Abstract

Cognitive models propose that elevated trait anxiety is associated with selective memory for negative information, although often no such effects are observed on tests of retrospective memory. One possibility is that no anxiety-linked biases in memory processes exists, however an alternative hypothesis is that trait anxiety may be associated with a bias in prospective memory, the process of remembering to carry out activities in the future. In two studies, high and low trait-anxious participants completed a prospective memory paradigm consisting of a lexical-decision task with embedded prospective memory targets. These targets signalled either negative (aversive noise burst) or benign (small monetary gain) future events. In both studies, results showed no significant effect of trait anxiety on prospective memory performance, and no interaction with target type. Thus, these results are in line with the research on anxiety-linked biases in retrospective memory, showing no evidence for a bias in prospective memory.

Keywords: Anxiety; Cognitive bias; Memory bias; Prospective memory

Trait anxiety and biased prospective memory for targets associated with negative future events.

Cognitive models of anxiety propose that heightened trait anxiety is associated with selective processing of negative information (Beck, Emery, & Greenberg, 1985; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998). As trait anxiety is associated with a preoccupation with negative future events, theorists have proposed that high trait-anxious individuals prioritize processing of information concerning potential future dangers (Barlow, 1988).

Empirical evidence has largely supported the existence of such anxiety-linked biases in prospective information processing. For example, risk perception literature has shown that higher levels of trait anxiety are associated with greater perceived likelihood of future dangers, and with the perception that these danger would have more severe negative outcomes (Maner & Schmidt, 2006; Notebaert, Masschelein, Wright, & MacLeod, 2016; Tripp, Tan, & Milne, 1995). In the domain of attention, research has shown that high trait-anxious individuals, relative to low trait-anxious individuals, display a disproportionate tendency to allocate attention to negative information (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzendoorn, 2007). In addition, high trait-anxious people show a heightened tendency to resolve emotionally ambiguous information to yield negative rather than benign meanings (Amir, Beard, & Bower, 2005; MacLeod & Cohen, 1993; Mathews, Richards, & Eysenck, 1989).

However, there is only weak evidence for the existence of an anxiety-linked bias favoring the retrospective retrieval of negative information from memory, despite the fact that such a memory bias is proposed by several theoretical models of emotion (Beck & Clark, 1997; Bower, 1981; Mitte, 2008). Such memory bias is typically examined using tasks consisting of an initial encoding and subsequent retrieval phase. During encoding,

participants are presented with retrospective memory targets (usually words). In the retrieval phase, participants are required to recover the previously encoded targets, either implicitly or explicitly. In implicit memory tasks, memory is revealed by the observed impact of previously encoded targets on current task performance (e.g. word-stem completion). In explicit memory tasks, participants can be asked to recall previously encoded targets, or to indicate whether or not they have previously seen information presented to them (Mathews, Mogg, May, & Eysenck, 1989).

A large body of literature has sought to investigate whether high trait-anxious individuals show a disproportionate retrospective memory bias for negative information. This is examined by introducing valence in the retrospective memory targets, for example by presenting participants with negative words (such as ‘failure’) and neutral words. A memory bias is revealed by superior memory for negative targets as compared to neutral targets. Across these studies, there is little consistent evidence to suggest that such an anxiety-linked retrospective memory bias exists. Reviews and meta-analyses have shown that, although high trait-anxious individuals occasionally are found to display better recall of negative as compared to neutral information, there is no consistent impact of trait anxiety on memory bias when retrospective retrieval is assessed implicitly or through recognition tasks (MacLeod & Mathews, 2004; Mitte, 2008).

While based on existing literature it could thus be hypothesized that no general anxiety-linked biases in memory processes may exist, it is important to evaluate this issue exhaustively given the value cognitive bias literature has had in other domains. For example, research into anxiety-linked attentional bias and interpretation bias has led to the development of training protocols to reduce these biases, and researchers are examining the utility of implementing these training protocols in clinical settings to reducing anxiety dysfunction (Price et al., 2016). As such, any observed anxiety-linked biases in memory

processes may not only enhance our understanding of trait anxiety, but also assist the development of tailored memory training programs (McDaniel & Bugg, 2012; Vrijzen et al., 2014).

