scores for the HA and LA groups

Group	State Anxiety Before	State Anxiety After	Trait Anxiety
Low Anxious	29.48 (*6.89)*	30.26 (*5.92)*	34.82 (*8.10)*
High Anxious	39.07 (*8.62)*	48.08 (*7.50)*	48.00 (*10.19)*

Design. This experiment measured memory accuracy, confidence, response time, and the relation between the accuracy-confidence as dependent variables for the two groups (HA and LA) but I also examined trials where participants switched responses. All switched responses were examined for accuracy, confidence, and response time.

Procedure and Materials. All materials were identical to those used in Experiment 1, the exception being that for the anxiety induction I only used the RP as there was not a significant difference in results depending on which of the two inductions was employed in Experiment 1. I also did not use the SC recording device as the results had not been significant in Experiment 1.

The procedure was identical to Experiment 1 except for the addition of an opportunity to change one's memory response, and a re-evaluation of one's confidence. Participants completed the STAI (state only) right before engaging in the memory task and then again after completing the entire experiment. I did not use the standard instructions. The first time they completed the state scale they were asked to report how they felt at the moment and the second time they were instructed to report how they felt during the experiment. Trait anxiety was collected at the same time as the second state anxiety and participants were asked to report how they felt in their everyday lives. Specifically, after making the initial recognition decision and confidence judgment as in Experiment 1, participants were given five seconds to change their response, to which they could reply "yes" or "no" using the "y" and "n" keys. Participants were then asked to rate their confidence for a second time, whether they had changed their response or not. Participants were given 3s to make these responses, the same amount of time as their initial recognition decision.

3.2 Results

Memory Accuracy. A 2 x 2 x 2 mixed ANOVA was conducted using d' memory accuracy as the dependent measure, with List (1 and 2) and State Anxiety Group (high anxiety (HA) and low anxiety (LA)) as between-participant factors. Time (before switch and after switch) was the within participants factor. There was no significant effect of List therefore it was excluded from further analysis F (1, 55) = 2.45, MSE = 1.41, $\eta_p^2 = 0.04$, p = 0.12. There was no significant effect of Group F (1, 55) = 0.62, MSE = 1.41, $\eta_p^2 = 0.01$, p = 0.44 or Time F (1, 55) = 0.50, MSE

= 0.06, η_p^2 = 0.01, p = 0.48 but there was a significant Group by Time Interaction *F* (1, 55) = 5.75, *MSE* = 0.06, η_p^2 = 0.09, p = 0.02 (see Figure 1).

The interaction was explored using 2 paired t-tests, one for each group. For the LA group, there was no significant difference in accuracy before (Time 1) to after having the opportunity to switch memory responses (Time 2), t (34) = 1.39, p = 0.17. However, the HA group had a trending effect of lower Accuracy after being given the option to change responses t (23) = 1.89, p = 0.07 (see Figure 1). The groups started with similar levels of memory accuracy but after making switch responses, the HA had worse memory performance than the LA group. Therefore the answer-switching manipulation was not beneficial to the HA group in that it did not increase memory performance.

Figure 1

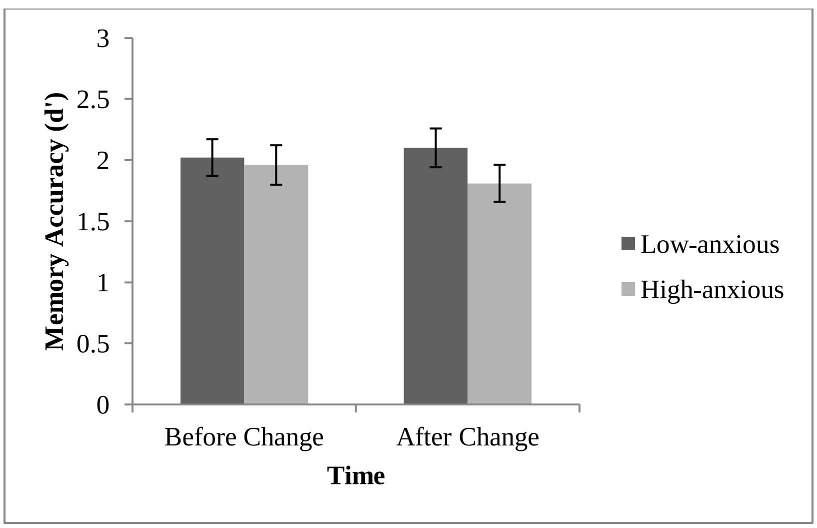


Figure 1. Mean memory accuracy by group with error bars displaying standard error of the mean

Memory Switch Responses. Overall, out of 3449 responses (~60 responses per participant as some participants missed button presses), participants changed their answers 128 times. While that seems very low (3.71% of responses overall), it is similar to other studies in this area (Welch

& Leichner, 1988). Ten participants did not make a change in any of their memory responses (n HA = 2, n LA = 8). The HA group made 47 incorrect switches and 18 correct while the LA group made 30 switches to incorrect and 33 to correct. This difference was tested using chi-square and was found to be significant across Groups (HA and LA), $\chi^2(1, N = 128) = 8.14$, $p = 0.004$ (see Table 5 for means). Therefore, answer switching did not affect the LA group but was a detriment to the HA group meaning that this manipulation was not beneficial to HA participants.

Table 5

Number and percentage of participants in each group who increased, decreased, or maintained their original memory accuracy level after changing responses (participants who did not make any switches were excluded)

Group	Increased	Decreased	Maintained
Low Anxious (n = 27)	12 (*44%*)	10 (*37%*)	5 (*19%)*
High Anxious (n = 22)	6 (*27%*)	14 (*63%*)	2 (*9%*)

Memory Response Times. RTs to make memory decisions were analyzed using two independent t-tests, one for the first memory response and a second for the possible switch response. The results were analyzed using a mixed ANOVA with Response (response 1 and switch response) as the within-participants factor and Group (HA and LA) as the between-participants factor. There was a main effect of Response F (1, 57) = 171.16, MSE = 63474.62, $\eta_p^2 = 0.75$, $p < 0.001$ such that the initial memory response took longer than the switch response. There was no main effect of Group (F = 1) but there was a significant Response x Group interaction F (1, 57) = 5.37, MSE = 63474.62, $\eta_p^2 = 0.09$, p = 0.02.

I followed up with two independent t-tests, one for each response type (response 1 and switch response). In the t-test for the first memory response, there was not a significant effect of Group ($t < 1$). The second t-test of RT to make switch response revealed a significant effect of Group t (1, 57) = 2.44, $p = 0.02$ such that the HA took longer to make their decision than the LA group. This shows evidence of a processing speed deficit in the HA group. See Table 6 for means and standard deviations. Therefore, in this experiment, the finding that the HA group takes longer to make post-memorial decisions than the LA group has been upheld as the option to switch is, similar to the confidence decisions in the previous experiment, an opportunity for the participant to critically evaluate their performance.

Table 6

Median (and Standard Deviation in parentheses) response times (in milliseconds) for memory decisions in HA and LA Participants

Group	RT for Hits Before Change	RT for Hits After Change
Low Anxious	1340 (*310*)	613 (*233*)
High Anxious	1285 (*228*)	777 (*280*)

Response Time Switch Responses. To determine whether participants took longer when switching an answer, a 2 x 2 mixed ANOVA was conducted with RT as the dependent measure and Group (HA and LA) as the between participants factor and Response Type (change or no change) as the within-participants factor. There was a significant effect of Response Type, F (1, 47) = 7.23, MSE = 65597.88, $\eta_p^2 = 0.13$, $p = 0.01$, such that participants took longer to make a response when they changed their answer compared to when it remained the same. There was not a main effect of Group, F (1, 47) = 1.86, MSE = 129504.03, $\eta_p^2 = 0.04$, $p = 0.18$, or an interaction ($F < 1$).

