Memory Bias for Threat-Related Information in Social Anxiety

by

Ryan Christopher Yeung

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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

Biases in what is committed to memory and ultimately remembered are a key feature in individuals plagued by high levels of social anxiety. By selectively remembering the unfavourable aspects of past social situations, early work has suggested that those high in social anxiety may have enhanced memory for threat-related information. Other research has suggested that because threatening material is also most often an unwanted, irrelevant distraction to the individual's task at hand, the effects of threat-relatedness have not been properly disentangled from the effects of task-relevance. In other words, although memories of social blunders are threat-related, as long as the individual is not intentionally attempting to re-experience their failures, these memories can also be seen as irrelevant distractors. Some have even suggested that highly socially anxious individuals may instead have enhanced memory for *all* distractors, not simply threat-related ones. Over the course of this thesis, the aims were to investigate the conditions under which a memory bias in high social anxiety is produced or eliminated, as well as to probe for the potential cognitive mechanisms underlying the bias.

In Experiment 1, the interaction between threat-relatedness and task-relevance was examined in individuals high compared to low in social anxiety. Using a target-distractor paradigm, participants either saw a series of neutral or threatening target words, which they were asked to commit to memory; each target was simultaneously paired with a neutral or threatening distractor word. Highly socially anxious participants showed enhanced memory for threat-related distractors on a subsequent recognition test, but only when the targets they were asked to commit to memory were also threat-related. Such a result suggests that it is only when they are primed, or in a socially threatening mindset, that a memory bias for threat-specific, and irrelevant information, emerges. Prior to becoming part of long-term memory, information is first maintained in one's

working memory buffer. Thus, it stands to reason that any bias in the processing of threatening material may originate at the level of working memory. In Experiment 2, a series of word span tasks was administered to participants that were high or low in social anxiety. All participants performed three word span tasks, each with a unique word list constructed to have a different level of threat-relatedness: neutral, general threat, or social threat. We found that those high relative to low in social anxiety had reduced working memory capacity for words related to socially threatening concepts, compared to words related to neutral or generally threatening concepts. These findings suggest a bias exists in terms of what is maintained in a working memory buffer, which could explain how long-term memories are ultimately distorted in favour of threatening information. In Experiment 3, the specificity of the working memory bias was further examined. We aimed to rule out a deficit in ability to cluster semantically similarity words, as an alternative explanation for the reduction to working memory capacity observed in Experiment 2. Even after introducing an additional word span task that was both neutral and semantically similar, highly socially anxious individuals still only showed reduced working memory capacity for socially threatening words.

In demonstrating that long-term and working memory biases only emerge under specific conditions, the current research suggests that the characterization of individuals with high social anxiety as having poor general attentional control is inaccurate. This thesis specifies the precise conditions, and potential mechanism of action, that lead to a memory bias in such individuals.

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Chapter 1

Introduction

Social anxiety (SA) is a phenomenon characterized by the fear and avoidance of scrutiny from others in social situations. These concerns about interpersonal encounters often manifest through the chronic, intrusive rehearsal of past social situations in a process referred to as post-event processing (PEP). Past research has suggested that PEP is not only specific to SA, but also indicative of deeper irregularities in cognition: while engaged in PEP, negative or unfavourable content from past encounters are preferentially ruminated upon (Fehm, Schneider, & Hoyer, 2007). According to early models of social anxiety disorder (SAD), this memory bias stems from the socially threatening information being encoded in better detail than competing neutral information (Clark & Wells, 1995). Thus, SA may be linked to a selective memory bias for threatening information. However, other models of SAD have suggested that the threat-relatedness of the memoranda is not sufficient to produce a memory bias (Heimberg, Brozovich, & Rapee, 2010; MacLeod & Mathews, 1991). Instead, these models have argued that the memory bias is driven by a general susceptibility to distraction: if a highly socially anxious individual selectively encodes threatening information as opposed to competing neutral information, this may represent an inability to disengage from unwanted, irrelevant information. As such, SA may also be linked to a memory bias for task-irrelevant information.

Beyond these cognitive models, early research has questioned if memory biases are even a feature of social anxiety that can be observed and studied in the laboratory. In one qualitative review of memory biases in a series of 11 studies of clinical anxiety disorders, very little support was found for recall or recognition biases across the disorders, as a group (Coles & Heimberg,

2002). Specifically, the observed lack of memory biases in participants with SAD seemed to be driven by a failure to find evidence for altered explicit memory. Similar conclusions were reported from studies of SAD in a review by Heinrichs and Hofmann (2001), however, their novel inclusion of studies using nonclinical populations yielded important distinctions: while meagre evidence was available for a memory bias in SAD, evidence of biased recall for threat was relatively strong in non-clinical SA (Heinrichs & Hofmann, 2001). Further building on this, a later meta-analysis incorporating a larger pool of 165 studies – also including studies of nonclinical populations – found substantial evidence for explicit memory biases in SA (Mitte, 2008). For instance, across all anxiety types as a group (including SA and generalized anxiety among others), a trend for high-anxious individuals was found wherein recall was elevated for threat information. Conversely, an overall trend across anxiety types could not be found when memory was assessed using a recognition test. This finding was nonetheless accompanied by the observation that much heterogeneity was present in the results of these recognition studies, including notable differences between the anxiety types. Critically, it was suggested by Mitte (2008) that SAD might be an exception: while other anxiety disorders such as obsessive-compulsive disorder or panic disorder showed no recognition bias, a recognition bias for threat was usually present in studies involving participants with SAD.

Potential Cognitive Mechanisms for Memory Bias

If these memory biases do exist for individuals high in SA, how might they come about and why? Support for potential cognitive mechanisms are in place, although largely in the domain of general anxiety rather than SA. For example, attention control theory (ACT; Eysenck, Derakshan, Santos, & Calvo, 2007) proposes that general anxiety may be associated with memory biases through its impact on working memory (WM), the memory system responsible for storing

and manipulating information in the short term (Baddeley, 2003). Specifically, ACT suggests that in general anxiety, worrisome and irrelevant thoughts place a greater burden on the limited resources of the central executive. Because the central executive is the major component of WM responsible for goal-directed action, and overriding habit or schema-driven behaviour (Baddeley, 2003), it is plausible that excessive demands on the central executive may influence what gains access to the limited-capacity WM buffer. Highly anxious individuals may selectively attend to only threat-relevant stimuli, or such stimuli may obligatorily gain access to the WM buffer, regardless of whether they were relevant targets or irrelevant distractors (Mitte, 2008). Electrophysiological evidence has since supported this idea of vulnerability to threat-related distractors in high anxiety through what is referred to as a 'failure to filter' hypothesis (Stout, Shackman, & Larson, 2013). By measuring contralateral delay activity, an indicator of the amount of items currently stored in WM (Vogel & Machizawa, 2004), the authors found that threat-related distractors gained obligatory access to the highly anxious individual's WM space. Conversely, neutral distractors were filtered out effectively such that WM space was not used to store them unnecessarily. Thus, these results suggest a potential mechanism by which general anxiety could be tied to memory biases for threat, by altering what gains access into WM.

This work has recently been extended beyond general anxiety using a variety of paradigms, which have suggested that a similar framework could be applied to memory biases in SA. Perhaps most notably, an impairment of attentional control has been found to be uniquely associated with SA after controlling for state anxiety and depression (Moriya & Tanno, 2008). Following the literature on general anxiety, this difficulty in focusing and shifting attention as one desires should lead to enhanced processing of threatening, task-irrelevant information (Eysenck et al., 2007). Indeed, the idea that task-irrelevant distractors see memory benefits in high SA has been supported

in a wide array of tasks including flanker, visual search, change-detection, and spatial blink tasks (Moriya & Tanno, 2010; Moriya & Sugiura, 2012a; Moriya & Sugiura, 2012b; Moriya & Sugiura, 2013). However, these studies showed that participants high in SA had an impaired ability to filter out task-irrelevant, neutral distractors from WM, rather than threatening. Because immediate memory was enhanced even for non-threatening distractors, in high relative to low SA, the authors suggest that SA may be linked to a general failure to filter any distraction. A drawback of these studies, however, is that all stimuli were neutral in valence. Without inclusion of threat-related stimuli, it remains to be seen whether distractors of all valence are poorly filtered in individuals with high SA, or just threat-relevant ones.

Goals for Current Thesis

This thesis sought to investigate the conditions under which a memory bias emerges in high SA. Specifically, two main factors were examined for their ability to create conditions necessary to produce a memory bias: threat-relatedness and task-relevance. By manipulating both of these factors, the current research explored how the threatening and/or distracting nature of the material being processed might lead to a memory bias in those high in SA. Furthermore, this research aimed to clarify the mechanism by which a long-term memory bias might arise. Although much of the literature claims that the long-term bias in high SA stems from working memory dysfunction, few studies have directly examined this claim. The current findings offer new insights into the subtle ways that both long-term and working memory can be systematically altered depending on one's trait level of SA.

Chapter 2

Experiment 1: Enhanced Long-Term Memory for Threat Distractors in High Social Anxiety

Introduction

Early work in the SA literature has argued that the threatening nature of perceived past social blunders is what drives those memories to become strengthened, therefore biasing high SA individuals in favour of these negative representations (Clark & Wells, 1995). However, more recent work has claimed that a general failure to direct attention away from irrelevant information – and thus any distractor, regardless of threat-relatedness – is what drives a memory bias in high SA (Heeren, Maurage, & Philippot, 2015; Moriya & Sugiura, 2012a; Moriya & Sugiura, 2012b; Moriya & Sugiura, 2013). Unfortunately, these recent studies have generally not included threat-related stimuli, which are thought to be the stimulus of interest for memory biases in SA (Clark & Wells, 1995). Furthermore, studies that have presented threat-related stimuli have almost exclusively used them with general anxiety populations and as to-be-ignored distractors rather than the to-be-remembered targets (Stout et al., 2013). Because the threatening material has almost always been positioned as a distractor (rather than a target) in these paradigms, one cannot disentangle the influence of the presence of threat in the target, from the presence of a threatening distractor. As such, it remains unclear whether it is specifically threat-related distractors that gain access to WM, or merely the presence of threat in WM that facilitates further entry for *any* distractors.

In the current study, we included both neutral and socially threatening stimuli as distractors in order to investigate whether threat-relatedness of a distractor, or a target, influences memory in

those with high compared to low SA. Threat is a major component of many of the models proposed to account for the relationship between SA and memory biases, as threat-related distracting stimuli are thought to be highly salient for the high SA individual and subsequently better remembered (Eysenck et al., 2007; Mitte, 2008). The goal of the current study was to investigate the conditions under which a memory bias for threat may manifest in SA.

Methods

Participants and Design

Sixty undergraduate students at the University of Waterloo participated for course credit towards an enrolled psychology course. Participation was restricted to individuals who identified themselves as being fluent in the English language, had learned English at or before the age of seven, and had normal or corrected-to-normal vision. Participants were also pre-screened using their scores on an online administration of the Social Phobia Inventory (SPIN; Connor et al., 2000). Participation was initially not limited by SPIN scores, meaning that any participant could sign up and participate regardless of SA status. Once the high SA group had reached the target 30 participants, further participation was restricted such that only participants with low SA, as defined by the cutoff score of 19 (Connor et al., 2000), were allowed to sign up. The low SA group had a mean SPIN score of 11.57 (SD = 4.17, range = 17) while the high SA group had a mean SPIN score of 33.87 (SD = 9.34, range = 34).