Importantly, research to date examining the relationship between trait anxiety and memory bias has focused exclusively on retrospective memory, and hence has tested memory for negative information that has no direct implications for the future. However, as previously indicated, anxiety is considered to be a future-oriented emotion, with high trait-anxious individuals demonstrating preoccupation with negative information pertinent to the future as evidenced by their heightened tendency to worry about negative future events (Barlow, 1988). Thus, it is possible that an anxiety-linked memory bias will manifest when the memory processes under assessment have direct relevance for the future.

Prospective memory is principally concerned with future events, being the mnemonic process through which a person remembers to carry out planned activities (Cherry & LeCompte, 1999). An example of prospective memory is remembering you have to post a letter on the way home from work. Prospective memory concerns infrequent activities that one has to remember to carry out among other every-day activities. Failures in prospective memory are common, and the severity of these failures varies widely (Dismukes, 2012). Some prospective memory failures can simply be annoying (after getting home, you can return to the mailbox to post the forgotten letter), while others can be catastrophic (for example a parent forgetting to drop off their child at daycare on the way to work, and leaving them in a hot car).

In laboratory settings, prospective memory tasks typically involve participants performing an ongoing task, with the additional instruction to execute a particular action in response to specific targets which occur infrequently. The defining feature of prospective memory tasks as compared to other tasks, is that there is no external signal for the

participants to engage in a memory search (a signal either given by the experimenter or through task instructions). Instead, participants need to self-initiate the recollection of the alternative response in response to stimulus targets that are also appropriate stimuli for the ongoing task (Einstein & McDaniel, 2005; Loft & Remington 2010, 2013). For example, Heathcote, Loft, and Remington (2015) had participants classify letter strings as either words or non-words. These stimuli were presented in different colours, and prospective memory targets were introduced by instructing participants to respond with a different response key to letter strings appearing in one particular colour. The measure of prospective memory was the proportion of prospective memory targets to which participants remembered to perform this correct response, as opposed to continuing with lexical decisions.

Researchers have identified several mechanisms that may underlie prospective memory performance in lab-based PM tasks (Heathcote et al., 2015). First, participants can share limited-capacity processing resources between the ongoing task and the prospective memory task (slowing down the rate of information accrual). Second, they can adopt a cautious response policy by requiring more evidence before responding to the ongoing task stimulus (elevating the response threshold), thereby allowing more time to detect the PM target. Thirdly, they can delay the ongoing task response even after the response has been selected, allowing them to double-check their decision is correct. Evidence shows that the vast majority of PM costs (slowing down of reaction time on the ongoing task), are due to participants elevating the response threshold (Heathcote et al., 2015).

A few studies have examined the relationship between trait anxiety and prospective memory, and generally studies found that higher trait anxiety was associated with lab-based prospective memory (Cockburn & Smith, 1994; Harris & Menzies, 1999). This negative relationship can perhaps in part be explained by research showing that anxiety impairs some of the cognitive mechanisms that underpin prospective memory capabilities. Specifically,

research has shown that performance on prospective tasks is predicted by higher order executive functions such as inhibition and shifting (Marsh & Hicks, 1998; Martin, Kliegel, & McDaniel, 2003; Schnitzspahn, Stahl, Zeintl, Kaller, & Kliegel, 2013). A separate line of research contends that these executive functions are impaired in trait anxiety (Derakshan & Ansari, 2007; Derakshan & Eysenck, 2009). As such, heightened trait anxiety may lead to impaired prospective memory capabilities, on part through impairments in the cognitive processes underlying prospective memory.

However, none of the studies examining the relationship between trait anxiety and prospective memory have employed valenced material therefore they cannot inform whether heightened trait anxiety is associated with a prospective memory bias for memory targets that are associated with negative future events. Typically, participants are instructed to respond to the prospective memory targets, but these targets have no negative or benign bearing on the future. It is not unlikely however that a disproportionate preoccupation with prospective memory tasks that signal negative future events could fuel worry about the future. Indeed, for prospective memory targets that are considered important, theories predict that prospective memory performance will be enhanced because additional resources are allocated to the prospective memory task, and participants engage in increased strategic monitoring (for a review, see Walter & Meier, 2014). As such, in high trait anxious individuals, enhanced strategic resource allocation to sources of potential danger could contribute to enhanced prospective memory performance for targets associated with future negative events.

For example, imagine a scenario in which a person needs to post a letter after work today, otherwise it will not reach its destination in time and the person will be fined. Remembering to post the letter constitutes prospective memory for information with negative future implications if the person forgets to perform the task. It is possible that a high anxious person, relative to a low anxious person, is more preoccupied throughout the day with this

prospective memory task, constantly thinking about the fine and reminding themselves of the need to post the letter. Indeed, if an individual is continuously rehearsing information that has future negative implications, this could increase negative thought content, drive the initiation of worry or impair one's ability to stop worrying, and thereby contribute to a heightened frequency of experiencing anxiety.