Confidence. A 2 x 2 x 2 mixed ANOVA was conducted with confidence as the dependant measure and Group (HA and LA) as the between participants factor. Time (before switch and after switch) and Accuracy (correct and incorrect) were the within participants factors. There was a main effect of Time, F (1, 57) = 13.81, MSE = 0.09, η_p^2 = 0.20, p < 0.001, such that participants were more confident after than before they were asked if they wanted to modify their responses. There was also a main effect of Accuracy, F (1, 57) = 161.82, MSE = 0.32, η_p^2 = 0.74, p < 0.001, such that correct responses were rated higher in confidence than incorrect responses. There was also a Time x Accuracy interaction, F (1, 57) = 2.45, MSE = 0.08, η_p^2 = 0.12, p = 0.007. The effect of Group and all other interactions were not significant (all Fs < 1) (see Figure 2).

To explore the source of the Time x Accuracy interaction 2 follow-up mixed ANOVAs were conducted, one for each Accuracy (correct and incorrect). For Correct responses, there was a main effect of Time, F (1, 57) = 6.26, MSE = 0.01, η_p^2 = 0.10, p = 0.02. For Incorrect responses, the effect size of Time was significant and larger, F (1, 57) = 11.25, MSE = 0.15, η_p^2 = 0.17, p = 0.001, than for correct responses (see Figure 2), accounting for the interaction. There was no significant effect of Group nor an interaction with Time (all *F*s < 1). Therefore, in Experiment 2, the HA was not found to be less confident than the LA group, suggesting that the ability to switch answers increased confidence in HA participants. However, while increasing confidence was a goal of this manipulation, it was not accompanied by an increase in memory accuracy.

Figure 2

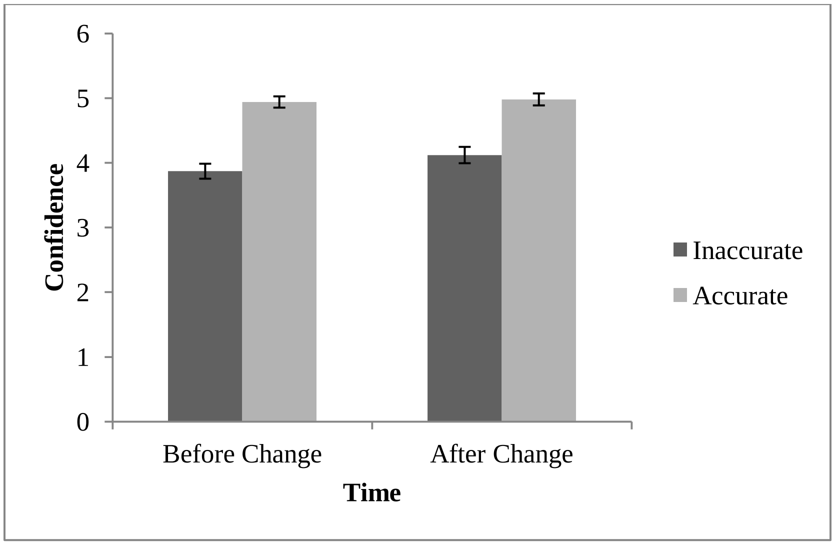


Figure 2. Mean reported confidence before and after change response by item accuracy; error bars show standard error of the mean

Confidence Switch Responses. The 128 switch responses were analyzed separately with a mixed 2 x 2 ANOVA with Time (before switch and after switch) as the within and Group (HA and LA) as the between participants factor. There was a main effect of Time, F (1, 126) = 27.34, MSE = 1.56, η_p^2 = 0.18, p < 0.001, such that confidence increased after switching a response. There was a trending Time X Group interaction F (1, 126) = 3.18, MSE = 1.56, η_p^2 = 0.03, p = 0.08 and no main effect of Group, F (1, 126) = 2.48, MSE = 4.57, η_p^2 = 0.02, p = 0.12.

Confidence Response Times. RTs to make Confidence ratings were analyzed in the same manner as confidence scores: a 2 x 2 x 2 mixed ANOVA was conducted with confidence as the dependent measure and Group (HA and LA) as the between-participants factor. Time (before switch and after switch) and Accuracy (correct and incorrect) were the within-participants factors. There was a main effect of Time, F (1, 57) = 11.92, MSE = 94024.52, η_p^2 = 0.17, p = 0.001, with participants making confidence judgments more quickly after being given the option to switch responses. There was also a main effect of Accuracy, F (1, 57) = 52.24, MSE =

28054.69, η_p^2 = 0.48, p < 0.001, such that participants were quicker to respond when correct. There was also a Time x Accuracy interaction, *F* (1, 57) = 14.07, *MSE* = 25518.14, η_p^2 = 0.20, p < 0.001 (see Figure 4). There was no significant effect of Group, *F* (1, 57) = 1.51, *MSE* = 210790.17, η_p^2 = 0.03, p = 0.22, and all other interactions were not significant (*F*s < 1) (see Figure 3).

The interaction between Time and Accuracy was explored in 2 follow-up ANOVAs, one for each Accuracy. For Correct responses, the effect of Time was non-significant, *F* (1, 57) = 2.85, *MSE* = 36988.34, η_p^2 = 0.05, p = 0.10. There was no significant effect of Group, *F* (1, 57) = 2.25, *MSE* = 110275.45, η_p^2 = 0.04, p = 0.14 and the interaction was also not significant (F < 1). For Incorrect responses, there was a main effect of Time, *F* (1, 57) = 16.64, *MSE* = 82554.32, η_p^2 = 0.23, p < 0.001, with participants responding more quickly after the opportunity to switch. There was no main effect of Group or interaction (*F*s < 1). Therefore, in the current experiment, a processing speed deficit was not found for confidence but rather for switch responses in the HA group. As deciding to switch responses is also a post-memorial decision this evidence does not conflict with the Experiment 1.

Figure 3

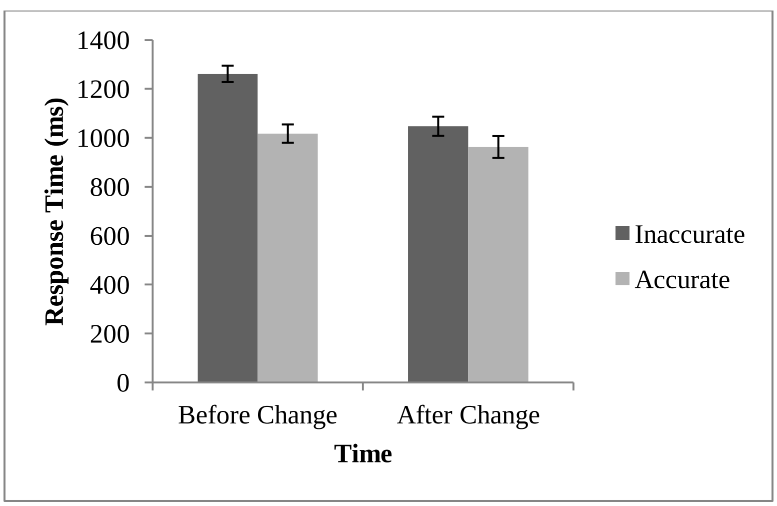


Figure 3. Mean confidence response time in milliseconds before and after making the change response by accuracy; error bars show standard error of the mean