All participants were tested alone in a single 30-minute session. Half of the participants were randomly assigned to the NT condition (M_{age} = 18.94, SD = 1.34, 26 female, 4 male), with the other half assigned to the TT condition (M_{age} = 20.96, SD = 5.76, 23 female, 7 male). Participants in both conditions were nearly identical in terms of the SPIN, with the NT condition

having a mean SPIN score of 23.23 (SD = 14.65) and the TT condition having a mean SPIN score of 22.20 (SD = 12.05).

In both conditions, participants performed the same sequence and number of tasks: pre-test digit span, study phase, test phases (target recall, surprise distractor recall, recognition), post-test digit span, Mill Hill Vocabulary Scale (Raven, Court, & Raven, 1977), and SPIN (Connor et al., 2000).

Materials

Digit Span. All participants were administered the unaltered digit span task (forward span) orally (Wechsler, 1939).

Word Lists. For the study phase, 30 socially threatening words were selected from previous studies on social anxiety (Asmundson & Stein, 1994; Hope, Rapee, Heimberg, & Dombeck, 1990; Lundh & Öst, 1996; Mathews, Mogg, May, & Eysenck, 1989; Ononaiye, Turpin, & Reidy, 2007; Pishyar, Harris, & Menzies, 2004; see Table 11 for full word lists). The normative valence ratings and word frequency of each word was then obtained from the Affective Norms for English Words (ANEW; Bradley & Lang, 1999). To produce 30 neutral words, each threat word was matched to another word of neutral valence from the ANEW with similar length and word frequency to the paired threat word. In addition to these 60 words, 20 additional words (10 neutral words and 10 threat words) were selected from the same sources to be used as plausible lures in the recognition test. After selection, independent-samples t-tests found that the threat words had a significantly more negative overall valence (M = 2.99) than the neutral words (M = 5.04, t(36.43) = 7.30, SE = 0.28, $p < .001$). Differences between word lists were non-significant for length and word frequency (all ps > .05).

Each word was visually presented to participants in 20–point Courier font, on a blank white background. In the study phase, one category of words (i.e., targets or distractors) was always presented in orange font colour, with the other category presented in purple. Colour of the text was counterbalanced across participants. In the recognition phase, all words were presented in black Courier font. All experimental stimuli were presented using E-prime (E-prime v.2.2 software, Psychology Software Tools Inc., Pittsburgh, PA).

Mill Hill Vocabulary Scale. All participants were administered Set A of the Mill Hill Vocabulary Scale to ensure fluency with the English language. In this task, participants were given a list of bolded words, and indicated in a multiple response format which word out of a group of six other words had the same meaning as the bolded word. The Mill Hill Vocabulary scale has been found to have excellent test-retest reliability (French & Beaumont, 1990; Raven et al., 1977). Fluency was defined as correct synonym identification for at least 30% of the questions (Raven et al., 1977). For the NT condition, the mean Mill Hill score was 56.67% (SD = 8.92%). Similarly, for the TT condition the mean Mill Hill score was 54.17% (SD = 11.53%). All participants scored at or above 30%, signifying ability to understand the verbal stimuli used in the experiment.

Social Phobia Inventory. All participants were administered the SPIN as part of a larger online pre-screening set of tests, for which they could receive course credit for participation. Our experiment was made available to a restricted set of participants based on the score obtained on the SPIN test, half of whom had initially reported a high SA score and the other half a low SA score using the cut-off of 19 (Connor et al., 2000). The SPIN was administered a second time at the conclusion of participation in our experiment, in-person in a written format, to allow categorization as either low or high SA. Classification into either the high or low SA group was determined solely using the in-person SPIN score.

To complete the SPIN, participants indicated on a scale from 0 (*not at all*) to 4 (*extremely*) the extent to which a series of problems (e.g., "Being embarrassed or looking stupid are among my worst fears") tended to bother them in a typical week. Although the established cut-off score of 19 is thought to distinguish between individuals with and without social anxiety disorder (SAD), formal diagnoses of SAD or any other psychopathology were not queried, nor confirmed by a clinician.

Procedure

After obtaining written informed consent and demographic information (age, gender, and years of formal education) from participants, the researcher administered the digit span task (Wechsler, 1939) orally to measure the participants' baseline verbal working memory capacity.

Participants then completed the study phase of the experiment on a computer with a 24-inch monitor. All participants were randomly assigned to one of two conditions: neutral targets (NT), which had all the studied target words as neutral, or threat targets (TT), which had all the studied target words as threatening. For both conditions, the study phase consisted of 20 trials with two words (the target word and the distractor word) presented on each trial. On half of these trials, the target was paired with a neutral distractor word, and on the other half the target was paired with a threat distractor word. Participants were instructed to memorize all the words presented in either orange or in purple (counterbalanced) and to ignore all the words presented in the other colour. Participants were told that their memory for only the target words (presented in either orange or purple, counterbalanced) would be later assessed. No mention was made of the later surprise test for the distractor words. Each trial began with a central fixation cross for 250 ms, which was followed by the word pairs presented for 500 ms each. Word pairs were presented 4 mm apart from each other vertically, with the centre of the top word offset 2 cm to the right and

the bottom offset 2 cm to the left. The words were slightly offset (see Figure 1) to mitigate any possible influences of cultural biases to fixate upon and make saccades towards the top-left of visual presentations (Abed, 1991).

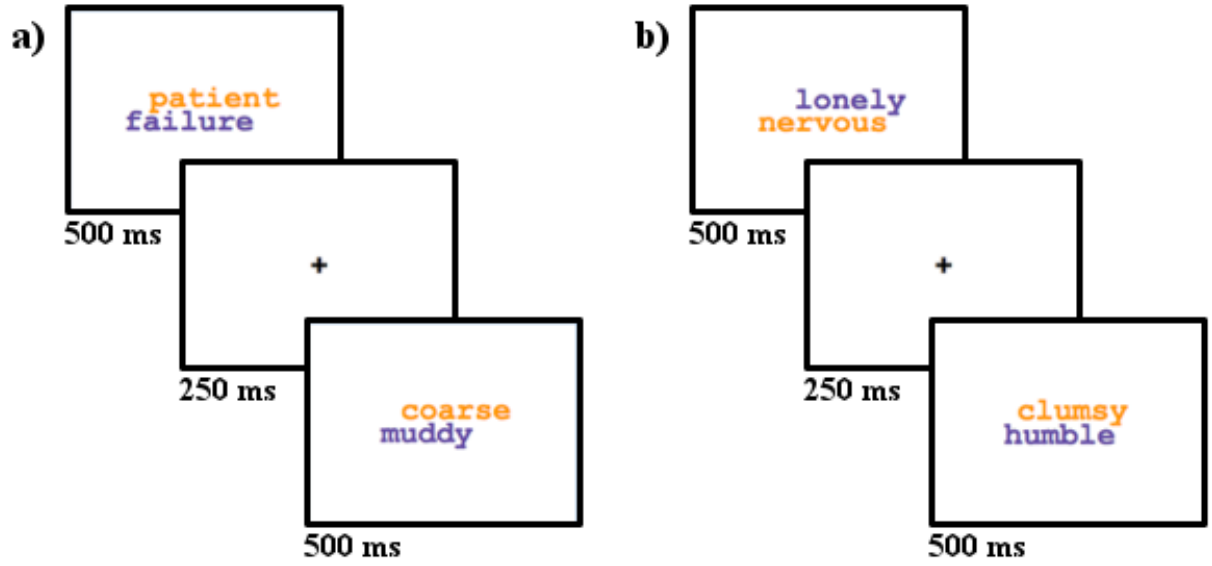

Figure 1. Sample trials for a) the neutral targets condition and b) the threat targets condition. In this example, targets are orange while distractors are purple.

Immediately after study, the computer monitor was turned off. Participants were given a blank piece of paper and 90 seconds to write down as many of the target words that they could remember. After handing the first paper to the researcher face-down, participants were then surprised with a second blank piece of paper and were asked to write down as many of the distractor words that they could remember, within a 90-second period.

Once both recall tests were complete, the computer monitor was turned back on and the participant completed a computerized recognition test. Participants were instructed that a series of words would appear in the center of the screen. One word appeared per trial in 20-point black Courier font for 3000 ms each, with a central fixation cross presented for 250 ms between trials.

Participants were asked to report whether they thought each item was old or new via key press (the 'h' and 'k' keys, respectively, labeled by stickers reading "O" and "N"). Old items were defined to participants as words that had been presented to them during the study phase, regardless of the ink colour in which the word was presented (e.g. all targets as well as all previously seen distractors were to be identified as old). New items were defined as words that had not been seen at all during the study phase.

The recognition test was composed of 40 trials: 20 old items and 20 new items. Of the 20 old items, 10 were previously seen targets (either all neutral or all threat depending on condition) and 10 were previously seen distractors (5 neutral and 5 threat). Of the 20 new items, 10 were neutral and 10 were threatening. New items were selected as plausible lures: half were new neutral words (with characteristics similar to the old neutral words) and half were new threat words (with characteristics similar to the old threat words). For example, the new neutral lures were chosen from the ANEW, matched for valence, word frequency, and word length to the old neutral items. Similarly, new threatening lures were chosen from the same previous studies on social anxiety (Asmundson & Stein, 1994; Hope et al., 1990; Lundh & Öst, 1996; Mathews et al., 1989; Ononaiye et al., 2007; Pishyar et al., 2004).

Following the recognition test, participants were administered the digit span task a second time to measure and compare re-test reliability of scores. Participants then completed the Mill Hill Vocabulary Scale and SPIN.

Results

Five participants were excluded from the analysis: Two of these had more than three standard deviations above the mean number of missing responses on the recognition test. The other

three participants were excluded for having an overall hit rate equal to their false alarm (FA) rate in the recognition test (i.e., accuracy at chance).

Recall

Recall performance is summarized in Table 1. Recall hits were measured as words that were successfully written down with the same root as a studied word. For example, if a participant wrote "embarrass" during test when "embarrassed" was studied, their response was coded as a hit. If a participant wrote a word whose root was not studied previously, their response was coded as a novel intrusion. As well, if a participant misattributed a word's source (e.g., reported a word as being a target when it was actually studied as a distractor) their response was recorded as a misattributed source intrusion.

TABLE 1

Mean memory performance in individuals low and high in social anxiety, in the neutral targets and threat targets conditions. Standard deviations in parentheses.

	Low SA		High SA	
	Neutral Targets (NT)	Threat Targets (TT)	Neutral Targets (NT)	Threat Targets (TT)
Target Recall				
Hits	5.08 (1.24)	5.36 (2.79)	4.73 (1.83)	6.36 (2.24)
Hit rate	0.25 (0.06)	0.27 (0.14)	0.24 (0.09)	0.32 (0.11)
Novel intrusions	1.33 (0.99)	0.79 (1.12)	0.53 (0.64)	0.86 (1.46)
Misattributed	0.33 (0.49)	0.29 (0.83)	0.40 (0.83)	0.29 (0.61)

source intrusions				
Distractor Recall				
Hits	0.33 (0.49)	0.50 (0.94)	0.33 (0.62)	0.36 (0.63)
Hit rate	0.02 (0.02)	0.03 (0.05)	0.02 (0.03)	0.02 (0.03)
Novel intrusions	0.75 (1.42)	0.64 (0.93)	0.73 (0.23)	1.21 (1.42)
Misattributed source intrusions	0.33 (0.49)	0.43 (0.65)	0.53 (0.17)	0.86 (1.41)

Note. *SA* = Social Anxiety, *NT* = Neutral Targets, *TT* = Threat Targets

Target Word Recall. We conducted a 2 (Group: low SA, high SA) X 2 (Condition: NT, TT) analysis of variance (ANOVA) using target recall hit rate as the dependent variable. Both main effects as well as the interaction were non-significant (all *p*s > .05). We also conducted 2 (Group: low SA, high SA) X 2 (Condition: NT, TT) ANOVAs using target novel intrusions or misattributed source intrusions as the dependent variables, though again both main effects as well as the interactions were all non-significant (all *p*s > .05).

