An investigation into the relationship between prospective memory and PTSD symptom severity in the general population

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Summary

Although we know that people with Posttraumatic Stress Disorder (PTSD) have difficulties with their memories for the past (e.g., McNally, 2006), my thesis explores whether a general population sample with varying levels of PTSD symptoms also report difficulties with memory for the *future*. Overall, little research has investigated the relationship between PTSD symptom severity and prospective memory—memory for actions to be completed in the future (Loftus, 1971). My thesis provides a new and original contribution to this literature in three key ways: 1) I examine the relationship between PTSD and prospective memory in a *general population*, 2) I use a variety of *measurement types* to explore the nature of this relationship, and 3) I investigate one mechanism that might contribute to the relationship—*metacognitive beliefs.*

First, prior literature has relied exclusively on veteran samples that do not allow us to disentangle PTSD symptoms from other physical (e.g., traumatic brain injury) and mental health (e.g., depression) symptoms. My thesis controlled for these comorbidities that might affect prospective memory similarly to PTSD symptoms themselves, and I found that PTSD symptom severity uniquely contributes to self-report prospective memory (Chapters 2-4), over and above these factors.

Second, my thesis explored the relationship between PTSD and prospective memory across different measurement types. Existing literature examining this relationship has relied exclusively on in-lab objective assessment tools (Glienke et al., 2017; Korinek et al., 2021; McFarland et al., 2016; Pagulayan et al. 2018; Scott et al., 2016), but we know that these tasks often lack ecological validity (i.e., poorly represent everyday tasks, and everyday environments), and that generally, different prospective memory assessment methods weakly correlate (e.g., see Uttl & Kibreab, 2011). My thesis is the first to report that in the general population, a relationship between prospective memory and PTSD symptom severity exists

for self-report (Chapters 2-4), and to a lesser extent, naturalistic diary recording (Chapter 4; i.e., tasks that examine errors in everyday life), but not for objective, in-lab tasks (Chapter 3).

Finally, my thesis explores one specific mechanism that might explain any relationship between prospective memory and PTSD symptoms—metacognitive beliefs (i.e., beliefs and appraisals about cognition and thinking; Papageorgiou & Wells, 2001). Using mediation analyses, I found that metacognitive beliefs consistently explain the relationship between PTSD symptoms and *self-report* prospective memory, but not other assessment methods (Chapters 2-4). Put differently, when a person holds more negative beliefs about themselves and their memory (e.g., I am useless), they are more likely to *self-report* greater everyday memory errors, and these beliefs might *exaggerate* the actual impairment they experience in everyday life. I therefore went on to experimentally examine whether self-report prospective memory is malleable, based on people's current negative appraisals of their ability. These experiments were the first to apply an ease of retrieval paradigm—recalling either fewer, or more details; specifically here instances of forgetting over the past week—to prospective memory. Critically, I report that self-report prospective memory can be experimentally manipulated, and therefore is likely malleable (Chapter 5).

Taken together, my findings suggest that there is a relationship between PTSD symptom severity and prospective memory, but this relationship might depend on the type of population, and the type of measurement used. I hypothesise that metacognitive beliefs play a key role in this relationship; specifically, traumatic events might affect people's beliefs about their memory and cognitive functioning. My thesis has clinical, methodological, and theoretical implications. Clinically, my findings provide insight into the impact of maladaptive beliefs in PTSD. Meaningful therapeutic engagement might be challenging if prospective memory—or just metacognitive beliefs about memory—are impaired in PTSD. Intervention could include psychoeducation around this idea. Methodologically,

metacognitive beliefs might affect how people report their abilities on self-report questionnaires examining cognitive variables (e.g., prospective memory). Thus, future work in the applied clinical field should use a variety of measurement methods to explore cognitive variables such as prospective memory. Theoretically, I propose that together my findings fit with what we know about PTSD as a "disorder of memory" (e.g., McNally, 2006), or a "disorder of forgetting" (e.g., Ursano et al., 2007).

Declaration

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Signed 

Date 13/05/2022

Acknowledgement of Country

I would like to acknowledge this work was produced on the lands of both the Kaurna and Barngarla nations. I recognise the Kaurna and Barngarla people are the Traditional Custodians of the land where my research was conducted, and pay my respect to Elders past, present, and emerging. I recognise Aboriginal staff members who have contributed to my PhD journey.

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Now, who's ready for a vino?

Publications

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Chapter 1: Literature review

In the Harry Potter book *Harry Potter and the Philosopher's Stone*, Neville Longbottom received a remembrall—a tennis ball-sized glass sphere that fills with red smoke to remind its owner they have forgotten something—as a gift from his Grandmother. Unfortunately, these objects don't exist in the muggle (i.e., non-magic) world, although they would serve a useful purpose in the case of *prospective memory (PM)*—memory for future actions or intentions (e.g., Cohen & Hicks, 2017; Loftus, 1971). For Neville, his prospective memory errors included forgetting to wear his school robe to dinner, and to contact his grandmother at the right time. Even as muggles, we might make any number of prospective memory errors, including forgetting to take or administer medication, or forgetting to lock the front door.

Indeed, people commonly make prospective memory failures in their everyday life. When asked to record memory failures over a week, or retrospectively recall failures in the past week, people report that nearly half (Crovitz & Daniel, 1984; Einstein & McDaniel, 1996; Kliegel & Martin, 2003; West, 1984), or even 70% (Terry, 1988) of those errors involve forgetting intentions, rather than forgetting information. Moreover, people only successfully complete intentions around 70-88% of the time (Ellis & Nimmo-Smith, 1993; Marsh et al., 1998). These failures appear to worsen with age (see Henry et al., 2004 for review), and in a variety of clinical populations (e.g., traumatic brain injury; see Shum et al., 2011 for review).

Research investigating PM is theoretically and practically important, both in the general population and in specific, clinical populations. In the general population, successful PM is important for everyday functioning. Poor PM is associated with dysfunctional outcomes, including medication non-adherence (Woods et al., 2009), engagement in risky behaviours (Weinborn et al., 2013), unemployment (Woods et al., 2011), poor treatment

outcomes (Withall, Harris, & Cumming, 2009), and difficulties with daily activities such as housekeeping, upkeeping finances, and medication management (Pirogovsky, Woods, Filoteo, & Gilbert, 2012). Thus, exploring what types of PM errors people make and why provides us the opportunity to intervene and reduce such instances of forgetting. PM research is also particularly important in clinical populations because prospective memory failures mirror the difficulties in everyday functioning that are often observed in these populations. We know PM deficits appear across clinical mental health disorders such as schizophrenia (Wang et al., 2018), depression (Zhou et al., 2017), bipolar disorder (Zhou et al., 2018) and obsessive compulsive disorder (e.g., Vafa et al., 2018), and up to 40% of people with neuropsychological deficits report PM concerns as their main symptom (Kliegel & Martin, 2003). So, exploring PM in clinical populations provides insight into both level of impairment, and potential strategies for support or rehabilitation. Finally, of course, investigating the ways in which prospective memory differs from other traditional memory phenomena (i.e., retrospective memory) provides insight into the mechanisms that might control and underpin our higher-order cognitive and memory functions (Kliegel & Martin, 2003).

One clinical disorder that has received little attention in the literature but is fraught with everyday impairments in functioning *and* is specifically associated with memory problems, is Posttraumatic Stress Disorder (PTSD). PTSD can arise after exposure to a stressful or traumatic event involving death, serious injury or sexual violence, and is characterised by symptoms such as intrusive thoughts, avoidance of situations or trauma reminders, alterations in thinking and mood, and heightened arousal (American Psychiatric Association, 2013). These symptoms interfere with functioning across domains including work performance (e.g., de Graaf et al., 2012), social relationships (e.g., Riggs et al., 1998), and cognition (e.g., attention; Brandes et al., 2002). Moreover, PTSD is labelled a “disorder

of forgetting" (Ursano et al., 2007, p. 203) and a "disorder of memory" (e.g., McNally, 2006, p. 271). People with PTSD often report disorganised or fragmented memories, or significant gaps in their memory (e.g., Ehlers & Clark, 2000; Rubin et al., 2004; van der Kolk & Fisler, 1995), that their trauma memories are worse or more severe over time (i.e., memory amplification; e.g., Engelhard et al., 2008; Oulton et al., 2016), and that they have difficulty with remembering and concentrating (Roca & Freeman, 2001; Solomon & Mikulincer, 2006). In fact, one diagnostic criterion for PTSD is *negative alterations in cognition and mood*—such as an inability to recall certain aspects of the trauma itself (American Psychiatric Association, 2013; Criterion D). These memory issues contribute to PTSD development and maintenance (e.g., Ehlers & Clark, 2000). For example, people who believe their memory is fragmented or contains gaps may negatively misinterpret these symptoms (e.g., "forgetting what happens means I will never recover"), and therefore experience ongoing feelings of current and serious threat (e.g., "nowhere is safe"), are more likely to develop, or experience persistent PTSD (Ehlers & Clark, 2000; for more detail see Figure 1).

Figure 1.1

The cognitive model of PTSD (Ehlers & Clark, 2000)

In summary then, although we know PTSD is characterised by everyday impairments in functioning and issues with memory and forgetting, limited literature has investigated the relationship between PTSD and PM specifically. Research investigating prospective memory

could provide further insight into whether PTSD sufferers experience issues with memory for future intentions, and how these issues might contribute to symptom maintenance. Thus, my thesis aims to answer the question: is there a relationship between prospective memory and PTSD?

Prospective memory: the beginnings

Time- and event-based prospective memory.

Our everyday lives are full of PM tasks, like remembering to feed the dog at the right time, remembering to take anti-histamines with breakfast, or even remembering to put on deodorant after a shower. To successfully complete PM tasks such as these, we must first remember: that something has to be done, and what it is that has to be done (Maylor, 1993). According to Craik (1986), PM is the memory task that requires the greatest degree of self-initiation (i.e., remembering in the absence of external cues). In fact, poor PM performance—when compared to retrospective memory (i.e., the forgetting of information)—likely arises *because* we rely heavily on these self-initiated processes (e.g., West & Krompinger, 2005). However, the level of self-initiation required depends on which prospective memory task *type* people are completing. Time-based PM involves completing a to-be-performed action at a particular time, or after an elapsed time period (e.g., taking medication at 9am, or every 2-hours). Event-based PM involves completing a to-be-performed action when a certain external event occurs (e.g., remembering to get milk when you pass the shops; Einstein & McDaniel, 1990). Time-based tasks, therefore, have no external cue and require people to monitor and self-initiate the to-be-performed action, whereas event-based tasks require less self-initiation because people can rely on external cues to prompt remembering (Einstein & McDaniel, 1990).

Both PM types are conceptualised as a multi-step process that functions in four stages

(Figure 2; Carey et al., 2006; Einstein & McDaniel, 1990; Knight, 1998; Piefke & Glienke, 2017). Take for example, the to-be-performed task of taking medication. The first stage, *planning*, involves encoding the intention and its corresponding action. During this stage we must encode—perhaps upon waking in the morning—that we are to take one tablet at 9am. During the second stage, *retention*, we must retain the intention in our mind, whilst completing unrelated activities, and may have to continually monitor the time. If we wake at 7am, for example, we must retain the plan to take medication until 9am arrives, whilst getting ready for work. During the third stage, *performance*, we must recognise a cue (i.e., the specified time or event), recall and execute the appropriate response. For example, we must realise the time at 9am and take the required pill, in the required amount. Of course, relying on alarms or reminders may seem like a solution to PM problems, but this solution is not feasible long-term, nor is it effective for event-based tasks. For example, the time consumed setting alarms, or requiring constant access to reminder devices, may also interfere with everyday life, in addition to the interference from PM failures specifically. Further, if failures occur at the first or second stage of the process (i.e., at planning or retention), then alarms or reminders will not help; for example, setting an alarm requires encoding and planning *prior* to performing the intention. The final stage, *evaluation*, involves reflecting on this process and reinforcing the prior stages in some way. For example, if we fail to take our medication, our symptoms might worsen, hopefully encouraging us to complete the intention successfully next time. Importantly, a PM failure could occur at any of these stages. Specifically, we can fail to: initially form or properly encode an intention, retain the intention or monitor the environment, self-initiate the process after a specified cue or time occurs, recall the appropriate response, actually execute the task, or inappropriately evaluate our PM performance.

Figure 1.2

The four stages of forming and performing a PM intention (Einstein & McDaniel, 1990, taken from Piefke & Glienke, 2017)

This image has been removed due to copyright restriction. Available online from: Piefke, M., & Glienke, K. (2017). The effects of stress on prospective memory: A systematic review. *Psychology & Neuroscience, 10(3)*, 345-362. http://dx.doi.org/10.1037/pne000010

The Multiprocess framework.

In addition to the four steps involved in PM performance, McDaniel and Einstein (2000) proposed a multiprocess framework to explain the cognitive processes underpinning PM, again highlighting the differences between time- and event-based tasks. According to McDaniel and Einstein, PM can involve either automatic or controlled cognitive processes. Controlled mental processes involve strategic resource-monitoring (i.e., monitoring the environment), which in turn rely heavily on executive functions (Yang et al., 2015), and therefore greater self-initiated processes. These processes are a top-down memory function where a person actively holds an intention in their mind, while scanning the environment for a cue (Guynn, 2003; McDaniel & Einstein, 2000; Piefke & Glienke, 2017). Comparatively, automatic processes, or spontaneous retrieval (i.e., a bottom-up process) rely to a lesser extent on self-initiated processes and therefore require fewer available resources for continual environment monitoring.

However, some situations may require us to use both automatic and controlled processes together. Whether we engage in automatic or controlled processing varies based on

several factors, including the characteristics of the PM task (e.g., task salience, the association between the PM cue and required response, and the cognitive demand of an ongoing task) and the characteristics of the person (e.g., conscientiousness and compulsiveness). Returning to the medication example, several factors could affect whether we successfully remember to take medication at 9am. On the one hand, this task is likely salient because medication is important to our health, and the consequences of not taking medication could be severe. And, because getting ready for work is not cognitively demanding we likely have resources available to monitor the environment (i.e., to watch for 9am). On the other hand, there is no association between the ongoing task (i.e., getting ready for work) and the PM task (i.e., taking medication). Because temporal cues are less obvious than external event-based cues, they require us to engage controlled mental processes (i.e., self-initiation). Importantly therefore, the more demanding an ongoing task is, the fewer resources we will have available for this strategic monitoring (i.e., monitoring the time; Piefke & Glienke, 2017). Comparatively, remembering to take the same medication with breakfast, rather than at a specific time, relies on automatic processes. Here, having a meal in the morning (i.e., the external cue) could automatically trigger the reminder to take medication.

Both the four-stage model and the multiprocess framework describe complex cognitive processes—such as planning, monitoring, decision-making and inhibitory control mechanisms—that are unique to PM performance (i.e., compared to retrospective memory; see Cockburn, 1995; Glisky, 1996; Reynolds, West, & Braver, 2009; Zöllig et al., 2007)—and facilitated by the frontal and pre-frontal brain regions. Supporting this idea, McDaniel and colleagues (1999), found that high-functioning frontal lobe participants demonstrated better prospective remembering than their low-functioning frontal lobe counterparts. Thus, PM failures may represent not only memory failure, but a broader executive function failure

mediated by the frontal areas of the brain (Shallice & Burgess, 1991).

Measurement of prospective memory

Given the varied nature of PM tasks (e.g., type of task, type of ongoing task, etc), there are multiple methods we can use to empirically measure PM. However, throughout the literature there is much debate about the utility of these different types of prospective memory measurement. Generally, there are four categories of prospective memory measurement; 1) self-report questionnaires, 2) objective performance-based measures, 3) naturalistic everyday life measures, and, 4) experience-sampling and diary methods.

Self-report measurement.

The first measurement type is subjective, self-report questionnaires where participants rate how often they experience failures—such as forgetting to buy something they had planned to—over a specified time-period (e.g., the past week). There exist three commonly used self-report questionnaires that assess prospective memory; 1) Prospective Memory Questionnaire (PMQ; Hannon et al., 1990; 1995), 2) Prospective and Retrospective Memory Questionnaire (PRMQ; Smith et al., 2000) and 3) Comprehensive Assessment of Prospective Memory (CAPM; Chau et al., 2007, see also Brief Assessment of Prospective Memory; BAPM; Man et al., 2011).

Prospective Memory Questionnaire (PMQ). Beginning with the PMQ, this questionnaire contains 52-items designed to measure prospective memory failures in a general population via four subscales; long-term episodic (infrequent tasks remembered over an extended period, e.g., “I miss appointments I had scheduled”), short-term habitual (regular tasks completed in the near future; e.g., “I forget to put deodorant on after showering”), internally cued (tasks without any cues; e.g., “I forget what I came into a room to get”) and memory aids (aids used to assist with prospective remembering, e.g., “I make a grocery list

whenever I go shopping for food"). The original PMQ used a visual analogue scale where anchors differed for each item. However, participants often experienced confusion and reporting difficulty using the scale due to the inconsistent visual anchors (Cuttler & Graf, 2009). A simplified version (Cuttler, 2016) allows participants to simply rate each failure on a Likert scale from 1 = "never" to 5 = "very often". The original scale has good internal consistency for the total scale and the subscales ($\alpha = 0.92$, and $\alpha = 0.84$-0.90 respectively; Hannon et al., 1995) and the updated version has good test-retest reliability (*r*s = .81-.88; Cuttler & Graf, 2009). However, scores on the PMQ mostly do not correlate with objective, performance-based measures of prospective memory—for example, pressing a key in response to a certain word appearing on the screen (only 28.2% of published studies report significant correlations between the PMQ and performance-based PM; see Sugden et al., 2021, for review).

Prospective and Retrospective Memory Questionnaire. The PRMQ is a brief 16-item questionnaire that measures *both* prospective and retrospective memory failures in everyday life for a general population (eight items for each type). This questionnaire has four, two-item subscales; prospective short-term self-cued (e.g., Do you decide to do something in a few minutes' time and then forget to do it?") , prospective short-term environmentally-cued (e.g., Do you fail to do something you were supposed to do a few minutes later even though it's there in front of you, like take a pill or turn off the kettle?"), prospective long-term self-cued (e.g., "If you tried to contact a friend or relative who was out, would you forget to try again later?"), and prospective long-term environmentally-cued (e.g., Do you fail to mention or give something to a visitor that you were asked to pass on?"). Participants rate the frequency of these everyday failures on a Likert scale from 1 = "never" to 5 = "very often". The prospective memory subscale has good internal consistency ($\alpha = 0.84$; Crawford et al., 2003) but there is no evidence for the scale's test-retest reliability. The PRMQ also poorly

correlates with performance-based PM measures (16.7% of published studies report significant correlations between the PRMQ and performance-based PM; see Sugden et al., 2021, for review).

Comprehensive Assessment of Prospective Memory (CAPM). Finally, the CAPM is a 54-item questionnaire specifically designed to measure the frequency of prospective memory failures amongst people with brain injury via three subscales (see also Brief Assessment of Prospective Memory for a brief version of this assessment tool; Man et al., 2011). Section A assesses the frequency of prospective memory failures on basic activities of daily living (e.g., forgetting to eat a meal) and instrumental activities of daily living (e.g., forgetting to pay a bill). Section B queries how concerned participants are about each of their previous failures. And, Section C investigates the reasons why these failures might have occurred (e.g., the more things I have to do, the more likely I am to forget to do them"). Section A has good internal consistency ($\alpha = 0.94$; Shum & Fleming, 2014) and reasonable test-retest reliability (total scale, $r = .76$; Chau et al., 2007), but there is no evidence for the internal consistency for Sections B and C. The CAPM also poorly correlates with performance-based PM measures (only 8.9% of published studies report significant correlations between the CAPM and performance-based PM; see Sugden et al., 2021, for review).

Analysis of self-report measures. Despite the similar nature of these questionnaires (i.e., designed to measure subjective reporting of typical errors over a specified time period), they are each useful in different situations. First, regarding target population, the PMQ and PRMQ are both designed to assess prospective memory failures in a general population, whilst the CAPM was designed specifically to measure these failures in populations with brain injury. Therefore, the CAPM subscales centre around prospective memory failures that occur in basic and independent activities of daily living (e.g., grooming [shaving or showering], forgetting to take medication, and other household duties; Waugh, 1999).

Comparatively, the PMQ and the PRMQ examine more general types of forgetting (e.g., entering a room and forgetting the task) *in addition* to these functional activities. Second, regarding validity, the PMQ best predicts in-lab, objective PM performance (*r*s = .00 to -.65; -.17 to -.25), compared to the prospective memory subscale of the PRMQ (*r*s = .00 to -.61; -.09 to -.22), and the CAPM (*r*s = -.02 to -.40; -.24 to .22; Uttl & Kibreab, 2011; Sugden et al., 2021). Third, regarding length, the PMQ and the CAPM both comprise 50+ items, compared to the PRMQ; a much briefer assessment option (i.e., eight PM items). The PMQ and the CAPM therefore might be more comprehensive, or alternatively, they might result in lazy or inattentive responding due to their length. Finally, the PRMQ and the CAPM provide informant measures to complement the self-report scales—i.e., where relatives and/or carers report on the other person's everyday PM performance—therefore mitigating self-awareness issues in self-report only (Sugden et al., 2021).