Confidence Response Time for Switch Responses. To determine whether participants took longer to report confidence when switching an answer, a 2 x 2 mixed ANOVA was conducted with RT as the dependent measure and Group (HA and LA) as the between participants factor and Response Type (change or no change) as the within participants factor. There was a significant effect of Response Type, $F(1, 47) = 25.99$, $MSE = 109761.08$, $\eta_p^2 = 0.36$, $p < 0.0001$, such that participants took longer to make a confidence response when they changed their answer compared to when it remained the same. There was not a main effect of Group, $F(1, 47) = 1.57$, $MSE = 187342.18$, $\eta_p^2 = 0.03$, $p = 0.22$, or an interaction ($F < 1$). Therefore, in this experiment, the only time that HA participants took longer than their LA peers was when making the decision to switch their answer or not. Neither confidence judgment was slower.

Confidence-Accuracy Relation. The accuracy-confidence relation was examined by calculating Gamma coefficients for each individual participant. I compared Gamma using a 2 x 2 ANOVA with Group (HA and LA) as the between-participants factor and Time (before switch and after switch) as the within-participants factor. There was a main effect of Time, $F(1, 57) = 8.15$, $MSE = 0.17$, $\eta_p^2 = 0.13$, $p = 0.006$, such that participants' resolution became lower after the change. This means that participants' confidence became a poorer predictor of their accuracy over time. There was no significant effect of Group nor an interaction ($Fs < 1$). See Table 7 for means and standard deviations. Therefore, neither group was more realistic in their confidence ratings, though with repeated questioning, confidence became a poorer indicator of accuracy. This means that once again, it was not found that HA participants more realistically appraise their performance.

Table 7

Mean (and standard deviation in parentheses) Gamma coefficients in HA and LA Participants

Group	Gamma Before Change	Gamma After Change
Low Anxious	0.56 (*0.28*)	0.42 (*0.38*)
High Anxious	0.59 (0.21)	0.48 (*0.22*)

3.3 Discussion

In the current experiment I examined the memory accuracy, response time, and confidence of HA and LA participants when they were able to modify responses. I examined whether having the opportunity to modify responses would increase memory accuracy or confidence in the HA group as it was possible that they were re-evaluating their responses during confidence rating in Experiment 1. As in Experiment 1, I found reduced memory accuracy in the HA compared to the LA group, though this time it was only after they modified their responses. I also found that the post-decision response took longer to make in the HA group, though in this experiment (unlike in Exp. 1) it was the switch response rather than confidence judgments that showed the Group effect on slowing. In the current experiment, I found that the HA was just as confident as the LA group which is different from others' findings (Nolan & Markham, 1998; Dobson & Markham, 2001; Ridley & Clifford, 2006; Valentine & Mesout 2009) as well as from my findings from Experiment 1. However, it could be that knowing they would have the opportunity to switch responses helped the HA group to feel more confident in their responses.

As for the switched responses themselves, I found that the HA group made more switches overall and that they were more often wrong when they switched. This is in line with the findings of Green (1981), who also reported higher rates of switching and lower test scores in a HA group. For the LA participants, switching was not beneficial to them as a group but left the average score unchanged. As for individual participants, outcomes were split between those who increased, decreased, and maintained their original scores. Usually an improvement in scores is reported in the literature (Welch & Leichner, 1988; Geiger, 1991; Kruger et al., 2005), though this may be related to how accuracy was scored. In multi-alternative choice examinations, which were used in all the experiments that found a facilitation of response switching, it was possible to have a wrong to wrong switch that did not change accuracy.

As for memory confidence, I found that confidence increased by the second response, regardless of whether participants changed their responses. The reason that I did not observe the drop in confidence after switching normally found in other experiments that examined multiple choice tests is most likely because I did not use the multi-alternative choice format (Geiger, 1991; Kruger et al., 2005). As cited by Welch and Leichner (1988), students are often advised orally or even in written instructions that they should "go with their first impression" in multiple choice examinations. Therefore researchers have found that participants become less confident when they switch answers on a multiple choice test (Geiger, 1991; Kruger et al., 2005). Participants may not have extended this idea to my task as they only were able to make two responses: yes and no. I did find support though, for the evidence provided by Shaw and McClure (1996) that repeated questioning can lead to higher confidence over time without influencing accuracy. In their experiment, memory tests were administered over several weeks or several days and confidence was shown to increase over the course of five examinations. In the current experiment, I was able to show a rapid increase of confidence, as participants reported higher confidence the second time, regardless of whether they had made a switch response. The act of confirming their decision increased confidence in both groups.

I did not uncover group differences in resolution of the accuracy-confidence relation. Yet, there was an increased level of confidence without accuracy increases after the option to switch responses, which led to lower overall gamma correlations. This result is similar to that of Shaw and McClure (1996), who also observed an increase of confidence but not memory accuracy in their experiment resulting in a loss of statistical correlation between accuracy and confidence. In my experiment, the accuracy-confidence relation was maintained though it did decrease significantly from before to after the change response. It is possible that if I had provided additional chances to confirm or change response the data would have more closely resembled those of Shaw and McClure (1996).

As in Experiment 1, I did not find that the HA took longer to make memory decisions than the LA group, despite the decrease in task effectiveness found in the HA group. This suggests that an amendment is needed to PET such that anxious participants can defer worry until after a recognition decision has been made. In my next experiment, I was interested in exploring whether these results would hold even without the presence of an anxiety manipulation.

4. Experiment 3: Role of encoding duration (Delleman & Fernandes, under revision).

In the final experiment of my master's thesis, I explored the effects of anxiety without having an induction manipulation. I also added a manipulation of encoding duration in hopes that increased time to memorize items would ameliorate the memory accuracy and confidence in HA individuals. In addition, I again explored RTs and the accuracy-confidence relation between HA and LA participants.

Encoding duration has been known to influence both memory accuracy and confidence as well as the relation between them. It is known that longer encoding time increases memory accuracy for studied words (Craik & Rabinowitz, 1985; Eisdorfer et al., 1963; Grenfell-Essam et al., 2013; Smith and Kimball, 2012) and that memory confidence increases as well (, Deffenbacher, 1980; Memon et al., 2003). The relation between accuracy and confidence, however, is less established. Bothwell and colleagues (1987) found in their meta-analysis that longer exposure to faces resulted in better predictability of accuracy from confidence judgments. Research by Memon and colleagues (2003), however, showed that the accuracy-confidence relation may be influenced negatively by increased encoding time. They manipulated exposure time during a simulated crime in which a culprit's face was shown either for 12s or 45s. While overall accuracy was greatly improved in the longer exposure condition, participants who made inaccurate identifications were just as confident as those who made accurate ones. In the short exposure condition, there was a significant difference in confidence levels based on accuracy. The authors suggested that longer exposure times unrealistically inflated witness confidence rather than making participants more realistic in their confidence ratings.