As such, introducing a valence manipulation into a prospective memory task would allow examining individual differences in relative memory performance for prospective memory targets associated with negative future events as compared to prospective memory targets associated with benign future events. The aim of the current study was to evaluate the novel hypothesis that heightened trait anxiety is associated with selective prospective memory for memory targets that are associated with negative future events.

To examine this, a prospective memory task was employed in which a valence distinction was introduced to the memory targets, which concerned the future implications of these memory targets. Participants high and low in trait anxiety completed a lexical-decision task, categorizing letter strings as words or non-words. Embedded within the word stimuli were words belonging to three categories for which participants needed to make an alternative response (the prospective memory targets). One category of prospective memory targets was not associated with a future event, one category of targets was associated with a benign future event (a small monetary gain), and one category of targets was associated with a negative future event (an aversive noise burst). This modification of a frequently-used prospective memory paradigm thus incorporates the defining feature for prospective memory tasks: participants need to self-initiate the memory search for an alternative response when particular stimuli -that are also appropriate stimuli for the ongoing lexical decision task- are presented. Prospective memory performance was assessed as the number of prospective memory targets for which participants remembered to make this alternative response.

If heightened trait anxiety is associated with a prospective memory bias favoring targets predicting a negative future event, then high trait-anxious participants, relative to low trait-anxious participants, will show better prospective memory performance for negative prospective memory targets than for benign prospective memory targets or targets not associated with a future event.

Study 1

Participants

In order to obtain a group of high trait-anxious and a group of low trait-anxious participants, study invitations were extended to students from the [blinded] School of Psychological Science undergraduate research participation pool, based on their scores on the Spielberger State-Trait Anxiety Inventory, trait subscale (STAI-T; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), completed at the start of the semester. Those scoring in the upper (above 48) and lower (below 38) third of the scores in the pool were eligible to participate. Sample size was guided by practical constraints. Sixty-two students (43 females and 19 males) participated, with ages ranging from 18 to 55 (mean 20.06). Students received partial course credit for participation.

Materials

Trait Anxiety Measure. The Spielberger Trait Anxiety Inventory (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) was used to assess trait anxiety at the start of semester to identify candidate participants, and again at the time of testing. The STAI is a valid and reliable self-report measure of dispositional anxiety (Barnes, Harp, & Jung, 2002).

Word stimuli. For the lexical decision targets, emotionally neutral words were sourced from the Affective Norms for English Words database (ANEW; Bradley & Lang, 1999). Nouns three to eight letters long with a valence no more than 1.5 points away from the

neutral mid-point of the 9-point emotional valence rating scale in the ANEW database were selected. Of the 264 selected words, half were converted into non-words by replacing each vowel with a randomly generated alternative vowel, with the constraint that the resulting letter string was not another English word (Marsh, Hicks, & Watson, 2002). For the prospective memory targets, animal, body part, and fruit words were also from the ANEW database using the same criteria as described above. Words were selected such that the average letter length was the same across categories. Ten independent raters completed pilot testing, judging category membership of the lexical decision and prospective memory words. Words were deemed suitable if there was 100% agreement that they belonged to their designated category (for prospective memory targets), or that they did not belong to these categories (for lexical decision targets). The eight words selected for each prospective memory category are presented in Table 1.

Table 1. Words in each of the prospective memory categories in Study 1.

Body part category		Animal category		Fruit category	
Chin	Hair	Mule	Donkey	Coconut	Lychee
Elbow	Thigh	Lizard	Cat	Banana	Avocado
Arm	Beard	Goat	Tiger	Apricot	Guava
Mouth	Hands	Crab	Leopard	Fig	Lemon

Prospective memory task. The prospective memory task was adapted from the task used by Heathcote and colleagues (2015), in which prospective memory targets were embedded within lexical-decision targets. Participants were asked to classify letter strings as words or non-words pressing ‘w’ or ‘n’ on the keyboard, respectively. Prospective memory was tested by requiring participants to press different response keys when words belonged to

one of three categories, body parts, animals, or fruits.