These self-report measures also have general advantages. First, self-report methods are practical and convenient, allowing researchers to collect large data samples in easy, cost-effective non-intrusive ways, without relying heavily on resources (e.g., Sugden et al., 2021). Second, self-report measures are based on subjective judgments about typical performance in a variety of realistic, unstructured situations (e.g., everyday performance; Dang et al., 2020). Therefore, they provide insight into how participants believe they would typically perform in their everyday life, and examine lapses that are often difficult to observe in the lab environment (e.g., forgetting to tell your friend an important story; Sugden et al., 2021); as such, they have good ecological validity (e.g., Philips et al., 2008). Third, prospective memory self-report questionnaires (i.e., PMQ, PRMQ and CAPM) have good internal reliability (α = .75-.90; e.g., Uttl & Kibreab, 2011), and seem reasonably reliable over time (i.e., test-retest reliability). Finally, subjective measures provide a research opportunity to explore how other variables such as beliefs (e.g., beliefs about the self, specifically about

memory) might bias reporting. Because self-report measures rely on internal, retrospective judgments they provide insight into how participants *believe* they typically perform, which tells us whether such judgments are vulnerable to bias in some way (for example, by current appraisals of memory ability).

However, subjective assessment methods also have weaknesses. The primary limitation is their supposed lack of validity. For example, prospective memory self-report measures demonstrate poor *convergent* validity; scores on these questionnaires (i.e., PMQ, PRMQ and CAPM) do not correlate with performance on other, in-lab tasks (Uttl and Kibreab, 2011). Similarly, Sugden et al. (2021) report few *significant* correlations—despite some studies finding even *large* correlations—between self-report and performance-based measures of prospective memory. Instead, these measures tend to correlate with retrospective memory measures, demonstrating poor *divergent* validity (i.e., the ability to discriminate between prospective memory and other types of memory; *r*s = .28 to .73; Uttl & Kibreab, 2011). There are multiple explanations for the poor validity of self-report measures. First, studies examining validity thus far are methodologically flawed—for example, by using small sample sizes, or binary scoring of performance-based tasks resulting in ceiling effects (i.e., scores are either correct/incorrect, and therefore often result in near perfect performance, compared to large ranges in self-report scores; e.g., Uttl, 2008; Uttl & Kibreab, 2011). Second, self-report measures might capture other variables in addition to PM (e.g., depressed mood, personality traits including neuroticism, memory aid usage, and memory self-awareness; see Sugden et al., 2021). Specifically, memory self-awareness (i.e., the ability to recognise any impairments or deficits in memory; Roche et al., 2002) is important in PM self-report measurement. Third, self-report questionnaires are vulnerable to biases because they require participants to retrospectively judge their prospective memory errors—without providing evidence for these errors—and therefore rely on *perceived* performance, rather

than performance itself (Dang et al., 2020; Sugden et al., 2021). In addition to these limitations pertaining to validity specifically, self-report questionnaires also do not tap into the prospective memory *types.* That is, although they have their own subscales (e.g., internally cued, short-term habitual) they do not specifically examine time- and event-based prospective memory. Altogether, if we want to assess an unbiased, realistic level of maximal performance of both time- and event-based PM, self-report measures are unlikely to provide this assessment.

Objective performance-based measurement.

Another common prospective memory assessment method is objective, in-lab, performance-based measures. Within objective assessment there are many different tasks. Beginning with Loftus (1971), the classic prospective memory paradigms involved researchers asking participants to do an unrelated task (e.g., an opinion survey) whilst holding an intention in their mind. For example, "when you are about to leave, tell me what state you were born in" (Loftus, 1971), "request a red pen when asked to draw a circle and a cube" (Dobbs & Rule, 1987), or, "write down your name on the dotted line when you see a slide picturing all males" (Maylor, 1993).

Structured Tests. One test designed to capture a number of these types of intentions from the classic paradigms is the Memory for Intentions Test (Raskin & Buckheit, 2000; Raskin, 2004; Raskin et al., 2010). The MIST involves participants completing eight, performance-based prospective memory tasks that are unrelated to the ongoing task (i.e., a non-focal task); a word search puzzle. These prospective memory tasks are both time- (e.g., "In exactly 15 minutes please tell me it is time to take a break") and event-based (e.g., "When I hand you a red pen, please sign your name on your paper"), have physical or verbal responses, and vary in the delay time (e.g., 2-minutes, 15-minutes; Raskin, 2009; Scott et al., 2016). Other, similar structured tests involve participants completing a specified number of

time- and event-based prospective memory tasks while they complete other "filler" tasks over a specified time period (e.g., Cambridge Behavioural Prospective Memory Test; Goot et al., 2002; Wilson et al., 2005, and, Royal Prince Alfred Prospective Memory Test; Radford et al., 2011). Researchers also commonly use procedures similar to those in the MIST, where participants complete unrelated prospective memory tasks (e.g., in 15-minutes tell me to take a break) over 30-minutes whilst engaged in the same distractor task; a word-search puzzle (Raskin, 2004; Woods et al., 2008).

The Einsten and McDaniel paradigm. The now standard laboratory paradigm Einstein and McDaniel (1990) developed also involves participants engaging in an ongoing task that participants perceive as their primary target, while holding a separate PM intention in mind—that, unlike the MIST, is actually somewhat related to the ongoing task (i.e., focal). The original paradigm involved a short-term memory task as the ongoing task: participants viewed a series of words on the computer screen and were required to read these words aloud. The prospective memory task was to press a response key when a certain word (e.g., "rake") appeared on the screen. Participants were told their primary task was performance on the ongoing task (i.e., the word-reading task), but that researchers were also interested in their ability to remember future tasks and therefore they must respond to particular words, or at particular times. Since its creation, many studies have used variations of this paradigm to assess prospective memory in the lab. Ongoing tasks include working memory (Park et al., 1997), general knowledge trivia (Einstein et al., 1995; Einstein et al., 2000; McDaniel et al., 1999; McFarland & Glisky, 2009), word rating (Einstein et al., 1997; Kliegel et al., 2001; Martin et al., 2003; Lamichhane et al., 2018), video recall (Logie et al., 2004) and lexical decision tasks (Hicks et al., 2005; Scullin & Bugg, 2013; Scullin et al., 2011; Scullin et al., 2013; Scullin et al., 2010; Smith, 2003).

Virtual Week. In this objective task, participants play a virtual boardgame that represents naturalistic, everyday tasks such as "pick up crayons from the shop on your way home", or "take the pasta bake out of the oven at 7pm" (Rendell & Craik, 2000). As participants move round the virtual board, they maintain and complete numerous time- and event-based intentions, whilst simultaneously encoding new ones. Albeit less commonly, some research also uses variations of these game-type tasks (e.g., "Plan a holiday", Glienke et al., 2017; "Dresden Breakfast Task", Craik & Bialystok, 2006).

Analysis of performance-based measures. All these objective performance-based tasks have been developed and used over decades, spanning diverse research fields, and therefore have their advantages. First, researchers can study PM efficiently and with limited resources (Rummel & Kvavilashvili, 2019). Typical paradigms take less than an hour in the lab, and—depending on the number of presented targets—result in multiple observations, which increases the reliability in measuring PM ability (Keleman et al., 2006). Researchers also have good experimental control over the conditions under which participants complete these tasks; for example, they can manipulate: task difficulty, task-type (e.g., verbal or pictorial), PM task-type (i.e., time- or event-based), and the timing and/or the number of intentions (see Sugden et al., 2021).

However, these tasks may poorly represent typical real-life PM performance. Generally, these measures tap into unrealistic, uncommon stimuli (e.g., unrelated word lists or numbers) in artificial environments (e.g., the absence of distractions or competing demands; Dang et al., 2020), and use researcher-generated intentions, and brief retention intervals (see Sugden et al., 2021). Therefore despite their widespread use across the PM field, if researchers want to examine actual everyday performance, or the consequences of such performance in everyday life, these objective tasks may not be the most ecologically valid way to do so.

Naturalistic everyday life measures.

To combat the limitations of these performance-based measures then, PM assessment has now moved towards measurement that better represents everyday life.

Actual Week. The first realistic assessment tool is *Actual Week* (Rendell & Craik, 2000). This task was designed to resemble the typical tasks people might perform in their everyday life (e.g., phone to arrange an appointment, check there is enough butter) thus measuring prospective memory performance in a naturalistic way. Participants are given a series of tasks to complete in their everyday life over one-week, and are asked to record whether they successfully completed each task. The advantage of this method is that experimenters dictate the to-be-completed tasks, and the cues associated with those tasks (e.g., take medication *with breakfast*), allowing them to maintain some experimental control. However, this control means participants do not actually carry out the tasks—rather just record whether or not they completed the tasks on a micro-recorder. This recording in itself is a PM task and thus participants are actually required to complete a *different* intention to the planned intention (i.e., they may not have medication to take, instead the task is to *record* whether they took the medication). Therefore, it is unclear whether participants remembered to actually complete the tasks, or just remembered to record them. Additionally, although the tasks were designed to represent typical tasks people perform regularly, they are applied across all participants. Therefore, how realistic the tasks are may differ for each person—for example, taking medication would be realistic and important for people who regularly take prescription medication in real-life, compared to those who do not.

Virtual reality. Researchers have also used virtual reality to replicate and measure everyday PM tasks. Initially these paradigms used computer software that allowed participants to negotiate simulated environments (e.g., navigating a virtual bungalow), on a 2D computer screen (e.g., Attree et al., 2009; Brooks et al., 2004; Knight et al., 2006; Kurtz

et al., 2007). More recent paradigms involve fully immersing participants in virtual environments, and asking them to complete intentions whilst undertaking an ongoing task (e.g., stop at the shops on the way to meet your friend at the train station at 2pm; e.g., Besnard et al., 2016; Gonneaud et al., 2012; Lecouvey et al., 2019; Mathews et al., 2015). In fact, several virtual reality environments were designed specifically to measure prospective memory (Virtual Reality Prospective Memory Test, Man et al., 2016; Virtual Reality Shopping Test, Canty et al., 2014). Whilst these tasks are naturalistic, similar to the limitations of Actual Week, participants cannot dictate tasks relevant to their own life. Performance also relies heavily on participants' adaptability to technology. That is, some participants may struggle to adapt to modern technology environments, even after a training phase (for example, learning to use a joystick; Mathews et al., 2015). Using virtual reality is also incredibly resource heavy; these studies often involving learning, practice and performance phases that require numerous hours of participant time, under constant experimenter supervision.

Experience-sampling and diary methods.

A less explored prospective memory assessment method outside the laboratory is experience-sampling and diary recording (Rummel & Kvavilashvili, 2019). Typical research using diary recording to explore memory failures often involves participants reporting *all* forgetting in everyday life—including forgetting of information, rather than specifically forgetting to complete intentions (e.g., Crovitz & Daniel, 1984; Terry, 1988; Unsworth et al., 2012). The studies that have used diary methods to target prospective memory failures specifically, significantly vary in their methodology. Two studies (Marsh et al.,1998; Schnitzpahn et al., 2016) involved researchers asking participants to note their plans for the coming week and then to record whether or not they completed these plans. Others have used experience-sampling techniques; probing participants via text message or phone call, over

several days to weeks, to judge whether they were making a PM error, or thinking about a future intention (Anderson & McDaniel, 2019; Gardner & Ascoli, 2015). Some researchers have used retrospective questionnaires completed at the end of each day (for 5-14 days), where participants checked whether or not they made specific errors (e.g., "to do an errand or chore"; Mogle et al., 2022), or free recalled errors they had made that day (Haas et al., 2020). Finally, Laughland and Kvavilashvili (2018), and Niedźwieńska and colleagues (2020), specifically asked participants to free record in a diary each time they made a prospective memory error over 1-7 days. Similarly, Brazauskiene and colleagues (2020), again used a free record diary over a 3-day period, but *additionally* prompted these participants a few times a day via a watch vibration as a reminder.

As with the other, more naturalistic PM measurement types (i.e., actual week and virtual reality), diary methods also have limitations. First, these real-life investigations again are resource heavy, demanding monetary and time investments, for both the researcher and the participant (Rummel & Kvavilashvili, 2019). Second, experimenter control is reduced because participants dictate their intentions, and therefore components of PM (e.g., retention interval, type of task) cannot be experimentally manipulated (Kvavilashvili, 1992). Third, diaries that involve reporting planned intentions in an initial meeting prior to the diary phase, do not capture the intention *execution* of any intentions made *after* the initial reporting phase, or any intentions that participants initially forgot to report. Finally, remembering to record PM tasks in a diary is in itself a prospective memory task, specifically for those studies that do not include prompting of some kind (e.g., via text message or watch vibration). Therefore, for people who do have poor prospective memory ability, diary recording might be a difficult task for them to complete.

Comparison of measurement types

Overall within the literature, there is wide variation in PM tasks and these tasks each have strengths and weaknesses. Researchers report that PM measurement has "come full circle" (Rummel & Kvavilashvili, 2019); PM investigations began with naturalistic observations, but the increase in lab-based paradigms caused researchers to instead rely heavily on these objective assessments that appear to validly assess PM and that allow for good experimental control. But, given lab-based paradigms capture optimal, rather than everyday performance, self-report questionnaires, naturalistic paradigms and experience-sampling methods might be more valid ways to examine realistic, everyday performance. However, self-report questionnaires appear to lack convergent and divergent validity in that they do not correlate with other, objective measurement tasks and instead correlate with measures of different memory constructs. And, alternative assessments that examine everyday life—like virtual reality and diary methods—require extensive resources that might not always be practical. Despite the limitations of naturalistic assessments, researchers have returned to directing extra resources towards naturalistic and experience-sampling methods that might be more valid ways to examine everyday performance. Altogether, it seems likely each prospective memory measurement method taps into different components of prospective memory. Indeed, research using clinical populations finds mixed results that possibly arise because of the differences in measurement highlighting such PM components.

Prospective memory and clinical populations

Turning now to clinical populations, existing research suggests a complex relationship between psychopathology and prospective memory, which likely depends on the type of population, and the type of assessment.

Schizophrenia.

Research suggests that amongst people with schizophrenia—compared to healthy

controls—PM is significantly impaired across numerous assessment methods, including self-report questionnaires, computerised tasks, psychometric batteries (including performance-based tasks such as the Cambridge Prospective Memory Test), and virtual reality (see Wang et al., 2018, for review), with performance on time-based tasks more impaired than on event-based tasks (Wang et al., 2009; Zhou et al., 2019). People with schizophrenia generally have poor insight (i.e., awareness of their mental disorder, their symptoms and subsequent consequences; e.g., Mintz et al., 2003). Thus, they may also be unaware of their prospective memory deficits and consequently fail to use compensatory strategies—e.g., setting reminders or writing lists—to improve performance (Ordemann et al., 2014). Impairment for people with schizophrenia likely results from difficulties with executive functioning including planning and executing goal-directed tasks, or Theory of Mind (i.e., understanding how people's beliefs, desires and intentions influence their behaviour; e.g., Pickup, 2008; Wang et al., 2018). As evidence of these difficulties, people with schizophrenia demonstrate decreased activation in brain regions that control prospective memory processes like attentional control, monitoring and maintenance (e.g., Chen et al., 2016); these processes are more crucial for time- compared to event-based tasks and therefore likely result in greater errors in time-based performance.

Depressive disorders.

Research also consistently finds that, compared to healthy controls, people with depression demonstrate significant prospective memory impairment (see Zhou et al., 2017, for a meta-analysis). Depression appears specifically related to prospective memory tasks that rely on higher-order executive functioning, including non-focal cues (i.e., the PM cue is unrelated to the ongoing task; Altgassen et al., 2009) and time-based tasks (Jeong & Cranney, 2009; Kliegel et al., 2005; Li et al., 2013, 2014; Rude et al., 1999; but see Albiński et al. 2012). However—except for one naturalistic study requiring participants to send text

messages at specific times three- and six-days after an appointment (Jeong & Cranney, 2009)—for people with depression, research thus far has relied only on performance-based prospective memory tasks (e.g., trivia, Rude et al., 1999; word decision task; Altgassen et al., 2011; Altgassen et al., 2009; pictorial tasks; Chen et al., 2013; Memory for Intentions Test; Li et al., 2013). Again, these PM impairments are thought to arise due to the structural and functional brain abnormalities that characterise clinical depression. These abnormalities result in a wide range of deficits including planning and problem solving (Andersson et al., 2010; Naismith et al., 2003), working memory (Gotlib & Joorman, 2010; Harvey et al., 2004; Rose & Ebmeier, 2006), inhibition (Gohier et al., 2009; Joorman, 2010), and task-switching (Lo & Allen, 2011; Murphy et al., 2012), which are all essential for effective prospective memory—and particularly for time-based PM tasks.

Bipolar Disorders.

For bipolar disorders, there is conflicting evidence for a relationship with prospective memory. However, a recent meta-analysis concluded that overall PM, and both time- and event-based performance, is impaired for people with bipolar, with larger effect sizes for time-based tasks (Zhou et al., 2018). However, similar to depression, these impairments have only been investigated and found using in-lab, objective tasks (e.g., Au et al., 2013; Chan et al., 2013; Zhou et al., 2013). Therefore, we don't know if this objective performance aligns with self-report or naturalistic PM assessment. Similar to depression and schizophrenia, the cognitive functions required for effective PM (i.e., retrospective memory in the encoding and maintenance phases and executive functions in the execution phases) are also impaired in bipolar disorders (e.g., Arts et al., 2008) and thus likely play a key role in PM impairment.

Obsessive-Compulsive Disorder.

Finally, for obsessive-compulsive disorder (OCD), the relationship between symptoms and prospective memory seems complicated. For self-report questionnaires, some

research reports sub-clinical compulsive checkers (i.e., people who compulsively check but do not meet the criteria for a diagnosis of OCD) self-report more everyday errors (Cuttler & Graf, 2007), and checking behaviours correlate with self-report PM (Palmer et al., 2015). People with OCD symptoms also self-report worse prospective memory compared to matched healthy controls (Vafa et al., 2018). Comparatively, other research finds no difference on self-report PM for people with high, compared to low, OCD symptoms (e.g., Harris & Cranney, 2012), and for people with OCD, compared to non-OCD control groups (Harris et al., 2010; Yang et al., 2015). These mixed results for self-report prospective memory and OCD likely arise due to sample characteristics. That is, people specifically with checking sub-types of OCD use compensatory checking behaviours to improve their PM, and might therefore judge their everyday prospective memory as better, compared to people with other subtypes (see Yang et al., 2015).

For lab-based tasks, the results are similarly mixed. Cuttler and Graf (2007) originally reported sub-clinical compulsive checkers performed worse on event-based tasks, but not time-based tasks. However, in a replication study, they found worse time-based performance for sub-clinical checkers, stating that the original null results for this relationship arose because of how the task was coded (i.e., unusually, time-based tasks were scored on punctuality rather than success/failure of intention completion; Cuttler & Graf, 2009). Multiple studies have similarly reported worse event-based performance on computerised in-lab tasks for people with OCD compared to healthy controls (Harris & Cranney, 2012; Harris et al., 2010; Racsmany et al., 2011). Yang et al. (2015), however, found no difference on event-based computerised PM tasks, but reported worse performance for people with OCD on time-based tasks. And, some research reports no difference on time-based tasks for people with OCD, compared to a non-OCD control group (Harris et al., 2010). One study reports prospective memory impairment for both time- and event-based tasks for people with OCD

compared to controls (Bhat et al., 2018), and another reported no difference on prospective memory when using a general memory test (Jelinek et al., 2006). Overall, it appears that cue type (i.e., time- vs event-based, e.g., Racsmany et al., 2011), ongoing task complexity (i.e., high vs low cognitive demand, e.g., Racsmany et al., 2011; see Yang et al., 2015) and symptom-related constructs (e.g., meta-awareness; i.e., knowledge of current contents of our thoughts; e.g., Yang et al., 2015) play a significant role in the relationship between OCD and prospective memory (Yang et al., 2015).

Similar to schizophrenia and mood disorders, PM impairments in OCD likely arise from deficits in executive functioning (Bhat et al., 2018). People with OCD demonstrate impairment in several cognitive functions important for successful PM including planning, mental flexibility, and response inhibition (e.g., Bannon et al., 2002; Okasha et al., 2000). Specifically, OCD and PM have "neurobiological overlap" (Bhat et al., 2018, p. 125) whereby the brain regions that play a role in OCD symptoms (e.g., hippocampal regions, thalamus), are also important for effective PM, and particularly for time-based tasks.

Mechanisms underpinning the relationship between prospective memory and clinical disorders.

Overall, despite these mixed results, PM does appear impaired in some way among a variety of clinical disorders. Although there are individual explanations for each disorder, one consistent explanation for this pattern of PM impairment is that PM relies on executive functions that are impaired in, or affected by, these clinical disorders. For example, frontal and pre-frontal regions of the brain—necessary for successful PM performance—are impaired (i.e., structural and electrophysiological abnormalities) in schizophrenia, bipolar and OCD (Bhat et al., 2018; Kim et al., 2004). Moreover, deficits in cognitive control, planning and self-initiated processes that characterise clinical disorders such as depression (Rude et al., 1999) are necessary for successful PM (e.g., to bring the intention to mind, especially in the

absence of a cue). Importantly, time-based tasks rely more heavily on these self-initiated processes and executive functions that appear impaired across these clinical conditions (Raskin et al., 2011).

Prospective memory framework in the context of PTSD

There are several similarities between these other disorders and PTSD. For example, OCD and PTSD are both characterised by intrusive cognitions and impaired executive function (e.g., De Silva & Marks, 2001; Lipinski & Pope, 1994), and depression and PTSD are both characterised by changes in thinking and mood, and overlap in themes of avoidance, numbing and dysphoria (e.g., Gros et al., 2010; 2012). Given this overlap, we could hypothesise a similar relationship between prospective memory and PTSD based on the way the presence or severity of PTSD symptoms might contribute to PM failure at any one of the stages in the multistep process.

Planning.