In the current experiment, I was interested in determining the effect of encoding time on the accuracy-confidence relation on long-term memory, as well as determining if this would be different in HA and LA participants. Previous research has found that time limits are particularly anxiety-provoking in those with test anxiety (Mattarella-Micke et al. 2011). I hypothesized that longer encoding times might specifically help the HA group become more confident in their responses, bringing their overall confidence closer to that of the LA group. To test the effect of encoding time in the current experiment I presented words for either 750 ms or 4000 ms. These encoding durations were chosen because previous research in memory and perception estimate that 1000 ms is sufficient time to encode a verbatim memory, while shorter durations lead to more gist-based memories (Smith & Magee, 1980). Participants were subsequently asked to make a recognition decision about each word and to rate their confidence in their responses. I, in accordance with the work of Bothwell and colleagues (1987), hypothesized that the longer relative to shorter encoding time would lead to superior memory accuracy and higher confidence in correct responses as well as higher resolution in the accuracy-confidence relation.

In the current experiment, anxiety was not manipulated in an effort to explore the role of trait anxiety rather than reaction to an anxiety induction. In addition, there is a chance that anxiety manipulations may have a motivating effect especially on the LA group (Nolan & Markham, 1998). I assessed anxiety using the State–Trait Inventory for Cognitive and Somatic Anxiety (STICSA; Ree, MacLeod, French, & Locke, 2000), which is designed to assess cognitive and somatic symptoms of anxiety as they pertain to one’s mood in the moment (state) and in general (trait). I used this scale because it has been shown that the resulting scores are less confounded with depression and therefore thought to be a purer measure of anxiety (Grös et al., 2007). I conducted a median split of the sample to create HA and LA groups instead of using a normative score for this experiment because the STICSA (Grös et al., 2007) does not have the same wealth of normative data as the STAI (Speilberger et al., 1983). I used trait anxiety rather than state anxiety because without a direct manipulation of anxiety I expected state anxiety to be quite low and therefore have small variance in scores between participants. I compared HA and LA groups on memory performance, confidence ratings, and the accuracy-confidence relation. I predicted that those with HA would have lower confidence overall compared to the LA group. I also predicted that encoding time would enhance accuracy and confidence in both groups. I was interested in determining whether a longer encoding duration would be more beneficial for HA than LA participants, and would help them to become more confident in their responses, bringing their overall confidence closer to that of the LA group.

4.1 Method

Participants. There were 137 undergraduate students from the University of Waterloo who took part in the experiment. Twenty participants were excluded: 2 for computer errors that inadvertently terminated the experiment, 11 for having response times on memory decisions 3 SD above or below the mean, and 7 because their memory accuracy as indexed by d’ was zero or below in the 4000ms encoding duration memory test, indicating that they were not following instructions or paying sufficient attention to the task. None of the participants had ever been diagnosed, been treated for, or currently had depression or clinical anxiety disorders.

The remaining 117 participants were separated into HA and LA groups based on a median split of trait anxiety scores from STICSA. The STICSA is a 21-item questionnaire in which participants rate, on a 4-point Likert scale, the frequency of somatic and cognitive components of anxiety. Test instructions are designed to assess ‘state anxiety’ by asking participants to respond based on how they felt during the experiment and to assess ‘trait anxiety’ by asking participants to respond based on frequency of occurrence of each symptom in their everyday lives. Participants were divided into HA and LA groups based on a median split of the trait anxiety score. Fifty-seven participants scored 32 and above making up the HA group (33 male, Age = 20.02, *sd* = 1.72, Years of Education = 14.48, *sd* = 1.50). Fifty-nine participants scored 31 and lower, making up the LA Group (29 male, Age = 20.24, *sd* = 1.72, Years of Education = 14.69, *sd* = 1.29). Neither age nor years of education differed significantly across groups (t (115) = 0.87, p = 0.39, t (115) = 0.47, p = 0.64).

Both state and trait anxiety scores differed significantly across groups. State t (115 = 6.78, $p < 0.001$ and trait anxiety t (115) = 15.89, $p < 0.001$ were higher in the HA than LA group (for means and standard deviations, see Table 8). The HA group reported higher trait anxiety than that reported in a normative study of control participants from Grös and colleagues (2007), but lower than that reported by clinical samples within that study. State and trait anxiety scores, collapsed across groups, were positively correlated, r (115) = 0.60, $p < 0.001$. Scores were positively correlated in the LA group (r (58) = 0.50, $p < 0.001$), and trended towards significance in the HA group, r (57) = 0.23, p = 0.08. This difference is most likely due to the HA group reporting relatively low rates of state anxiety but high trait anxiety whereas the LA group reported low anxiety on both measures.

Table 8

Mean (and standard deviation) state and trait anxiety scores for the HA and LA groups

Group	State Anxiety	Trait Anxiety
Low Anxious	26.46 (*5.19)*	25.68 (*3.17)*
High Anxious	34.60 (*7.60)*	40.78 (*6.56)*

Design and Materials. I compared memory accuracy, confidence, as well as the accuracy-confidence resolution in the two groups. This was both a within- (long vs. short encoding duration) and between- (HA vs. LA) participant design.

Memory task materials. The same word lists from Experiment 1 and 2 were used in this experiment. For the purposes of this experiment, each list was divided randomly into 2 lists, one for each encoding block of 750 or 4000 ms.

Procedure. A computer task was designed using E-prime (v.2.2 software, Psychology Software Tools Inc., Pittsburg, PA) to control stimulus presentation on a 17” computer monitor and response recording for the memory task. Participants were tested individually in a quiet room.

Encoding was separated into two blocks of 15 words which were both presented before the recognition test. Words were presented one at a time, for either a short (750 ms) or long (4000 ms) duration depending on the block, counterbalanced across participants. Prior to each block, participants were instructed that the list would be presented either quickly or slowly and were told to remember all of the words as best they could. After completing both blocks of encoding, they were asked to count backwards by threes from 200 for 30 s, during which time the computer screen was blank, to reduce recency effects.

Following encoding of words from both encoding durations, the recognition phase began. Participants completed two different 30-item recognition test blocks, one for each encoding block, with order counterbalanced across participants. Participants were informed prior to each test block that they would be presented with a list of words, half of which came from the short (or long) encoding block, and half of which were brand new, unstudied, words. Each recognition block contained 15 ‘old’ words and 15 lures. It was emphasized to participants that the recognition blocks were not mixed (e.g., no words would appear from the ‘short duration’ list during the ‘long duration’ recognition block). In each recognition block, words were presented sequentially on the screen for 6000 ms followed by a fixation cross for 500 ms. During presentation of each word, participants were asked to make an ‘old’ or ‘new’ recognition decision by pressing the ‘n’ or ‘m’ key respectively, on a QWERTY keyboard. Following that decision, they made a rating indicating their confidence in their decision on a 6-point scale using the number keys on the top row of the keyboard: 1-2 indicating not very confident, 3-4 indicating moderately confident, and 5-6 indicating very confident.

After recognition was completed, participants were asked to complete the STICSA. Prior to commencing the experimental phase, participants completed an encoding phase consisting of a 5-word list at 2000 ms duration followed by a practice 10-word recognition memory test with the same presentation rate as the experimental test, consisting of the 5 studied words and 5 lures, to familiarize participants with stimulus presentation and timing.