Words belonging to one of the prospective memory target categories were associated with a small monetary win (benign PM targets), words of the second category were associated with an aversive noise burst (negative PM targets), and words of the third category were not associated with a future events (neutral PM targets). Participants were instructed to categorise letter strings as words or non-words by pressing ‘w’ or ‘n’, but to instead press ‘a’ if the letter string was a word that belonged to the animal category, ‘b’ if the letter string was a word that belonged to the body part category, and ‘f’ if the letter string was a word that belonged to the fruit category.

The allocation of word category to future event (benign, negative, neutral) was counterbalanced across participants. Participants were explicitly informed about the association between word categories and future events. Specifically, they were told that if a word from their benign PM target category was presented (e.g. “*If a word that belongs to the category Animals is presented*”), they had the opportunity to win 10 cents if they remembered to press the relevant response key. Words belonging to the negative PM target category signalled that a noise burst would be delivered at the end of the trial unless they pressed the relevant response key. This noise burst was 500ms of 100dB white noise—known to be aversive, but not harmful (Hobbs, 1990). Participants were informed there was no future event associated with words belonging to their neutral PM target category.

Of the 264 letter strings presented, half were words and half were non-words. Of the 132 words, 108 did not belong to the body part, animal, or fruit category and thus required a ‘w’ response. The other 24 words were prospective memory targets (i.e. words belonging to one of these categories) and required an alternative response. Prospective memory performance was assessed by considering the average accuracy of prospective memory responses for each type of prospective memory target (negative, benign, neutral).

Each trial consisted of a centrally-presented fixation cross for 500ms, followed by the presentation of a letter string until a response was made, or until 3000ms had elapsed. The letter strings were presented in black on a grey background, using lower-case Arial font, size 22. There was a 1000ms inter-trial interval. For trials on which prospective memory targets were presented, the words ‘gained 10 cents’ appeared onscreen for 500ms after a correct response was given for benign PM targets, and a noise burst was delivered at the end of the trial if participants did not respond correctly to negative PM targets.

The ratio of prospective memory to lexical-decision targets was one in twelve (Heathcote et al., 2015), with the 24 prospective memory targets dispersed among the 264 lexical-decision targets. Prospective memory targets were randomly embedded between lexical-decision targets, with the constraints that there were a minimum of six and a maximum of seventeen lexical-decision trials between each prospective memory target. The first prospective memory target was presented after twelve lexical-decision targets.

Procedure

Ethics approval for the study was obtained from the Human Research Ethics Committee of [blinded]. Participants gave informed consent, before providing demographic information and completing the STAI-T. Participants were then given instructions for the lexical-decision targets, which emphasized the need to respond as quickly and accurately as possible. They then completed 20 practice trials in which error feedback was given. Stimuli for this practice task were different from the stimuli in the main task. At the end of this lexical decision practice phase, participants were given the opportunity to ask any clarification questions. Following this, the instructions for the prospective memory targets were given. Next, participants completed a three-minute distractor task (Einstein & McDaniel, 1990; Heathcote et al., 2015) consisting of indicating whether the majority of three digits presented on screen were odd or even, after which the test block began. When the

prospective memory task finished, participants were given their winnings (\$1.20 max) and were debriefed.

Results

Data handling

Inspection of the data (Notebaert, Jones, Clarke, & MacLeod, 2018) showed that some participants failed to comply with task instructions. Seven participants were removed due to not making any responses to prospective memory targets, and a further three participants were removed due to performing at chance level for the remaining lexical-decision targets. Furthermore, one participant indicated they were only moderately fluent in English, and was also removed from further analyses. The final sample size was 51. A post-hoc sensitivity power analysis indicates this sample size can detect a small-to-medium sized ($f = .21$) two level between-group by three level within-group interaction with a power of .80 (Faul, Erdfelder, Lang, & Buchner, 2007).

Multivariate outliers analyses were conducted considering trait anxiety and prospective memory performance on each category. Inspection of Mahalanobis Distances revealed no outliers. Trait anxiety scores could have changed since completion of the STAI at screening (Clarke, MacLeod, & Shirazee, 2008), therefore participants were allocated to groups based on their STAI-T score obtained within the test session. As the mean STAI-T score in screened pool was 43, participants with a score up to 42 were allocated to the low trait-anxious group, whereas participants with a score of 43 or above were allocated to the high trait-anxious group.

Descriptive statistics for each of the anxiety groups are presented in Table 2. The high trait-anxious group consisted of a significantly greater proportion of women, Mann-Whitney

$U = 183.00$, $p = .002$. There were no significant group difference on any other measures other than trait anxiety (all $p > .3$).