In terms of general executive functioning abilities, planning behaviour—i.e., developing and implementing specific steps (e.g., emptying the full rubbish before you can add another item) to obtain a future goal (Aupperele et al., 2012)—generally appears preserved in PTSD (e.g., Lagarde et al., 2010; Twamley et al., 2004, see Aupperele et al., 2012 for review). That is, participants with PTSD perform similarly on measures of planning abilities (i.e., the Tower of London task; Lagarde et al., 2010), compared to trauma-exposed controls. To explore the idea of PM impairment at different stages, Glienke et al. (2017) asked veterans with and without PTSD, and non-military controls, to plan, retain and perform PM intentions in a real life-related PM paradigm (i.e., plan a holiday). Unlike the preserved planning found in general memory studies, participants with PTSD performed significantly worse during the planning stage of PM, compared to the other groups. Glienke et al. proposed

that perhaps the planning stage for PM is more complex—involving planning everyday-type intentions completed at a distinct point in the future—than typically measured via general planning tasks—involving immediate planning of visuospatial puzzles (e.g., Tower of London Task; Lezak, 1995). Therefore, PM planning specifically might better represent a deeper encoding process that we know is often impaired in PTSD (e.g., Dickie et al., 2008). Thus, typical measures of planning abilities within PTSD (i.e., Tower of London task) might not fully examine the entire planning process required for successful PM, thus there might indeed be PM specific planning impairment in PTSD.

Retention.

To retain encoded information in our mind, we use working memory (i.e., active maintenance or manipulation of information in our mind; Aupperele, 2012). Although the evidence is minimal, research suggests that working memory is impaired in PTSD. In fact, we know that people with PTSD, compared to trauma-exposed controls, perform worse on spatial working memory tasks (i.e., retaining and manipulating spatial information; Olff et al., 2014) and emotionally valenced working memory tasks (i.e., retaining and manipulating negatively valenced verbal information; Schweizer & Dalgleish, 2011). Moreover, veterans with PTSD, compared to those without PTSD, perform worse on verbal working memory tasks (i.e., learning and maintenance of verbal information; e.g., Vasterling et al., 1998; 2002). We also know that people with PTSD inefficiently allocate their cognitive resources to working memory tasks involving visual and verbal cues (i.e., respond to a series of visual targets presented on the screen; Shaw et al., 2009). Indeed, people with PTSD, compared to matched controls, show greater activation of other brain regions *not* required for working memory performance, which suggests such people are prioritising PTSD symptoms (e.g., monitoring the environment for threat, managing intrusive thoughts; Shaw et al., 2009),

instead of prioritising cognitive functions required for effective PM. In summary, PM retention might be ineffective in PTSD via its reliance on impaired working memory.

Performance.

If PTSD symptoms contribute to impairment in the planning and retention PM stages, then PM performance will too be impaired, because the necessary preceding steps have failed. Essentially, if we fail to initially encode or maintain PM information, we are then unable to perform the required task. In addition to failure of the first steps, resulting in failure of the third, performance itself could be independently impaired in PTSD. Retrieval processes engaged in PM performance require cognitive control (i.e., regulating, ordering, and coordinating thoughts and actions to align with current goals; Braver, 2012) which is associated with prefrontal activity and executive functions that are often impaired in PTSD (Aupperele et al., 2012). Again referring to Glienke et al.'s (2017) investigation of different PM stages, PTSD symptom severity negatively correlated with PM retrieval; participants with higher PTSD symptoms implemented fewer fictional appointments. In addition, both combat-exposed groups demonstrated poorer PM retrieval, compared to non-military controls. Thus, PM performance might be independently impaired in PTSD, or might be impaired resulting from failure in the preceding stages.

Evaluation.

Finally, the evaluation stage relies heavily on metacognition (i.e., beliefs and appraisals about one's cognition and thinking; e.g., Papageorgiou & Wells, 2001). That is, this evaluation requires judgement and reinforcement of the planning, retention and performance phases (e.g., "I did, or did not, perform all those tasks successfully"), leaving it open to biases. In the case of PTSD, we know that core beliefs and environmental factors (e.g., perceived level of threat; e.g., Ehlers & Clark, 2000; Wells, 2000) after a trauma lead to a thinking style that blocks the return of "normal" cognitive processing (Wells & Sembi,

2004). This style of metacognition often produces thoughts like “I should be alert to all sources of danger”, “to be prepared, I must worry” and “I must not think about what happened or I won’t cope”. All of these negative metacognitions could change the way people with PTSD evaluate the outcomes of their intentions, by disinhibiting the reward system (i.e., fail to recognise successfully completed PM intentions) or by failing to recognise the error entirely, due to a lack of resources. In summary, metacognitive impairment in PTSD might result in impaired evaluation of PM processes.

The multiprocess framework and PTSD

PTSD symptoms might also interfere with the automatic and/or controlled processes required for effective PM. In fact, we know that the degree to which people engage in either automatic or controlled processes to help them remember, likely depends on individual difference factors (e.g., personality factors such as compulsiveness and conscientiousness; for review see McDaniel & Einstein, 2000). Another important individual difference factor might be PTSD symptom severity. When referring to automatic or controlled processes, people must willingly engage in remembering that draws their attention towards the PM task. Again using the example of taking medication, people must effortfully *want* to take that medication, *encode* the relevant information and then attempt to *associate* the task with salient cues (e.g., a reminder). Generally, PTSD can influence attentional processes including sustained attention (e.g., Vasterling et al., 2002), shifting attention (Bryant & Harvey, 1997) and inhibitory attentional control (Leskin & White, 2007; Vasterling et al., 1998). Moreover, PTSD symptoms themselves indicate poor attentional control (i.e., the inability to control intrusive thoughts, heightened environmental monitoring and difficulty concentrating; Esterman et al., 2013). Taken together, these data suggest that people with PTSD, or worse PTSD symptom severity, might have difficulty prioritising prospective memory tasks,

because their symptoms draw attention away from competing demands, and consequently they fail to engage important PM processes.

Automatic processes are responsive to environmental cues rather than being self-initiated and goal-directed (McDaniel & Einstein, 2007; see also Snyder & Chatterjee, 2006). Thus, if the cognitive priority for people with PTSD, or worse PTSD symptoms, is to scan the environment for threat, or avoid trauma reminders, there might be too few resources left to engage in monitoring and other PM processes. Importantly, McDaniel and Einstein (2000) suggest there is likely a general bias in this process; where possible, we rely on automatic processes to reduce: the cognitive demands of PM tasks and any subsequent impact on other ongoing tasks (e.g., slowing performance; Smith, 2003). This bias might be particularly salient for people with PTSD who are even less likely to willingly engage in controlled, strategic processes, instead relying on automatic ones, to free-up cognitive resources for symptom management. If these automatic processes are again occupied in other monitoring tasks related to their PTSD symptoms, there are fewer resources available to plan, retain, and perform prospective memory tasks.

Altogether then, it is likely a relationship exists between prospective memory and PTSD based on the role PTSD symptoms might play in any of the PM stages, and in the multiprocess framework. Existing evidence suggests the planning, retention (i.e., via working memory) and performance stages (e.g., Glienke et al., 2017; Vasterling et al., 1998; 2002) are impaired in PTSD. And, we could hypothesise that, based on negatively biased metacognitive processes in PTSD (e.g., Ehlers & Clark, 2000; Wells, 2000), the evaluation stage might also be impaired. Impairment at each stage arises because of deficits in executive function for people with PTSD, and these deficits would therefore impair both automatic and controlled cognitive processes.

PTSD and prospective memory: research so far

Limited research has investigated the relationship between PM and PTSD specifically (refer to Table 1.1 for full summary of comparison between these studies). McFarland et al. (2016) had veterans respond to a series of multiple-choice trivia questions in the lab, whilst maintaining an event-based prospective memory task in their mind. Participants pressed the "6" key when the word "president" appeared during the trivia task. McFarland et al. found greater PTSD symptom severity among veterans was associated with poorer performance on the event-based PM task. Specifically, the avoidance and hyperarousal symptom clusters (i.e., Criterion B and D) were associated with worse event-based PM performance.

A series of studies also investigating the PM-PTSD relationship used the Memory for Intentions Test (MIST). Scott et al. (2016) had combat veterans with and without PTSD maintain time- and event-based intentions whilst completing ongoing puzzles. Veterans with PTSD performed worse on time-based prospective memory tasks, but similarly on event-based tasks. Like McFarland et al. (2016), Scott et al. reported hyperarousal symptoms in particular were associated with time-based errors. In another example, Rau et al. (2017) had veterans respond to the same prospective memory assessment (i.e., the MIST), but specifically investigated the role of sleep quality and fatigue. They found veterans' prospective memory performance correlated with PTSD diagnosis, but PTSD was only related to prospective memory via its influence on fatigue. That is, PTSD symptoms cause daytime fatigue, which then contributes to poorer PM performance. In another study using the MIST, Pagulayan et al. (2018) examined veterans with self-report history of blast-related TBI (further classified into those with and without PTSD), and those without (control group). The TBI group with current PTSD performed worse on the prospective memory task compared to both the TBI group without PTSD and the control group, however only the difference with the control group was statistically significant. Finally, Korinek et al. (2021)

used the MIST to examine PTSD symptoms—in addition to other comorbidities including anxiety, depression and sleep disturbance—amongst veterans with confirmed PTSD, and combat-exposed matched controls who did not meet PTSD diagnostic criteria. Unlike the other studies using the same task, although PTSD symptom severity negatively correlated with PM performance (i.e., greater symptom severity was related to worse PM performance), there were no significant differences between the groups on PM performance.

One study has used a more realistic PM assessment task to explore the PM-PTSD relationship. Glienke and colleagues (2017), had veterans with PTSD, without PTSD, and non-military controls, complete the "Plan a Holiday" paradigm requiring them to plan and retrieve both time- and event-based tasks in a fictional holiday week (e.g., time-based: "at 10:30, eat breakfast", event-based: "after your appointment, go to the sports centre"). Regardless of PTSD status, veterans performed worse on *both* event- and time-based PM tasks than non-military controls without PTSD. Specifically, veterans with PTSD had poorer planning performance compared to only the non-military control group on event-based tasks, and both veteran groups, regardless of PTSD status, performed worse on planning time-based tasks. For prospective memory retrieval, both veterans with and without PTSD performed worse on time- and event-based retrieval than the non-military controls.

Taken together, these findings suggest a complex relationship between PM and PTSD. Similar to research investigating PM in other clinical disorders, PM deficits in PTSD among veterans are sometimes unique to time- or event-based tasks, but sometimes appears across both task types. For veteran samples, the presence of the relationship seems dependant on the characteristics of the sample group. That is, when veterans are compared to a veteran comparison group (e.g., combat-exposed controls, or TBI group without PTSD) the relationship between PM and PTSD is non-significant, or weaker (e.g., Korinek et al., 2021; Pagulayan, 2018), and event-based tasks seem more vulnerable to such comparison groups

(e.g., Glienke et al., 2017; Scott et al., 2016). Therefore, the presence, or absence, of a relationship with PM performance likely depends on variables including the size and characteristics of the population (e.g., type of trauma exposure), the type of measurement (including which PM phases are examined), and the type of research environment.

Table 1.1

Summary of previous literature (see also Piefke & Glienke, 2017)

	Population	***Type of PM task***	***Type of ongoing task***	***Effect sizes***	***Key findings***
McFarland et al. (2016)	Combat veterans with PTSD (*N* = 40)	Event-based PM	Ongoing in lab task paradigm	Event-based PM, *d* = -.96	Elevated PTSD symptoms are associated with greater event-based PM failures.
Scott et al. (2016)	Combat veterans with PTSD (*n* = 40) and non-PTSD combat veterans (*n* = 38)	Time-based PM *and* event-based PM	Memory for intentions test (MIST)	PM performance overall, *d* = -.58 Event-based PM, *d* = -.39, Time-based PM, *d* = -.56	Participants with PTSD show poorer prospective memory performance, particularly for time-based tasks.
Glienke et al. (2017)	Veterans with PTSD (*n* = 13), veterans without PTSD (*n* = 12), and, non-military controls without PTSD (*n* = 21)	Time-based PM *and* event-based PM	"Plan a Holiday" – real-life related PM paradigm	PM performance overall: PTSD & non-military, *U* = -4.17 Event-based PM, PTSD & non-military, U = -4.02 Time-based PM, PTSD & non-military, U = -4.22	Combat-related stress has deteriorating effects on real-life related PM and other memory functions, even in the absence of a PTSD diagnosis.
Pagulayan et al. (2018)	Veterans with and without mTBI history (*N* = 61)	Time-based PM *and* event-based PM	Memory for intentions test (MIST)	TBI & PTSD positive vs control, PM total: d = -1.08, TBI & PTSD positive vs control, PM time-based: d = -1.02,	Veterans with TBI with current PTSD demonstrated significantly lower performance on the PM measure than Veterans in the control group.
Rau et al. (2018)	Veterans with and without mTBI history (*N* = 82)	Time-based PM *and* event-based PM	Memory for intentions test (MIST)	PM score overall and PTSD diagnosis, *r* = -.314	Fatigue is a greater contributor to prospective memory performance than PTSD symptoms. Fatigue fully mediates the relationship.
Korinek et al. (2021)	Veterans with PTSD (*n* = 26) and matched, combat-exposure controls without PTSD (*n* = 26)	Time-based PM *and* event-based PM	Memory for intentions test (MIST)	PM score overall and PTSD score, r = -.366, Event-based PM, *r* = -.37, Time-based PM, *r* = -.25	Although total PM performance and event-based PM correlated with PTSD symptoms, no significant differences between groups. Generalised anxiety better explained PM.

The extant literature on PM and PTSD has significant limitations. First, it has focused almost exclusively on veterans, who are typically male, and are likely to present with numerous comorbidities, including physical injuries (Hourani, Yuan, & Bray, 2003; Scott et al., 2016), and somatoform symptoms (Hoge et al., 2007), or other mental health issues like substance use disorders (Scott et al., 2016), anxiety and depression (e.g., Dekel et al., 2014; O'Toole et al., 1998; Shalev et al., 1996). In particular, the type of exposure (e.g., combat-related) and related physical injuries (e.g., traumatic brain injury) seem important in the PM-PTSD relationship. All of these comorbidities could negatively contribute to cognitive performance—and PM in particular—and cannot be separated from the influence of PTSD symptoms on PM. Indeed, poor physical health (specifically traumatic brain injury; e.g., Shum et al., 2011), substance use and depression severity can impair executive cognition in a variety of ways (e.g., processing deficits and working memory; Crean et al., 2011; Hultsch et al., 1993; McDermott & Ebmeier, 2009; Mullahy & Sindelar, 1998). Second, likely given the difficulty recruiting clinical samples, existing research on PM and PTSD has used limited sample sizes, and hence is potentially underpowered, with no studies of $N > 100$ participants (see Brysbaert, 2019), including those that analyse correlational relationships (see Schonbrodt & Periguini, 2013; 2018). These limitations mean that we cannot generalise the findings from this prior research to the wider, general population, or be certain about the true effect sizes or stability of the reported findings. Consequently, we don't know the nature and extent of PM deficits among adults with varying levels of PTSD symptomatology.

Mechanisms underpinning the relationship between prospective memory and PTSD

There are several reasons we might predict a relationship between PTSD and PM in the general population. Some of these reasons—e.g., impairments in the brain areas required for effective PM—may apply to a variety of physical and mental health disorders, including

PTSD. However, there are also reasons unique to PTSD (e.g., memory problems and negative appraisals in PTSD) that suggest a relationship with PM is likely.

General memory impairment.

As I briefly discussed earlier, PTSD is associated with several types of memory problems. Not only do the symptoms of distressing and intrusive memories and flashbacks characterise the disorder (American Psychiatric Association, 2013), but people exhibiting worse PTSD symptoms demonstrate poorer sustained attention, working memory, learning and retrospective memory (e.g., Johnsen & Asbjørnsen, 2008; Uddo et al., 1993; Vasterling et al., 2002; Vasterling et al., 1998). This impaired retrospective memory is characterised by autobiographical memory issues (i.e., overgeneral memory; recalling only general events to avoid retrieving specific details that could be related to a distressing memory; Schonfeld et al., 2007; for review see Lapidow & Brown, 2015), and a tendency to encode only trauma-specific details (e.g., greater recall for trauma-specific and negatively valenced language; e.g., Bryant & Harvey, 1997; McNally et al., 1987, see Dolcos, 2013). People with PTSD also often report disorganised or fragmented memories, or significant gaps in their memory, and their memories for trauma are often reported as worse or more severe over time (i.e., memory amplification). Thus, given these general memory issues that arise in PTSD, we could assume that PTSD may be related to deterioration in memory for both the past, *and* the future (Piefke & Glienke, 2017), and therefore would similarly result in PM impairment.

Metacognitive impairment.

The metacognitive features that characterise PTSD—specifically negative appraisals—also suggest we might see a unique relationship with PM. According to cognitive models of PTSD, people with PTSD appraise their traumatic experience in a way that produces feelings of current and serious threat (Ehlers & Clark, 2000), which can be external (i.e., “the world is a dangerous place”), or internal (e.g., “I am now unable to complete my

life goals"). These internalised negative appraisals could lead people to have negative beliefs about themselves (e.g., "I am a useless person"), or to negatively interpret their symptoms (e.g., "I am broken"; see Ehlers & Steil, 1995). These negative beliefs might then generalise to cognitive abilities, and specifically to prospective memory (e.g., "I have poor memory ability because I am a useless person"). We know that people tend to attribute poor PM performance to themselves, rather than their memory, as being unreliable (Maylor, 1990). So, people with PTSD may negatively appraise their memory failures in a way that attributes those failures to their own abilities rather than their memory per se. Importantly, both negative beliefs about the self, and negative beliefs about memory, are detrimental. We know that people who exhibit negative beliefs about their memory (e.g., "having gaps in my memory means I am not normal") are more likely to display PTSD symptoms after a traumatic event (Bennett & Wells, 2010; Takarangi et al., 2017). So, in the context of PM specifically, negative appraisals may encourage poor PM behaviours (e.g., planning), poor reinforcement or recognition of successes (e.g., evaluation), and inaccurate reporting of these behaviours, consistent with the appraisal. For example, if people with PTSD believe that their memory is poor, they might stop effortfully trying to plan, retain and perform intentions, and evaluation of their performance is likely to represent the negative appraisal, rather than their performance.

Maladaptive strategies.

The types of maladaptive strategies used to control ongoing threat and unpleasant symptoms in PTSD may also contribute to PM impairment (Ehlers & Clark, 2000). For example, avoiding making future plans—to avoid encountering any more stressful or traumatic experiences—could mean that people with PTSD do not effectively encode intentions. Moreover, when people avoid trauma-related thoughts—for example, by attempting to occupy their mind with other things—they may then have insufficient resources

for PM. Indeed, according to Ironic Processing Theory (Wegner, 1994), *the intentional operating process*, which is conscious and effortful, helps us control our thoughts for example by searching for distractors when trying to suppress a thought (Wegner, 1997). The *monitoring process*, which is unconscious, less effortful, and uninterruptible, searches for signs of failure—e.g., the presence of trauma-related intrusive thoughts—that would derail this process (Wegner, 1997). Ironically, in searching for failures, the monitoring process may actually highlight unwanted thoughts. Thus, due to the operating and monitoring processes being occupied in an attempt to suppress intrusive thoughts, there are insufficient resources left to complete other executive functions. In the case of PM then, there are two possibilities. First, perhaps to-be-completed intentions are accidentally suppressed as a by-product of this control process, because there are too few resources available to bring the intention to mind. Second, there may be insufficient resources for people to monitor the environment and thus recognise PM cues, or recall their intentions at the appropriate time.

Hyperarousal.

Finally, according to attentional control theory—due to the state of hyperarousal people with PTSD experience—resources required for executive functions (i.e., planning, monitoring and attention) are often directed towards external stimuli instead (i.e., monitoring of environmental threat; Eysenck et al., 2007), causing potential PM impairment. Specifically, people with PTSD may be unable to adequately encode information or focus attention. Supporting this idea, Scott et al. (2016), found that poorer time-based PM was specifically related to hyperarousal PTSD symptoms (measured in accordance with Criterion E from the DSM-5; alterations in arousal and reactivity; APA, 2013), suggesting that these tasks require greater executive resources and therefore are particularly impaired due to external stimuli occupying such resources. Similarly, perhaps increased stress and anxiety resulting from hyperarousal cause fatigue (Inman et al., 1990; Shen et al., 2006), which in

turn impairs PM. Indeed, Rau et al. (2017), found that PTSD causes significant daytime fatigue, which then leads to impairments in PM. Consequently, perhaps the hyperarousal symptoms of PTSD result in both fatigue and fewer resources, and both impair PM.

Summary

Taken together, we know that prospective memory errors are particularly common in our everyday life (e.g., Crovitz & Daniel, 1984; Einstein & McDaniel, 1996; Kliegel & Martin, 2003; West, 1984), and perhaps even more so in clinical populations (e.g., schizophrenia, depression, bipolar, and OCD). Over the past two decades, prospective memory research has significantly evolved, trialling numerous measurement methods including self-report questionnaires and performance-based tasks, and now has returned to more naturalistic methods. Much of this research involved investigating prospective memory in different populations including older adults, and people with physical and clinical disorders. For clinical disorders, existing vulnerabilities result in these people making more prospective memory errors, compared to those with lesser symptoms, or without these diagnoses. Moreover, the complexity of the prospective memory process relies heavily on neurological and executive functioning resources often impaired in such disorders.