4.2 Results

Memory[1]. Memory accuracy was computed using d’ (Snodgrass & Corwin, 1988), which was calculated as z hits minus z false alarms, and analyzed using a mixed ANOVA with Duration (750 ms and 4000 ms) as the within-participant factor and Group (HA and LA), as well as Order of experimental conditions (1-8), as between-participant factors. As expected, there was a main effect of Duration, F (1, 113) = 53.13, MSE = 0.49, $\eta_p^2 = 0.32$, p < 0.001, with all participants achieving higher d’ scores for words presented in the long compared to short duration block at encoding. The main effect of Group was significant, F (1, 113) = 3.74, MSE = 0.80, $\eta_p^2 = 0.04$, p = 0.03, with the LA group having higher d’ scores than the HA group. All interactions and other effects were not significant. As Order was not significant, it was not included in further analysis. Means and standard deviations for both groups are presented in Table 9. In the current

[1] Regardless of whether groups were formed using a median split based on trait or state scores from STICSA, the direction of results was the same.

experiment therefore, I again replicated previous results of reduced memory performance in the HA compared to the LA group despite the lack of anxiety-induction.

Table 9

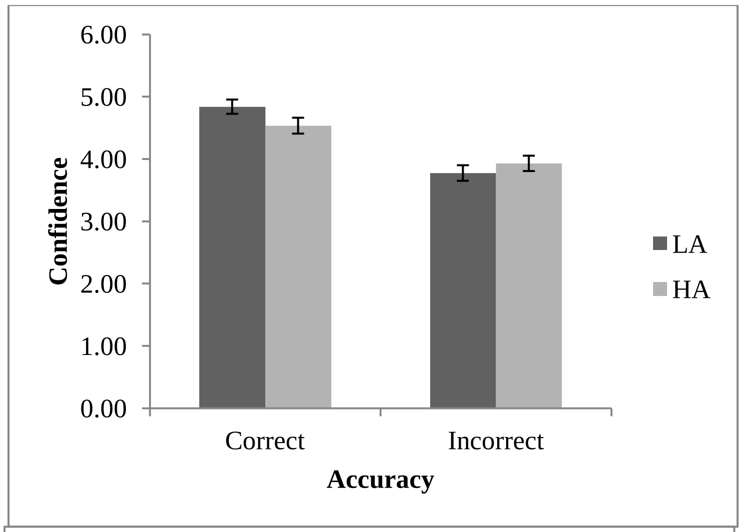
Mean recognition memory performance measured as d' (with standard deviations in parentheses) following short and long encoding durations in HA and LA Groups

Group	Duration 750 ms	Duration 4000 ms
Low Anxious	1.60 (*0.77*)	2.23 (*0.94*)
High Anxious	1.30 (*0.65*)	2.01 (*0.83*)

Memory Response Times. Memory RTs were analyzed using a mixed ANOVA with Duration (750 ms and 4000 ms) as the within-participants factor and Group (HA and LA) as the between-participants factor. There was a main effect of Duration, F (1, 115) = 6.07, MSE = 25589.97, η_p^2 = 0.05, p = 0.02, such that participants took longer to respond for the words presented for 750 ms than those presented for 4000 ms. There was no main effect of Group, F (1, 115) = 1.11, MSE = 110116.72, η_p^2 = 0.01, p = 0.30, or interaction, F (1, 115) = 1.78, MSE = 25589.97, η_p^2 = 0.02, p = 0.18. Therefore, I have shown for the third time that there is not a processing speed deficit in recognition decisions in the HA group.

Confidence. Confidence was analyzed in a mixed ANOVA with Duration (750 ms and 4000 ms) and Accuracy (correct and incorrect) as the within-participant factors and Group (HA and LA) as the between-participant factor. Participants who did not have any incorrect responses (i.e., no false alarms or misses; n = 8, 4 HA and 4 LA) were excluded from this analysis. Overall, the LA group made 669 incorrect (or 19%) and the HA group made 773 incorrect (or 23%) responses. There was a main effect of Duration, F (1, 103) = 13.30, MSE = 0.51, η_p^2 = 0.12, p < 0.001, with words encoded in the longer duration block having higher reported confidence. There was also a main effect of Accuracy, F (1, 103) = 105.20, MSE = 0.58, η_p^2 = 0.51, p < 0.001, with participants reporting higher confidence for correct answers. The main effect of Group was non-significant ($F < 1$). There was a significant Accuracy x Group interaction, F (1, 103) = 4.55, $MSE = 0.58$, $\eta_p^2 = 0.04$, p = 0.04, and a significant Accuracy x Duration interaction, F (1, 103) = 27.19, $MSE = 0.35$, $\eta_p^2 = 0.21$, $p < 0.001$ (see Figure 4). The Group X Duration and the three-way interaction were non-significant ($F < 1$).

Figure 4



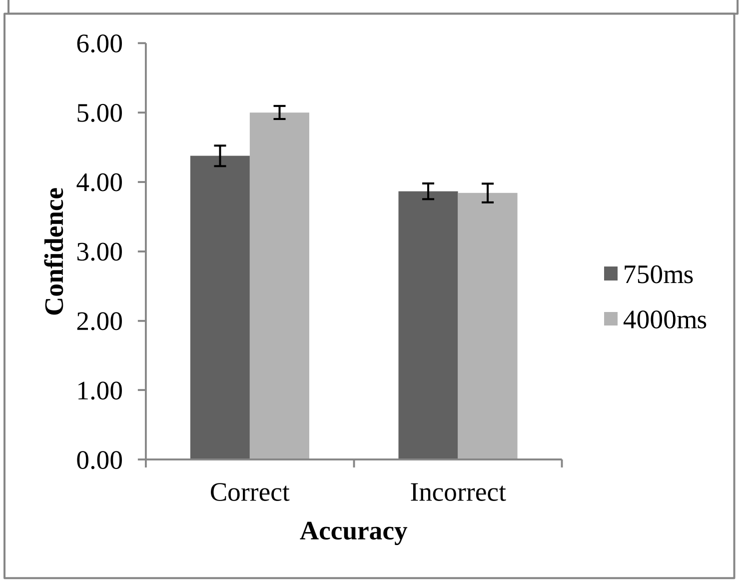


Figure 4. Top panel shows mean confidence reported with standard error bars for accuracy by group. Bottom panel shows mean confidence reported with standard error bars for accuracy by encoding duration.

The significant 2-way interactions were explored by conducting 2 additional mixed ANOVAs, one for Accurate and one for Inaccurate responses with Duration (within) and Group (between) as factors. For Inaccurate responses, there were no main effects or interactions (all *F*s < 1). For Accurate responses, the main effect of Duration was significant, F (1, 115) = 41.29, $MSE = 0.51$, $\eta_p^2 = 0.27$, $p < 0.001$, with participants reporting higher confidence in their responses to words from the longer encoding duration. There was also a significant main effect of Group, F (1, 115) = 5.26, $MSE = 1.01$, $\eta_p^2 = 0.04$, $p = 0.02$, with the HA reporting significantly lower confidence in correct responses compared to the LA group. The Group X Duration interaction was non-significant, F (1, 115) = 1.79, $MSE = 0.52$, $\eta_p^2 = 0.02$, $p = 0.18$. In this experiment, HA again report lower confidence than the LA participants despite the lack of an anxiety-induction. This suggests that the decreased confidence found in the literature and in this series of experiments may be a semi-permanent state for HA individuals.