Table 2. Study 1 group characteristics (standard deviations reported between brackets).

	Low trait-anxious group	High trait-anxious group
N	29	22
Gender	14 Female	20 Female
Age	21.03 (8.65)	19.36 (2.72)
STAI-T score	34.48 (4.63)	53.18 (6.98)
LD Accuracy	92.03% (6.17)	92.68% (3.72)
Benign PM target ACC	80.41% (16.52)	81.55% (14.36)
Negative PM target ACC	79.59% (21.15)	83.77% (15.61)
Neutral PM target ACC	76.55% (24.43)	75.82% (20.83)

Note. LD = Lexical decision, PM = Prospective memory, ACC = Accuracy

Prospective memory performance

Prospective memory accuracy rates were subjected to a mixed-design ANOVA that considered the between-subjects factor of Anxiety Group (high and low trait-anxious groups), and the within-subjects factor of Prospective Memory Target (Benign, Negative, Neutral). If there is an anxiety-linked bias in prospective memory, this would result in a significant interaction, demonstrating better performance for Negative PM targets than for Neutral PM targets and/or Benign PM targets for high anxious, relative to low anxious participants.

To complement the traditional frequentist analyses and support inferences that were based on the null hypothesis, a Bayesian ANOVAs was also conducted using JASP (version 8.3.1, University of Amsterdam). The resulting Bayes factors (BFs) are reported alongside p

values. BF01 values are reported alongside non-significant results of the traditional ANOVA, to quantify the degree to which the data favours the null hypothesis over the alternative hypothesis. For significant results, BF10 values are reported to quantify the degree to which the data favours the alternative hypothesis relative to the null. A BF of 1 can be interpreted as ‘No evidence’, a BF of 1-3 as ‘Anecdotal evidence’, a BF of 3-10 as ‘Substantial evidence’, a BF of 11-30 as ‘Strong evidence’, a BF of 30-100 as ‘Very strong evidence’, and a BF > 100 as ‘Decisive evidence’.

Results showed that there was neither a significant main effect of Prospective Memory Target, $F(2,48) = 1.688$, $p = .190$, $\eta_p^2 = .033$, BF01 = 3.996, nor a significant main effect of Anxiety Group, $F(1,49) = 0.146$, $p = .704$, $\eta_p^2 = .003$, BF01 = 3.746. In addition, there was no significant interaction between these factors, $F(2,48) = .291$, $p = .748$, $\eta_p^2 = .006$, BF01 = 102.998. This pattern of results remains unchanged when adding gender and/or lexical decision accuracy as a covariate¹.

Interim Discussion

The results of this study show no evidence that heightened trait anxiety is associated with a bias in prospective memory, as there was no anxiety-linked increased performance for negative PM targets compared to either benign PM targets or neutral PM targets. As this was the first test of our novel hypothesis, we deemed it important to replicate the study to examine whether the same pattern of findings would be observed. As Study 1 presented a relatively small number of prospective memory targets (eight items per category), we aimed to increase the task’s sensitivity to detect differential performance for negative and benign

¹ An Anxiety Group by Prospective Memory Target ANOVA on response latencies showed no significant main effect of or interaction with Trait anxiety (all $F < 1$).

PM targets. Therefore, in Study 2, the neutral PM target category was omitted, and an extra four items were added to the negative PM and benign PM categories.

Study 2

Participants

An independent sample of students from the [blinded] School of Psychological Science undergraduate research participation pool were invited to participate based on their scores on the Spielberger State-Trait Anxiety Inventory, trait subscale (STAI-T; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), completed at the start of the semester. Again, those scoring in the upper (above 48) and lower third (below 38) of the distribution of scores in the pool were eligible to participate. Sample size was guided by practical constraints. Sixty-eight students (43 females and 25 males) participated, with ages ranging from 17 to 38 (mean 19.65). Students received partial course credit for participation.

Materials

All materials in this study were identical to those in Study 1, with the exception of the prospective memory targets. Given the omission of the neutral PM category, the fruit category was omitted, and an additional four words were selected (in the same manner as described in Study 1) for both animal and body part categories, see Table 3. To ensure equivalent average letter length across the two categories, some of the original body part and animal words were replaced. Pilot testing (N=10) again ensured there was 100% agreement all newly selected words (presented among filler words) belonged to their respective categories.