Another disorder that is characterised by neurological and executive functioning deficits that might, in turn, result in PM impairment, is Posttraumatic Stress Disorder (PTSD). The extant literature examining the relationship between PTSD and prospective memory has produced mixed results and is fraught with limitations such as methodological variations (e.g., population size and characteristics, prospective memory type, assessment method type) and reliance on only veteran samples. Despite these limitations, there are still several convincing lines of evidence to predict a relationship between PM and PTSD. First, as for other clinical disorders, neurological and executive function deficits that exist in PTSD

likely contribute to PM performance. Second, PTSD is uniquely characterised by general memory errors that might too apply to memory for the future. Third, the metacognitive strategies that characterise PTSD, specifically negative metacognitive beliefs (e.g., about the self and about memory) and maladaptive strategies might underpin the relationship with PM, particularly in the case of self-report judgments about PM performance. Finally, the greater allocation of resources towards hyperarousal symptoms likely also contributes to impaired PM.

Research investigating this relationship might provide insight into understanding and providing more relevant strategies in PTSD therapies. For example, low engagement in therapy (i.e., missing therapy appointments, not completing homework) might not result from poor motivation, rather from poor prospective memory. And, providing strategies like psychoeducation and encouraging people to use memory aids might increase engagement and therapy outcomes, and overall quality of life.

Overview of Thesis Studies

The purpose of my thesis is threefold. First, I aimed to explore the relationship between PTSD symptoms and prospective memory in a general population sample. The literature that currently exists exploring this relationship (e.g., Glienke et al., 2017; Korinek et al., 2021; McFarland et al., 2016; Pagulayan et al., 2018; Rau et al., 2017; Scott et al., 2016) relies exclusively on small (*N*s = 40-82) veteran samples who present with comorbidities (e.g., traumatic brain injury) that might similarly contribute to prospective memory, in addition to PTSD symptoms. Furthermore, the size and presence of the relationship between PTSD and prospective memory significantly differs across these studies. Thus, in my thesis I explored the relationship using adequately powered general population samples with a full range of PTSD symptoms, whilst controlling for these comorbidities.

Second, we know that prospective memory measurement significantly varies in the literature (e.g., self-report questionnaires, performance-based tasks, naturalistic diary-based or experience-sampling methods), and often findings differ depending on measurement type. Therefore, I used a variety of prospective memory measurement methods to investigate the generalisability of the relationship between PTSD and prospective memory, across different prospective memory tasks and experimental environments. Finally, and importantly, I aimed to explore one particular mechanism that might underpin the relationship between PTSD symptoms and prospective memory—metacognitive beliefs (e.g., negative beliefs about the self, and about memory, and Criterion D from the DSM-5; negative alterations in cognition and mood). Given the variation in results from previous studies dependant on the type of measurement and the type of population, I hypothesised that metacognitive beliefs may play a key role in explaining some of these measurement inconsistencies dependant on measurement (e.g., self-report). I focused specifically on metacognitive beliefs throughout my thesis, however I also consistently measured maladaptive strategies (e.g., suppression and willingness to future plan).

Study 1

My first study was an online cross-sectional survey to explore the correlational relationship between prospective memory and PTSD symptom severity in a general population. This first study had three main aims. First, given that all prior literature examining this relationship used clinical populations, specifically veterans (e.g., Glienke et al., 2017; Korinek et al., 2021; McFarland et al., 2016; Pagulayan et al. 2018; Scott et al., 2016), I wanted to establish the presence (or absence), and size, of a relationship between self-report prospective memory and PTSD, in a general population. Second, I wanted to confirm that this relationship existed independent of comorbidities or other physical health variables that commonly exist within clinical populations (e.g., depression, anxiety and stress

symptoms, possibility of traumatic brain injury) and could otherwise result in a spurious relationship between PTSD symptoms and PM. Indeed, clinical populations with PTSD are also likely to have these comorbidities, that could account for difficulties with PM, over and above PTSD symptoms. Finally, I aimed explore the role of metacognition and maladaptive strategies as mechanisms that might underpin the relationship between prospective memory and PTSD. I hypothesised that—given the important role negative beliefs play in the development and maintenance of PTSD (e.g., Ehlers & Clark, 2000)—metacognitive variables (i.e., cognitive confidence, beliefs about memory, negative cognitions about the self, suppression tendency and willingness to future plan) would contribute to the relationship between PM and PTSD. That is, people reporting worse PTSD symptoms would also report more negative metacognitive beliefs, (e.g., people's perceptions, beliefs and concerns about their memory; Sugden et al., 2021), which would in turn result in greater reporting of PM errors. I found a medium correlation between self-report prospective memory (i.e., scores on the PMQ and PRMQ) and PTSD symptom severity (*r*s = .42-49), and that this relationship existed independently of comorbidities and other physical health variables. In terms of the mechanisms, the relationship between PTSD and self-report PM was stronger for people with more negative appraisals about themselves and their memory, and who are more likely to engage in maladaptive strategies (e.g., suppression).

Study 2

I relied on only self-report questionnaires in Study 1. We know that one type of measurement alone may not capture the entire construct of prospective memory (e.g., Dang et al., 2020). Indeed, these measures typically do not correlate with performance-based prospective memory tasks (see Sugden et al., 2021 for review). Moreover, self-report prospective memory questionnaires also do not differentiate between time- and event-based prospective memory types. I proposed that this distinction might be particularly important for

the relationship with PTSD given that time-based tasks rely more heavily on executive functions (Yang et al., 2015)—that are often impaired in PTSD (e.g., Aupperle, Melrose, Stein, & Paulus, 2012)—compared to their event-based counterparts.

To address these limitations, I asked undergraduates to complete the same survey battery from Study 1, but additionally asked these participants to complete two, in-lab objective prospective memory tasks (i.e., one time-based, and one event-based). As a secondary interest, I asked people about their everyday impairment (e.g., basic performance in daily activities like work, social and occupational functioning) to explore whether prospective memory deficits might contribute to the functional impairment we see amongst people with PTSD, or people with worse PTSD symptom severity (e.g., difficulty in social situations, or with occupational tasks). I replicated the self-report relationship from Study 1: again, I found PTSD symptom severity correlated with self-report prospective memory (scores on the PMQ and PRMQ; *r*s = .32-.42)—but there was no relationship with lab-based prospective memory performance. The self-report and lab-based measures of prospective memory also did not correlate. Therefore, I proposed that the limitations of self-report—i.e., pre-existing negative beliefs biasing reporting—and performance-based prospective memory tasks—i.e., lacking in generalisability to everyday life tasks and environments—might explain these mixed findings.

Study 3

In Studies 1 and 2, I consistently found a relationship between PTSD symptom severity and self-report prospective memory, but in Study 2, contrastingly, PTSD symptom severity did *not* correlate with objective, in-lab prospective memory performance. I argue—in addition to other flaws—neither measurement type adequately represents accurate typical, everyday behaviour. Specifically, objective, in-lab tasks lack ecological validity and therefore do not generalise to the types of prospective memory tasks we complete regularly (for

example, forgetting to send an important email, or forgetting to take washing out the machine), or to the everyday environment. In addition, self-report measures are an imperfect measure of everyday experience, because they are likely biased by metacognitive beliefs (i.e., beliefs and appraisals about one's cognition and thinking; Papageorgiou & Wells, 2001). Indeed, as I found in Studies 1 and 2, metacognitive beliefs contribute to the relationship between PTSD symptom severity and self-report prospective memory. Therefore, to increase generalisability of the prospective memory tasks and simultaneously reduce the subjective nature of self-report questionnaires (i.e., reducing the retrospective load and requiring objective examples rather than judgment only), I used a naturalistic diary paradigm. I asked community participants to record their prospective memory errors in everyday life over a four-day period. I also used the same questionnaire battery from Studies 1 and 2, to replicate the self-report relationship. In Study 3, I again replicated the relationship with PTSD symptom severity and self-report PM (*r*s = .34) *and* I found a small correlation between diary-recorded prospective memory errors and PTSD symptom severity ($r = .21$). However, although metacognitive beliefs again contributed to the relationship between PTSD symptom severity and self-report PM, these beliefs did not contribute to the relationship between diary-recorded PM and PTSD symptom severity. Therefore, I suggest a small correlation exists between everyday prospective memory failures and PTSD symptom severity, and this relationship is *exaggerated* on self-report measures of prospective memory.

Study 4

In Studies 1-3, I consistently found that PTSD symptom severity was related to self-report prospective memory (i.e., scores on questionnaires), but was inconsistently related to other assessment tools (i.e., computerised tasks in the lab, diary-recording). I also consistently found that PTSD symptoms affected self-report PM via negative beliefs about the self and about memory (i.e., metacognitive beliefs), but not the other assessment types.

Put differently, one key take home message of these studies was that people with worse PTSD symptoms reported increased negative metacognitive beliefs, which contributed to their reporting of greater prospective memory errors on self-report questionnaires, but not weaker in-lab or everyday PM performance. Therefore, I hypothesised that the relationship between PTSD symptom severity and self-report PM likely arises from biases in reporting, rather than representing actual PM performance. In Study 4, I sought evidence for this hypothesis, by investigating whether self-report prospective memory is malleable and vulnerable to momentary change. To test this idea experimentally, I used a variation on the Ease of Retrieval paradigm (e.g., Schwarz, 1988). Online participants recalled either two, or 10, instances of forgetting (i.e., PM failures) over the past week. I aimed to manipulate how participants felt about their memory, and examine whether their recall experience would change the way they subsequently self-reported on their PM. As a secondary interest—given my findings from Studies 1-3 and the role of negative beliefs in PTSD (e.g., Ehlers & Clark, 2020)—I also explored if people with PTSD, or worse PTSD symptom severity are more vulnerable in changing their beliefs and subsequently report differently on their prospective memory. I found that, consistent with my hypothesis, participants recalling two instances of forgetting self-reported making *fewer* PM errors over the past week, compared to those recalling 10. This evidence suggests that self-report prospective memory *is* malleable and vulnerable to momentary change, based on how people presently *feel* about their prospective memory ability which suggests that indeed my prior findings in Studies 1-3—reporting a relationship between self-report prospective memory and PTSD symptoms severity—could have arisen due to reporting biases. In terms of my secondary interest, PTSD symptom severity moderated the relationship between recall condition (i.e., recall two vs 10) and self-report prospective memory such that the difference between the recall conditions on self-

reported prospective memory was strongest at lower levels of symptom severity, with the pattern reversing at high symptom levels.

Chapter 2: Preliminary evidence for a relationship between prospective memory and PTSD symptoms in the general population[1]

Author contributions: I developed the study design with the guidance of MKTT. I collected the data, cleaned the data for analysis, and performed the data analysis and interpretation. I drafted the manuscript and MKTT provided critical revisions. MKTT approved the final version of the manuscript for submission.

Abstract

Introduction: PTSD sufferers often have problems with remembering the past, but do they also have trouble remembering tasks to be completed in the future? We argue characteristics of PTSD—such as negative appraisals and maladaptive strategies—might contribute to biased reporting of prospective memory failures among PTSD suffers—or people with severe PTSD symptoms—within a general population. **Methods:** Mechanical Turk participants completed a questionnaire battery measuring self-report prospective memory, PTSD symptoms, negative appraisals and maladaptive strategies (e.g., suppression), and depression, anxiety and stress symptoms. **Results:** PTSD symptom severity positively correlated with self-report prospective memory failures (*r*s = .42-49). PTSD symptoms affected self-report prospective memory via their influence on negative appraisals and maladaptive strategies. **Limitations:** Our findings rely on self-report, therefore we do not know if this relationship generalizes to objective prospective memory tasks. **Conclusions:** Our data provide preliminary evidence for a relationship between PTSD symptomatology and subjective prospective memory in the general population and suggest that the negative appraisals and maladaptive strategies that commonly accompany PTSD might underpin this relationship.

[1] Swain, T. L., & Takarangi, M. K. T. (2021). Preliminary evidence for a relationship between prospective memory and PTSD symptoms in the general population. *Journal of Anxiety Disorders*, *77*, 102325.

Introduction

Posttraumatic Stress Disorder (PTSD) is characterized by cognitive impairments and memory problems (e.g., overgeneral memory; see Lapidow & Brown, 2015). Research has typically focused on problems with memory for the *past*; however, it is possible that people with PTSD, or more severe PTSD symptoms, also experience problems with memory for *future* intentions, or *prospective memory* (PM; Loftus, 1971). Although PM failures can have trivial consequences, such as milk spoiling after you forget to put it in the fridge, they can also have more serious consequences, such as missing work deadlines, social events, or medication. Indeed, for people with psychopathologies such as PTSD, chronic PM failures may create a vicious cycle; for example, missing medication could affect symptom management, which could, in turn, reduce functioning in other areas. Despite these potential consequences, limited research has examined the relationship between PM and PTSD symptoms. To seek preliminary evidence for this relationship, and the mechanisms that might underpin it—including the possibility that maladaptive metacognitive beliefs and strategies might exacerbate reporting of PM failures—we administered self-report questionnaires to a general population sample.

Before considering what mechanisms might underpin the PTSD-PM relationship, we first turn to issues concerning the two broad PM measurement methods. The first is subjective, self-report questionnaires: participants rate the frequency of failures, such as forgetting to buy something they had planned to buy (e.g., prospective and retrospective memory questionnaire; PRMQ; Smith et al., 2000). The second is objective, performance-type measures: participants perform an ongoing task in the lab (e.g., lexical decision) while maintaining a PM intention (e.g. to press a certain key, or complete a certain task when a word appears/is spoken), or via computerized simulation (e.g., virtual week; Rendell & Craik, 2000). There is mixed evidence for the relationship between these two measurement types.

Some research shows subjective PM and objective performance on a variety of tasks do not correlate in older adults (Foley, 2007; Hering et al., 2018), adolescents (Arnold & Bayen, 2019), or people with schizophrenia (Chan et al., 2008). Yet other studies have found a relationship between subjective PM and performance on similar objective tasks; in the general population (Kliegel & Jager, 2006), amongst older adults with few depressive symptoms or memory concerns (Zeintl et al., 2006), and in cognitively impaired older adults (Foley, 2007).

This pattern of mixed results fits with findings in the broader psychological literature, where self-report and behavioural measures often only weakly correlate (Dang et al., 2020). One explanation for this pattern is that only subjective *or* objective responses represent true performance. In line with this idea, perhaps self-report PM represents how good people *think* their memory is, not how good their memory actually is (Foley, 2007; see also Chan et al., 2008). A second explanation is that subjective and objective measurements simply represent different types of PM performance. Whilst behavioural measures might be more valid (i.e., convergent and divergent validity; Uttl & Kibreab, 2010), and are typically measured under controlled conditions, they are likely less representative of how people would typically behave when completing everyday PM intentions. Comparatively, although subjective measures might be biased—for example, by social desirability or symptom underreporting—these judgments may better predict real-life PM failures (e.g., Dang et al., 2020).

In the case of PTSD, several characteristics, working as a vicious cycle, might bias how people subjectively experience PM failures. Specifically, people with PTSD often appraise their trauma in a way that produces external (i.e., “the world is dangerous”), or internal (e.g., “I am useless”) feelings of threat (Ehlers & Clark, 2000). Such negative thought patterns, in turn, can encourage people to use maladaptive strategies—such as avoiding future planning, or suppressing unwanted thoughts—to control feelings of threat

and unpleasant symptoms (Ehlers & Clark, 2000). But, paradoxically, these strategies perpetuate appraisals by increasing negative thought frequency. For example, using maladaptive strategies such as suppression increases negative thoughts both directly (e.g., Beck et al., 2006) and indirectly via alterations in arousal such as irritability, hypervigilance, and difficulty concentrating (e.g., Nixon & Bryant, 2005; Nixon et al., 2007). Throughout this cycle, people might use these negative appraisals as a lens through which to evaluate their memory ability (e.g., "I have poor memory because I am useless"). If people appraise their *PM failures* in this way (see Graf, 2012, for review), they may over-report the PM errors they experience in everyday life. Subjective judgments of poor PM, *regardless of their accuracy,* may discourage people from effortfully encoding and recalling intentions, contributing to their experience of failures.

Although existing research does not investigate these mechanisms, it does support the idea of a PTSD-PM relationship. However, this extant literature is limited; it focuses on objective measurement, and both the methodology and results are mixed. McFarland et al. (2016) found self-reported PTSD symptom severity predicted poorer PM performance (i.e., press a key in response to seeing the word "president" within trivia questions) amongst veterans. Scott et al. (2016), by contrast, found no difference between veterans with and without PTSD for a similar PM task (e.g., "When I hand you a red pen, please sign your name"). But, participants with PTSD were more likely to fail at a PM task after a time-period elapsed (e.g., "In 15-minutes tell me to take a break"). However, Glienke et al. (2017) found that veterans, regardless of PTSD status, performed worse on a computerized PM task (i.e., appointments during a fictional holiday week), than controls without PTSD.

This literature also focuses almost exclusively on veterans who are particularly likely to present with comorbidities including physical injuries (e.g., TBI; Scott et al., 2016; Taylor et al., 2012), somatoform symptoms (e.g., Hoge et al., 2007), and mental health issues (e.g.,

substance use; Scott et al., 2016, anxiety and depression; e.g., Dekel et al., 2014). These comorbidities may impair executive function (e.g., by impairing working memory; e.g., Crean et al., 2011; Hultsch et al., 1993) independently of PTSD, such that we cannot generalize the findings to the wider population. Importantly, these results also do not consider participants' subjective experience of everyday PM performance.

In summary, we do not know the nature and extent of subjective PM failures among adults with varying PTSD symptomatology. Our primary hypothesis was that subjective PM failures would positively correlate with PTSD symptoms. To control for comorbidities that could account for a relationship between PM failures and PTSD symptoms, we measured possible traumatic brain injury (TBI), alcohol dependency, presence of a learning disorder and childhood trauma (historical and physical comorbidity variables). Our second hypothesis was exploratory; we predicted that the relationship between PTSD symptoms and subjective PM failures might be *stronger* for people with problematic appraisals or strategies (i.e., moderation), and/or PTSD may lead people to use these appraisals or strategies, resulting in poorer PM (i.e., mediation). Thus, we measured negative appraisals (i.e., cognitive confidence, beliefs about memory, negative cognitions about the self) and maladaptive strategies (i.e., suppression tendency, willingness to future plan). Finally, because they are often comorbid with PTSD and could similarly affect PM performance (e.g., Rude et al., 1999), we measured depression, anxiety and stress symptoms as current mental health comorbidity variables.

Method

Participants

For the magnitude of a correlation to be deemed stable, the sample size should approach 260 (Schonbrodt & Perugini, 2013; 2018). Given that PTSD can only be diagnosed in line with a *specific* exposure to real or threatened death or serious injury (American

Psychiatric Association, 2013), we planned to analyze a subset of participants reporting Criterion A trauma. Our previous research using the same population suggests ~67% will have experienced a qualifying trauma, so we collected 405 participants through Amazon's Mechanical Turk (MTurk), to obtain ~260 meeting Criterion A. Several studies have demonstrated MTurk data is reliable (e.g., Buhrmester et al., 2011; Casler et al., 2013) and sometimes even superior to university sourced participants (e.g., fail less attention checks; Hauser & Schwarz, 2015). The prevalence of mental health disorders in MTurk populations matches or exceeds that of the general population (Shapiro et al., 2013), suggesting MTurk is an excellent source for collecting clinical and subclinical populations.

We excluded 11 people for failing all three embedded attention checks (Berinsky et al., 2014; Hauser & Schwarz, 2015). Our final sample was 394 (Criterion A; $n = 262$), comprised of 44.9% males ($n = 177$), 54.8% females ($n = 216$) and 0.3% non-binary ($n = 1$), aged between 20-72 years ($M = 38.42$, $SD = 11.17$; demographic variables appear in Table 2.1).

Table 2.1

Demographic information

	%	*n*
Gender		
Female	54.8	216
Male	44.9	177
Non-binary	0.3	1
Ethnicity		
Caucasian	77.4	303
African American	10.6	41
Asian	6.1	24
Hispanic	4.3	17
Arabic	0.5	2
Highest qualification		
Doctoral studies	1.0	4
Master's studies	9.1	36
Bachelor's degree	40.6	160
Associate degree or certificate	22.8	90
Senior high school or equivalent	26.1	103
Junior high school	0.3	1

Materials

Historical and physical comorbidity variables.

Learning/Developmental disorder screening. We asked participants whether they had ever been: (a) diagnosed with a learning disorder (e.g., Attention-Deficit Disorder [ADHD]), (b) placed in a learning/emotionally handicapped special class, or (c) told they had a learning disorder and by whom (e.g., teacher). We classified participants as having a learning disorder when they responded "yes" to the first or second question, *and* listed doctor/other specialist or teacher on the final question.

The Alcohol Use Disorders Identification Test (AUDIT; Babor et al., 1989). The AUDIT has 10-questions that assess participants' alcohol consumption (e.g., "how often do you have a drink containing alcohol?"). The questions vary in format but typically are answered using a Likert scale from '0' (e.g., never) to '4' (e.g., 4 or more times per week). Internal consistency and test-retest reliability are good, $\alpha = .80$ and $\alpha = .85$, respectively (de Meneses-Gaya et al., 2009).

HELPS Screening Tool (Picard et al., 1991). The HELPS screens for potential TBI across three categories: (a) an *event* that could have caused a brain injury ("H"; Have you ever Hit your Head, or been Hit on the Head?; "E"; Were you ever seen in the Emergency room, hospital, or by a doctor because of an injury to your head?; or "S"; Any significant Sicknesses?), (b) *medical assessment* for a head injury or a loss of consciousness sufficient enough to result in brain damage ("E" or "L"; Did you ever Lose consciousness or experience a period of being dazed because of an injury to your head?), and (c) *chronic problems* resulting from the injury ("P"; Do you experience any of these Problems in your life daily since you hit your head?). Participants are classified as having a potential TBI when they respond "yes" to at least one event, at least one medical assessment option, and report two or more chronic problems.

Prospective Memory Questionnaires.