Distractor Word Recall. We conducted a 2 (Group: low SA, high SA) X 2 (Condition: NT, TT) ANOVA using distractor recall hit rate as the dependent variable. Separate 2 (Group: low SA, high SA) X 2 (Condition: NT, TT) ANOVAs were also conducted using distractor novel intrusions or misattributed source intrusions as the dependent variables. No significant main effects or interactions were found from these ANOVAs, though we acknowledge that there was likely a floor effect with participants successfully recalling an average of only 0.38 distractors (SD = 0.68, all *p*s > .05).

Recognition

Target Word Hit Rate. We calculated target hit rate as the number of correctly identified words (out of 20) that were previously presented as targets. A 2 (Group: low SA, high SA) X 2 (Condition: NT, TT) ANOVA was conducted using target recognition hit rate as the dependent variable, with Group and Condition as between-subjects factors. There was no main effect of Group. The main effect of Condition was approaching significance, $F(1, 51) = 3.79$, $MSE = .027$, $p = .057$, $\eta_p^2 = .069$, with higher recognition in the TT condition ($M = .76$) than the NT condition ($M = .68$). The 2-way interaction was non-significant ($p > .05$), see Table 2 for means.

TABLE 2

Target recognition performance in individuals low and high in social anxiety, in the neutral and threat targets conditions. Standard deviations in parentheses.

	Low SA		High SA	
	Neutral Targets (NT)	Threat Targets (TT)	Neutral Targets (NT)	Threat Targets (TT)
Target hit rate	0.68 (0.18)	0.76 (0.17)	0.68 (0.15)	0.76 (0.15)
Overall FA rate	0.28 (0.20)	0.25 (0.11)	0.24 (0.15)	0.31 (0.11)
Neutral lure FA rate	0.26 (0.17)	0.11 (0.12)	0.26 (0.16)	0.11 (0.10)
Threat lure FA rate	0.30 (0.24)	0.39 (0.19)	0.21 (0.19)	0.51 (0.21)

Note. *SA* = Social Anxiety, *NT* = Neutral Targets, *TT* = Threat Targets, *FA* = False Alarm

Distractor Word Hit Rate. We calculated distractor hit rate as the number of correctly identified words (out of 10) that were previously presented as distractors. A 2 (Distractor Type: Neutral, Threat) X 2 (Group: low SA, high SA) X 2 (Condition: NT, TT) mixed ANOVA was

conducted using distractor hit rate as the dependent variable, with Group and Condition as between-subjects factors and Distractor Type as a within-subjects variable. There was a main effect of Distractor Type $F(1, 51) = 21.76$, MSE = 0.037, $p < .001$, $\eta_p^2 = .30$, such that hit rate for threat distractor words ($M = .43$, SD = .24) was significantly higher than for neutral distractor words ($M = .25$, SD = .26). There were no main effects of Group or Condition (ps > .05).

The Distractor Type X Condition interaction was significant, $F(1, 51) = 32.09$, MSE = 0.037, $p < .001$, $\eta_p^2 = .39$. There was also a significant interaction of Group X Condition, $F(1, 51) = 9.78$, MSE = 0.043, $p = .003$, $\eta_p^2 = .16$. Additionally, the interaction of Distractor Type X Group was significant, $F(1, 26) = 13.00$, MSE = 0.020, $p = .001$, $\eta_p^2 = .33$.

Importantly, there was also a significant 3-way interaction of Distractor Type X Group X Condition, $F(1, 51) = 4.51$, MSE = 0.037, $p = .04$, $\eta_p^2 = .08$. Figure 2 shows the pattern of memory performance. The 3-way interaction could be accounted for in that the 2-way interaction of Distractor Type X Condition differed across SA Group. For low SA participants, the 2-way interaction was significant, $F(1, 24) = 6.03$, MSE = 0.036, $p = .022$, $\eta_p^2 = .20$. Participants in the TT condition showed a higher threat ($M = .39$, SD = .21) compared to neutral distractor hit rate ($M = .14$, SD = .15. For high SA participants, however, the 2-way interaction of Distractor Type X Condition showed a greater effect size ($F(1, 24) = 31.69$, MSE = 0.036, $p < .001$, $\eta_p^2 = .54$). That is, those in the TT condition showed much better memory for threat ($M = .63$, SD = .19) than neutral distractors ($M = .11$, SD = .15; see Figure 2). For both low and high SA, memory performance for those in the NT condition did not differ between the neutral ($M_{low} = .42$, SD = .28; $M_{high} = .35$, SD = .30) and threat distractor types ($M_{low} = .40$, SD = .17; $M_{high} = .29$, SD = .24; see Table 3).

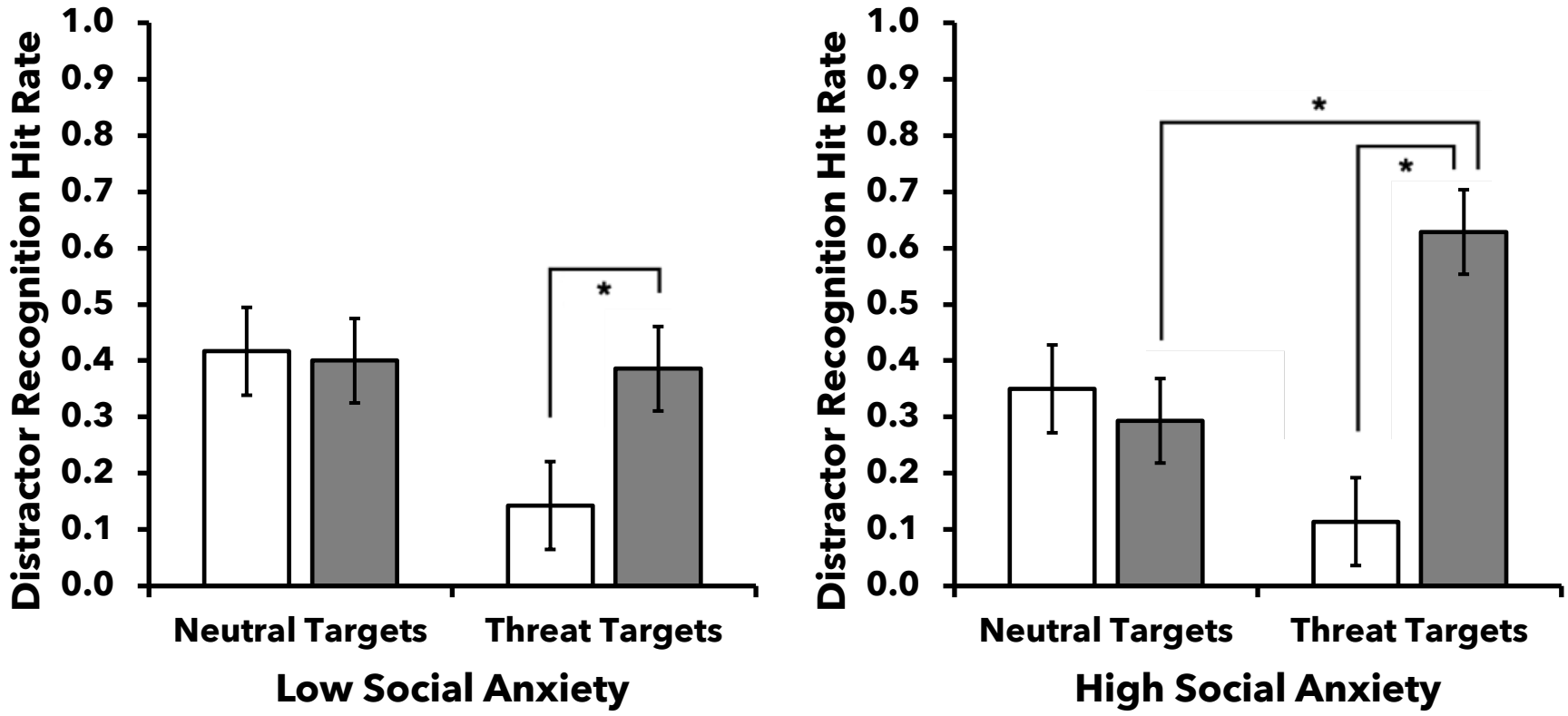

Figure. 2. Distractor hit rates for low and high SA groups in both NT and TT conditions. Neutral distractor hit rate represented by white bars and threat distractor hit rate represented by dark gray bars. Error bars show the standard error of the means. Significance of $p < .01$ represented by an asterisk symbol.

TABLE 3

Distractor recognition in individuals low and high in social anxiety, in the neutral and threat targets conditions. Standard deviation in parentheses.

	Low SA		High SA	
	Neutral Targets (NT)	Threat Targets (TT)	Neutral Targets (NT)	Threat Targets (TT)
Neutral distractor hit rate	0.42 (0.28)	0.14 (0.15)	0.35 (0.30)	0.11 (0.15)
Threat distractor hit rate	0.40 (0.17)	0.39 (0.21)	0.29 (0.24)	0.63 (0.19)

Note. *SA* = Social Anxiety, *NT* = Neutral Targets, *TT* = Threat Targets

False Alarm Rate

We calculated FA rate as the number of new words (out of 20) that were incorrectly identified as old. Further, lure recognition was broken down by the lure's threat-relatedness: neutral lure FA rate, calculated as the number of neutral new words (out of 10) that were incorrectly identified as old, and threat lure FA rate, calculated as the number of threatening new words (out of 10) that were incorrectly identified as old.

A 2 (Lure Type: Neutral, Threat) X 2 (Group: low SA, high SA) X 2 (Condition: NT, TT) mixed ANOVA was then conducted using FA rate as the dependent variable, with Group and Condition as between-subjects factors and Lure Type as a within-subject variable. A significant main effect of Lure Type was revealed, $F(1, 51) = 40.00$, MSE = 0.020, $p < .001$, $\eta_p^2 = .44$, such that threat lures ($M = 0.35$, SD = 0.23) were false alarmed to significantly more than neutral lures ($M = 0.18$, SD = 0.16).

There was also a significant two-way interaction of Lure Type X Condition, $F(1, 51) = 43.20$, MSE = 0.020, $p < .001$, $\eta_p^2 = .46$. For participants in the TT condition, there was a main effect of Lure Type, $F(1, 26) = 61.25$, MSE = 0.027, $p < 0.01$, $\eta_p^2 = .70$, such that participants false alarmed to threat lures ($M = 0.45$, SD = 0.21) significantly more than to neutral lures ($M = 0.11$, SD = 0.11). For participants in the NT condition, there was no such main effect of Lure Type ($p > .05$). The 3-way Lure Type X Group X Condition interaction was non-significant ($p > .05$).

Digit Span

For all participants, digit span was measured as the length of the longest series of digits the participant could successfully recall. No significant differences in digit span were found between SA group or condition at pre-test or post-test (see Table 4).

TABLE 4

Mean performance on the digit span tasks, SPIN, and Mill Hill in individuals low and high in social anxiety, in the neutral and threat targets conditions. Standard deviation in parentheses.

