Cognitive Therapy and Research (2019) 43:550–560
https://doi.org/10.1007/s10608-018-9986-6

ORIGINAL ARTICLE

# Trait Anxiety and Biased Prospective Memory for Targets Associated with Negative Future Events

**Lies Notebaert**[1] · **Eleanor Jones**[1] · **Patrick J. F. Clarke**[1,2] · **Colin MacLeod**[1]

Published online: 3 December 2018


**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

Cognitive models of anxiety propose that heightened trait anxiety is associated with selective processing of negative information (Beck et al. 1985; Mathews and Mackintosh 1998; Mogg and 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 and Schmidt 2006; Notebaert et al. 2016; Tripp et al. 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 et al. 2007). In addition, high trait-anxious people show a heightened tendency to resolve emotionally ambiguous information to yield negative rather than benign meanings (Amir et al. 2005; MacLeod and Cohen 1993; Mathews et al. 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 and 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 et al. 1989).

✉ Lies Notebaert
lies.notebaert@uwa.edu.au

[1] Centre for the Advancement of Research on Emotion, School of Psychological Science, The University of Western Australia, 35 Stirling Highway, Crawley, Perth, WA 6009, Australia

[2] School of Psychology, Curtin University, Perth, Australia

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 and 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 and Bugg 2012; Vrijsen 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 and 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 (PM) 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 are also appropriate stimuli for the ongoing task (Einstein and McDaniel 2005; Loft and Remington 2010, 2013). For example, Heathcote et al. (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 poorer lab-based prospective memory (Cockburn and Smith 1994; Harris and 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 and Hicks 1998; Martin et al. 2003; Schnitzspahn et al. 2013). A separate line of research contends that these executive functions are impaired in trait anxiety (Derakshan and Ansari 2007; Derakshan and Eysenck 2009). As such, heightened trait anxiety may lead to impaired prospective memory capabilities, in 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 targets 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 and 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 that day, 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 or neutral future events. The aim of the current study was to evaluate the novel hypothesis that heightened trait anxiety is associated with selective enhanced 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

To obtain a group of high trait-anxious and a group of low trait-anxious participants, study invitations were extended to students from the University of Western Australia School of Psychological Science undergraduate research participation pool, based on their scores on the Spielberger State-Trait Anxiety Inventory, trait subscale (STAI-T; Spielberger et al. 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 et al. 1983) was used to assess trait anxiety at the start of semester to identify candidate participants, and again at the time of

**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 |

testing. The STAI is a valid and reliable self-report measure of dispositional anxiety (Barnes et al. 2002).

### Word Stimuli

For the lexical decision targets, emotionally neutral words were sourced from the Affective Norms for English Words database (ANEW; Bradley and 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 et al. 2002). For the prospective memory targets, animal, body part, and fruit words were also selected 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.

### Prospective Memory Task

The prospective memory task was adapted from the task used by Heathcote et al. (2015), in which prospective memory targets were embedded within lexical-decision targets. Participants were asked to classify letter stings 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 500 ms of 100 dB 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 500 ms, followed by the presentation of a letter string until a response was made, or until 3000 ms had elapsed. The letter strings were presented in black on a grey background, using lower-case Arial font, size 22. There was a 1000 ms inter-trial interval. For trials on which prospective memory targets were presented, the words ‘gained 10 cents’ appeared onscreen for 500 ms 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 17 lexical-decision trials between each prospective memory target. The first prospective memory target was presented after 12 lexical-decision targets.

**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) |

*LD* lexical decision, *PM* prospective memory, *ACC* accuracy

## Procedure

Ethics approval for the study was obtained from the Human Research Ethics Committee of the University of Western Australia. 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 3 min distractor task (Einstein and 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 et al. 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 et al. 2007).

Multivariate outliers analyses were conducted considering trait anxiety and prospective memory performance on each target category. Inspection of Mahalanobis Distances revealed no outliers. Trait anxiety scores could have changed since completion of the STAI at screening (Clarke et al. 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-Withney $U = 183.00$, $p = .002$. There were no significant group difference on any other measures other than trait anxiety (all $p > .3$).

### 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 ANOVA 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 covariate[1].

### 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 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 University of Western Australia 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 et al. 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.

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

**Table 3** Words in each of the prospective memory categories in Study

| 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 |

### 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.

### 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.

**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) |

*LD* lexical decision, *PM* prospective memory, *ACC* accuracy

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.

### 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 ANOVA 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 targets[2].

## 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-liked memory bias may be observed (e.g. Large et al. 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 and Mathews 2004; Mitte 2008), and extends this to memory processes that have valenced future implications.

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 posting 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.