To comprehensively assess subjective PM we used two common PM questionnaires in a randomized order. These scales demonstrated good convergent validity ($r = .81$).

Prospective Memory Questionnaire (PMQ, revised version; Hannon et al., 1990; 1995). We used a modified version of the PMQ (Cuttler et al., 2016) because participants have difficulties understanding the original scale (Cuttler & Taylor, 2012; Uttl & Kibreab, 2010). Participants respond to 52-items (e.g., "I missed appointments I had scheduled") using a Likert scale from '1' (never) to '5' (very often). They can select "not applicable" if the task

does not apply (e.g., “I forget to return books to the library by the due date” if they do not borrow books), which is scored as ‘0’. Higher scores indicate more failures. Each subscale is reliable (α = 0.78-0.90), has good 2-week test–retest reliabilities (0.64-0.88; Hannon et al., 1995). The full scale was reliable in the current study (α = .96).

Prospective and Retrospective Memory Questionnaire (PRMQ; Smith et al., 2000). The PRMQ is a self-report measure of prospective and retrospective memory slips in everyday life. We used only the 8-item PM subscale (α = .92 in the current study). Participants rated how often various occurrences (e.g., “Do you forget to buy something you planned to buy, like a birthday card, when you go to the shop?”) happen to them, using a 5-point scale, from ‘1’ (never) to ‘5’ (very often). Higher scores indicate greater failures.

Mediator/moderator variables.

Metacognitions Questionnaire (MCQ-30; Cartwright-Hatton & Wells, 1997); cognitive confidence subscale. Participants respond to a series of six statements such as “I have a poor memory” (α = .93 in the current study). These statements are rated on a Likert scale from ‘1’ (do not agree) to ‘4’ (agree very much). Higher scores indicate lower cognitive confidence.

Beliefs About Memory Questionnaire (BAMQ; Bennett & Wells, 2010). Participants respond to 17-statements (e.g., “having memory blanks means there is something seriously wrong with me”) on a scale from ‘1’ (do not agree) to ‘4’ (agree very much). There are two subscales; positive and negative beliefs about memory, where higher scores on each reflect greater beliefs (α = .85 for negative and α = .93 for positive beliefs in the current study).

Posttraumatic Cognitions Inventory (PTCI; Foa et al., 1999); negative cognitions about the self subscale. This subscale has 21-items measuring thoughts about the self in relation to a traumatic experience (e.g., “If I think about the event, I will not be able to handle

it"; α = .96 in the current study). Participants respond on a 7-point scale from '1' (totally disagree) to '7' (totally agree). Higher scores indicate greater negative cognitions.

Continuous Planning Scale (CPS; Prenda & Lachman, 2001). We used the CPS to measure willingness to future plan. Participants respond to five statements (e.g., "I find it helpful to set goals for the near future"; α = .72 in the current study) on a Likert scale describing how much each statement is representative of themselves from '1' (not at all) to '4' (a lot).

White Bear Suppression Inventory (WBSI; Muris et al., 1996; Wegner & Zanakos, 1994). We used this 15-item questionnaire to measure the maladaptive strategy of not thinking about the trauma (α = .96 in the current study). Participants respond to statements (e.g., "there are things I prefer not to think about") demonstrating their agreeance from '1' (strongly disagree) to '5' (strongly agree). Higher scores indicate greater suppression.

PTSD symptoms and current mental health comorbidity variables.

Trauma History Screen (THS; Carlson et al., 2011). The THS provides examples of traumatic events participants may have experienced (e.g., "a really bad car, boat, train or airplane accident"). Participants indicate whether they have experienced each event (Yes/No), how many times each event(s) occurred, if any bothered them emotionally, and then describe their most traumatic experience. Participants who do not report experiencing any of the listed events are asked to describe their "most stressful event". The THS has excellent test-retest reliability for high magnitude stressors (r = .93) and persisting posttraumatic distress (r = .73; Carlson et al., 2011).

The Posttraumatic Stress Disorder Checklist (PCL-5; Weathers et al., 2013). The PCL-5 contains 20 self-report items that correspond to PTSD symptoms in the *Diagnostic and Statistical Manual of Mental Disorders* (APA, 2013). Participants rate whether they have been bothered by symptoms (e.g., repeated, disturbing, and unwanted memories of the

stressful experience) in the past month; '0' (not at all) to '4' (extremely). Higher scores indicate greater symptom severity. The PCL-5 has excellent internal consistency (α = .96 in the current study).

Depression, Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995). The DASS-21 is a 21-item measure of depression, anxiety and stress. Participants rate the degree to which each statement (e.g., "I found it hard to wind down") applied to them over the past week; '0' (did not apply to me at all) to '3' (applied to me very much, or most of the time). The DASS-21 has excellent internal consistency (Depression, α = .94; Anxiety, α = .90; Stress, α = .91 in the current study).

Procedure

To avoid Bots completing the survey (Bai, 2018; Stokel-Walker, 2018), participants had to pass a captcha question and score at least 8/10 on an English proficiency test. Following consent procedures, participants completed demographic questions, including the learning/developmental disorder questions, the AUDIT and HELPS (in a randomized order), then the PM questionnaires (PMQ, PRMQ) and the cognitive confidence scale (MCQ-30). We presented these measures first because they are ostensibly unrelated to trauma exposure and could have been influenced by reporting a trauma beforehand. We next presented the THS and PCL-5, followed by the PTCI and BAMQ, which related to participants' reported THS event. Finally, we presented the CPS, WBSI and DASS-21 in a randomized order. Participants were debriefed and reimbursed $2.00 USD for 20 minutes. The Flinders University Social and Behavioural Research Ethics Committee approved this research. We preregistered the study and provide all data and supplementary materials on the Open Science Framework (OSF; https://osf.io/26ena/).

Statistical analyses

We used SPSS Version 25 for all analyses. Since symptoms attributed to PTSD must be in the context of a Criterion A event, we ran all analyses on the Criterion A subsample first. We repeated these analyses using the whole sample, given that people can have posttraumatic stress-like symptoms without the occurrence of a Criterion A event (e.g., Boals & Schuettler, 2009), and because we were interested in subjective PM at varying levels of PTSD symptomatology. We used correlational analyses to assess the relationship between PTSD symptoms and self-report PM measures, and all comorbidity and mediator variables. To assess the relative contribution of PTSD symptom clusters to subjective PM, we conducted hierarchical regressions. To examine the relationship between PTSD symptoms and self-report PM after controlling for comorbidity variables, we ran a series of regressions entering each of these variables, in turn, at Step 1. Finally, to test the idea that the relationship between PTSD and subjective PM might be explained by PTSD *causing* problematic appraisals and strategies, we ran a series of moderated and mediated regressions. We ran each analysis with the PMQ, then the PRMQ as outcome variables.

Results

Importantly, on average, participants reported subthreshold levels of PTSD symptoms, but 22.8% (n = 90) of participants met the cut-off score for probable PTSD (Ashbaugh et al., 2016; see Table 2.2). Additionally, 18.3% (n = 72) of participants were in the severe or extremely severe range for depression, 19.8% (n = 78) for anxiety, and 15.0% (n = 59) for stress (Lovibond & Lovibond, 1995).

Table 2.2

Descriptive statistics for all variables

	Scale	Mean (SD)
PRMQ	8-40	18.28 (6.51)
PMQ	52-260	106.57 (30.77)
PMQ Episodic	14-70	28.98 (10.73)
PMQ Habitual	14-70	20.01 (7.93)
PMQ Internal	10-50	19.53 (7.29)
PMQ Aids	14-70	38.05 (11.98)
PCL total	0-80	18.41 (18.29)
PCL Re-experiencing	0-20	4.54 (5.38)
PCL Avoidance	0-8	2.48 (2.50)
PCL Alterations in cog/mood	0-12	6.44 (6.75)
PCL Alterations in arousal	0-16	4.94 (5.56)
BAMQ positive	8-32	13.82 (6.56)
BAMQ negative	7-28	9.46 (3.65)
MCQ	6-24	10.12 (4.50)
PTCI self	1-7	2.33 (1.32)
DASS depression	0-21	5.18 (6.00)
DASS anxiety	0-21	3.76 (4.69)
DASS stress	0-21	5.87 (5.44)
CPS	5-20	10.71 (3.39)
WBSI	15-75	43.40 (15.92)

PRMQ = Prospective and Retrospective Memory Questionnaire; PMQ = Prospective Memory Questionnaire; PCL = Posttraumatic Stress Disorder Checklist; BAMQ = Beliefs about Memory Questionnaire; MCQ = Metacognitions Questionnaire; cognitive confidence subscale; PTCI self = Posttraumatic Cognitions Inventory; negative cognitions about the self subscale; DASS = Depression, Anxiety and Stress Questionnaire, CPS = Continuous Planning Scale; WBS = White Bear Suppression

We began by analyzing our main research question: do PTSD symptoms correlate with subjective prospective memory? As we hypothesized, PTSD symptoms positively correlated with self-reported PM failures in the Criterion A subsample (n = 262; PMQ: r = .49, CI [.39, .58]; PRMQ: r = .45, CI [.35, .54]), and the whole sample (PMQ: r = .49, CI

[.41, .56]; PRMQ: r = .42, CI [.36, .50]), with medium effect sizes[2]. Further correlations confirmed PTSD symptom severity positively correlated with our mediator and comorbidity variables (Table 2.3 for Criterion A sample, Table 2.4 for whole sample).

[2] Refer to supplementary materials for scatterplots

Table 2.3

Correlations between PTSD symptoms, prospective memory scales and all other comorbidity and mediator variables (Criterion A only)

	PRMQ	PMQ	PMQ Episodic	PMQ Habitual	PMQ Internal	PMQ Aids	PCL Total	PCL B	PCL C	PCL D	PCL E	BAMQ Neg	BAMQ Pos	MCQ	PTCI Self	DASS D	DASS A	DASS S	CPS	WBS
PRMQ	-	.83	.86	.61	.81	.48	.45	.31	.33	.46	.47	.47	.24	.75	.48	.55	.50	.56	.26	.49
PMQ	.83	-	-	-	-	-	.49	.37	.34	.49	.51	.55	.27	.69	.48	.52	.55	.55	.23	.44
PMQ Episodic	.86	-	-	-	-	-	.44	.31	.28	.44	.48	.48	.21	.68	.43	.50	.52	.52	.27	.41
PMQ Habitual	.61	-	-	-	-	-	.45	.36	.32	.45	.46	.59	.26	.52	.47	.48	.54	.45	.26	.31
PMQ Internal	.81	-	-	-	-	-	.49	.35	.35	.49	.51	.57	.26	.69	.49	.55	.55	.55	.28	.48
PMQ Aids	.48	-	-	-	-	-	.28	.23	.19	.28	.27	.26	.18	.41	.24	.23	.28	.34	.02*	.29
PCL Total	.45	.49	.44	.45	.49	.28	-	.90	.80	.95	.92	.55	.46	.36	.72	.66	.66	.64	.22	.56
PCL B	.31	.37	.31	.36	.35	.23	.90	-	.75	.78	.73	.40	.38	.21	.56	.47	.55	.48	.13	.43
PCL C	.33	.34	.28	.32	.35	.19	.80	.75	-	.68	.63	.32	.31	.22	.54	.46	.47	.51	.23	.44
PCL D	.46	.49	.44	.45	.49	.28	.95	.78	.68	-	.85	.59	.47	.38	.76	.71	.66	.63	.24	.57
PCL E	.47	.51	.48	.46	.51	.27	.92	.73	.63	.85	-	.57	.43	.41	.68	.64	.64	.67	.21	.53
BAMQ Neg	.47	.55	.48	.59	.57	.26	.55	.40	.32	.59	.57	-	.48	.48	.61	.53	.50	.48	.17	.38
BAMQ Pos	.24	.27	.21	.26	.26	.18	.46	.38	.31	.47	.43	.48	-	.23	.46	.38	.37	.36	-.001*	.36
MCQ	.75	.69	.68	.52	.69	.41	.36	.21	.22	.38	.41	.48	.23	-	.43	.47	.41	.48	.21	.43
PTCI Self	.48	.48	.43	.47	.49	.24	.72	.56	.54	.76	.68	.61	.46	.43	-	.75	.62	.65	.34	.61
DASS D	.55	.52	.50	.48	.55	.23	.66	.47	.46	.71	.64	.53	.38	.47	.75	-	.73	.79	.34	.61
DASS A	.50	.55	.52	.54	.55	.28	.66	.55	.47	.66	.64	.50	.37	.41	.62	.73	-	.77	.22	.54
DASS S	.56	.55	.52	.45	.55	.34	.64	.48	.51	.63	.67	.48	.36	.48	.65	.79	.77	-	.27	.61
CPS	.26	.23	.27	.26	.28	.02*	.22	.13	.23	.24	.21	.17	-.001*	.21	.34	.34	.22	.27	-	.26
WBS	.49	.44	.41	.31	.48	.29	.56	.43	.44	.57	.53	.38	.36	.43	.61	.61	.54	.61	.26	-

*denotes a non-significant value

Table 2.4

Correlations between PTSD symptoms, prospective memory scales and all other comorbidity and mediator variables (full sample)

	PRMQ	PMQ	PMQ Episodic	PMQ Habitual	PMQ Internal	PMQ Aids	PCL Total	PCL B	PCL C	PCL D	PCL E	BAMQ Neg	BAMQ Pos	MCQ	PTCI Self	DASS D	DASS A	DASS S	CPS	WBS
PRMQ	-	.81	.84	.56	.79	.48	.42	.30	.31	.42	.43	.41	.22	.71	.42	.46	.46	.52	.24	.47
PMQ	.81	-	-	-	-	-	.49	.38	.35	.48	.50	.50	.27	.65	.46	.46	.53	.54	.22	.45
PMQ Episodic	.84	-	-	-	-	-	.43	.31	.28	.44	.46	.45	.21	.64	.42	.45	.49	.51	.26	.40
PMQ Habitual	.56	-	-	-	-	-	.46	.37	.30	.44	.47	.57	.27	.48	.46	.41	.52	.42	.26	.29
PMQ Internal	.79	-	-	-	-	-	.48	.34	.35	.47	.50	.53	.24	.65	.47	.46	.52	.51	.26	.48
PMQ Aids	.48	-	-	-	-	-	.28	.24	.23	.26	.26	.22	.18	.38	.23	.22	.26	.34	.007	.31
PCL Total	.42	.49	.43	.46	.48	.28	-	.90	.78	.95	.92	.55	.41	.34	.68	.60	.65	.64	.24	.54
PCL B	.30	.38	.31	.37	.34	.24	.90	-	.72	.77	.74	.42	.36	.21	.51	.42	.55	.48	.16	.41
PCL C	.31	.35	.28	.30	.35	.23	.78	.72	-	.67	.62	.34	.27	.23	.51	.42	.44	.50	.20	.46
PCL D	.42	.48	.44	.44	.47	.26	.95	.77	.67	-	.85	.58	.41	.37	.73	.67	.65	.62	.26	.53
PCL E	.43	.50	.46	.47	.50	.26	.92	.74	.62	.85	-	.56	.39	.37	.63	.59	.62	.65	.25	.51
BAMQ Neg	.41	.51	.45	.57	.53	.22	.55	.42	.34	.58	.56	-	.46	.43	.60	.51	.52	.49	.19	.36
BAMQ Pos	.22	.27	.21	.27	.24	.18	.41	.36	.27	.41	.39	.46	-	.19		.32	.35	.33	.04	.29
MCQ	.71	.65	.64	.48	.65	.38	.34	.21	.23	.37	.37	.43	.19	-	.42	.39	.39	.44	.21	.42
PTCI Self	.42	.46	.42	.46	.47	.23	.68	.51	.51	.73	.63	.60	.39	.42	-	.74	.60	.64	.37	.61
DASS D	.45	.39	.45	.41	.46	.22	.60	.42	.42	.67	.59	.51	.32	.39	.74	-	.71	.78	.34	.60
DASS A	.46	.39	.49	.52	.52	.26	.65	.55	.44	.65	.62	.52	.35	.39	.60	.71	-	.77	.22	.51
DASS S	.52	.44	.51	.42	.51	.34	.64	.48	.50	.62	.65	.49	.33	.44	.64	.78	.77	-	.25	.63
CPS	.24	.21	.26	.26	.26	.007*	.24	.16	.20	.26	.25	.19	.04*	.21	.37	.34	.22	.25	-	.25
WBS	.48	.42	.40	.29	.48	.31	.54	.41	.46	.53	.51	.36	.29	.42	.61	.60	.51	.63	.25	-

*denotes a non-significant value

We next assessed the relative contribution of PTSD symptoms to PM—on the PMQ and PRMQ—by simultaneously entering each PTSD subscale into a regression model, beginning with the Criterion A subsample. Together, the PTSD subscales explained 27.0% of variance in PMQ scores, $R^2 = .27$, $F(4, 261) = 23.81$, $p < .001$. Interestingly, re-experiencing ($b = -.09$, $p = .34$) and avoidance ($b = .01$, $p = .89$) did not contribute unique variance to failures on the PMQ. Negative alterations in cognition/mood was the strongest predictor of PMQ scores ($b = .35$, $p = .001$) and alterations in arousal also contributed unique variance ($b = .25$, $p = .03$). For the PRMQ, the PTSD subscales explained 24.8% of variance in PM, $R^2 = .25$, $F(4, 261) = 21.15$, $p < .001$. Similar to the PMQ, avoidance ($b = .09$, $p = .27$) did not contribute unique variance to PM failures on the PRMQ, but in contrast to the PMQ, re-experiencing ($b = -.23$, $p = .02$) *negatively* predicted PRMQ scores. Negative alterations in cognition/mood ($b = .34$, $p = .001$) was again the strongest predictor for the PRMQ; alterations in arousal also contributed unique variance ($b = .28$, $p = .02$).

We ran the same analyses and found similar results for the whole sample. Together, the PTSD subscales explained 26.7% of variance in PMQ scores, $R^2 = .27$, $F(4, 389) = 35.42$, $p < .001$. Re-experiencing ($b = -.09$, $p = .26$) and avoidance ($b = .05$, $p = .43$) did not contribute unique variance to failures on the PMQ. Alterations in arousal ($b = .36$, $p < .001$) and negative alterations in cognition/mood contributed significant unique variance to PMQ scores ($b = .21$, $p = .02$). For the PRMQ, the PTSD subscales explained 20.7% of the variance in subjective PM, $R^2 = .21$, $F(4, 389) = 25.44$, $p < .001$. Similar to the PMQ, avoidance ($b = .08$, $p = .26$) did not contribute unique variance to failures on the PRMQ, but in contrast to the PMQ, re-experiencing ($b = -.16$, $p = .04$) *negatively* predicted PRMQ scores. Alterations in arousal ($b = .31$, $p < .001$) and negative alterations in cognition/mood also contributed unique variance ($b = .23$, $p = .01$).

To address the possibility that the relationship between PTSD symptom severity and subjective PM arises because of comorbidities, we regressed PMQ scores on these variables, first with the Criterion A subsample. We entered possible TBI (b = .20, p < .001), alcohol dependency (b = .06, p = .24), presence of a learning disorder (b = .24, p < .001) and childhood trauma (b = -.08, p =.13) simultaneously in Step 1. Together, these variables explained 26.1% variance in PMQ scores, R^2 = .26, $F(4, 261) = 22.69$, p < .001. In Step 2, we entered PTSD symptom severity (b = .37), which explained an additional 8.8% of the variance in PMQ scores, $R^2change$ = .09, $Fchange(4, 261) = 27.39$, p < .001.

We repeated the analysis with PRMQ scores as the outcome variable. In Step 1, possible TBI (b = .19, p = .001), alcohol dependency (b = .05, p = .33), presence of a learning disorder (b = .15, p = .007) and childhood trauma (b = -.08, p = .12) explained 19.2% of the variance in PRMQ scores, R^2 = .19, $F(4, 261) = 15.26$, p < .001. Their relative contributions were similar to the PMQ. In Step 2, PTSD symptoms (b = .32, p < .001) explained an additional 7.9% of the variance in PRMQ scores, $R^2change$ = .08, $Fchange(4, 261) = 27.89$, p < .001; again PTSD symptom severity was the strongest predictor of PRMQ scores. The beta values suggest possible TBI and developmental disorder affect PM, but PTSD symptom severity was the strongest predictor of PMQ scores.

We repeated these analyses on the full sample and found similar results. We entered possible TBI (b = .26, p < .001), alcohol dependency (b = .16, p = .001), presence of a learning disorder (b = .26, p < .001) and childhood trauma (b = -.03, p =.58) simultaneously in Step 1. Together, these variables explained 20.2% variance in PMQ scores, R^2 = .20, $Fchange(4, 389) = 24.67$, p < .001. In Step 2, PTSD symptom severity (b = .37) explained an additional 11.3% of the variance in PMQ scores, $R^2change$ = .11, $F(1, 388) = 63.98$, p < .001. The beta values suggest possible TBI and developmental disorder affect PM, but PTSD symptom severity contributes to PMQ scores above these variables alone.

We repeated the analysis with PRMQ scores as the outcome variable. In Step 1, possible TBI (b = .21, p < .001), alcohol dependency (b = .15, p = .002), presence of a learning disorder (b = .26, p < .001) and childhood trauma (b = -.04, p = .34) explained 16.6% of the variance in PRMQ scores, R^2 = .17, F(4, 389) = 19.29, p < .001. Their relative contributions were similar to the PMQ. In Step 2, PTSD symptoms (b = .30, p < .001) explained an additional 7.6% of the variance in PRMQ scores, $R^2change$ = .08, $Fchange$(1, 388) = 38.84, p < .001; again PTSD symptom severity predicted PRMQ scores above these variables alone. Taken together, these analyses suggest although comorbidities contribute to PM, the relationship between PTSD symptom severity and PM failures does not arise because of these factors.