	Low SA		High SA	
	Neutral Targets (NT)	Threat Targets (TT)	Neutral Targets (NT)	Threat Targets (TT)
Pre-test digit span	6.83 (0.94)	6.57 (1.16)	6.57 (1.22)	6.57 (1.34)
Post-test digit span	6.33 (0.98)	6.57 (1.16)	6.87 (1.30)	7.14 (1.23)
SPIN	10.50 (3.83)	12.43 (4.94)	35.73 (9.90)	32.00 (8.65)
Mill Hill	16.50 (2.35)	16.29 (3.69)	17.40 (2.92)	16.21 (3.36)

Note. *SA* = Social Anxiety, *SPIN* = Social Phobia Inventory

Discussion

Past research is mixed regarding the conditions under which memory biases emerge in individuals with high levels of social anxiety. The current study examined whether individuals with high SA would show a memory bias for threatening, but task-irrelevant information, or whether they have a memory bias for both threatening as well as neutral distractors. Recognition of socially threatening distractors was particularly enhanced for participants with high compared to low SA, but only when they were presented with targets that were also socially threatening. No difference in memory for the distractors was found when the targets were of neutral valence, in either the high or low SA group. Findings suggest that when SA is primed, attention to irrelevant, but socially threatening, information is heightened. In the following, we discuss the implications of our findings and offer some insights into why such a bias might occur.

Specificity of Filtering Deficit in High SA

Some past research suggests that high SA produces a *general* memory bias for all distractors. In a series of experiments, highly socially anxious individuals have demonstrated enhanced immediate memory for distractors, even when those distractors were emotionally neutral (Moriya & Tanno, 2010; Moriya & Sugiura, 2012a; Moriya & Sugiura, 2012b; Moriya & Sugiura, 2013). As such, these authors' findings are in line with the idea that individuals high in SA may simply have a general impairment in top-down attentional control, hindering their ability to disengage from any task-irrelevant material. Findings from Heeren and colleagues (2015) have recently lent support to this hypothesis of general attentional impairment, suggesting that individuals with SAD are poorer at orienting attention than non-anxious controls due to being faster to engage with distractors. However, each of these previous studies supporting the hypothesis of a general deficit in filtering distractors has presented *only* neutral stimuli. Because

none of these experiments had directly compared the effects that threat-relatedness of the to-be-remembered or to-be-ignored material on memory, one cannot draw strong conclusions about how specific a memory bias may be in high SA. To address this, we manipulated the presence of threat in both the targets and distractors to properly investigate the content specificity of a memory bias in high SA.

The main finding of the current study was that a memory bias in high SA appeared to be specific rather than general: only the socially threatening distractors received a memory benefit in the high SA participants. If high SA were associated with a general failure to filter out distractors, neutral distractors ought to have shown a similar memory benefit as the socially threatening distractors. Because this was not the case, we have little evidence to support the claim that all distractors, including non-emotional ones, are poorly filtered in high SA. Instead, our results support the hypothesis that memory is specifically biased for socially threatening, task-irrelevant information in high SA (Eysenck et al., 2007; Mitte, 2008; Stout et al., 2013). Rather than failing to disengage from all distractors as past work would suggest (Moriya & Tanno, 2010; Moriya & Sugiura, 2012a; Moriya & Sugiura, 2012b; Moriya & Sugiura, 2013), the current results suggest that when neutral *and* socially threatening stimuli are presented to high SA individuals, disengagement issues are specifically limited to the more salient social threat stimuli.

Role of Target Valence in Ability to Filter Distractions

Our results also showed that it was only when SA was primed, did memory for socially threatening distractors show a bias in high versus low SA. That is, it was only for those in the threat targets condition, who were instructed to commit socially threatening words to memory, that the processing of the congruent socially threatening distractors was elevated. Given this, it appears that memory biases for irrelevant threats are not only dependent on the threat-relatedness of the

distractors one is attempting to ignore, but also the valence of the targets one is attempting to encode. We propose that because participants were purposefully attending to, and rehearsing, socially threatening words for the target task, these were maintained in WM, and this placed high SA individuals in a heightened state of social anxiety. However, we also acknowledge that our current data are unable to fully disentangle the induction of a socially anxious state from the maintenance of socially threatening information in WM. In other words, because we did not directly measure state social anxiety during the experiment, we cannot conclude with absolute certainty that the act of holding socially threatening target words in WM successfully induced feelings of social anxiety. Future research could work towards isolating these two factors in order to better characterize the state in which a memory bias for threat-related distractors occurs.

Although social anxiety inductions are often carried out by requiring participants to perform very stressful, socially threatening acts (such as performing an unpracticed speech in front of an evaluative audience), work by Heeren, Peschard, and Philippot (2012) has shown that being trained to attend to threat-related words is enough to induce more state anxiety and negative mood than those trained to attend to neutral words. As such, being assigned to encode a series of socially threatening target words (as opposed to neutral target words) could have triggered highly socially anxious individuals to enter a frame of mind or mode of processing wherein their social anxiety was primed.

In order to explain how state social anxiety could affect how distractors are filtered, we look to early cognitive models of social anxiety. Clark and Wells' model of social anxiety (1995) claims that those with high social anxiety will selectively dwell on socially threatening memories only when they are currently engaged in a state of increased social anxiety, such as worrying about future encounters or ruminating about past ones. In response to this model's assertion,

administering social threat manipulations (such as instructing participants to perform anxiety-provoking tasks) is required to observe any kind of a memory bias in individuals with high levels of social anxiety (Morgan, 2010). That is, activation of the negative self-schemas characteristic of high social anxiety is a necessary pre-requisite for specific memory biases to emerge.

In conclusion, the current study investigated the conditions that lead to memory biases in high SA. There were no group differences in memory for threat versus neutral targets. However, recognition of socially threatening distractors was significantly enhanced in high relative to low SA, but only when targets were also socially threatening. Findings suggest that when SA is primed, attention to irrelevant, but socially threatening, information is heightened.

Chapter 3

Experiment 2: Reduced Working Memory Capacity for Social Threat in High vs. Low Social Anxiety

Introduction

Altered long-term memory is a commonly reported feature in individuals with high levels of social anxiety, such that threatening information appears to be favoured relative to neutral information (Clark & Wells, 1995; Heimberg et al., 2010; Krans, Bree, & Bryant, 2014; Mitte, 2008; Morgan, 2010). However, the mechanisms by which this long-term memory bias arises are still unclear. Numerous cognitive models of SA have identified that the initial processing of threatening information is a potential source of the memory bias. For instance, Clark and Wells (1995) argue that during anxiety-provoking social situations, highly socially anxious individuals may process irrelevant, threatening material in greater detail than neutral material, leading to strengthened memories for threat. In other words, a partygoer with a high level of SA may selectively process background conversations about negative topics rather than benign small talk, and end up with an unfavourable representation of the entire event.

The idea of enhanced processing of unwanted, irrelevant material in high SA has been further elaborated upon by Heimberg and colleagues (2010). In their model, they suggest that it is the act of unnecessarily dedicating limited processing resources towards the threatening information that enhances memory of said threat. More specifically, these authors propose that inadvertently maintaining the threatening information in mind is what leads to long-term memory biases such as distorted, overly negative representations of past social encounters. Interestingly, the ability to maintain limited amounts of information over time has previously been noted as the

primary responsibility of another memory system: working memory (WM; Baddeley, 2003). It would seem that these models therefore implicate altered WM function as a causal factor for a memory bias in high social anxiety.

Given that WM has been suggested to have a critical role in the production of a long-term memory bias, WM seems to present an excellent opportunity to better examine the cognitive mechanisms that drive a memory bias for threat. Unfortunately, relatively few studies have investigated the relationship between WM and social anxiety. In a meta-analysis and review, Moran (2016) remarks that existing theory has failed to provide specific predictions regarding how social anxiety might interact with WM capacity. Instead, some insight can be drawn from the literature on WM capacity for social information. Evidence from functional magnetic resonance imaging work has suggested that in the general population, social information is more easily chunked in WM than non-social information – that is, although all information is maintained worse at larger loads (e.g., longer strings of to-be-maintained information), social material is significantly less impacted by increasing the load, compared to non-social material (Thornton & Conway, 2013). The authors contend that this general ability to chunk social information more efficiently relies on up-front costs, where appropriate high-level chunks must be identified in a deliberate and effortful manner during encoding. Highly socially anxious individuals may be unable to 'afford' paying these up-front costs, given that intrusive cognitions such as worry already impinge upon executive function during social situations (Brozovich & Heimberg, 2008; Fehm et al., 2007). It could therefore by hypothesized that high social anxiety may interrupt the typical efficient chunking process, resulting in a decreased WM capacity for social threat relative to low social anxiety.

Although some models of SA have predicted that a long-term memory bias for threat is supported by a WM bias, few studies have directly assessed WM in individuals with high compared to low levels of social anxiety. In one such study, patients with social anxiety disorder were compared to non-anxious controls based on their performance on an operation span task (Amir & Bomyea, 2011). In this task, participants were asked to remember a series of words while also performing arithmetic tasks between each word presentation. Afterwards, participants reported the studied words in the order they had first seen them, on a recognition test. The authors found that, in this case, the social anxiety disorder group had significantly worse performance than the non-anxious group when the to-be-remembered words were neutral. In contrast, this relative deficit was not present if the words were socially threatening. However, a number of issues were identified by the authors. For example, the social anxiety disorder patients also displayed significantly higher scores on trait general anxiety, state general anxiety, and depression measures than the non-anxious controls. Because each of these factors could have influenced operation span, it becomes difficult to pinpoint how much of the working memory differences can be specifically tied to social anxiety.

Furthermore, we argue that the choice of stimuli in past work has limited their ability to draw conclusions. Although social threat is theoretically most salient to a highly socially anxious individual, most past paradigms have not compared social threat (e.g., social evaluation) to any other kind of threat (e.g., physical harm). For instance, Amir and Bomyea (2011) found differences between social anxiety disorder patients and non-anxious controls in operation span for words that were either neutral (e.g., "chair") or socially threatening (e.g., "stupid"). It therefore becomes uncertain whether their observed group differences can be attributed to the social aspect of the words, the threatening aspect, or some combination of the two. In a similar vein, Yoon, Kutz,

LeMoult, and Joormann (2017) found no differences between a social anxiety disorder group and non-anxious controls in the ability to maintain information in working memory. However, only working memory performance with neutral versus emotional pictures was compared, with no social content presented. Recent work has begun to disentangle the effects of social content from threatening content by presenting generally threatening material in addition to socially threatening and neutral material (Waechter, Moscovitch, Vidovic, Bielak, Rowa, & McCabe, 2018), although important low-level differences between material types were found, such as increased letter length in their socially threatening words. To isolate the type of content that social anxiety might impact working memory for, it becomes vital to directly compare WMC for different types of emotionality or threat while controlling for low-level differences in material types.

To address these concerns, in Experiment 2, a variety of span tasks were administered. In the current study, we examined the influence of social threat on WM capacity by manipulating the threat-relatedness of words in a word span task adapted from the digit span task (Wechsler, 1939). In addition to a digit span task, participants performed three different word span tasks, each with specific word lists constructed to activate generally threatening concepts, socially threatening concepts, or neither. Given that socially threatening information (as opposed to neutral, or non-social negative information) should specifically promote intrusive cognitions that disrupt executive function (Eysenck et al., 2007; Brozovich & Heimberg, 2008) in those high in SA, we hypothesized that capacity for social threat words should suffer relative to those low in SA. In contrast, the high and low SA groups should not differ on any of the digit, neutral, or general threat capacity measures since none of this material should provoke the worry or post-event processing that characterizes those with high social anxiety.