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

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 and 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 and Hicks 1998; Martin et al. 2003; Schnitzspahn et al. 2013). Inhibition and shifting functions are thought to be impaired in trait anxiety (Derakshan and Ansari 2007; Derakshan and 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 et al. 2009; Visu-Petra et al. 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 thus 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 noise 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 et al. 2002; Scholten et al. 2006) and impaired attention to positive information (Ellis et al. 2011; Strauss et al. 2008), it is possible that these depression and schizophrenia-related 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 to those tasks on which performance is most impaired (McDaniel and 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 bias 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 and 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 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 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 and McDaniel 2005; McDaniel et al. 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 et al. 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.

## Compliance with Ethical Standards

**Conflict of Interest** LN and CM were supported in part by the Australian Research Council under Grant FL170100167. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. Authors PC and EJ declare that they have no conflict of interest.

**Informed Consent** All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (national and institutional). Informed consent was obtained from all individual subjects participating in the study.

**Animal Rights Statements** No animal studies were carried out by the authors for this article.

## References

Amir, N., Beard, C., & Bower, E. (2005). Interpretation bias and social anxiety. *Cognitive Therapy and Research, 29*(4), 433–443. https://doi.org/10.1007/s10608-005-2834-5.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van Ijzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin, 133*(1), 1–24. https://doi.org/10.1037/0033-2909.133.1.1.

Barlow, D. H. (1988). *Anxiety and its disorders: The nature and treatment of anxiety and panic*. New York: Guilford Press.

Barnes, L. L., Harp, D., & Jung, W. S. (2002). Reliability generalization of scores on the Spielberger State-Trait Anxiety Inventory. *Educational and Psychological Measurement, 62*(4), 603–618. https://doi.org/10.1177/0013164402062004005.

Beck, A. T., & Clark, D. A. (1997). An information processing model of anxiety: Automatic and strategic processes. *Behaviour Research and Therapy, 35*(1), 49–58.

Beck, A. T., Emery, G., & Greenberg, R. L. (1985). *Anxiety disorders and phobias: a cognitive perspective*. New York: Basic Books.

Bower, G. H. (1981). Mood and memory. *American Psychologist, 36*(2), 129–148.

Bradley, M. M., & Lang, P. J. (1999). *Affective norms for English words (ANEW): Instruction manual and affective ratings*. Gainesville: University of Florida.

Chambers, J. A., Power, K. G., & Durham, R. C. (2004). The relationship between trait vulnerability and anxiety and depressive diagnoses at long-term follow-up of Generalized Anxiety Disorder. *Journal of Anxiety Disorders, 18*(5), 587–607. https://doi.org/10.1016/j.janxdis.2003.09.001.

Cherry, K. E., & LeCompte, D. C. (1999). Age and individual differences influence prospective memory. *Psychology and Aging, 14*(1), 60–76.

Clarke, P. J. F., MacLeod, C., & Shirazee, N. (2008). Prepared for the worst: Readiness to acquire threat bias and susceptibility to elevate trait anxiety. *Emotion, 8*(1), 47–57.

Cockburn, J., & Smith, P. T. (1994). Anxiety and errors of prospective memory among elderly people. *British Journal of Psychology, 85*(2), 273–282. https://doi.org/10.1111/j.2044-8295.1994.tb02523.x.

Derakshan, N., & Ansari, T. (2007). Anxiety reduces top down attentional control: Evidence from the antisaccade task. *Psychophysiology, 44*, S24–S24.

Derakshan, N., & Eysenck, M. W. (2009). Anxiety, processing efficiency, and cognitive performance. New developments from attentional control theory. *European Psychologist, 14*(2), 168–176. https://doi.org/10.1027/1016-9040.14.2.168.

Derakshan, N., Smyth, S., & Eysenck, M. W. (2009). Effects of state anxiety on performance using a task-switching paradigm: An investigation of attentional control theory. *Psychonomic Bulletin & Review, 16*(6), 1112–1117. https://doi.org/10.3758/pbr.16.6.1112.

Dismukes, R. K. (2012). Prospective Memory in Workplace and Everyday Situations. *Current Directions in Psychological Science, 21*(4), 215–220. https://doi.org/10.1177/0963721412447621.

Dobbs, A. R., & Reeves, M. B. (1996). *Prospective memory: More than memory prospective memory: Theory and applications* (pp. 199–225). Mahwah: Lawrence Erlbaum Associates Publishers.

Einstein, G. O., & McDaniel, M. A. (1990). Normal aging and prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*(4), 717–726. https://doi.org/10.1037/0278-7393.16.4.717.