Table 3. Words in each of the prospective memory categories in Study 2.

Body part category	Animal category

Ankle	Finger	Mouth	Bear	Hen	Pigeon
Arm	Foot	Nose	Coyote	Lizard	Snail
Chin	Knee	Stomach	Crab	Mule	Toad
Elbow	Lung	Tooth	Goat	Pig	Wolf

Procedure

The procedure was identical to the procedure in Study 1.

Results

Data handling

Inspection of the data (Notebaert et al., 2018) showed that some participants failed to comply with task instructions, as they failed to make any responses to either lexical-decision targets or prospective memory targets. Four participants were removed due to not making any responses to prospective memory targets, and a further three participants were removed due to not making any responses to any lexical-decision targets. Furthermore, two participants indicated they were only moderately fluent in English, and were also removed from further analyses. The final sample size was 58. A post-hoc sensitivity power analysis indicates this sample size can detect a small-to-medium sized ($f = .19$) two level between-group by two level within-group interaction with a power of .80 (Faul et al., 2007).

Examining Mahalanobis' Distance, one participants was identified as an outlier and subsequently removed. Again participants were allocated to groups based on their STAI-T scores obtained at the time of testing, with those scoring 42 or below allocated to the low trait anxious group, and those score 43 or higher allocated to the high trait anxious group.

Descriptive statistics for each of the anxiety groups are presented in Table 4. There were no significant group difference on any measures other than trait anxiety (all $p > .1$). This pattern of results remains unchanged when adding lexical decision accuracy as a covariate.

Table 4. Study 2 group characteristics (standard deviations reported between brackets).

	Low trait-anxious group	High trait-anxious group
N	30	28
Gender	18 Female	19 Female
Age	20.53 (5.27)	19.07 (2.39)
STAI-T score	32.83 (5.18)	58.14 (6.47)
LD Accuracy	92.97% (3.82)	93.36% (4.89)
Benign PM target ACC	83.40% (12.06)	83.89% (13.50)
Negative PM target ACC	76.77% (19.99)	81.54% (10.00)

Note. LD = Lexical decision, PM = Prospective memory, ACC = Accuracy

Prospective memory performance

Prospective memory accuracy rates were subjected to a mixed-design ANOVA that considered the between-subjects factor of Anxiety Group (high and low trait-anxious groups), and the within-subjects factor of Prospective Memory Target (Negative and Benign). As in Study 1, a Bayesian ANOVAs was also conducted, and BF01 values are reported alongside non-significant results, as well as BF10 values for significant results.

Results of the mixed-design ANOVA showed that there was a significant main effect of Prospective Memory Target, in that average accuracy for Benign PM targets, $M = 83.64\%$, $SD = 12.67$, was higher than the average accuracy for the Negative PM targets, $M = 79.07$, $SD = 16.02$, $F(1,56) = 4.793$, $p = .033$, $\eta_p^2 = .079$, $BF10 = 1.728$. There was no significant

effect of Anxiety Group on prospective memory accuracy, $F(1,56) = .677, p = .414, \eta_p^2 = .012, BF01 = 2.744$. Additionally, there was no significant interaction between Prospective Memory Target and Anxiety Group, $F(1,56) = 1.084, p = .302, \eta_p^2 = .019, BF01 = 3.438$, suggesting Anxiety Group did not differentially impact performance for the two types of prospective memory targets².

General Discussion

The aim of these two studies was to evaluate the novel hypothesis that heightened trait anxiety is associated with selective prospective memory for memory targets that are associated with negative future events. Our results do not provide support for this hypothesis, as in both studies high trait anxious individuals did not show better memory for negative prospective memory targets relative to benign or neutral prospective memory targets, as compared to low trait anxious participants. In addition, when combining data across the two studies, it is apparent there is no significant correlation between trait anxiety scores and accuracy on benign prospective memory targets, $r(109) = -.049, p = .612$, or between trait anxiety scores and accuracy on negative prospective memory targets, $r(109) = .028, p = .772$. In contrast, Bayesian analyses suggested there is very strong to decisive evidence (Study 1) and substantial evidence (Study 2) to support the null hypothesis, i.e. that there is no anxiety-linked bias in prospective memory.

It appears that under some very specific conditions an anxiety-linked memory bias may be observed (e.g. Large, MacLeod, Clarke, & Notebaert, 2016; Mitte, 2008). However, our findings corroborate the general trend in the memory bias literature, suggesting there is no relationship between trait anxiety and memory bias (MacLeod & Mathews, 2004; Mitte, 2008), and extends this to memory processes that have valenced future implications.