Methods

Participants

Eighty undergraduate students at the University of Waterloo participated for course credit towards an enrolled psychology course. The mean age of the sample was 19.8 (*SD* = 1.9), with 68% of the participants being female. Participation was restricted to individuals who identified themselves as being fluent in the English language, and had learned English at or before the age of seven. Participants were also pre-screened using their scores on an online administration of the Social Phobia Inventory (SPIN; Connor et al., 2000). Participation was initially not limited by SPIN scores, such that any participant regardless of SPIN score could sign up. Once the high social anxiety (SA) group had reached the target of 40 participants, further participation was restricted to only those who had earlier reported low SA through the online SPIN administration. As such, 40 high SA (*M* = 32.33, *SD* = 8.38) and 40 low SA (*M* = 11.22, *SD* = 4.72) participants were recruited. High SA was defined using the established cut-off score of 19 or higher, with those below 19 defined as low SA (Connor et al., 2000).

Materials

Digit Span. All participants were administered the unaltered digit span task (forward span) orally (Wechsler, 1939).

Word Lists. All participants were administered three word span tasks adapted from the digit span task (Wechsler, 1939). Although past work has used adaptations of an operation span task (Amir & Bomyea, 2011; Waechter et al., 2018), the added difficulty of performing a secondary task was a concern. Given that studies investigating the impact of general anxiety on

WM under stressful conditions have found inconsistent results (Eysenck et al., 2007), we used the digit span to avoid inducing stress.

For each of the three word span tasks, a word list was created such that each digit could be replaced with a word. The three word lists were constructed such that they differed on threat-relatedness: neutral, general threat, and social threat. The neutral word list was constructed to include words that were unrelated to any kind of threat. The general threat word list was constructed to include words that were related to threatening concepts, while also being unrelated to social concepts. The social threat word list was constructed to include words that were related to both threat as well as social concepts. In addition, these socially threatening words were specifically chosen from past studies on social anxiety (Hope et al., 1990; Mathews et al., 1989; Ononaiye et al., 2007; Pishyar et al., 2004; Vassilopoulos, 2005). All words were selected from the Affective Norms for English Words (ANEW; Bradley & Lang, 1999). From the ANEW, ratings for each word's valence, arousal, and frequency was obtained.

The three word lists were then compared in terms of valence, arousal, word frequency, and word length using a series of between-subjects univariate ANOVAs. Only the effect on valence was significant, $F(2, 24) = 7.52$, MSE = 1.31, $p = .003$, $\eta^2 = .39$; all other ps > .05). As expected, post hoc Tukey tests revealed that the general threat ($M = 3.37$, $SD = 0.60$) and social threat ($M = 3.64$, $SD = 1.85$) word lists were significantly more negative than the neutral ($M = 5.30$, $SD = 0.38$) word list (ps < .05). In contrast, the general threat and social threat word lists were not significantly different from each other (ps > .05). Full word lists are shown below (Table 5).

TABLE 5

Word lists for each of the word span tasks.

Neutral	General Threat	Social Threat
context	abuse	boring
errand	bankrupt	clumsy
hard	broken	failure
humble	evil	insult
item	hungry	lonely
limber	pressure	nervous
mischief	revolt	party
noisy	rigid	shy
patient	weary	timid

TABLE 6

Mean valence, arousal, word frequency, word length, and LSA coefficient for each word list.

	Mean Valence	Mean Arousal	Mean Word Frequency	Mean Word Length	Mean LSA Coefficient
Neutral	5.30 (0.38)	4.57 (1.01)	42.44 (66.47)	5.89 (1.36)	0.10 (0.10)
General Threat	3.37 (0.60)	5.68 (1.00)	46.11 (57.06)	5.89 (1.36)	0.10 (0.09)
Social Threat	3.64 (1.85)	4.96 (1.31)	44.33 (69.43)	5.67 (1.22)	0.16 (0.12)

Mill Hill Vocabulary Scale. All participants were administered Set A of the Mill Hill Vocabulary Scale to ensure fluency with the English language. Fluency was defined as correct synonym identification for at least 30% of the questions (Raven et al., 1977). All participants scored at or above 30%, signifying ability to understand the verbal stimuli used in the experiment.

State-Trait Inventory of Cognitive and Somatic Anxiety. The STICSA assessed participants' state and trait levels of general anxiety (Grös, Antony, Simms, & McCabe, 2007). The STICSA consists of 21 items that represent both cognitive (e.g., "I feel agonized over my

problems") and somatic (e.g., "My heart beats fast") aspects of anxiety. Participants responded to each item on a 4-point Likert scale as to how much the statement described them, ranging from 1 (*not at all*) to 4 (*very much so*). First, participants indicated whether each statement described them at that moment (state) and afterward indicated whether each statement described them in general (trait). The STICSA has been found to have excellent internal consistency, and good convergent and divergent validity (Grös et al., 2007).

Depression Anxiety Stress Scales. Participants completed the DASS-21 (Lovibond & Lovibond, 1995) as part of a larger set of online pre-screening tests, for which they could receive course credit for participation. The DASS-21 consists of 21 items, each of which falls under one of three subscales: depression (DASS-D; e.g., "I felt that I had nothing to look forward to"), anxiety (DASS-A; e.g., "I felt I was close to panic"), and stress (DASS-S; e.g., "I found it hard to wind down"). Participants responded to each item on a 4-point Likert scale as to how much the statement applied to them over the past week, ranging from 0 (*did not apply to me at all*) to 3 (*applied to me very much, or most of the time*). The DASS-21 has been found to have excellent internal consistency, and adequate concurrent validity (Antony, Bieling, Cox, Enns, & Swinson, 1998).

Social Phobia Inventory. Participants completed the SPIN as part of a larger set of online pre-screening tests, for which they could receive course credit for participation. Our study was made available to a restricted set of participants based on the score obtained on the SPIN test, half of whom had initially reported a high SA score and the other half a low SA score using the cut-off of 19 (Connor et al., 2000). The SPIN was administered a second time at the conclusion of our experiment, in-person in a written format, to allow categorization as either low or high SA. Classification into either the high or low SA group was determined solely using the in-person SPIN

score. The SPIN has been found to have good test-retest reliability, internal consistency, convergent and divergent validity, and construct validity (Connor et al., 2000).

To complete the SPIN, participants indicated on a scale from 0 (*not at all*) to 4 (*extremely*) the extent to which a series of problems (e.g., "Being embarrassed or looking stupid are among my worst fears") tended to bother them in a typical week. Although the established cut-off score of 19 is thought to have some ability to distinguish between individuals with and without social anxiety disorder (SAD), formal diagnoses of SAD or any other psychopathology were not queried, nor confirmed by a clinician.

Procedure

All participants were tested alone in a single 30-minute session. Participants performed a digit span task (Wechsler, 1939), a series of a word span tasks adapted from the digit span task, the Mill Hill Vocabulary Scale (Raven, Court, & Raven, 1977), the STICSA (Grös et al., 2007), and the SPIN (Connor et al., 2000). The order in which participants completed the span tasks was counterbalanced by balanced Latin Square.

After providing written consent, participants were seated at a desk facing away from the researcher, who was also seated at a desk facing away from the participant. Participants were instructed to listen carefully to a string of either numbers or words that the researcher was to read aloud to them. Participants were also instructed that as soon as the researcher finished reading the string, the participant was to repeat back the string aloud in the same order that they had first heard it. Once the participant confirmed that they understood the task, the researcher administered the digit span task and three word span tasks in a pre-determined, counterbalanced order. Each of these three word span tasks corresponded to a different word list (i.e., neutral, general threat, or social

threat). During the span tasks, each number or word was read aloud at a pace of one per second. After each trial where the participant accurately reported the entire string, the researcher read aloud a new string that was one number or word longer than the last. The task was terminated when a participant failed to correctly report a string twice at the same length. The length of the longest string the participant could accurately report was defined as their WMC for each list type.

After completing the span tasks, the participant was administered computerized versions of the STICSA and SPIN. This computerized version was programmed using E-prime (E-prime v.2.2 software, Psychology Software Tools Inc., Pittsburgh, PA) such that each item was presented once at a time in centre the screen in 20-point black Courier font. Along the bottom of the screen, a series of numbers were presented, each representing a possible response that the participant could choose (e.g., the numbers 0 through 4 during the SPIN). Below the extremes of the responses, the written meaning of the response was presented (e.g., below "0", "not at all" during the SPIN). Preceding each scale, instructions screens were presented to participants, at which point the researcher also gave an oral explanation of the task.

Results

Digit Span Performance

An independent samples t-test on digit span scores indicated that baseline WMC did not significantly differ between low SA (M = 7.05, SD = 0.99) and high SA (M = 6.75, SD = 1.26; p > .05).

Comparison of Word Span Performance in Individuals with High vs. Low Social Anxiety

A 2 (social anxiety: high SA, low SA) x 3 (list type: neutral, general threat, social threat) mixed factorial ANOVA was conducted with social anxiety as a between-subjects factor and list

type as a within-subjects factor. The ANOVA revealed a significant interaction between SA and list type, $F(2, 156) = 3.37$, MSE = 0.42, $p = .04$, $\eta^2 = .04$. To probe this interaction, further between-subjects one-way ANOVAs were conducted to compare the effects of social anxiety at each list type independently. Only the social threat list type produced a significant difference between low and high SA ($F(1, 78) = 11.00$, MSE = 0.60, $p = .04$, $\eta^2 = .12$), such that the high SA group had a reduced WMC ($M = 4.85$, $SD = 0.74$) compared to the low SA group ($M = 5.43$, $SD = 0.81$). Neither the neutral nor general threat word lists showed a significant difference between low and high SA ($ps > .05$).

The interaction was further probed to compare the effects of list type at each level of social anxiety using a within-subjects ANOVA. This ANOVA showed a significant effect of list type only for the low SA group, $F(2, 78) = 10.58$, MSE = 0.52, $p < .001$, $\eta^2 = .21$. Post hoc Fisher tests determined that the low SA group had a significantly larger WMC for the social threat list ($M = 5.43$, $SD = 0.81$) compared to the neutral ($M = 4.75$, $SD = 0.90$) and general threat lists ($M = 4.83$, $SD = 0.71$; $ps < .05$). The high SA group showed no such differences between list types ($p > .05$).

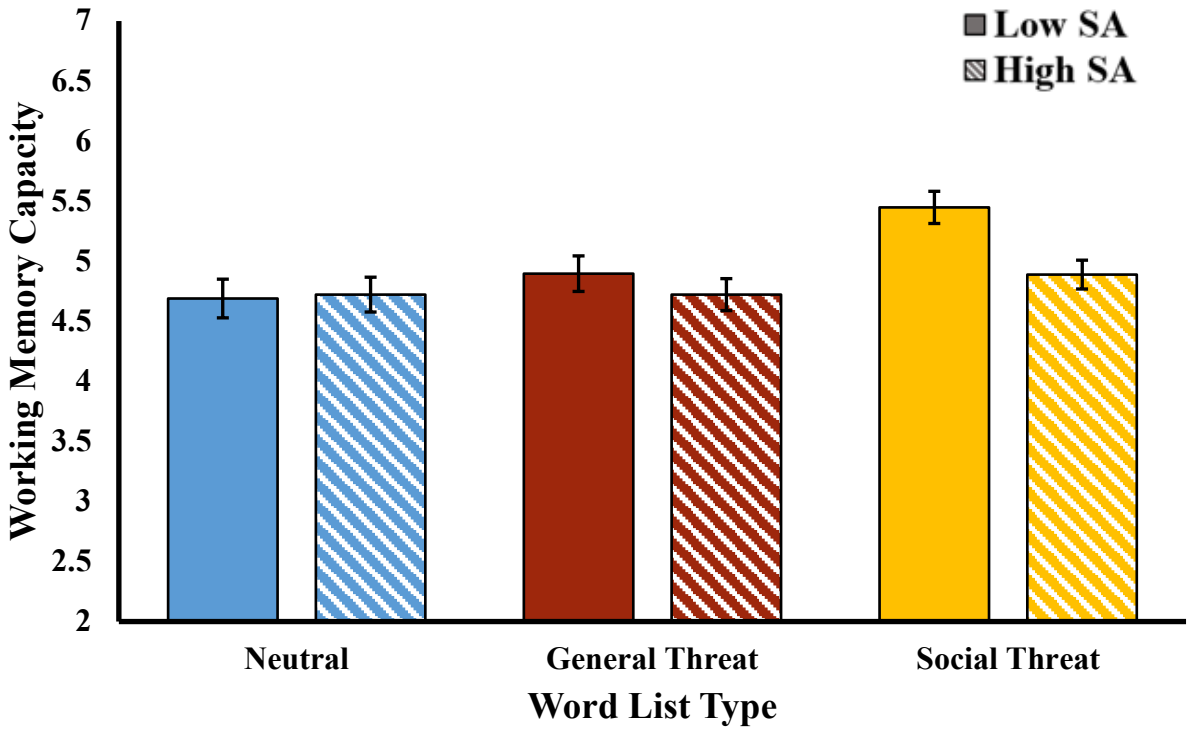

Figure 3. Working memory capacity by word list type and social anxiety group. Low social anxiety is defined as a SPIN score below 19, while high social anxiety is defined as a SPIN score at or above 19. Error bars represent ± 1 standard error of the mean.