Confidence Response Times. Confidence was analyzed in a mixed ANOVA with Duration (750 ms and 4000 ms) and Accuracy (correct and incorrect) as the within-participant factors and Group (HA and LA) as the between-participant factor. As with confidence, participants who did not have any incorrect responses were excluded from this analysis. There was a main effect of Duration, F (1, 103) = 9.81, $MSE = 44782.39$, $\eta_p^2 = 0.09$, $p = 0.002$, such that participants took longer to respond when rating confidence for 4000 ms than 750 ms words. There was also a main effect of Accuracy, F (1, 103) = 34.48, $MSE = 43630.01$, $\eta_p^2 = 0.25$, $p < 0.001$, such that participants were faster to respond when correct than incorrect. The effect of Group approached significance, F (1, 103) = 2.62, MSE = 288052.31, η_p^2 = 0.03, p = 0.109, with the HA responding more slowly than the LA group. There was also a Duration x Accuracy interaction, F (1, 103) = 5.32, MSE = 24028.01, η_p^2 = 0.05, p = 0.02 (see Figure 5). No other interactions were significant (Fs < 1).

The significant 2-way interactions were explored by conducting 2 additional mixed ANOVAs, one for Accurate and one for Inaccurate responses with Duration (within) and Group (between) as factors. For Accurate responses, there was no longer a main effect of Duration (F < 1) or Group, F (1, 115) = 2.15, MSE = 336132.70, η_p^2 = 0.02, p = 0.15, and the interaction was also non-significant (F < 1). For Inaccurate responses, there effect of Duration remained, F (1, 103) = 9.50, MSE = 54776.86, η_p^2 = 0.08, p = 0.003, in the same direction as before and there was also a trending effect of Group, F (1, 103) = 3.62, MSE = 177163.84, η_p^2 = 0.03, p = 0.060, such that the HA was responding more slowly than the LA group. This finding again confirms what was found in Experiments 1 and 2, that the HA group takes more time than the LA group to make post-memorial decisions but not the initial recognition judgment.

Figure 5

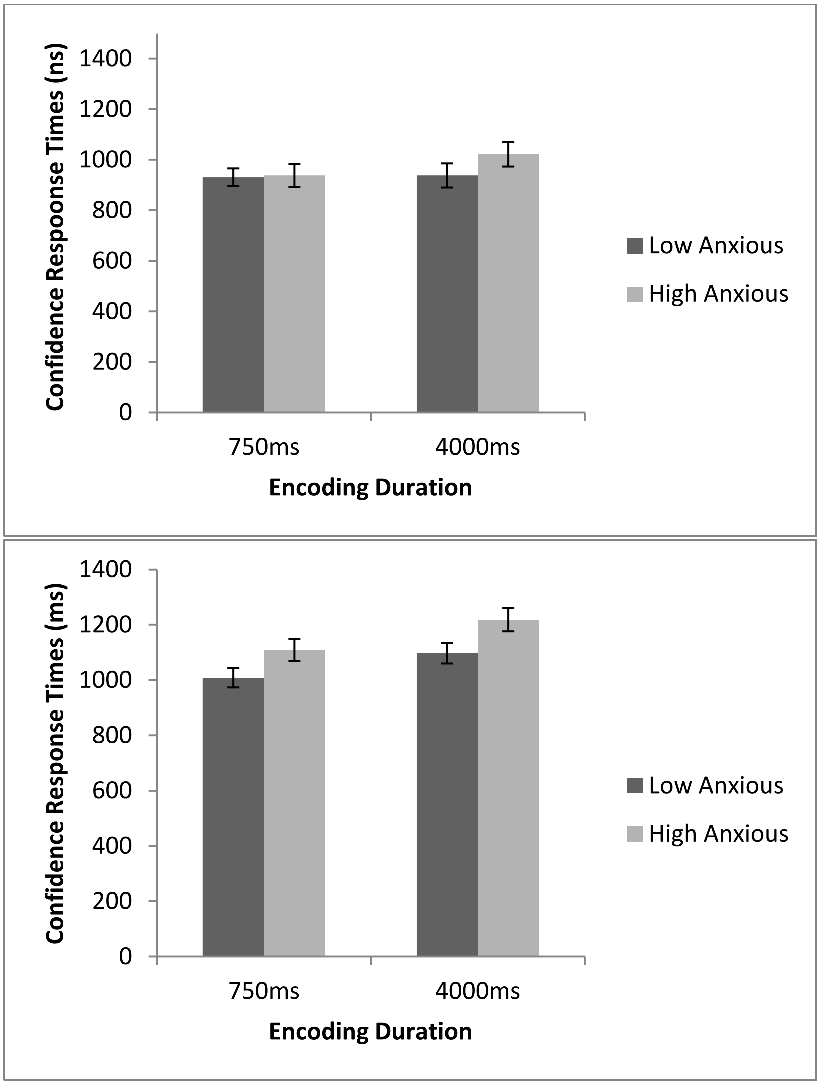


Figure 5. Top panel shows mean confidence response times with standard error bars for accurate responses by group. Bottom panel shows mean confidence response times with standard error bars for inaccurate responses by group.

Accuracy-Confidence Resolution. To examine the relation between accuracy and confidence, I calculated Goodman-Kruskal (1954) Gamma coefficients for each person at each of the two durations. The resulting Gamma correlations were analyzed using a mixed ANOVA with Duration (750 ms and 4000 ms) as the within-participants factor and Group (HA and LA) as the between-participants factor. There was a main effect of Duration, *F* (1, 115) = 16.21, *MSE* = 0.08, η_p^2 = 0.12, p < 0.001, with higher Gamma correlations for the longer encoding duration block. There was also a significant effect of Group, *F* (1, 115) = 5.12, *MSE* = 0.21, η_p^2 = 0.04, p = 0.04, such that the LA group had higher Gamma correlations than the HA group. The Group x Duration interaction was non-significant, *F* (1, 115) = 1.07, *MSE* = 0.08, η_p^2 = 0.01, p = 0.30. Means and standard deviations are shown in Table 10. Therefore, in this experiment a difference in resolution was found between the HA and LA groups, however, the HA group was not found to be more realistic, instead under-confidence led to a poorer predictive association between confidence and memory accuracy.

Table 10

Mean Gamma coefficients (with standard deviations in parentheses) following short and long encoding durations in HA and LA Groups

Group	Duration 750ms	Duration 4000ms
Low Anxious	0.46 (*0.34*)	0.57 (*0.44*)
High Anxious	0.29 (*0.35*)	0.47 (*0.38*)

4.3 Discussion

I examined memory accuracy and confidence, as well as the relation between these measures, for words presented at two different encoding durations in participants with high and low self-reported levels of anxiety. I aimed to determine whether HA individuals had more or less realistic appraisals of confidence than LA participants and to explore whether a longer encoding duration would increase confidence in the HA group. While encoding duration did not lead to a differential benefit in HA and LA participants, I demonstrated the expected finding that longer encoding time improves memory and increases confidence. I also showed that differences in self-reported anxiety led to significant deficits in memory accuracy, consistent with some studies (Cheie & Visu-Petra, 2012; Dodson & Markham, 2001; Glover & Cravens, 1974; Salthouse, 2012; Valentine & Mesout, 2009) and Experiment 1 and 2. In line with other research, my HA group showed lower confidence judgments than those in the LA group (Nolan & Markham, 1998; Ridley & Clifford, 2006; Valentine & Mesout, 2009). I additionally showed that longer encoding duration improves the accuracy-confidence resolution, suggesting that longer encoding times lead to a more realistic appraisal of confidence instead of over-confidence as suggested by Memon and colleagues (2003) since overconfidence would have led to less positive accuracy-confidence Gamma correlations.