To test the idea that depression, anxiety and stress might influence the relationship between PM and PTSD symptoms, we reran the hierarchical regressions controlling for these variables. Beginning with the Criterion A subsample, depression (b = .08, p = .35.), anxiety (b = .23, p = .008) and stress (b = .22, p = .02)—entered at Step 1—explained 35.1% of the variance in PMQ scores, R^2 = .35, F(3, 261) = 46.52, p < .001. In Step 2, PTSD symptoms did not explain any significant additional variance in PMQ scores, $R^2change$ = .01, $Fchange$(4, 261) = 3.65, p = .057, b = .14. We repeated this analysis using the PRMQ; depression (b = .23, p = .009), anxiety (b = .07, p = .40) and stress (b = .27, p = .004)—entered at Step 1—explained 34.3% of the variance in PRMQ scores, R^2 = .34, F(3, 261) = 44.83, p < .001. Interestingly at Step 2, PTSD symptoms (b = .07, p = .36) did not explain any additional variance in PRMQ scores, $R^2change$ = .002, $Fchange$(4, 261) = 0.84, p = .36. These results suggest for the PMQ, anxiety and stress predict scores, but for the PRMQ, scores are predicted by depression and stress.

We reran these regressions on the whole population. For the PMQ, results were similar to the Criterion A subsample; depression (b = .02, p = .83.), anxiety (b = .28, p <

.001) and stress (b = .31, p < .001)—entered at Step 1—explained 32.2% of the variance in PMQ scores, R^2 = .32, F(3, 390) = 61.83, p < .001. In Step 2, PTSD symptoms explained a small but significant additional 1.9% of the variance in PMQ scores, $R^2change$ = .02, F(1, 389) = 11.43, p = .001, b = .19. We repeated this analysis using the PRMQ; depression (b = .08, p = .29), anxiety (b = .13, p = .07) and stress (b = .36, p < .001)—entered at Step 1—explained 27.9% of the variance in PRMQ scores, R^2 = .28, F(3, 390) = 50.19, p < .001. In contrast to the PMQ, for the PRMQ, stress was the only significant predictor, and in Step 2, PTSD symptoms (b = .11, p = .06) did not explain additional variance in PRMQ scores, $R^2change$ = .01, $Fchange$(1, 389) = 3.68, p = .06. Also in comparison to the Criterion A subsample where depression and stress predicted scores on the PRMQ, stress was the only significant contributor for the whole sample. Interestingly, stress was the only consistent predictor for both samples on both PM measures.

To test our prediction that cognitive confidence, negative cognitions about the self, beliefs about memory, thought suppression tendency, and willingness to future plan might *moderate* the relationship between subjective PM and PTSD, we ran a series of moderated regressions. Although we found some significant models for the PMQ and PRMQ, all models were of borderline significance and the unique variance explained after controlling for the interactions was <2%[3].

To test the idea that the relationship between PTSD and subjective PM might be explained by PTSD *causing* maladaptive appraisals and strategies, we ran a series of mediated regressions. We used a Bonferroni corrected alpha of 0.005 to correct for multiple tests (0.05/5). First, for the Criterion A subsample, for the PMQ, PTSD symptom severity was a significant predictor of PM, explaining 23.7% of the variance in PMQ scores, R^2 = .24, F(1, 261) = 80.84, p < .001. All mediators partially explained the relationship between PM

[3] Detailed results appear in supplementary materials.

scores on the PMQ and PTSD symptoms, but PTSD symptoms also contributed unique variance to PMQ scores (Table 2.5). For the PRMQ, PTSD symptoms were a significant predictor of PM, explaining 19.8% of the variance in PM, $R^2 = .20$, $F(1, 261) = 64.02$, $p < .001$. When entered individually, all variables partially mediated the relationship between PM scores on the PRMQ and PTSD symptoms. Interestingly, for negative cognitions about the self, PTSD symptoms contributed borderline significant variance to PRMQ scores after applying Bonferroni corrections (Table 2.6).

Table 2.5

Inferential statistics from regression analyses on PTSD and PMQ with maladaptive strategies and negative appraisals as mediators (Criterion A sample)

	Beta	Variance explained (%)	R^2	R^2_{change}	F	F_{change}	df	p
Cognitive confidence								
1. MCQ-30	.69	46.9	.47		229.67		1, 261	< .001
2. MCQ-30	.59	53.6		.07		37.64	2, 261	< .001
PCL-5 (PTSD symptoms)	.28							
Beliefs about memory								
1. BAMQ - Positive	.002	30.1	.30		55.89		2, 261	< .001
BAMQ - Negative	.55							
2. BAMQ - Positive	-.07	35.3		.05		20.62	3, 361	< .001
BAMQ - Negative	.43							
PCL-5 (PTSD symptoms)	.28							
Negative cognitions about the self								
1. PTCI – Negative cognitions about the self	.48	22.6	.23		76.01		1, 261	< .001
2. PTCI – Negative cognitions about the self	.26	26.9		.04		15.29	2, 261	< .001
PCL-5 (PTSD symptoms)	.30							
Willingness to future plan								
1. CPS	.23	5.5	.06		15.00		1, 261	< .001
2. CPS	.13	25.4		.20		69.19	2, 261	< .001
PCL-5 (PTSD symptoms)	.46							
Suppression tendency								
1. WBSI	.44	19.5	.20		63.06		1, 261	< .001
2. WBSI	.25	27.9		.08		30.25	2, 261	< .001
PCL-5 (PTSD symptoms)	.35							

MCQ-30 = Metacognitions Questionnaire; PCL-5 = Posttraumatic Stress Disorder Checklist; BAMQ = Beliefs about Memory Questionnaire; PTCI = Posttraumatic Cognitions Inventory; CPS = Continuous Planning Scale; WBS = White Bear Suppression Inventory

Table 2.6

Inferential statistics from regression analyses on PTSD and PRMQ with maladaptive strategies and negative appraisals as mediators (Criterion A sample)

Cognitive confidence	Beta	Variance explained (%)	R^2	R^2_{change}	F	F_{change}	df	p
1. MCQ-30	.75	55.7	.56		327.54		1, 261	< .001
2. MCQ-30	.67	59.4		.04		23.12	2, 261	< .001
PCL-5 (PTSD symptoms)	.20							
Beliefs about memory								
1. BAMQ - Positive	.02	22.1	.22		36.74		2, 261	< .001
BAMQ - Negative	.46							
2. BAMQ - Positive	-.05	27.1		.05		17.80	3, 361	< .001
BAMQ - Negative	.34							
PCL-5 (PTSD symptoms)	.28							
Negative cognitions about the self								
1. PTCI – Negative cognitions about the self	.48	23.2	.23		78.72		1, 261	< .001
2. PTCI – Negative cognitions about the self	.34	25.2		.02		6.74	2, 261	.01*
PCL-5 (PTSD symptoms)	.20							
Willingness to future plan								
1. CPS	.26	6.9	.07		19.39		1, 261	< .001
2. CPS	.17	22.6		.16		52.52	2, 261	< .001
PCL-5 (PTSD symptoms)	.41							
Suppression tendency								
1. WBSI	.49	23.8	.24		81.25		1, 261	< .001
2. WBSI	.35	28.1		.04		15.60	2, 261	< .001
PCL-5 (PTSD symptoms)	.25							

*No longer significant after Bonferroni correction

MCQ-30 = Metacognitions Questionnaire; PCL-5 = Posttraumatic Stress Disorder Checklist; BAMQ = Beliefs about Memory Questionnaire; PTCI = Posttraumatic Cognitions Inventory; CPS = Continuous Planning Scale; WBS = White Bear Suppression Inventory

We repeated these analyses for the whole sample, again applying a Bonferroni corrected alpha of 0.005 to correct for multiple tests (0.05/5). For the PMQ, PTSD symptoms were again a significant predictor, explaining 23.9% of the variance in PMQ scores, $R^2 = .24$, $F(1, 391) = 123.26$, $p < .001$. All mediators partially explained the relationship between PMQ scores and PTSD symptoms, but PTSD symptoms also contributed unique variance (Table 2.7). With the PRMQ, PTSD symptoms were a significant predictor of PM, explaining 17.4% of the variance in PM, $R^2 = .17$, $F(1, 391) = 123.26$, $p < .001$. When entered individually, all variables partially mediated the relationship between PM scores on the PRMQ and PTSD symptoms. But PTSD symptoms also contributed unique variance to PM scores (Table 2.8).

Table 2.7

Inferential statistics from regression analyses on PTSD and PMQ with maladaptive strategies and negative appraisals as mediators (full sample)

Cognitive confidence	Beta	Variance explained (%)	R^2	R^2_{change}	F	F_{change}	df	p
1. MCQ-30	.65	41.8	.42		281.85		1, 392	< .001
2. MCQ-30	.54	49.9		.08		63.17	1, 391	< .001
PCL-5 (PTSD symptoms)	.30							
Beliefs about memory								
1. BAMQ - Positive	.04	26.1	.26		69.19		2, 391	< .001
BAMQ - Negative	.49							
2. BAMQ - Positive	-.02	32.2		.06		34.70	1, 391	< .001
BAMQ - Negative	.35							
PCL-5 (PTSD symptoms)	.30							
Negative cognitions about the self								
1. PTCI – Negative cognitions about the self	.46	21.5	.22		107.47		1, 392	< .001
2. PTCI – Negative cognitions about the self	.24	27.1		.06		30.14	1, 391	< .001
PCL-5 (PTSD symptoms)	.32							
Willingness to future plan								
1. CPS	.22	4.9	.05		20.38		1, 392	< .001
2. CPS	.11	20.1		.20		104.89	1, 391	< .001
PCL-5 (PTSD symptoms)	.46							
Suppression tendency								
1. WBSI	.45	20.4	.20		100.34		1, 392	< .001
2. WBSI	.26	28.9		.09		47.13	1, 391	< .001
PCL-5 (PTSD symptoms)	.35							

MCQ-30 = Metacognitions Questionnaire; PCL-5 = Posttraumatic Stress Disorder Checklist; BAMQ = Beliefs about Memory Questionnaire; PTCI = Posttraumatic Cognitions Inventory; CPS = Continuous Planning Scale; WBS = White Bear Suppression Inventory

Table 2.8

Inferential statistics from regression analyses on PTSD and PRMQ with maladaptive strategies and negative appraisals as mediators (full sample)

	Beta	Variance explained (%)	R^2	R^2_{change}	F	F_{change}	df	p
Cognitive confidence								
1. MCQ-30	.71	50.0	.50		391.50		1, 392	< .001
2. MCQ-30	.64	53.4		.04		29.04	1, 391	< .001
PCL-5 (PTSD symptoms)	.20							
Beliefs about memory								
1. BAMQ - Positive	.04	16.9	.17		39.85		2, 391	< .001
BAMQ - Negative	.39							
2. BAMQ - Positive	-.02	22.1		.05		25.73	1, 390	< .001
BAMQ - Negative	.27							
PCL-5 (PTSD symptoms)	.28							
Negative cognitions about the self								
1. PTCI – Negative cognitions about the self	.42	17.3	.17		81.82		1, 392	< .001
2. PTCI – Negative cognitions about the self	.25	20.6		.03		16.65	1, 391	< .001
PCL-5 (PTSD symptoms)	.25							
Willingness to future plan								
1. CPS	.24	5.9	.06		24.76		1, 392	< .001
2. CPS	.15	19.6		.14		66.16	1, 391	< .001
PCL-5 (PTSD symptoms)	.38							
Suppression tendency								
1. WBSI	.47	22.5	.23		113.70		1, 392	< .001
2. WBSI	.35	26.2		.04		19.76	1, 391	< .001
PCL-5 (PTSD symptoms)	.23							

MCQ-30 = Metacognitions Questionnaire; PCL-5 = Posttraumatic Stress Disorder Checklist; BAMQ = Beliefs about Memory Questionnaire; PTCI = Posttraumatic Cognitions Inventory; CPS = Continuous Planning Scale; WBS = White Bear Suppression Inventory

Discussion

In line with our predictions, subjective PM failures—measured by the PMQ and PRMQ—correlated with PTSD symptom severity; alterations in arousal contributed the most unique variance in PM scores compared to the other symptom clusters. Possible TBI, alcohol dependency, presence of a learning disorder and childhood trauma did not explain this relationship. Our findings are consistent with the hypothesis that the relationship between PTSD and subjective PM is stronger for people with more negative appraisals about themselves and their memory, and who are more likely to engage in maladaptive strategies. Unexpectedly, stress was the only consistent contributor to PM scores in both populations and on both the PMQ and the PRMQ.

Although we found similar patterns for the PMQ and PRMQ, there were small inconsistencies. All effects were slightly larger for the PMQ, and borderline effects on the PMQ were often non-significant for the PRMQ. The PMQ has more questions, and divides into more detailed sub-themes (i.e., episodic, habitual, and internally cued PM, and memory aids) and thus is likely a more comprehensive assessment of failures. Indeed, PMQ items are more specific (e.g., I forget to send a card for a birthday/anniversary) than PRMQ items (e.g., Do you decide to do something in a few minutes' time then forget to do it?). Additionally, perhaps the “not applicable” option provided in the PMQ (not the PRMQ) provides a more accurate measure by limiting PM assessment to responses that are relevant to each participant.

Nonetheless, our data suggest that both PTSD symptoms and recent chronic stress (i.e., stress scores on the DASS) negatively influence subjective PM. Indeed, if we characterize PTSD as a type of long-term or chronic stress, then our data fits with prior research with clinical participants showing a deteriorating effect of chronic stress—operationalized as presence or severity of PTSD—on PM (McFarland et al., 2016; average

effect size: d = -.48; Scott et al., 2016; d = -.58). By contrast, other evidence suggests acute stress *enhances* PM performance (average effect size: d = .24; see Piefke & Glienke, 2017). These studies have used healthy participants, manipulated stress using the Cold Pressor Task (Glienke & Piefke, 2016), the Trier Social Stress Test (Nater et al., 2006; Walser et al., 2013), or progressive muscle relaxation (Ilhe et al., 2012; 2014). Future research could explore this discrepancy manipulating acute stress or comparing chronic and. acute stress in healthy participants.

Extending on this idea, the recency of symptom ratings may be important. Specifically, chronic stress and associated symptoms over the *past week* (i.e., DASS scores) may contribute to PM failures more than PTSD symptoms over the *past month* (i.e., PCL scores), because recalling symptoms over the past week is an easier task. Indeed, PTSD is known as a disorder of forgetting (Ursano et al., 2007), so more distant symptoms may be more difficult to bring to mind and thus underestimated, compared to more recent symptoms. Future research could equate symptom rating instructions on recency to disentangle symptom type (stress vs. PTSD) from recency.

Our mediation findings support the hypothesis that PTSD symptoms affect subjective PM partly via their influence on negative appraisals and maladaptive strategies. Consequently, PTSD symptoms, specifically alterations in arousal, may increase maladaptive beliefs—importantly, beliefs about memory and PM—and behaviours—such as suppression and avoidance—and in turn, increase subjective experiences of PM failures in everyday life. Indeed, prior research supports the idea that *meta-memory* beliefs, as well as other maladaptive metacognitions, contribute to the maintenance of PTSD symptoms (Takarangi et al., 2016). Future research could test possible mechanisms by manipulating negative beliefs about memory (e.g., have participants complete a task with negative feedback about their cognitive ability) to examine their impact on PM.

Our study has several key limitations. First, subjective PM does not always correlate with actual performance (e.g., Arnold & Bayen, 2019; Chan et al., 2008; Foley, 2007; Hering et al., 2018), thus we do not know whether its relationship with PTSD generalizes to objective PM. Although we argue that self-report measures are based on subjective judgments that might be more representative of typical PM performance in realistic, environments (Dang et al., 2020), future research should investigate whether this relationship, and the role of negative appraisals and maladaptive strategies that commonly arise alongside PTSD symptoms, generalize to objective tasks. If the pattern is similar for objective tasks, then we could conclude that negative appraisals and maladaptive strategies might directly contribute to PM performance. However, if the relationship only exists for subjective PM, then we could conclude that meta-memory judgments contribute to PM impairment, and simultaneously perpetuate PTSD symptoms.

Although prior research has found that self-report PM measures have good reliability, but poor convergent and divergent validity (Buchanan, 2017; Uttl & Kibreab, 2011), we found that the PMQ and PRMQ were highly correlated, suggesting these measures tapped into the same construct, and thus neither measure is more or less valid. But given PTSD in particular is characterized by forgetting (Ursano et al., 2007) it is possible that self-report PM measures are unreliable in people with greater PTSD symptoms. Relatedly, TBI and developmental disorder are typically diagnosed via methods requiring clinical judgment, such as a diagnostic interview (Picard et al., 1991), and AUDIT scores may be vulnerable to social desirability (Anderson et al., 1996). Consequently, because self-report requires insight and honesty from participants, our data might be skewed by biases in reporting or understanding.

Second, because we used a general population, our results may not generalize to clinical populations. However, although many trauma-exposed people do not meet the diagnostic threshold, they may still develop PTSD symptoms (Bonanno et al., 2010), or

experience everyday impairments (e.g., Marshall et al., 2007). Indeed, we found a similar relationship between PTSD symptom severity and subjective PM for our Criterion A subsample and the whole sample. Additionally, an exploratory analysis—using a clinical cut-off score of 31 on the PCL (Ashbaugh et al., 2016)—revealed participants above the cut-off reported significantly greater PM failures than those below; on the PMQ (M = 129.18, SD = 36.44 vs. M = 99.88, SD = 25.31, $t(115.56) = -7.14$, $p < .005$, $d = 1.04$), and the PRMQ, (M = 22.46, SD = 7.28 vs. M = 17.04, SD = 5.72, $t(123.30) = -6.49$, $p < .005$, $d = .89$. These data point to a detrimental effect of PTSD symptoms on subjective PM that might generalize to clinical populations.

Conclusions

Overall, our results suggest there is a meaningful relationship between subjective PM and PTSD—particularly arousal symptoms—in the general population. Further, the negative appraisals and maladaptive strategies that often present with PTSD could underpin this relationship, and recent stress may be an important contributor. We believe our findings have broad clinical implications. Research on other psychiatric and neurological disorders finds poor PM is associated with dysfunctional outcomes, including medication non-adherence (Woods et al., 2009), unemployment (Woods et al., 2011), poorer treatment outcomes (Withall et al., 2009), and everyday difficulties (e.g., housekeeping, Pirogovsky et al., 2012). Thus, more PM failures, or even more *perceived* failures, among people with greater symptomatology could perpetuate symptom severity and everyday impairment among people with PTSD.

Supplementary Materials

Moderation analyses results

We predicted it was possible that cognitive confidence, negative cognitions about the self, beliefs about memory, thought suppression tendency, and willingness to plan for the future could moderate the relationship between prospective memory and PTSD. For example, we proposed that higher PTSD symptoms could be associated with poorer prospective memory performance, but this effect would be greater for people who hold higher negative beliefs about memory.

For the PMQ, with all variables entered together in Step 1, without the interaction both PTSD and all variables explained a significant amount of variance in prospective memory, $F(7, 386) = 60.87$, $p < .001$, $R^2 = .53$. But, in Step 2, when accounting for the interaction between PTSD symptoms and these moderator variables, the model was no longer significant, $Fchange(6, 380) = 2.01$, $p = .06$, $R^2change = .02$. For the PRMQ, with all variables entered together in Step 1, without the interaction both PTSD and all variables explained a significant amount of variance in prospective memory, $F(7, 386) = 68.93$, $p < .001$, $R^2 = .56$. But, in Step 2, when accounting for the interaction between PTSD symptoms and these moderator variables, the model was no longer significant, $F(6, 380) = 1.92$, $p = .08$, $R^2change = .01$.

For the following tests, a Bonferroni corrected alpha of 0.01 was used to correct for multiple tests (0.05/10). For the PMQ, at step 1, without the interaction both PTSD symptoms and negative beliefs about memory accounted for a significant amount of variance in prospective memory, $F(2, 393) = 92.66$, $p < .001$, $R^2 = .32$. Then, in step 2, when accounting for the interaction between PTSD symptoms and negative beliefs about memory, the model remained significant, $Fchange(3, 390) = 65.32$, $p = .006$, $R^2change = .01$. For the PRMQ, at step 1, without the interaction both PTSD symptoms and negative beliefs about memory

accounted for a significant amount of variance in prospective memory, $F(2, 393) = 55.28$, $p < .001$, $R^2 = .22$. Then, in step 2, when accounting for the interaction between PTSD symptoms and negative beliefs about memory, the model remained significant, $Fchange(3, 390) = 7.28$, $p = .007$, $R^2change = .01$.

For the PMQ, positive beliefs about memory and PTSD symptoms at Step 1, without the interaction, explained a significant amount of variance in prospective memory scores, $F(2, 393) = 63.42$, $p < .001$, $R^2 = .25$. In Step 2, when accounting for the interaction between PTSD symptoms and cognitive confidence, the model was no longer significant, $Fchange(3, 393) = 4.59$, $p = .03$, $R^2change = .01$. For the PRMQ, positive beliefs about memory and PTSD symptoms at Step 1, without the interaction, explained a significant amount of variance in prospective memory scores, $F(2, 393) = 41.93$, $p < .001$, $R^2 = .18$. In Step 2, when accounting for the interaction between PTSD symptoms and cognitive confidence, the model was significant, $F(3, 393) = 7.06$, $p = .007$, $R^2change = .02$.