² An Anxiety Group by Prospective Memory Target ANOVA on response latencies showed no significant main effect of or interaction with Trait anxiety (all $F < 1$).

The design developed to test the prospective memory bias hypothesis is the first to implement associations with valenced future events into a prospective memory task. Some studies have included negatively valenced words in prospective memory tasks (e.g. Marsh et al., 2009), however these tasks measure the type of prospective memory that is triggered by events that have an inherent valence, for example, a person remembering to do something when they start cleaning (an event that is negative for that person) or when they open a drink (an event that is positive for that person). In contrast, our aim was to examine prospective memory for events that have important implications for the future, when these implications are negative (e.g. getting a fine if you do not post that letter in time) and when these are positive (e.g. getting cash-back on a purchase when positing a voucher within 30 days of purchase). In this case, the event that triggers the prospective memory (e.g. seeing the envelop on the table or driving past the mailbox) is neutral, but the future event (getting a fine or getting cash-back) is valenced. As such, we manipulated the valence of the future events associated with memory targets.

Prospective memory performance, both in real life and in laboratory based experimental tasks such as the one employed in the current study, is likely influenced by a range of higher order cognitive processes. For example, models of prospective memory acknowledge the role of executive functions (e.g. Dobbs & Reeves, 1996), and previous research has shown that executive functions such as shifting and inhibition do indeed contribute to event-based prospective memory performance in laboratory tasks (Marsh & Hicks, 1998; Martin et al., 2003; Schnitzspahn et al., 2013). Inhibition and shifting functions are thought to be impaired in trait anxiety (Derakshan & Ansari, 2007; Derakshan & Eysenck, 2009), however in the current studies, high trait anxious individuals did not show overall worse prospective memory performance as compared to low trait anxious participants. Given that executive functions are also negatively impacted by state anxiety

(Derakshan, Smyth, & Eysenck, 2009; Visu-Petra, Miclea, & Visu-Petra, 2013), one possibility is that perhaps the detrimental impact of trait anxiety on prospective memory will be most apparent when high trait anxious individuals experience high state anxiety. This represents an interesting avenue for future research.

Furthermore, in our adaptation of the prospective memory paradigm, it is possible that individual differences in fear learning may have also contributed to performance on negative PM targets. The influence of individual differences in fear learning was minimised as participants were instructed before the start of the task which category predicted the benign event and which predicted the negative event. Participants did not need to learn the associations between the categories and outcomes through performing the task, and the measure of prospective memory did not assess the relative strength of the association between prospective memory target and outcome valence. Despite this however, some individuals may have developed a stronger association between the word category predicting the nose burst and the negative outcome. Research has shown that such fear learning is enhanced in trait anxiety (Lissek et al., 2008), therefore increased fear learning represents one potential mechanism through which high trait anxious individuals could show better prospective memory performance for targets associated with negative outcomes. However, this pattern of effects was not observed in the current studies.

Although our hypothesis was not supported, our modified prospective memory task may serve to enhance understanding about individual differences in prospective memory processes for valenced future events across a range of conditions. For example, research has shown that depression and schizophrenia are both associated with diminished prospective memory performance (Wang et al., 2009; Zhou et al., 2017). Since both conditions are also associated with increased sensitivity of the behavioural inhibition system (Kasch, Rottenberg, Arnow, & Gotlib, 2002; Scholten, van Honk, Aleman, & Kahn, 2006) and impaired attention

to positive information (Ellis, Beevers, & Wells, 2011; Strauss, Allen, Duke, Ross, & Schwartz, 2008), it is possible that these prospective memory failures may be especially apparent for tasks that are associated with positive future events. If such selectivity in prospective memory failures is observed, this may not only enhance our understanding of these psychological conditions, but also enhance the effectiveness of prospective memory training programs by tailoring them those tasks on which performance is most impaired (McDaniel & Bugg, 2012).

While our results do not support the hypothesis that anxiety is associated with a bias in prospective memory, our experimental task represents only the first approach to test this hypothesis, therefore future research may seek to take on additional approaches by examining different components of prospective memory. Prospective memory can be differentiated into event-based prospective memory (remembering to do something in response to a certain event), and time-based prospective memory (remembering to do something at a particular point in time). Future research could therefore further test the prospective memory hypothesis by similarly associating time-based prospective memory targets with negative and benign events.