I did not find that encoding duration led to any differential effects for HA and LA participants, although I did replicate past findings of higher memory accuracy with longer encoding duration (Craik & Rabinowitz, 1985; Eisdorfer et al., 1963; Grenfell-Essam et al., 2013; Smith & Kimball, 2012). I also supported Bothwell and colleagues' (1987) assertion that longer encoding durations results in a higher accuracy-confidence resolution. I acknowledge, however, that the low number of incorrect trials in my study may limit the strength of my conclusion. Yet, the ratio of difference between correct and incorrect trails that went into the Gamma correlation is similar to that reported in other studies using this statistic (Bornstien & Zickafoose, 1999, Brewer & Sampaio, 2006). My findings run counter to Memon and colleagues' (2003) findings that longer encoding leads to overconfidence in false alarms. Memon and colleagues (2003) used much longer encoding durations, of 12 s and 45 s, than in my experiment, which may also be the reason for the disparity in results as the researchers argued that the participants felt that after such a long encoding duration they "ought" to know the answer. Their experiment also had a simultaneous line-up presentation during recognition, and it has been demonstrated previously (Deffenbacher, 1980) that forced choice tasks of this nature result in higher confidence judgments overall, compared to single response presentation, as was used in my experiment.

The accuracy-confidence relation in this experiment was analyzed using Gamma correlations and it was shown that high levels of self-reported anxiety reduced the accuracy-confidence correlation, regardless of encoding duration. Gamma correlations are driven by the difference in participant's confidence between correct and incorrect responses. The HA group had low levels of confidence specifically for correct responses which meant that the difference between correct and incorrect responses was smaller than in the LA group, accounting for the low correlation between accuracy and confidence in the HA group. My findings support the suggestion by Ridley and Clifford (2006) that HA participants have unrealistically low reports of confidence in their accurate responses. I was unable to determine whether this effect was driven by state or trait anxiety as both were significantly higher in the HA group and they were also correlated.

My results show that increasing encoding time is beneficial to memory accuracy, confidence, and the relation between them. Moreover, I demonstrated that HA have poorer accuracy-confidence resolution than LA individuals. My results suggest that anxious individuals have less realistic confidence ratings than their low-anxious peers, and increasing encoding duration did not alleviate this deficit.

5. General Discussion

Across three experiments, I examined how individual differences in anxiety in a non-clinical population influenced memory, confidence, and the relation between them. It was consistently found that the anxious group had poorer memory, lower confidence and/or greater hesitation when evaluating memory decisions. Experiments 1 and 3 found both of these while in Experiment 2 confidence was not different between anxious and low-anxious participants. In addition, I did not find any evidence that anxious participants are more realistic in their assessments of confidence; instead, the anxious group was either equal to the low-anxious group or less realistic. Two manipulations were introduced in an attempt to increase confidence and accuracy in the anxious group: the ability to modify responses and longer encoding durations. Longer encoding time did not differentially improve the anxious group while the ability to modify responses increased confidence but actually decreased accuracy. Overall, this series of experiments shows that even non-clinical levels of anxiety can impair memory performance even without any overt manipulation or induction of anxiety.

Anxiety and Memory

Not all studies have found that high levels of anxiety reduce memory, especially when anxiety is induced experimentally. One of the studies that did not find an effect of anxiety on memory (Taylor, 1958) used ego threat (that is telling participants that they are performing worse than others) as an anxiety manipulation. Given that persons with high anxiety have been found to be especially sensitive to negative appraisal (Eysenck & Calvo, 1992), they may have increased task effort to avoid additional negative evaluation, thereby inadvertently enhancing memory performance. Similarly, Nolan and Markham (1998) induced anxiety by showing participants video recordings of their responses while they were recalling details of a crime, and informed participants that their responses would be watched by raters afterwards. It is resonable to assume that in that situation anxious participants would have again been aware of possible negative evaluation by others and increased task effort to avoid embarrassment, again enhancing memory in this group.

For this reason, I tested memory accuracy in HA and LA participants both when anxiety was induced and when it was not. When inducing anxiety in Experiment 1 and 2, I did not use ego threat, which could increase on-task effort, but instead introduced an unrelated but anxiety-provoking task. In the second experiment, I did not induce anxiety at all, though there is some concern that the memory test and experimental setting would induce some anxiety on its own, and memory deficits in the HA group still emerged. These effects were more subtle and I required a much larger sample size than in Experiments 1 and 2. By not including a direct manipulation of anxiety in Experiment 3, I was able to suggest that there are individual differences that extend beyond particularly anxiety-provoking settings.

Processing Efficiency Theory and Long-term Memory

I have shown consistently throughout these three experiments that processing efficiency on a word recognition task, as indexed by RT, was not affected by anxiety. Instead, I saw a decrease in effectiveness, memory accuracy, without corresponding RT differences. Differences in RTs emerged in every experiment but they were all in post-decision processes, rating confidence or deciding whether to change a response. This suggests that, in a design where a response can be evaluated after it is made, highly anxious individuals are able to defer task-performance worry until that time. Clearly, in all experiments, HA participants were able to identify or reject a word as quickly as their LA peers. This finding suggests an amendment to processing efficiency theory (PET) such that worry slows only post-decisional processes and not recognition decisions themselves. Studies in the past that examined anxiety, confidence, and memory did not report RTs (Dodson & Marksham, 2001; Nolan & Markham, 1998; Ridley & Clifford, 2006) making it difficult to compare my findings to others.

Interestingly, and in line with my findings, a study in clinical participants by MacDonald and colleagues (1997) also failed to find support for PET on a long-term memory test. The experiment compared patients with checking subtype obsessive-compulsive disorder (OCD), other subtypes of OCD, and healthy controls. Participants were asked to remember a list of words and response times and confidence were also recorded. There was a marginal difference in RTs between the checking group and the other two collapsed but no other contrasts were significant. Unfortunately, confidence response times were not reported. The researchers argued that the results may not have been significant because participants were given unlimited time to respond and were also not given instructions about responding as quickly as possible. In my experiments both of those elements were present and an RT difference was still not observed. In addition, the non-checker OCD group had an average RT that was virtually identical to the controls despite having very high levels of state anxiety. This provides converging evidence from a clinical sample that in long-term memory task, processing efficiency is not affected before effectiveness.

Memory Confidence and Anxiety

I replicated past findings of reduced memory confidence in Experiments 1 and 3 but not in Experiment 2, where HA and LA participants had similar levels of confidence. Lower confidence has been found in most examinations of sub-clinical anxious participants (Nolan & Markham, 1998; Ridley & Clifford, 2006; Valentine & Mesout, 2009), yet one examination of clinical participants that also included a sub-clinical anxious group found that confidence in that group did not differ from controls (Tuna et al., 2005). As the answer-switching paradigm from Experiment 2 had not been used in previous studies and as the effect of anxiety on confidence has been reasonably consistent in the literature, my results suggest that knowing there would be an opportunity to switch answers increased the confidence of the HA group. In addition, there was not a large difference in overall confidence between experiments (average overall confidence was consistently about 5.00 on a 1-6 point scale).

Experiment 3 also showed that the lack of confidence in HA individuals, reported in the literature, is present even in the absence of a specific anxiety induction. This suggests that individuals with high levels of trait anxiety may experience low levels of confidence often, especially when engaged in tasks that test their memories. This effect was alleviated when participants were given time to change their responses but not when encoding time was lengthened. More investigation would be required to determine whether this apparently persistent lack of confidence interferes with everyday functioning and whether there would be performance improvements in this population if their confidence deficits were ameliorated.