Einstein, G. O., & McDaniel, M. A. (2005). Prospective memory: multiple retrieval processes. *Current Directions in Psychological Science, 14*(6), 286–290. https://doi.org/10.1111/j.0963-7214.2005.00382.x.

Ellis, A. J., Beevers, C. G., & Wells, T. T. (2011). Attention allocation and incidental recognition of emotional information in dysphoria. *Cognitive Therapy and Research, 35*(5), 425–433. https://doi.org/10.1007/s10608-010-9305-3.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191.

Harris, L. M., & Menzies, R. G. (1999). Mood and prospective memory. *Memory, 7*(1), 117–127. https://doi.org/10.1080/741943717.

Heathcote, A., Loft, S., & Remington, R. W. (2015). Slow down and remember to remember! A delay theory of prospective memory costs. *Psychological Review, 122*(2), 376–410. https://doi.org/10.1037/a0038952.

Hobbs, R. (1990). Noise and vibration. In J. Riley (Ed.), *Safety at work*. London: Butterworth-Heinemann.

Kasch, K. L., Rottenberg, J., Arnow, B. A., & Gotlib, I. H. (2002). Behavioral activation and inhibition systems and the severity and course of depression. *Journal of Abnormal Psychology, 111*(4), 589–597. https://doi.org/10.1037/0021-843x.111.4.589.

Large, B., MacLeod, C., Clarke, P. J. F., & Notebaert, L. (2016). It's all about control: Memory bias in anxiety is restricted to threat cues that signal controllable danger. *Journal of Experimental Psychopathology, 7*(2), 190–204. https://doi.org/10.5127/jep.048515.

Lissek, S., Levenson, J., Biggs, A. L., Johnson, L. L., Ameli, R., Pine, D. S., et al. (2008). Elevated fear conditioning to socially relevant unconditioned stimuli in social anxiety disorder. *The American Journal of Psychiatry, 165*(1), 124–132.

Loft, S., & Remington, R. W. (2010). Prospective memory and task interference in a continuous monitoring dynamic display task. *Journal of Experimental Psychology-Applied, 16*(2), 145–147.

Loft, S., & Remington, R. W. (2013). Wait a second: Brief delays in responding reduce focality effects inevent-based prospective memory. *Quarterly Journal of Experimental Psychology, 66*(7), 1432–1447.

MacLeod, C., & Cohen, I. L. (1993). Anxiety and the interpretation of ambiguity: A text comprehension study. *Journal of Abnormal Psychology, 102*(2), 238–247. https://doi.org/10.1037/0021-843X.102.2.238.

MacLeod, C., & Mathews, A. (2004). Selective memory effects in anxiety disorders: An overview of research findings and their implications. In D. Reisberg & P. Hertel (Eds.), *Memory and emotion* (pp. 155–185). London: Oxford University Press.

Maner, J. K., & Schmidt, N. B. (2006). The role of risk avoidance in anxiety. *Behavior Therapy, 37*(2), 181–189. https://doi.org/10.1016/j.beth.2005.11.003.

Marsh, R. L., Brewer, G. A., Jameson, J. P., Cook, G. I., Amir, N., & Hicks, J. L. (2009). Threat-related processing supports prospective memory retrieval for people with obsessive tendencies. *Memory, 17*(6), 679–686. https://doi.org/10.1080/09658210903032762.

Marsh, R. L., & Hicks, J. L. (1998). Event-based prospective memory and executive control of working memory. *Journal of Experimental Psychology-Learning Memory and Cognition, 24*(2), 336–349. https://doi.org/10.1037/0278-7393.24.2.336.

Marsh, R. L., Hicks, J. L., & Watson, V. (2002). The dynamics of intention retrieval and coordination of action in event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*(4), 652–659. https://doi.org/10.1037/0278-7393.28.4.652.

Martin, M., Kliegel, M., & McDaniel, M. A. (2003). The involvement of executive functions in prospective memory performance of adults. *International Journal of Psychology, 38*(4), 195–206. https://doi.org/10.1080/00207590244000205.

Mathews, A., & Mackintosh, B. (1998). A cognitive model of selective processing in anxiety. *Cognitive Therapy and Research, 22*(6), 539–560. https://doi.org/10.1023/a:1018738019346.

Mathews, A., Mogg, K., May, J., & Eysenck, M. (1989). Implicit and explicit memory bias in anxiety. *Journal of Abnormal Psychology, 98*(3), 236–240.

Mathews, A., Richards, A., & Eysenck, M. W. (1989). Interpretation of homophones related to threat in anxiety states. *Journal of Abnormal Psychology, 98*(1), 31–34. https://doi.org/10.1037/0021-843X.98.1.31.