In addition, prospective memory consists of both a prospective and a retrospective component (Einstein & McDaniel, 1990). The prospective component refers to remembering that something as to be done in response to a particular event or at a particular time (in the current task: press a different response key for animal, body part, and fruit words). The retrospective component consists of remembering what needs to be done (i.e. press 'a', 'b' and 'f', respectively). Given the simplicity of the retrospective component in the current task, variability in performance likely reflected the degree to which participants remembered the prospective component. Future research may seek to increase the complexity of the retrospective component (e.g. by requiring a difference response key sequence for each

prospective memory target), to examine whether this component of prospective memory is impacted by trait anxiety.

It is important to recognize both the strengths and limitations of the current studies. The negative and benign future events in the current studies were an aversive noise burst and small monetary gain, respectively. In study 2, results suggested that participants were more motivated to gain the money (a maximum of \$1.20 in total), than to avoid the noise burst. This effect was not observed in Study 1, although it is possible that the reduced number of prospective memory target types in study 2 reduced the cognitive load associated with the prospective memory task, and allowed greater influence of other variables (such as the desire to pursue monetary gain) on task performance. To reduce the impact of such potential motivation differences, future research may seek to implement alternative benign or negative events, for example by replacing the monetary gain with an applause sound, or by replacing the negative event with a monetary loss.

Relatedly, future research may also examine whether events that have a stronger emotional valence would lead to different prospective memory performance. In the current design, it is possible that the emotional valence of the positive outcome, and the negative outcome were not sufficiently strong to trigger individual differences in prospective memory performance. Moreover, it is possible that memory for affective (positive and negative) PM targets and memory for neutral PM targets may be the results of different processes. Specifically, it could be argued that memory for affective PM targets may be the result of reflexive responding, whereas memory for neutral targets may be driven by more controlled monitoring strategic processes (Einstein & McDaniel, 2005; McDaniel, Umanath, Einstein, & Waldum, 2015). This would be the case especially if participants developed a stronger association between the affective PM targets and their associated responses than for the neutral PM target and its associated response. If this is the case, future research may

maximise the capacity to observe individual differences, by comparing performance for targets that may be driven by different processes, for example by comparing memory for negative PM targets to memory for neutral PM targets.

A strength of the current design is that both positive and negative prospective memory targets were associated with an outcome, with the only difference being the valence of the outcome (therefore, any differential pattern of results could not be attributed to one target type being associated with an outcome while the other is not). As a result of this experimental control however, the ecological validity of the task may be reduced. Future research may therefore wish to examine prospective memory for targets associated with valenced future events in more naturalistic settings. This could be done for example by deducting money from (or adding money to) a participant's earnings in an unrelated task if they forget to (or remember to) carry out a specified activity at the end of the task.

Although there appear to be no differences in prospective memory between clinical and subclinical anxious samples (Mitte, 2008), the restriction of our sample to high trait anxious non-clinically anxious participants prevents generalisation of the current findings to clinical populations. It is nonetheless important to examine the processes associated with heightened trait anxiety, as this is experienced by a large proportion of the population and is a vulnerability factor for developing an anxiety disorder (Chambers, Power, & Durham, 2004). Anxiety and depression are highly co-morbid, and research has shown that depression is associated with a deficit in prospective memory (Zhou et al., 2017). As such, future research into anxiety and prospective memory may wish to control for depression symptoms. In addition, while our screening procedure was intended to recruit samples from the top and bottom third of the distribution of trait anxiety scores, there was some regression to the mean at the time of testing. Minor changes in trait anxiety scores are not uncommon in student samples, particularly across a period (first semester at university) that could be considered

stressful for some, and a source of enjoyment for others (Clarke et al., 2008). Nonetheless, there was a large difference in trait anxiety between the two groups.

In conclusion, we have presented a novel hypothesis regarding biased memory processes in trait anxiety, and conducted the first studies to evaluate whether heightened trait anxiety is associated with biased prospective memory for targets that are associated with negative future events. We hope we have been to convey to the reader the importance of thoroughly testing this novel hypothesis, and that our proposed task and future directions will provide the foundation for an exciting new line of research in this area.

Disclosure of potential conflicts of interest

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Research involving Human Participants and/or Animals

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. We reported how we determined our sample size, all data exclusions, and all manipulations. The questionnaire battery included additional self-report questionnaires not relevant to the proposed hypotheses, which are therefore not reported.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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