The Accuracy and Confidence Relation

Across the 3 experiments, I only discovered a difference in the accuracy-confidence relation once, when I did not directly induce anxiety. When anxiety was induced, highly anxious participants had similar resolution to the low anxiety group. My findings overall suggest that Ridley and Clifford (2004) were correct in their assertion that highly anxious participants are less realistic than their low-anxious peers. Despite low-anxious participants often being found to be overconfident (Adams & Adams, 1960; Chua et al., 2012; Fichhoff et al., 1977), the HA group has been shown to be under-confident, though not always to a level that affects their accuracy-confidence relation.

Since there was not an experiment in the sub-clinical literature that performed similar analysis to mine, I examined the clinical literature. An experiment that examined both OCD patient checkers and sub-clinical checkers on memory for words found that OCD patients had gamma correlations that were not significantly different from zero (Tuna et al., 2005). The sub-clinical participants were not different from the control group and both scored within the normal range found in similar experiments. This experiment included both a paired-recall test and a forced-choice recognition test. However, the control sample had higher levels of state and trait anxiety than my sample since inclusion in that group was dependent on checking symptoms and not anxiety. There was also no anxiety induction included in this experiment. Despite above average levels of anxiety in the sub-clinical group in this experiment, no memory deficits and no deficit in confidence were found relative to the controls. Again, this may be because of the grouping criteria. This experiment again provides converging evidence with mine as the most highly anxious group did not have a reliable accuracy-confidence relation.

Limitations and Conclusions

There are several limitations to this thesis that will be discussed here. Firstly, the distinction between anxious and low-anxious participants was varied across experiments as I used two different standardized tests, the STAI and the STICSA. STICSA was used in Experiment 3 because it has been reported to be less confounded with depression and has also been found to be well correlated with STAI results (Grös et al., 2007). I also separated the groups in Experiments 1 and 2 by the normative average on STAI, but in Experiment 3 performed a median split. The reason for this difference was twofold. Firstly the STICSA does not have the a wealth of normative data that the STAI does so I was not as certain of the average level of anxiety found in undergraduate students, and second, anxiety levels were much lower overall in

Experiment 3 as there was not a direct manipulation of anxiety so it would have been difficult to use the same cut-off scores as Experiments 1 and 2.

In all the experiments, cut-off scores were used to divide participants into high and low anxiety groups. There are two commonly used ways of dividing participants into anxiety groups: experimenters can use the extreme ends of the scale to represent each group (e.g., the upper and lower quartiles) or a single cut-off point (e.g., either a median split or a point derived from normative data). However, in this study we wanted to use data from all participants and therefore opted to use a single cut-off score for grouping. Because of this participants were included who fell only 1 point apart from each other on the STIA or STICSA scale and yet were in different groups. There is not a theoretical difference in 1 point on either of those scales. However, as this experiment was concerned with healthy undergraduate students without clinical anxiety, there was restriction in the range of scores provided because a high enough score would denote clinical anxiety. Methods of dividing participants into high versus low-anxious groups in past literature have been varied as well, with some experiments using different scales such as the Test Anxiety Scale (Dobson & Markham, 2001, Nolan & Markham, 1998) and those who used the STAI using median splits (Valentine & Mesout, 2011), or analyzing results using anxiety as a continuous variable (Salthouse, 2012). A higher level of standardization in the classification of participants in this area of research might help to produce more consistent results in cognitive performance in anxious persons.

In addition, I was unable to establish a difference is arousal levels through SC to confirm self-report levels of anxiety. Eysenck and Calvo (1992) noted that it is extremely difficult to match physiological arousal with self-reported anxiety. The researchers suggested that part of the reason for this may be that even with similar levels of arousal, anxious participants report higher self-perceived arousal than low-anxious individuals. Valentine and Mesout (2011) measured arousal using heart rate in a manipulation check during their London Dungeon experiment and found that changes in heart rate accounted for fifty-eight percent of the variance in state anxiety. However, their experiment had a much higher level of state anxiety reported (average of 49 overall) and a much longer anxiety induction (~ 45 minutes). In Experiment 1, I was unable to show an association between SC and state anxiety, even during my ten-minute anxiety induction. Unfortunately, the transient nature of the association between self-reported anxiety and physiological arousal can make results less convincing as self-report measures can be flawed.

However, even with these limitations, this series of experiments has uncovered some interesting new evidence. First, I discovered and then confirmed that when participants are given time to evaluate responses through confidence ratings or deciding to change an answer, there is not a processing speed deficit in anxious participants for the recognition response. Anxious participants are able to make recognition decisions from long-term memory as quickly as their low-anxious peers. I also showed that when reviewing responses, either with a confidence judgment or a decision to modify an answer, anxious participants had longer response times, indicating greater hesitation or worry. This finding does not support processing efficiency theory which predicts that processing speed deficits should be present in recognition judgments in anxious individuals. The increased hesitation seen in post-memorial evaluation may have practical implications. Anxious individuals may require greater amounts of time when completing tests as they need more time to reflect on their memory classifications. Despite normal processing speed for memory responses, from my evidence it seems likely that on a test an anxious person would take longer moving from one question to another because they would be evaluating the accuracy of their previous response.

Second, I introduced two manipulations in an attempt to alleviate the effect of anxiety on both memory accuracy and confidence, both of which were lower in the anxious group in Experiment 1. Neither of these manipulations resulted in the anxious group reaching parity with the low-anxious except in the case of Experiment 2, where anxious participants were no longer significantly different in confidence from the low-anxious group. However, an increase in confidence is not helpful to the anxious group without an accompanying increase in memory accuracy. The two manipulations had different effects: increased encoding time, while not beneficial to a greater amount in the anxious than low-anxious group, did improve memory accuracy scores for the anxious group, while the ability to change responses decreased accuracy. Therefore, in a practical sense, anxious individuals should be encouraged, with the rest of the population, to study information longer if they wish to recognize it with greater accuracy, but unlike low-anxious individuals, anxious persons might not want to change their memorial responses on examinations.

Further work is required for the response switching paradigm, though, as I did not test anxious individuals using a multiple-choice paradigm. Multiple-choice questions and answer switching have been studied more extensively because multiple choice is a common testing method in both high school, university, and on standardized tests such as the SAT and GRE.

Lastly, I have replicated past findings that anxious participants report lower levels of confidence on tests of long-term memory, and I have expanded this finding by examining how realistic or predictive of accuracy this level of confidence is in anxious and low-anxious participants. Overall, anxious participants had either the same predictive resolution or had lower predictive resolution when compared to their low-anxious peers. This relation has not been tested extensively in the literature. This finding is important, because given the frequency of overconfidence reported in the literature, it was possible that anxious individuals were reporting lower confidence because they were better able to assess their own performance. This view was not supported. As such, results indicate that anxious participants are under-confident; this lack of confidence could be affecting their everyday functioning. It is possible that anxious persons are less likely to speak up in discussions because they doubt their responses, are less likely to be selected as witnesses in court (Dobson & Markham, 2001), and are perceived by others as less reliable (Nolan & Markam, 1998). For these reasons, I would encourage future research to explore ways of alleviating the effects of anxiety on long-term memory to help anxious individuals to respond more accurately and to feel more confident in their abilities.

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