Unique Contributions of Social Anxiety on WMC for Socially Threatening Words

A series of hierarchical regression analyses were performed to test the effects of SA on WMC for words, as well as control for the effects of state anxiety, trait anxiety, and depressive symptoms. If SA has a unique impact on WMC, these analyses would find that SA predicts a significant amount of the variance in WMC above and beyond that of theoretically similar constructs. Furthermore, if a WM bias in SA is specific to certain types of material (e.g., only threat-related material), one's level of SA should only predict WMC for only certain word lists. Four participants were missing scores for the DASS-D, so all further analyses were conducted using pairwise deletion.

The first hierarchical regression analysis tested SA as a predictor of social threat WMC, starting with SA due to theoretical primacy. This analysis showed that SA (as measured by the raw SPIN score) was a significant negative predictor of social threat WMC in Model 1 (p = .008; see Table 7). The addition of state anxiety, trait anxiety, and depressive symptoms in Model 2 caused the model overall to drop to non-significance (p = .11), though SA as a predictor alone remained significant (p = .009). State anxiety, trait anxiety, and depressive symptoms, however, were not significant predictors (p > .05). As such, one's level of trait SA significantly predicted one's ability to accurately maintain socially threatening information in working memory, beyond other theoretically related constructs such as state anxiety, trait anxiety, and depressive symptoms.

TABLE 7

Hierarchical regression analysis with SA predicting social threat WMC, SA added first.

Variable	B	SE B	ß
Model 1			
SPIN	-0.02	0.01	-0.30**
Model 2			
SPIN	-0.02	0.01	-0.32**
SICSA	-0.01	0.01	0.01
TICSA	-0.01	0.01	-0.02
DASS-D	0.02	0.03	0.09

Note. *SPIN* = Social Phobia Inventory, *SICSA* = State Inventory of Cognitive and Somatic Anxiety, *TICSA* = Trait Inventory of Cognitive and Somatic Anxiety, *DASS-D* = Depression Anxiety Stress Scales, Depression Subscale.

Model 1 R^2 = .09, adjusted R^2 = .08, p = .008, significant F change = .01; Model 2 ΔR^2 = .008, p = .11, significant F change = .89.

**p < .01.

Two additional hierarchical regression analyses were conducted with the same procedure for each of neutral WMC and general threat WMC. None of the models for any of these outcome

variables were significant (all *p*s > .05). These results suggest that SA uniquely predicts working memory capacity for specifically socially threatening information, and not just any information (neutral WMC) or negatively valenced information (general threat WMC).

As an alternative method, this hierarchical regression analysis was also performed by adding the nuisance variables before, rather than after SA. The first hierarchical regression analysis tested SA as a predictor as a predictor of social threat WMC, starting with state general anxiety, trait general anxiety, and depression as nuisance variables and ending with SA due to theoretical primacy. From Model 1 (see Table 8), state anxiety, trait anxiety, and depressive symptoms were not found to be significant predictors ($p = .98$). The addition of SA in Model 2 caused the model overall to remain non-significant ($p = .37$), though SA as a predictor alone was significant ($p = .046$). Further, the addition of SA increased R^2 value by .053, and the significant F change was .01. This analysis showed that SA (as measured by the raw SPIN score) was a significant negative predictor of social threat WMC in Model 2 (see Table 8), although Model 2 overall was not statistically significant. As such, one's level of trait SA significantly predicted one's ability to accurately maintain socially threatening information in working memory, beyond other theoretically related constructs such as state anxiety, trait anxiety, and depressive symptoms.

TABLE 8

Hierarchical regression analysis with SA predicting social threat WMC, SA added last.

Variable	B	SE B	ß
Model 1			
SICSA	0.01	0.01	0.05
TICSA	-0.01	0.01	-0.07
DASS-D	-0.01	0.03	-0.02

Model 2			
SICSA	0.01	0.01	0.01
TICSA	0.01	0.01	0.01
DASS-D	0.01	0.03	0.03
SPIN	-0.02	0.01	-0.24*

Note. *SPIN* = Social Phobia Inventory, *SICSA* = State Inventory of Cognitive and Somatic Anxiety, *TICSA* = Trait Inventory of Cognitive and Somatic Anxiety, *DASS-D* = Depression Anxiety Stress Scales, Depression Subscale.

Model 1 R^2 = .003, adjusted R^2 = -.04, p = .98, significant F change = .94; Model 2 ΔR^2 = .05, p = .37, significant F change = .01.

*p < .05.

Two additional hierarchical regression analyses were conducted with the same procedure for each of neutral WMC and general threat WMC. None of the models for any of these outcome variables were significant (all ps > .05). These results suggest that SA uniquely predicts working memory capacity for specifically socially threatening information, and not just any information (neutral WMC) or negatively valenced information (general threat WMC).

A latent semantic analysis (LSA; Deerwester, Dumais, Furnas, Landauer, & Harshman, 1990) was performed on each of the three word lists to determine within-list semantic similarity. A between-subjects one-way ANOVA comparing the mean association coefficients (as calculated by the LSA) between the 3 list types (neutral, general threat, social threat) was found to be significant, $F(2, 105) = 4.38$, MSE = 0.01, p = .02, η^2 = .08. Post hoc Tukey tests determined that the social threat word list (M = 0.16, SD = 0.12) was significantly more interrelated (p = .03) than the neutral or general threat lists ($M_{neutral}$ = 0.10, $SD_{neutral}$ = 0.10; $M_{general}$ = 0.10, $SD_{neutral}$ = 0.09), which were not significantly different from each other (p > .05).

Discussion

Many models of social anxiety suggest that disruptions in the maintenance of socially threatening information forms the basis for a downstream long-term memory bias. Despite the fact that working memory is responsible for storing information over short periods of time, few studies have attempted to directly measure how socially threatening information affects working memory capacity across different levels of social anxiety. Instead, we look towards studies investigating how working memory capacity is altered by the maintenance of social versus non-social information.

Working memory capacity can be enhanced through the use of chunking, a process by which high-level structure is used to effectively collapse groups of information into smaller, related 'chunks' (Bor, Duncan, Wiseman, & Owen, 2003; Miller, 1994). For instance, within the general population, social information such as trustworthiness judgments have been shown as more easily chunked than non-social information such as spatial locations (Thornton & Conway, 2013). In this case, it has been hypothesized that the complex, high-load facial information related to trustworthiness is collapsed into smaller representations using the overarching structure of social relatedness. Although Thornton and Conway (2013) suggest that applying this structure is cognitively taxing up-front, it results in more efficient chunking at higher information loads. The current study hypothesized that those high in social anxiety may be unable to benefit from this efficient chunking process, as highly socially anxious individuals have been suggested to have difficulty with executive functioning tasks, especially while processing social information (Wieser et al., 2009). Indeed, the current results reveal that working memory capacity for socially threatening information is reduced in high social anxiety relative to low social anxiety. As such, our findings suggest that low socially anxious individuals show expanded working memory

capacities for social threat information relative to neutral or general threat information, and that highly socially anxious individuals may fail to upregulate WMC in the face of social information.

Limitations

As determined by LSA, the words in the social threat list were more semantically similar to each other than any other list. Given this, the current experiment could not confidently claim that the observed working memory capacity reduction was due to the socially threatening words' meanings, as a deficit in semantic chunking in high SA could also account for our observed pattern of results. As such, a follow-up experiment was conducted to test the hypothesis that the semantic similarity of the words in a list could have a differential effect on working memory capacity depending on one's trait level of social anxiety.

Experiment 3: Reduced Working Memory Capacity for Social Threat – Discounting Semantic Similarity

Introduction

An extant finding in the WM literature is that strings of information with easily identifiable structure are more easily chunked in WM (Bor et al., 2003). As such, a potential issue was detected in the word lists from Experiment 2: using LSA, it was found that the social threat word list contained more semantically similar words (e.g., "shy" and "timid" versus "hungry" and "bankrupt"), relative to the neutral and general threat word lists. Given that the socially threatening words were more semantically similar than the words in other lists, it remained possible that the highly socially anxious individuals were failing to make use of semantic structure, which enables semantic clustering to boost output, rather than failing to chunk due to the activation of social threat concepts.

As such, in Experiment 3, a fourth word list was constructed to have similar within-list semantic similarity as the social threat word list, but without being related to threatening or social concepts. This additional neutral semantically similar list allowed the influence of semantic similarity to be examined, free of any relatedness to social threat.

Methods

Participants and Design

Eighty undergraduate students at the University of Waterloo (who had not participated in the previous experiment) participated for course credit towards an enrolled psychology course. The mean age of the sample was 19.9 (SD = 2.7), and 78% of the participants were female. All

recruitment methods and restrictions were kept identical to the previous study. 40 high SA (M = 32.75, SD = 9.04) and 40 low SA (M = 11.13, SD = 4.94) participants were recruited.

The design was identical to the previous experiment, except for two additions: 1) a fourth word list was administered along with the three word lists from the previous experiment. This fourth list was mixed into the span tasks in a counterbalanced order by balanced Latin Square and 2) the DASS-21 was administered in-person between the administrations of the STICSA and the SPIN. Rather than obtaining DASS-21 scores from an earlier, online administration as per the previous study, participants completed the DASS-21 in-person to minimize potential unreliability caused by time delay between taking the DASS-21 and completing the current experiment.

Materials

All materials were identical to the previous study except for the additional, fourth word list and the in-person administration of a computerized DASS-21 (Lovibond & Lovibond, 1995).

Word Lists. A fourth word list, henceforth referred to as the neutral semantically similar list, was constructed to have no obvious relatedness to threatening concepts, while still maintaining comparable semantic similarity to that of the social threat word list. Using the same construction procedure as the previous experiment, words were chosen from the ANEW (Bradley & Lang, 1999) to ensure that valence, arousal, frequency, and word length were similar between the neutral and neutral semantically similar word lists. The four word lists (neutral, general threat, social threat, and neutral semantically similar) were then compared for each of these low-level variables (valence, arousal, word frequency, and word length) using a series of between-subjects univariate ANOVAs. Only the effect on valence was significant, $F(3, 32) = 8.26$, MSE = 1.07, $p < .001$, $\eta^2 = .44$; all other ps > .05). As expected, post hoc Tukey tests revealed that the general threat (M =

3.37, *SD* = 0.60) and social threat (*M* = 3.64, *SD* = 1.85) word lists were significantly more negative than the neutral (*M* = 5.30, *SD* = 0.38) or neutral semantically similar (*M* = 5.11, *SD* = 0.60) word lists (*p*s < .05). The general threat and social threat word lists were not significantly different from each other in terms of valence, as were the neutral and neutral semantically similar word lists (*p*s > .05).