For the PMQ, cognitive confidence and PTSD symptoms in Step 1, without the interaction, explained a significant amount of variance in prospective memory scores, $F(2, 393) = 194.86$, $p < .001$, $R^2 = .50$. In Step 2, when accounting for the interaction between PTSD symptoms and cognitive confidence, the model was not significant, $Fchange(3, 393) = 4.17$, $p = .04$, $R^2change = .005$. For the PRMQ, cognitive confidence and PTSD symptoms in Step 1, without the interaction, explained a significant amount of variance in prospective memory scores, $F(2, 393) = 224.28$, $p < .001$, $R^2 = .53$. In Step 2, when accounting for the interaction between PTSD symptoms and cognitive confidence, the model was no longer significant, $Fchange(3, 393) = .39$, $p = .54$, $R^2change < .001$.

For the PMQ, negative cognitions about the self and PTSD symptoms at Step 1, without the interaction, explained a significant amount of variance in prospective memory scores, $F(2, 393) = 72.80$, $p < .001$, $R^2 = .27$. But, in Step 2, when accounting for the

interaction between PTSD symptoms and negative cognitions about the self, the model was no longer significant, $Fchange(3, 393) = .58$, $p = .45$, $R^2change = .001$. For the PRMQ, negative cognitions about the self and PTSD symptoms at Step 1, without the interaction, explained a significant amount of variance in prospective memory scores, $F(2, 393) = 50.87$, $p < .001$, $R^2 = .21$. But, in Step 2, when accounting for the interaction between PTSD symptoms and negative cognitions about the self, the model was no longer significant, $Fchange(3, 393) = 3.19$, $p = .07$, $R^2change = .01$.

For the PMQ, willingness to future plan and PTSD symptoms at Step 1, without the interaction, explained a significant amount of variance in prospective memory scores, $F(2, 393) = 65.34$, $p < .001$, $R^2 = .25$. But, in Step 2, when accounting for the interaction between PTSD symptoms and negative cognitions about the self, the model was no longer significant, $Fchange(3, 393) = .01$, $p = .92$, $R^2change < .001$. For the PRMQ, willingness to future plan and PTSD symptoms at Step 1, without the interaction, explained a significant amount of variance in prospective memory scores, $F(2, 393) = 47.51$, $p < .001$, $R^2 = .20$. But, in Step 2, when accounting for the interaction between PTSD symptoms and negative cognitions about the self, the model was no longer significant, $Fchange(3, 393) = .02$, $p = .89$, $R^2change < .001$.

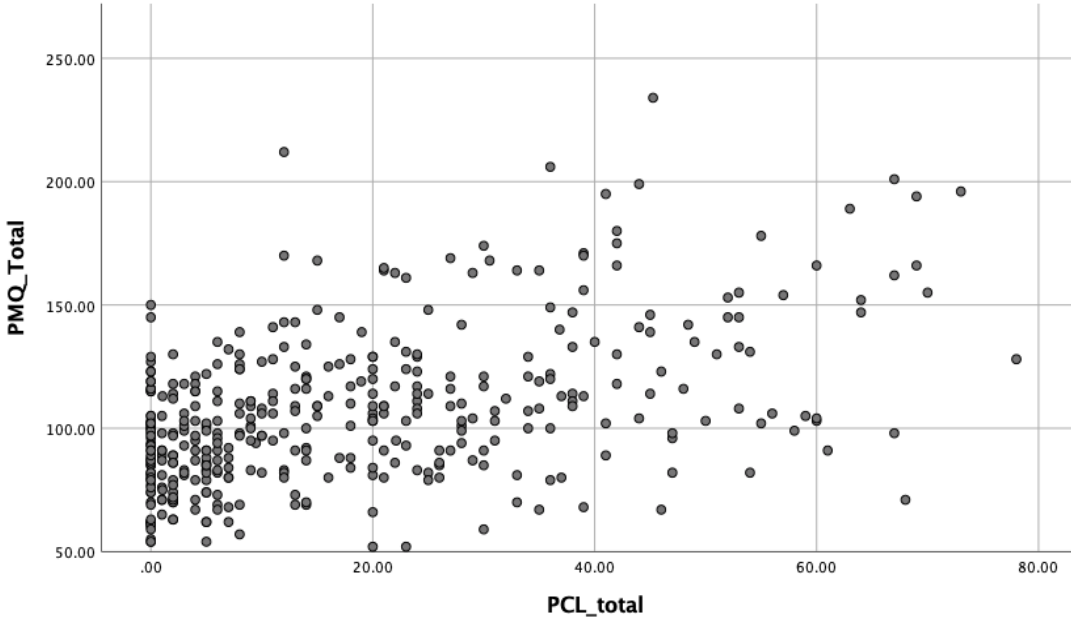
For the PMQ, suppression tendency and PTSD symptoms at Step 1, without the interaction, explained a significant amount of variance in prospective memory scores, $F(2, 393) = 79.64$, $p < .001$, $R^2 = .29$. But, in Step 2, when accounting for the interaction between PTSD symptoms and suppression tendency, the model was no longer significant, $Fchange(3, 393) = .03$, $p = .87$, $R^2change < .001$. For the PRMQ, suppression tendency and PTSD symptoms at Step 1, without the interaction, explained a significant amount of variance in prospective memory scores, $F(2, 393) = 69.45$, $p < .001$, $R^2 = .26$. But, in Step 2, when

accounting for the interaction between PTSD symptoms and suppression tendency, the model was no longer significant, $Fchange(3, 393) = .1.33$, $p = .25$, $R^2change = .003$.

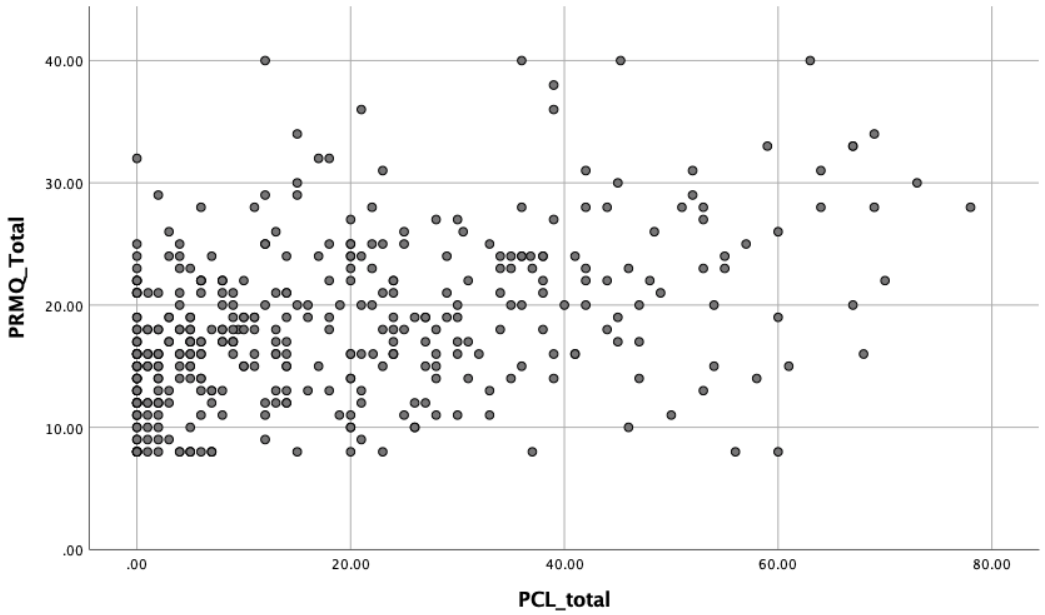
For the Criterion A subsample, we similarly ran the moderated regressions. We found only one significant model; negative beliefs about memory and the PRMQ. For the PRMQ, at step 1, without the interaction both PTSD symptoms and negative beliefs about memory accounted for a significant amount of variance in prospective memory, $F(2, 261) = 47.82$, $p < .001$, $R^2 = .27$. Then, in step 2, when accounting for the interaction between PTSD symptoms and negative beliefs about memory, the model remained significant, $Fchange(3, 261) = 4.71$, $p = .03$, $R^2change = .01$.

Scatterplots for main analyses

A scatterplot of PTSD symptoms and self-report PM on the PMQ



A scatterplot of PTSD symptoms and self-report PM on the PRMQ



Chapter 3: Self-reported, but not lab-based, prospective memory failures relate to PTSD symptom severity in a general population[4]

Author contributions: I developed the study design with the guidance of MKTT. I collected the data, cleaned the data for analysis, and performed the data analysis and interpretation. I drafted the manuscript and MKTT provided critical revisions. MKTT approved the final version of the manuscript for submission.

Abstract

Recent research suggests a relationship between Posttraumatic Stress Disorder (PTSD) symptom severity and prospective memory—memory for future intentions—in clinical samples (i.e., veterans with PTSD; e.g., Glienke et al., 2017; Korinek et al., 2021; McFarland et al., 2016; Scott et al., 2016) and a general, non-clinical population (i.e., university students; e.g., Swain & Takarangi, 2021). However, research using this non-clinical sample relied solely on self-report measures of prospective memory which might be biased (e.g., by negative beliefs). Here, we asked non-clinical participants to complete self-report measures, in addition to in-lab, behavioral prospective memory tasks. PTSD symptom severity correlated with self-report prospective memory (*r*s = .32-.42), but we found no relationship with lab-based prospective memory performance. The self-report and behavioral measures of prospective memory also did not correlate. We note these discrepancies might be explained by biased beliefs, the representativeness of each measure, and/or the nature of the experimental environment.

[4] Swain, T. L., & Takarangi, M. K. (2022). Posttraumatic stress disorder symptoms in a general population and prospective memory in the lab. *Journal of Applied Research in Memory and Cognition*. Advance online publication.

Introduction

Prospective memory failures (PM)—forgetting future intentions—are common in the general population (e.g., Kliegel & Martin, 2003), and amongst people with psychopathologies such as schizophrenia (e.g., Ordemann et al., 2014), Obsessive Compulsive Disorder (OCD; e.g., Cuttler & Graf, 2007), and depression (e.g., Rude et al., 1999). A recent finding that participants who reported worse Posttraumatic Stress Disorder (PTSD) symptoms also self-reported more everyday PM errors suggests PTSD, too, may be characterized by PM failures (Swain & Takarangi, 2021). Indeed, persistent PM failures—e.g., forgetting medication, or to complete therapy homework—might perpetuate PTSD symptoms. But we don't know if the relationship between self-report PM and PTSD symptom severity generalizes to actual PM performance, or across different PM types (i.e., time-based; completing intentions at particular times, or after elapsed time periods, e.g., taking medication at 9am, or every 2-hours, vs. event-based; completing intentions when external events occur, e.g., taking medication with breakfast). We address these gaps here.

There are several conceptual reasons to predict a relationship between PM and PTSD. Generally speaking, we know PTSD is associated with difficulties remembering the past—e.g., subjectively disorganized or fragmented memories, or gaps in memory (e.g., Ehlers & Clark, 2000; van der Kolk & Fisler, 1995). Thus, we might expect a similar pattern for PTSD and memory for the future.

Prevailing theoretical PTSD models support this idea. People with PTSD often appraise their trauma in a way that produces feelings of threat (Ehlers & Clark, 2000). This threat can be external (i.e., "the world is dangerous"), or internal (e.g., "I can't complete my goals"). Internalized negative appraisals lead people to develop negative beliefs about themselves (e.g., "I'm useless"), or to negatively interpret symptoms (e.g., "I am broken"; Ehlers & Steil, 1995); such beliefs may then generalize to cognitive abilities like memory

(e.g., “I have poor memory because I’m useless”). Another possibility is that negative appraisals encourage poor PM behaviors; e.g., if people with PTSD believe their memory is poor, they might stop effortfully encoding and recalling intentions—or bias how people report these behaviors—they might report consistent with their appraisals. We know that more generally, metamemory judgments (i.e., memory self-efficacy, metacognitive beliefs) are associated with retrospective and prospective memory performance—e.g., recalling word lists, pressing a target key every 2-minutes (e.g., Irak & Capan, 2018; Kliegel & Jäger, 2006, for review: Beaudoin & Desrichard, 2011)—and that people’s appraisals of their memory and cognitive abilities correlate with self-report PM (i.e., Swain & Takarangi, 2021). However, we know of no existing evidence that appraisals directly change PM behaviors.

Moreover, resources required for threat-monitoring, or managing other cognitive PTSD symptoms (e.g., intrusive thoughts), may reduce the resources simultaneously required for effective PM. Indeed, people with worse PTSD symptoms might fail to engage higher-order cognitive processes, e.g., planning, monitoring (i.e., for environmental cues), and decision-making (i.e., whether to respond to cues; Cockburn, 1995; Glisky, 1996), resulting in poor PM—particularly for time-based tasks that rely more on higher-order processes.

Research in clinical samples and the general population also suggests PTSD and PM are related. Scott et al. (2016) found veterans with PTSD—compared to non-PTSD veterans—were more likely to fail time-based (e.g., “In 15-minutes tell me to break”), but not event-based (e.g., “When handed a red pen, sign your name”) tasks. By contrast, McFarland et al. (2016) found veterans’ PTSD symptoms predicted poorer event-based PM performance (i.e., press a key when “president” appears). In Glienke et al. (2017), veterans—regardless of PTSD status—performed worse on both event- and time-based tasks (i.e., fictional holiday appointments), than non-military controls without PTSD. Comparatively, Korinek et al.

(2021) found no differences in time- or event-based PM (i.e., Memory for Intentions Test) for veterans with and without PTSD.

Thus, the PTSD-PM relationship appears inconsistent across time- and event-based tasks and between measurement types, in clinical samples. We previously found this relationship for self-report everyday PM errors in a non-clinical sample (Mechanical Turk; Swain & Takarangi, 2021). However, considering variations in methodological approaches, there are multiple interpretations of these mixed findings.

First, relying on one PM measurement—self-report or behavior—may not capture the entire construct; self-report and behavioral measures of the same psychological construct do not necessarily measure the same thing (e.g., emotional intelligence; see Dang et al., 2020). Self-report measures rely on subjective judgments about typical performance in realistic, unstructured situations (e.g., everyday performance), whereas behavioral measures aim to measure maximal, objective performance (e.g., accuracy, response time) in structured, uncommon situations (e.g., lab-based cognitive tasks; Dang et al., 2020), albeit subject to participants' task effort and motivation. Indeed, other PM research using a general population finds a dissociation between self-report (i.e., questionnaires) and lab-based assessments (e.g., Arnold & Bayen, 2019; Meeks et al., 2007; see Uttl & Kibreab, 2011 for review).

Second, self-report PM judgments in people with worse PTSD symptoms might align more with biased negative beliefs than with memory ability. Indeed, Swain and Takarangi (2021) previously found that PTSD symptoms influenced PM errors via people's negative appraisals of the self, and specifically of their memory (i.e., metamemory judgments). Although in non-clinical samples predictions and actual performance appear aligned (Kuhlmann, 2019, for review), in clinical samples there is a dissociation between predictions and actual performance. For example, participants with Parkinson's disease are inaccurate at predicting their time-based PM performance (Smith et al., 2011), participants with HIV-

Associated Neurocognitive Disorders or a Traumatic Brain Injury overestimate their performance (Casaletto et al., 2014; Knight et al., 2005), and checkers with OCD both under- and over-estimate their performance (Cuttler & Graf, 2009; Harris et al., 2010). Similarly, veterans with PTSD—despite self-reporting more memory problems than non-PTSD combat and non-combat controls—did not differ from these groups in memory performance (Carlozzi et al., 2010). These discrepancies between metamemory PM judgments and actual PM performance may reflect self-report biases.

To overcome some limitations of past research, and specifically explore the idea that self-report biases may drive the PTSD-PM relationship, we assessed subjective and objective PM (time- and event-based) tasks in a non-clinical population. If previous data from clinical samples (e.g., Glienke et al., 2017; McFarland et al., 2016; Scott et al., 2016) generalize to the general population, then we would expect lab-based PM failures (i.e., failing to press a specific key when certain words appear or a certain time elapses) to positively correlate with PTSD symptom severity, with a larger correlation for time- than event-based tasks. However, if self-report measures are biased by metamemory judgements, and/or there is a dissociation between self-report and behavioral PM tasks (e.g., Arnold & Bayen, 2019; Meeks et al., 2007), then we would expect self-report, but not lab-based PM failures, to correlate with PTSD symptoms.

Based on the idea that biased metamemory judgments might underpin the PM-PTSD relationship, we predict that negative appraisals and strategies—cognitive confidence (i.e., confidence in memory/attention), negative cognitions about the self, beliefs about memory, thought suppression tendency, willingness to future plan—would mediate the relationship between PTSD symptoms and both self-report and lab-based PM. As a secondary interest—because PM errors might mirror the everyday impairment observed amongst people with PTSD—we predict a positive correlation between PM and psychosocial functioning. Since

physical and mental health comorbidities might contribute to the relationship between PM failures and PTSD symptom severity (Swain & Takarangi, 2021), we measured possible TBI, alcohol dependency, learning/developmental disorder and childhood trauma, and depression, anxiety and stress symptoms.

Method

Design

We used a 2 (type of ongoing task: lexical decision, trivia) x 2 (type of PM task: event-based, time-based) x 2 (task presented first: lexical decision, trivia) mixed design. The combination of ongoing task and PM task was manipulated between-subjects but type of ongoing task and type of PM task was within-subjects; that is, participants completed both ongoing tasks and both PM tasks (i.e., one event- and one time-based task). The task presented first was counterbalanced between-subjects. The independent variables were PTSD symptom severity, type of PM task, and type of ongoing task. The key dependent variable was PM failures.

Participants

For the magnitude of a correlation to be deemed stable, the sample size should approach 260 (Schönbrodt & Perugini, 2013; 2018), therefore we recruited 297 participants through the Flinders University SONA system. Participants were all students at Flinders University and received either course credit (n = 204) or monetary reimbursement ($20; n = 87) for their time. We excluded 15 people for not meeting our pre-registered performance thresholds (higher than 75% accuracy on the lexical decision task [LDT], and, higher than chance accuracy on the multiple choice trivia, i.e., 25%), 17 participants for not recalling and understanding the prospective memory tasks, and six people for technical issues. Our final sample was 261. According to G Power, with this sample size we are able to detect correlations and regressions of the size found in previous literature (rs = .30-.50; e.g., Swain

& Takarangi, 2021) with 80% power. Our sample comprised of 25.7% males (sex; *n* = 67, gender; *n* = 66) , 74.3% females (sex; *n* = 194, gender; *n* = 190) and 1.9% non-binary (*n* = 5), aged between 18 and 60 (*M* = 22.36, *SD* = 6.13) years. The majority of our participants were Caucasian (65.1%, *n* = 170), followed by Asian (16.1%, *n* = 42), European (6.5%, *n* = 17), Indian (3.8%, *n* = 10), Middle Eastern (3.5%, *n* = 9), African (1.5%, *n* = 4), Indigenous (1.5%, *n* = 4), Hispanic (0.8%, *n* = 2) or Pacific islander (0.4%, *n* = 1).[5] As their highest qualification, our sample had completed: master's studies (3.1%; *n* = 8), bachelor's degree (1.1%; *n* = 3), associate degree or certificate (13.4%; *n* = 35), senior high school or equivalent (68.2%; *n* = 178), and junior high school (1.1%; *n* = 3).

Apparatus/Measures

Pilot Testing

We pilot tested our experimental tasks with 30 participants. We asked these participants to complete the same two ongoing tasks as in the final study, to ensure we attained a range of PM errors and to explore any floor or ceiling effects. We also ensured participants would see the six required task blocks within the specified time limit (i.e., 13-minutes). We asked participants to report the difficulty of both the ongoing tasks, and the PM tasks, from "1" *Extremely Easy* to "7" *Extremely Difficult*. We also determined average performance on both tasks to define our exclusion criteria as per the study pre-registration (https://osf.io/vb4g7).

In-lab prospective memory tasks

Lexical decision task (LDT; Hicks et al., 2005). During this ongoing task, participants saw either a word (e.g., *monkey*) or a non-word (where one letter of a real word is replaced to remove meaning, e.g., *wook*) on each trial. We drew on stimuli from two previously published papers investigating PM performance in the lab (Scullin & Bugg, 2013; Scullin et

[5] Two people did not report their ethnicity (0.8%)

al., 2013). Participants responded using only one hand, according to whether each word was a "word" (i.e., *press B*), or a "non-word" (i.e., *press N*) and were told they should try to respond within one second. The fixation point between trials appeared on the screen for 500ms and the inter-trial interval was random within 500-800ms. There was one practice block, and seven possible target blocks consisting of 103 trials within each block (of the target blocks, the first six each had one PM trial per block, but the seventh had no PM trials). The LDT began with three additional practice trials embedded in the first target block that were the same for every participant and not scored. All participants completed all six blocks containing a PM trial. The task was self-paced; participants completed as many trials as took them to 13-minutes, at which point the task finished.

General knowledge test (McFarland & Glisky, 2009). This ongoing task was a multiple-choice general knowledge test. We combined questions from McDaniel et al. (1999), questions from "Who Wants to Be a Millionaire – The Quiz Book" (Joseph, 2018), and questions we had used in a prior study. Participants responded using one hand to select one of four buttons corresponding to the correct answer (A, B, C, D), and had 12-seconds to do so. There were 209 possible questions arranged into eight blocks—the first six of which contained a PM trial—but participants completed 13-minutes of questions, after which the task automatically finished[6].

Prospective memory (PM) tasks. Each ongoing task also involved either a time- or event-based PM task; participants completed one ongoing task with the time-based task and one with the event-based task. Participants completed six prospective memory targets in each ongoing task, regardless of the type of ongoing task (i.e., LDT or MCQ), or the type of prospective memory task (i.e., time- or event-based). Because participants were told to

[6] Participants only saw questions from the seventh and eighth blocks if they had completed all other questions at a fast pace and therefore required additional questions to see them to the end of the 13-minute period.

complete the PM response (i.e., press F6) *instead* of the ongoing task response, any trial that was supposed to be a PM cue (i.e., every 2-minutes, or when the words "bone" or "theory" appeared) was counted as incorrect if the participant failed to complete the PM task, regardless of whether their word/non-word or multiple choice response was correct or not.