McDaniel, M. A., & Bugg, J. M. (2012). Memory training interventions: What has been forgotten? *Journal of Applied Research in Memory and Cognition, 1*(1), 45–50. https://doi.org/10.1016/j.jarmac.2011.11.002.

McDaniel, M. A., Umanath, S., Einstein, G. O., & Waldum, E. R. (2015). Dual pathways to prospective remembering. *Frontiers in Human Neuroscience, 9*, 392–392. https://doi.org/10.3389/fnhum.2015.00392.

Mitte, K. (2008). Memory bias for threatening information in anxiety and anxiety disorders: A meta-analytic review. *Psychological Bulletin, 134*(6), 886–911. https://doi.org/10.1037/a0013343.

Mogg, K., & Bradley, B. P. (1998). A cognitive-motivational analysis of anxiety. *Behaviour Research and Therapy, 36*(9), 809–848. https://doi.org/10.1016/s0005-7967(98)00063-1.

Notebaert, L., Jones, E., Clarke, P. J. F., & MacLeod, C. (2018). Trait anxiety and biased prospective memory for targets associated with negative future events—Dataset.

Notebaert, L., Masschelein, S., Wright, B., & MacLeod, C. (2016). To risk or not to risk: Anxiety and the calibration between risk perception and danger mitigation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 42*(6), 985–995. https://doi.org/10.1037/xlm0000210.

Price, R. B., Wallace, M., Kuckertz, J. M., Amir, N., Graur, S., Cummings, L., et al. (2016). Pooled patient-level meta-analysis of children and adults completing a computer-based anxiety intervention targeting attentional bias. *Clinical Psychology Review, 50*, 37–49. https://doi.org/10.1016/j.cpr.2016.09.009.

Schnitzspahn, K. M., Stahl, C., Zeintl, M., Kaller, C. P., & Kliegel, M. (2013). The role of shifting, updating, and inhibition in prospective memory performance in young and older adults. *Developmental Psychology, 49*(8), 1544–1553. https://doi.org/10.1037/a0030579.

Scholten, M. R., van Honk, J., Aleman, A., & Kahn, R. S. (2006). Behavioral inhibition system (BIS), behavioral activation system (BAS) and schizophrenia: Relationship with psychopathology and physiology. *Journal of Psychiatric Research, 40*(7), 638–645. https://doi.org/10.1016/j.jpsychires.2006.03.005.

Spielberger, C. D., Gorsuch, R., Lushene, R., Vagg, P., & Jacobs, G. (1983). *Manual for the State-Trait Anxiety Inventory STAI (Form Y): Self-Evaluation Questionnaire*. Alto: Consulting Psychologist Press.

Strauss, G. P., Allen, D. N., Duke, L. A., Ross, S. A., & Schwartz, J. (2008). Automatic affective processing impairments in patients with deficit syndrome schizophrenia. *Schizophrenia Research, 102*(1–3), 76–87. https://doi.org/10.1016/j.schres.2008.01.014.

Tripp, G., Tan, S., & Milne, J. (1995). Risk perception and anxiety. *New Zealand Journal of Psychology. 24*(2), 37–43.

Visu-Petra, L., Miclea, M., & Visu-Petra, G. (2013). Individual differences in anxiety and executive functioning: A multidimensional view. *International Journal of Psychology, 48*(4), 649–659. https://doi.org/10.1080/00207594.2012.656132.

Vrijsen, J. N., Becker, E. S., Rinck, M., van Oostrom, I., Speckens, A., Whitmer, A., & Gotlib, I. H. (2014). Can memory bias be modified? The effects of an explicit cued-recall training in two independent samples. *Cognitive Therapy and Research, 38*(2), 217–225. https://doi.org/10.1007/s10608-013-9563-y.

Walter, S., & Meier, B. (2014). How important is importance for prospective memory? A review. *Frontiers in Psychology, 5*, 657–657. https://doi.org/10.3389/fpsyg.2014.00657.

Wang, Y., Cui, J., Chan, R. C. K., Deng, Y., Shi, H., Hong, X., et al. (2009). Meta-analysis of prospective memory in schizophrenia: Nature, extent, and correlates. *Schizophrenia Research, 114*(1), 64–70. https://doi.org/10.1016/j.schres.2009.07.009.

Zhou, F.-C., Wang, Y.-Y., Zheng, W., Zhang, Q., Ungvari, G. S., Ng, C. H., et al. (2017). Prospective memory deficits in patients with depression: A meta-analysis. *Journal of Affective Disorders, 220*(Supplement C), 79–85. https://doi.org/10.1016/j.jad.2017.05.042.