Words for the neutral semantically similar list were specifically chosen to be moderately semantically similar, which was later quantified via LSA. In other words, they were selected to have similar themes in terms of meaning (e.g., "office", "machine", and "patent" seem related to workplaces or industry). An ANOVA was then performed to compare mean association coefficients between the four word lists (neutral, general threat, social threat, neutral semantically similar). The main effect of list type on semantic similarity was again found to be significant, $F(3, 140) = 5.65$, MSE = 0.01, $p = .001$, $\eta^2 = .11$. Post hoc Tukey tests confirmed that the neutral semantically similar list (*M* = 0.18, *SD* = 0.09) was significantly greater in semantic similarity than the neutral or general threat word lists ($p = .01$), but not significantly different from the social threat word list (all *p*s > .05).

TABLE 9

Full word lists for each of the four word span tasks.

Neutral	General Threat	Social Threat	Neutral Semantically Similar
context	abuse	boring	chaos
errand	bankrupt	clumsy	custom
hard	broken	failure	detail
humble	evil	insult	machine

item	hungry	lonely	modest
limber	pressure	nervous	office
mischief	revolt	party	patent
noisy	rigid	shy	rough
patient	weary	timid	solemn

TABLE 10

Mean valence, arousal, word frequency, word length, and LSA coefficient for each word list.

	Mean Valence	**Mean Arousal**	**Mean Word Frequency**	**Mean Word Length**	**Mean LSA Coefficient**
Neutral	5.30 (0.38)	4.57 (1.01)	42.44 (66.47)	5.89 (1.36)	0.10 (0.10)
General Threat	3.37 (0.60)	5.68 (1.00)	46.11 (57.06)	5.89 (1.36)	0.10 (0.09)
Social Threat	3.64 (1.85)	4.96 (1.31)	44.33 (69.43)	5.67 (1.22)	0.16 (0.12)
Neutral Semantically Similar	5.11 (0.60)	4.41 (1.02)	64.22 (77.52)	5.89 (0.60)	0.18 (0.09)

Depression Anxiety Stress Scales. The DASS-21 (Lovibond & Lovibond, 1995) assessed participants' dysphoric moods. Our previous experiment obtained DASS-21 scores from an online administration completed by the participants prior to signing up for the experiment. Because there may have been a delay between taking the online DASS-21 and participating in the previous experiment, it was possible that this delay could have introduced some unreliability to their scores. To avoid this potential issue in the current experiment, a computerized version was administered in-person at the end of the experiment. Only the in-person DASS-21 scores were used in the current experiment. The method by which the DASS-21 was computerized was identical to that of the STICSA and SPIN, as described in Experiment 2.

Results

Digit Span Performance

An independent samples t-test on digit span scores indicated that baseline WMC did not significantly differ between low SA (M = 7.05, SD = 0.99) and high SA (M = 6.75, SD = 1.26; p > .05).

Comparison of Word Span Performance in Individuals with High vs. Low Social Anxiety

A 2 (social anxiety: high SA, low SA) x 4 (list type: neutral, general threat, social threat, neutral semantically similar) mixed factorial ANOVA was conducted with social anxiety as a between-subjects factor and list type as a within-subjects factor. The ANOVA revealed a significant interaction between SA and list type, $F(3, 234) = 12.75$, MSE = 0.31, $p < .001$, $\eta^2 = .14$. To probe this interaction, further between-subjects one-way ANOVAs were conducted to compare the effects of social anxiety at each list type independently. Only the social threat list type produced a significant difference between low and high SA ($F(1, 78) = 10.58$, MSE = 0.74, $p = .002$, $\eta^2 = .12$), such that the high SA group had a reduced WMC (M = 5.10, SD = 0.98) compared to the low SA group (M = 5.73, SD = 0.72). Neither the neutral, general threat, nor neutral semantically similar word lists showed a significant difference between low and high SA (ps > .05). The interaction was further probed to compare the effects of list type at each level of social anxiety using a within-subjects ANOVA. This ANOVA showed a significant effect of list type only for the low SA group, $F(3, 117) = 11.02$, MSE = 0.25, $p < .001$, $\eta^2 = .53$. Post hoc Fisher tests determined that the low SA group had a significantly larger WMC for the social threat list (M = 5.73, SD = 0.72) compared to the neutral (M = 4.63, SD = 0.63), general threat (M = 4.78, SD =

0.77) and neutral semantically similar lists (M = 4.65, SD = 0.74; ps < .05). The high SA group showed no such differences between list types (p > .05).

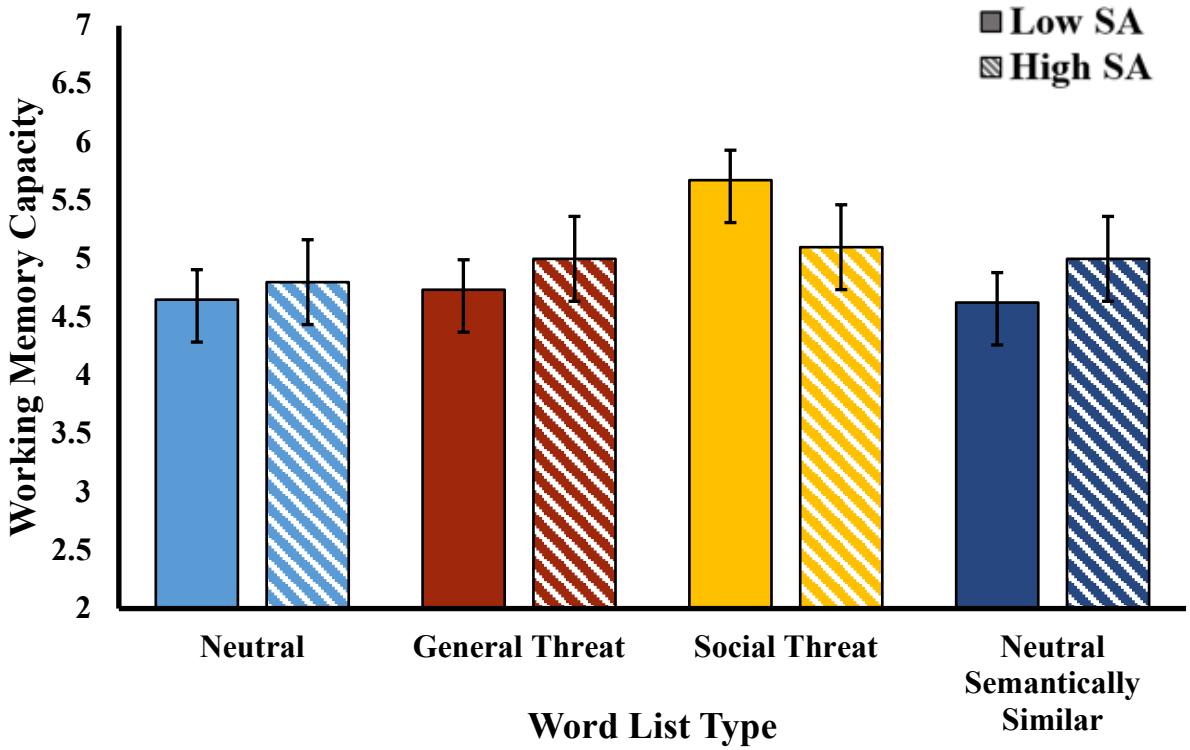

Figure 4. Working memory capacity by word list type and social anxiety group. Low social anxiety is defined as a SPIN score below 19, while high social anxiety is defined as a SPIN score at or above 19. Error bars represent ± 1 standard error of the mean.

Unique Contributions of Social Anxiety on WMC for Socially Threatening Words

A series of hierarchical regression analyses were performed to test the effects of SA on WMC for words, as well as controlling for the effects of state anxiety, trait anxiety, and depressive symptoms.

The first hierarchical regression analysis tested SA as a predictor of social threat WMC, starting with SA due to theoretical primacy. This analysis showed that SA (as measured by the raw SPIN score) was a significant negative predictor of social threat WMC in Model 1 (p = .004; see

Table 11). The addition of state anxiety, trait anxiety, and depressive symptoms in Model 2 caused the model overall to drop to non-significance (p = .05), though SA as a predictor alone remained significant (p = .04). State anxiety, trait anxiety, and depressive symptoms, however, were not significant predictors (p > .05). As such, one's level of trait SA seems to significantly predict one's ability to accurately maintain socially threatening information in working memory, beyond other theoretically related constructs such as state anxiety, trait anxiety, and depressive symptoms.

TABLE 11

Hierarchical regression analysis with SA predicting social threat WMC, SA added first.

Variable	B	SE B	ß
Model 1			
SPIN	-0.02	0.01	-0.32**
Model 2			
SPIN	-0.02	0.01	-0.27*
SICSA	-0.01	0.02	-0.14
TICSA	-0.004	0.02	-0.05
DASS-D	0.02	0.03	0.07

Note. *SPIN* = Social Phobia Inventory, *SICSA* = State Inventory of Cognitive and Somatic Anxiety, *TICSA* = Trait Inventory of Cognitive and Somatic Anxiety, *DASS-D* = Depression Anxiety Stress Scales, Depression Subscale.

Model 1 R^2 = .10, adjusted R^2 = .09, p = .004, significant F change = .004; Model 2 ΔR^2 = .02, p = .05, significant F change = .68.

*p < .05. **p < .01.

Three additional hierarchical regression analyses were conducted with the same procedure for each of neutral WMC, general threat WMC, and neutral semantically similar WMC. None of the models for any of these outcome variables were significant (all ps > .05). These results suggest that SA uniquely predicts working memory capacity for specifically socially threatening

information, and not just any information (neutral WMC), negatively valenced information (general threat WMC), nor semantically similar information (neutral semantically similar WMC).

As an alternative method, these hierarchical regression analyses were also performed by adding the nuisance variables before, rather than after SA. The first hierarchical regression analysis tested SA as a predictor as a predictor of social threat WMC, starting with state general anxiety, trait general anxiety, and depression as nuisance variables and ending with SA due to theoretical primacy. From Model 1 (see Table 12), state anxiety, trait anxiety, and depressive symptoms were not found to be significant predictors (p = .17). The addition of SA in Model 2 caused the model overall to become marginally significant (p = .05), with SA as the only predictor that was significant alone (p = .036). Importantly, the R^2 change for Model 2 was 0.05, with a significant F change of 0.04. This analysis showed that SA (as measured by the raw SPIN score) was a significant negative predictor of social threat WMC in Model 2 (see Table 12). As such, one's level of trait SA significantly predicted one's ability to accurately maintain socially threatening information in working memory, beyond other theoretically related constructs such as state anxiety, trait anxiety, and depressive symptoms.

TABLE 12

Hierarchical regression analysis with SA predicting social threat WMC, SA added last.

Variable	B	SE B	ß
Model 1			
SICSA	-0.01	0.02	-0.11
TICSA	-0.02	0.02	-0.20
DASS-D	0.02	0.03	0.08
Model 2			
SICSA	-0.01	0.02	0.14

TICSA	-0.01	0.02	-0.05
DASS-D	0.02	0.03	0.07
SPIN	-0.02	0.01	-0.27*

Note. *SPIN* = Social Phobia Inventory, *SICSA* = State Inventory of Cognitive and Somatic Anxiety, *TICSA* = Trait Inventory of Cognitive and Somatic Anxiety, *DASS-D* = Depression Anxiety Stress Scales, Depression Subscale.

Model 1 $R^2 = .063$, adjusted $R^2 = .026$, $p = .17$, significant F change = .17; Model 2 $\Delta R^2 = .05$, $p = .05$, significant F change = .04.

*$p < .05$.

Three additional hierarchical regression analyses were conducted with the same procedure for each of neutral WMC, general threat WMC, and neutral semantically similar WMC. None of the models for any of these outcome variables were significant (all *p*s > .05). These results suggest that SA uniquely predicts working memory capacity for specifically socially threatening information, and not just any information (neutral WMC), negatively valenced information (general threat WMC), nor semantically similar information (neutral semantically similar WMC).

Discussion

Experiment 3 aimed to discount semantic similarity as a potential factor driving the differences in social threat WMC between those with low and high SA. First, the key finding of reduced working memory capacity in high relative to low SA for social threat words was replicated. Importantly, performance was only impaired for social threat WMC and not for neutral semantically similar WMC in high relative to low SA. Our findings therefore provide converging evidence for the hypothesis that the socially threatening meaning of the words (rather than the semantic similarity of the words within a list) drives the reduction in WMC for highly socially anxious individuals.

WMC can be enhanced through the use of chunking, a process by which high-level structure is used to effectively collapse groups of information into smaller, related 'chunks' (Bor et al., 2003; Miller, 1994). It follows that information with a more obvious, identifiable structure should therefore be more easily chunked. Due to the greater semantic similarity of the social threat word list in the previous study, one could argue that any effects seen in working memory capacity could be due to the more identifiable structure of the word list rather than the activation of social threat concepts. The current study addressed this by introducing another word list that was both neutral (unrelated to threat) and semantically similar. If semantic similarity was driving the reduction in WMC seen in high social anxiety, the highly socially anxious group should have also shown decrements on the neutral semantically similar list. However, this was not the case: performance was not significantly different between high and low social anxiety on the neutral semantically similar list. Furthermore, the results of the previous study were replicated such that the high social anxiety group showed a significantly smaller working memory capacity for social threat compared to the low social anxiety group.

Chapter 4

General Discussion

The goal of the current thesis was to investigate the conditions under which a memory bias emerges in individuals with a high level of social anxiety. Although cognitive models of SA have proposed that the nature of the material encountered by the individual drives the memory bias (Clark & Wells, 1995; Heimberg et al., 2010), these hypotheses have not yet been fully examined experimentally. By reviewing the dominant cognitive models of SA, two major factors were identified for their theoretical ability to induce the conditions necessary for a memory bias: threat-relatedness and task-relevance.

An additional goal of the current work was to clarify the cognitive mechanism by which this memory bias might operate. Past work has suggested that the long-term bias for threatening distractors seen in highly socially anxious individuals is due to a deficit at the level of working memory (Eysenck et al., 2007). Despite this theoretical link, past studies have rarely measured working memory function directly.

Specificity of a Memory Bias in High Social Anxiety

Over the course of three experiments, a number of results emerged across experiments. One such finding was the specificity of a memory bias in high social anxiety: memory is *specifically* enhanced for information that is socially threatening, rather than being biased *generally* (e.g., for either *any* threat-related material or *any* distractor). When individuals high in social anxiety attempted to encode a series of target words while either neutral or socially threatening words distracted them (Experiment 1), only their recognition of the socially threatening distractors was benefited. This memory bias did not extend to socially threatening targets

(representing *any* threat-related information), nor neutral distractors (representing *any* task-irrelevant information). These results lend support to the idea that a memory bias in high social anxiety is specific to only threat-related distractors, under instructions to attend to threat. As well, our evidence suggests that highly socially anxious individuals are not adequately described by past reports that these populations are merely easily distracted in general: if this were the case, their memory for neutral distractors should have benefited to a similar degree as the socially threatening distractors. Because an overall enhancement for distractor memory was not observed, a general susceptibility to distraction is not supported by the current thesis.

The specific nature of a memory bias was further reinforced in a series of working memory span tasks (Experiments 2 and 3). In these experiments, participants performed a number of word span tasks adapted from the digit span task, allowing for the manipulation of threat-relatedness by selecting a unique list of words for each span task. For Experiment 2, the word lists were constructed such that each of the words in a given list belonged to exactly one of three categories: neutral, general threat, or social threat. Working memory capacity was found to differ based on both the type of word list, as well as the individual's trait level of social anxiety such that highly socially anxious individuals showed reduced capacity for only the social threat words relative to those low in social anxiety. In a replication, Experiment 3 revealed the same pattern in addition to showing that the socially threatening meaning of the words drove the working memory reduction, not the semantic similarity of the words within a list. As such, our findings emphasize that a memory bias is specific, rather than general. This important distinction suggests that there is nothing globally deficient about memory functions in highly socially anxious individuals – instead, our work provides evidence that circumscribed conditions caused by factors such as threat-relatedness and task-relevance lead to altered memory function.

Working Memory Capacity in High Social Anxiety

Another main finding of the current thesis is that social anxiety uniquely predicted a reduction in WMC for social threat information. Importantly, the relative decrement in capacity for those high in social anxiety was statistically driven by the low social anxiety group performing especially well with socially threatening words. These current key findings seem consistent with the previous finding that social information is more efficiently chunked in the general population (Thornton & Conway, 2013), while also suggesting that high social anxiety may be linked to a deficit with this typical efficient chunking process. Moreover, our results are also consistent with work by Yoon, Kutz, LeMoult, and Joormann (2017), which showed no significant differences in maintaining neutral or emotional (generally threatening) material between social anxiety disorder and healthy control groups. However, our current results seem to not align with other past work investigating working memory in social anxiety disorder patients (Amir & Bomyea, 2011; Waechter et al., 2018). For instance, Amir and Bomyea (2011) reported significantly worse working memory performance in social anxiety disorder patients when presented with neutral words, but not when presented with socially threatening words. Further, recent work by Waechter and colleagues (2018) did not find significant differences in working memory performance for neutral, socially threatening, or generally threatening words between a social anxiety disorder group and a healthy control group. It remains worth noting that Waechter and colleagues found dissimilar results to Amir and Bomyea despite recreating their paradigm closely. Nonetheless, both studies' results appear to have inconsistencies with the current results, which may stem from the different working memory task. In both of these past studies, an operation span task was used, which is a complex span task that entails task-switching between encoding the to-be-remembered words and performing arithmetic (Kane, Conway, Miura, & Colflesh, 2007). In contrast to a simple

span task like the current word span tasks adapted from the digit span task, a complex span task adds another layer of difficulty since multiple tasks must be performed rather than a single one. This added difficulty may have eliminated the key between-groups difference responsible for the currently observed WMC benefit: by putting further strain on executive functioning, the low social anxiety group may have lost the advantage of having relatively more executive resources, whereas the executive resources of the high social anxiety group were already depleted. Future work should consider employing multiple working memory tasks (i.e., both simple and complex span tasks) to better examine these inconsistencies.

Though working memory function has been examined in social anxiety disorder patients (Amir & Bomyea, 2011; Yoon et al., 2017; Waechter et al., 2018), the specific contributions of social anxiety to the observed effects have not been fully clear. As an example, Amir and Bomyea (2011) report that their social anxiety disorder patients also had significantly higher levels of trait general anxiety, state general anxiety, and depression than the non-anxious controls. To build upon this work, the current research included measures of each of these factors such that the unique predictive value of participants' social anxiety scores could be evaluated. In Experiments 2 and 3, social anxiety was found to significantly predict between 9 and 10% of the variance in working memory capacity for social threat words, such that higher scores on the SPIN corresponded to lower capacities. Once trait general anxiety, state general anxiety, and depression were added to the linear regression analyses, the overall models dropped to non-significance although the SPIN alone retained some significant value as a singular predictor. Because no factor besides social anxiety could adequately explain variations in working memory capacity, our work supports the idea that a working memory bias may be particular to social anxiety and not just distress or general psychopathology.

Conclusion

Altered memory function is a common feature of social anxiety, such that individuals high in social anxiety often report re-experiencing past social encounters in a repetitive and overly negative fashion. As such, some researchers suggest that individuals high in social anxiety have enhanced memory specifically for threat-related material relative to neutral material. In contrast, other authors claim that the threatening nature of the material is not responsible for a memory bias. Instead, they argue that memory is enhanced for distractors, and that those high in social anxiety are easily distracted in general by any task-irrelevant information. The current thesis examined these hypotheses about the conditions that produce and eliminate a memory bias across different levels of social anxiety. Across three experiments, we present evidence that a memory bias is specific to task-irrelevant, socially threatening material as opposed to a general bias for any distractor. Furthermore, the current results show that a long-term memory bias may be linked to an upstream working memory bias, where one's trait level of social anxiety alters one's ability to maintain socially threatening information in the short-term. Overall, this thesis suggests that both long-term and working memory biases are present in individuals high in social anxiety, and that these biases rely on the socially threatening nature of the to-be-remembered material.

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Appendices

TABLE 13

List of words used for the study phase and recognition tests in Experiment 1.

Neutral		Threat-Related	
activate	kick	annoying	mistake
appliance	limber	ashamed	nervous
black	muddy	boring	offended
coarse	nonchalant	clumsy	panic
concentrate	obsession	despised	party
consoled	pamphlet	embarrassed	rejected
contents	patient	failure	ridiculous
context	phase	hated	selfish
defiant	repentant	hostile	shy
derelict	reverent	humiliated	silly
detail	rough	immature	stupid
errand	seat	inferior	suffocate
garment	spray	insecure	tense
humble	stagnant	insult	terrified
item	subdued	lonely	useless

TABLE 14

Bivariate correlations and descriptives for social anxiety, general anxiety, and depression measures in Experiment 2.

	Bivariate Correlations				Descriptives			
Variable	**SPIN**	**SICSA**	**TICSA**	**DASS-D**	**Mean**	***SD***	**Skew**	**Kurtosis**
SPIN	---				21.78	12.58	0.43	-0.79
SICSA	.13	---			39.29	12.07	0.85	0.30
TICSA	.24*	.78**	---		40.76	13.67	1.08	1.20

DASS-D	.24*	.12	.16	---	4.34	3.52	0.97	0.34

Note. *SPIN* = Social Phobia Inventory, *SICSA* = State Inventory of Cognitive and Somatic Anxiety, *TICSA* = Trait Inventory of Cognitive and Somatic Anxiety, *DASS-D* = Depression Anxiety Stress Scales, Depression Subscale.

**$p < .01$, *$p < .05$.

TABLE 15

Bivariate correlations and descriptives for social anxiety, general anxiety, and depression measures in Experiment 3.

	Bivariate Correlations				**Descriptives**			
Variable	**SPIN**	**SICSA**	**TICSA**	**DASS-D**	**Mean**	***SD***	**Skew**	**Kurtosis**
SPIN	---				22.08	12.92	0.53	-0.56
SICSA	.37**	---			35.05	9.14	0.75	0.19
TICSA	.49**	.81**	---		37.86	10.63	0.65	-0.09
DASS-D	.36**	.62**	.75**	---	5.49	4.58	1.56	2.87

Note. *SPIN* = Social Phobia Inventory, *SICSA* = State Inventory of Cognitive and Somatic Anxiety, *TICSA* = Trait Inventory of Cognitive and Somatic Anxiety, *DASS-D* = Depression Anxiety Stress Scales, Depression Subscale.

**$p < .01$.