The event-based PM task was to press the "F6" key when presented with the target words "bone" and "theory". For the event-based task, the words "bone" and "theory" each appeared three times during either the LDT or the MCQ. One event-based PM trial was randomly presented within each of the first six target blocks. Each of these blocks ran for 2-minutes, thereby exposing participants to one event-based trial within each block. Participants were required to immediately respond with "F6" *instead* of their ongoing task response (i.e., "B" or "N", or A, B, C, D) for this PM trial to be scored as correct.

The time-based task was to press the "F6" key every 2-minutes (based on our pilot testing and previous research; e.g., Hicks et al., 2005). During the time-based task, participants could monitor the time by pressing the space bar and a digital clock would appear in the top right-hand corner of the screen for one second. The ongoing task allowed for six, two-minute intervals. Participants who pressed "F6" within ten seconds of the two-minute interval were coded as correct.

Questionnaires

Historical/physical health comorbidities.

Learning/developmental disorder screening. We asked participants whether they had ever been: (a) diagnosed with a learning disorder (e.g., Attention-Deficit Disorder [ADHD]), (b) placed in a learning/emotionally handicapped special class, or (c) told they had a learning disorder and by whom (e.g., teacher). We classified participants as having a learning disorder when they responded "yes" to the first or second question, *and* listed doctor/other specialist or teacher on the final question (Swain & Takarangi, 2021).

HELPS Screening Tool (HELPS; Picard et al., 1991). The HELPS is designed to screen for Traumatic Brain Injury (TBI). It includes five general questions about TBI events, and aftermath associated with each event. "H" (Have you ever *H*it your *H*ead, or been *H*it on the *H*ead?); "E" (Were you ever seen in the *E*mergency room, hospital, or by a doctor because of an injury to your head?); "L" (Did you ever *L*ose consciousness or experience a period of being dazed or confused because of an injury to your head?); "P" (Do you experience any of these *P*roblems in your life daily since you hit your head? E.g., headaches and dizziness); "S" (Any significant *S*icknesses?). Participants are classified as having a potential TBI when they respond "yes" to at least one event (*H, E*, or *S*), at least one medical assessment option (*E* or *L*), and report two or more chronic problems (*P*).

The Alcohol Use Disorders Identification Test (AUDIT; Babor et al., 1989). The AUDIT was developed by the World Health Organisation (WHO) to identify persons whose alcohol consumption has become harmful to their health. The AUDIT has 10-questions, here used in self-report form (e.g., "H*ow often do you have a drink containing alcohol?*"). These questions vary in format but typically people respond on a Likert scale ("*0*" e.g., *never*, *1 or 2,* to "*4*" e.g., "*4 or more times per week", "daily or almost daily"*). Internal consistency and test-retest reliability are good, α = .80 and α = .85, respectively (Meneses-Gaya et al., 2009). Internal consistency was good in the current study (α =.82).

Prospective Memory Questionnaires.

Prospective and Retrospective Memory Questionnaire (PRMQ; Smith et al., 2000). The PRMQ provides a self-report measure of prospective and retrospective memory lapses in everyday life. Here, we used only the prospective memory scale, which consists of eight items (e.g., "*Do you forget to buy something you planned to buy, like a birthday card, when you go to the shop?*"). Participants responded on a five-point Likert scale rating how often these occurrences happen to them ("*1*" *Never,* to "*5*" *Very Often*). The prospective memory

subscale of the PRMQ has good internal consistency (α = .87 in the current study).

Prospective Memory Questionnaire (PMQ, revised version; Hannon et al., 1990; 1995). We used a modified version of the PMQ (Cuttler et al., 2016) because participants have difficulties understanding the original scale (Cuttler & Taylor, 2012; Uttl & Kibreab, 2010). Participants responded to 52-items (e.g., "*I missed appointments I had scheduled*") using a Likert scale ("1" *Never,* to "5" *Very often*). They can select "not applicable" if the task does not apply (e.g., "*I forget to return books to the library by the due date*" if they do not borrow books) and this response then counts as a "0". Each subscale is reliable (α = 0.78-0.90), has good 2-week test–retest reliabilities (0.64 to 0.88; Hannon et al., 1995). The full scale had good internal consistency in the current study (α = .93).

Mediator Variables.

Beliefs About Memory Questionnaire (BAMQ; Bennett & Wells, 2010). The BAMQ is used to measure metacognition about trauma memory, and here we used it to measure maladaptive beliefs about memory. Participants respond to 17 statements (e.g., "*having memory blanks means there is something seriously wrong with me*" [only 15 are included for analyses; Bennett & Wells, 2010]) on a Likert scale ("*1*" *Do not agree,* to "*4*" *Agree very much*). The subscales have good convergent validity and internal consistency (α = .70-.90; Bennett & Wells, 2010; α = .88 in the current study).

Cognitive Confidence Subscale of the Metacognitions Questionnaire (MCQ; Cartwright-Hatton & Wells, 1997). The MCQ consists of five subscales designed to measure beliefs about worry and intrusive thoughts. Here we used only the cognitive confidence subscale to measure judgments of memory ability. Participants responded to a series of six statements such as "*I have a poor memory*". These statements were rated on a Likert scale ("*1*" *Do not agree,* to "*4*" *Agree very much*). The cognitive confidence subscale has good

reliability (α = .84 in the current study), and good test-retest reliability α = .84 (Cartwright-Hatton & Wells, 1997).

Negative Cognitions About the Subscale from the Posttraumatic Cognitions Inventory (PTCI; Foa et al., 1999). The PTCI contains 36-items used to measure thoughts related to a traumatic experience. Prior analyses established three factors; negative cognitions about the self, negative cognitions about the world and self-blame. Here, we used only the negative cognitions about the self subscale, which has 21-items. Participants rated a series of statements that might be representative of their thinking (e.g., "*The event happened because of the way I reacted"*; *"1" Totally disagree,* to *"7" Totally agree).* This scale has excellent reliability (α = .96 in the current study); and good test-retest reliability, *r* = .74 (Foa et al., 1999).

White Bear Suppression Inventory (WBSI; Muris et al., 1996; Wegner & Zanakos, 1994). The WBSI is a 15-item self-report questionnaire used to measure people's tendency to suppress negative thoughts. Here, we used the scale to measure the maladaptive strategy of not thinking about the trauma. Participants responded on a 5-point scale demonstrating their agreement ("*1" Strongly disagree,* to *"5" Strongly agree*) with statements such as "*There are things I prefer not to think about*", where higher scores indicate greater suppression. The scale has good internal validity (α = .94 in the current study) and test-retest reliability (0.80; Muris et al., 1996).

Continuous Planning Scale (CPS; Prenda & Lachman, 2001). We used the CPS to measure willingness to future plan. Participants responded to five statements (e.g., "*I find it helpful to set goals for the near future*") describing how much each statement represents them ("4" *A lot*, to "1" *Not at all*). Internal validity for this questionnaire is within an acceptable range; α = .63-.67 (Prenda & Lachman, 2001; α = .68 in the current study).

PTSD Symptoms and Current Mental Health Comorbidity Variables.

Trauma History Screen* (*THS; Carlson et al., 2011) and PTSD Checklist-5 (PCL-5; Blevins et al., 2015). The THS provides examples of high magnitude stressor events participants might have experienced (e.g., "*a really bad car , boat, train, or airplane accident*"). Participants describe their most distressing traumatic or stressful event. Here, participants who had not experienced one of the listed THS events were asked to index their symptoms to their "most stressful" event. The PCL measures self-reported PTSD symptom severity over the last month in reference to participants' most distressing negative or traumatic event. Participants rated their symptoms (e.g., "*repeated, disturbing, and unwanted memories of the stressful experience*?") on a 5-point scale ("0" *Not at all,* to "4" *Extremely*). The PCL-5 has excellent internal consistency (α = .95 in the current study).

Depression and Anxiety Symptoms (DASS-21; Lovibond & Lovibond, 1995). The DASS-21 is a 21-item measure of depression, anxiety and stress. Participants rated the degree to which each statement (e.g., "*I found it hard to wind down*") applied to them over the past week ("0" *Did not apply to me at all*, to "3" *Applied to me very much or most of the time*). The DASS-21 has acceptable concurrent validity with established measures as well as excellent internal consistency (depression, α = .92; anxiety, α = .87; stress, α = .87 in the current study).

Brief Inventory of Psychosocial Functioning (B-IPF; Bovin et al., 2018). The B-IPF measures everyday functioning through seven questions; one related to each domain of impairment in everyday life (e.g., social activities, work and education). Participants respond to how much (*"0" Not at all,* to *"6" Very much*) trouble they experience with issues related to the domains of functioning over the past 30 days (e.g., "*I had trouble with my family relationships*"). The B-IPF has acceptable internal consistency (α = .76 in the current study), adequate test-retest reliability (r = .65, p >.001) and correlates with measures of mental health impairment and quality of life (all rs >.50).

Procedure

Participants attended a one-hour session in the lab; they completed the two ongoing tasks in a counterbalanced order. The type of prospective memory task completed in the ongoing tasks was also counterbalanced (i.e., event-based first, time-based first). The sample size was similar across task versions (i.e., LDT with an event-based task, and the MCQ with a time-based task, n = 129; LDT with a time-based task and the MCQ with an event-based task, n = 132; LDT first, n = 128, MCQ first, n = 133).

For each task, participants received both verbal and written instructions on the screen before completing a practice block that involved practicing the ongoing task in isolation, then practicing it *with* the prospective memory component. During the practice trials participants received feedback about the speed and accuracy of their performance. After completing the practice sessions, participants completed the real task. After completing both ongoing tasks, participants completed the battery of questionnaires, which began with three questions used to assess whether participants remembered the PM task action (i.e., retrospective memory): 1) "When a certain word appeared or after a certain period of time elapsed, what button were you required to press (during the main task only, not the practice trials)?", 2) "Please list the two words we asked you to respond to using the F6 key (during the main task only, not the practice trials)", 3) "Please list the time at which we asked you to respond using the F6 key (during the main task only, not the practice trials)."

Participants then completed the remainder of the questionnaire battery, which began with demographic questions (i.e., age, gender, highest level of education, history of developmental disorder), followed by the HELPS and AUDIT (i.e., presence of possible traumatic brain injury and alcohol use) presented in a randomized order. The prospective memory questionnaires (PMQ; PRMQ) and the cognitive confidence scale from the MCQ-30 appeared in one block, in a randomized order. We presented these measures before

participants reported a trauma because they are ostensibly unrelated to the reported trauma and we believe that reporting a trauma could have influenced scores on these measures. Next, participants completed the trauma-related questionnaires (Trauma History Screen; THS, PTSD symptoms; PCL-5, Posttraumatic Cognitions Inventory; PTCI, Beliefs About Memory Questionnaire; BAMQ), with the THS and PCL-5 presented before the PTCI and the BAMQ (randomized order). Finally, the continuous planning and suppression tendency scales, psychosocial functioning, and depression, anxiety and stress symptom measures (i.e., CPS, WBSI, B-IPF and DASS) were presented in a randomized order, followed by a debrief. The Flinders University Social and Behavioural Research Ethics Committee approved this research. We preregistered the study (https://osf.io/vb4g7) and provide all data and supplementary materials on the Open Science Framework (OSF; https://osf.io/ur3ed/).

Results

To first examine the clinical relevance of our sample—particularly in comparison to Swain and Takarangi (2021), where the sample was sourced from MTurk rather than undergraduates—we report descriptive statistics for all our self-report scales (Table 3.1). On average, participants reported subthreshold levels of PTSD symptoms, but 29.1% (n = 76) of participants met the cut-off score for probable PTSD (i.e., >= 31; Ashbaugh et al., 2016). Additionally, 10.3% (n = 27) of participants were in the severe or extremely severe range for depression, 20.7% (n = 54) for anxiety, and 8.42% (n = 22) for stress (Lovibond & Lovibond, 1995).

Table 3.1

Descriptive Statistics for All Variables

Scale	Range	Mean (SD)
PRMQ	8-40	22.41 (5.95)
PMQ	52-260	117.03 (25.48)
PMQ Episodic	14-70	32.33 (9.71)
PMQ Habitual	14-70	20.07 (6.17)
PMQ Internal	10-50	22.32 (6.62)
PMQ Aids	14-70	42.31 (11.65)
PCL total	0-80	23.17 (18.52)
PCL Re-experiencing	0-20	5.77 (5.05)
PCL Avoidance	0-8	3.10 (2.62)
PCL Alterations in cog/mood	0-12	8.04 (7.09)
PCL Alterations in arousal	0-16	6.25 (5.93)
BAMQ Positive	8-32	12.96 (5.45)
BAMQ Negative	7-28	9.66 (3.08)
MCQ	6-24	11.52 (3.94)
PTCI Self	1-7	2.12 (1.22)
DASS Depression	0-21	5.62 (5.36)
DASS Anxiety	0-21	5.55 (5.22)
DASS Stress	0-21	7.65 (5.41)
CPS	5-20	10.75 (3.07)
WBSI	15-75	47.66 (15.10)
B-IPF	0-48	21.39 (11.49)

PRMQ = Prospective and Retrospective Memory Questionnaire; PMQ = Prospective Memory Questionnaire; PCL = Posttraumatic Stress Disorder Checklist; BAMQ = Beliefs about Memory Questionnaire; MCQ = Metacognitions Questionnaire; cognitive confidence subscale; PTCI self = Posttraumatic Cognitions Inventory; negative cognitions about the self subscale; DASS = Depression, Anxiety and Stress Questionnaire, CPS = Continuous Planning Scale; WBS = White Bear Suppression; B-IPF = Brief Inventory of Psychosocial Functioning

Before testing our primary predictions, we wanted to explore participants' overall performance. On average, participants made 4.01 (*SD* = 2.08) prospective memory errors across the tasks. Considered as a proportion, participants, on average, failed to complete

33.43% of their prospective memory tasks (*SD* = 17.36); 44.70% (*SD* = 25.50) of their event-based tasks, and 22.22% of their time-based tasks (*SD* = 22.88). In terms of ongoing task performance, on average, participants correctly answered 93.26% (*SD* = 4.85) of their LDT trials, and correctly answered 42.71% (*SD* = 8.34) of the multiple choice trivia questions[7].

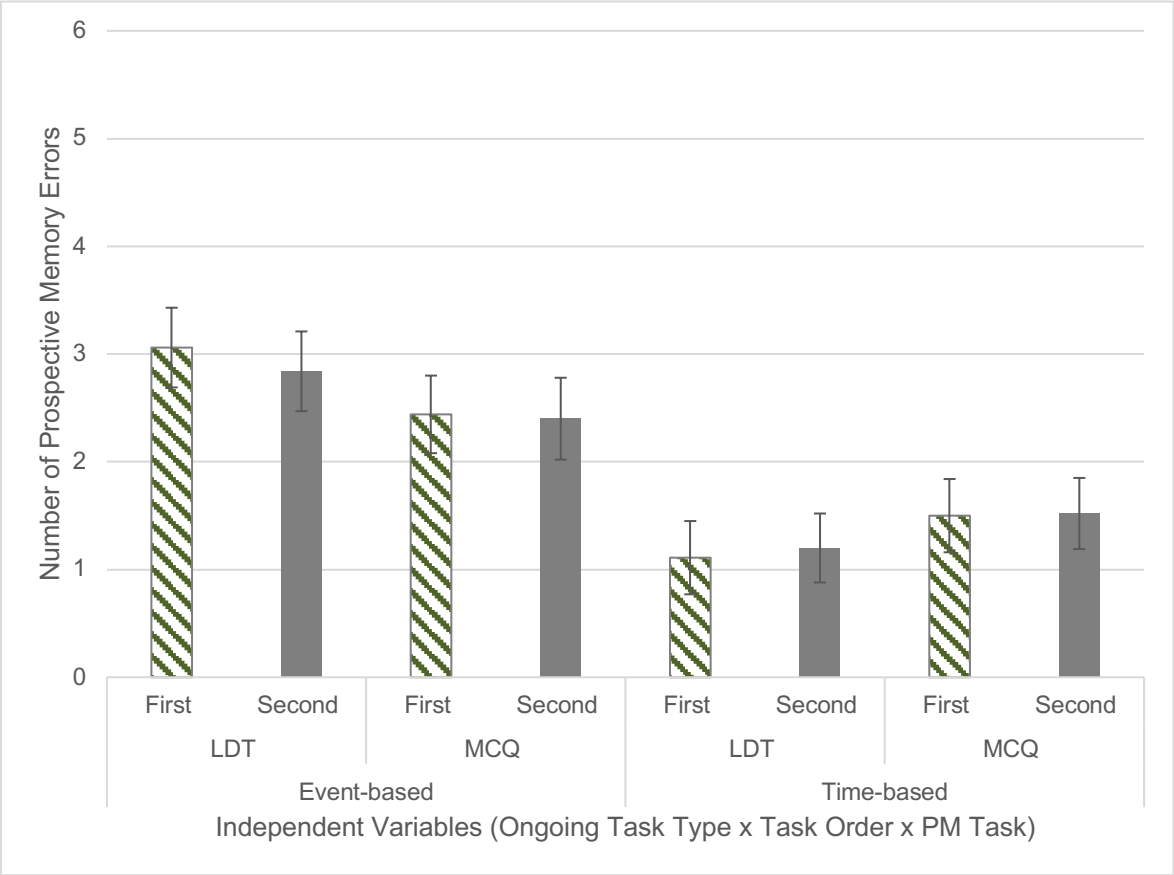
We also wanted to determine whether participants' PM errors differed according to the ongoing task, the PM task, or the order the tasks appeared (i.e., first or second). Based on the way our tasks were programmed, we ran a mixed 2 (condition: LDT with event-based PMT and MCQ with time-based PMT, LDT with time-based PMT and MCQ with event-based PMT) x 2 (order: LDT first, MCQ first) x 2 (PM task type: time-based, event-based) ANOVA with Bonferroni adjustment to allow for multiple comparisons. Condition (which reflects the combinations of ongoing task type and task sequence), and order (which reflects which ongoing task was first) were between-subjects, while PM task type was within-subjects. As shown in Figure 3.1—which breaks down performance according to the ongoing task, PM task type, and the order the tasks appeared—overall, participants made more event-based prospective memory errors (*M* = 2.68, *SD* = 1.53) than time-based prospective memory errors (*M* = 1.33, *SD* = 1.37), $F(1, 257) = 113.92$, $p < .001$, $d = .93$. That is, there was a significant main effect of PM task type. There was no main effect of sequence; there was no significant difference in prospective memory errors depending on the order of the tasks, $F<1$. There were no significant two-way or three-way interactions between prospective memory error type, ongoing task type, and sequence of tasks (Fs > 1). Taken together then, the multiple-choice trivia and the LDT seem to be equally difficult ongoing lab-based tasks. But

[7] We ran reliability analyses on a subset of participants (n = 20) for each of these ongoing tasks. The LDT had excellent internal consistency, whilst the MCQ had only moderate consistency. This difference is not surprising given the difference in task composition. That is, the LDT is a common, standardized task where errors are infrequent and error rates do not substantially vary across prospective memory tasks and experiments (e.g., Hicks et al., 2005; Marsh et al., 2003; Smith, 2003), whereas our trivia questions were taken from a number of sources and varied in degree of difficulty. Although these reliability scores might suggest caution in interpreting results from the MCQ specifically, our key findings (i.e., the relationship with self-report PM; PMQ and PRMQ, and PTSD symptom severity) did not change when analyzing only data from the LDT.

event-based prospective memory—operationalized as pressing F6 in response to the words "bone" and "theory"—appears to be more difficult than time-based tasks—operationalized as pressing F6 after every 2-minutes.

Figure 3.1

Prospective Memory Errors per Ongoing Task, PM Task Type and Task Order (with 95% Confidence Interval Error Bars)



Next, we turned to our primary research aim, to test whether the relationship between self-report PM and PTSD symptom severity generalizes to actual PM performance, and across PM types. Recall that on the one hand, if previous data from clinical samples are generalizable to a general population sample, then lab-based PM failures should positively correlate with PTSD symptom severity. On the other hand, if self-report measures are biased by metamemory judgements, and/or there is a dissociation between self-report and behavioral

PM tasks, then lab-based PM failures should *not* correlate with PTSD symptoms. In line with the latter idea that there is a dissociation between self-report and lab-based tasks, simple correlations showed that both the PMQ (r = .42, p < .001, CI [.32, .52]) and the PRMQ (r = .32, p < .001, CI [.21, .42]) were moderately related to PTSD symptoms (see Table 3.2), but PTSD symptoms did *not* correlate with total in-lab PM failures (r = -.01, CI [-.13, .11]), or with time-based (r = .03, CI [-.09, .15]) or event-based (r = -.04, CI [-.16, .08]) PM errors[8].

To examine whether there was a dissociation between behavioral and self-report PM tasks, we correlated performance in the lab with scores on self-report prospective memory measures. We found no correlation between total in-lab failures and scores on the PMQ (r = -.05, CI [-.17, .07]) and the PRMQ (r = -.01, CI [-.13, .11]), and this was the case for both time-based errors (PMQ; r = .01, CI [-.11, .13], PRMQ; r = .03, CI [-.09, .15]) and event-based errors (PMQ; r = -.08, CI [-.20, .04], PRMQ; r = -.04, CI [-.16, .08]).

[8] Because we found no significant relationship between PTSD symptoms and prospective memory errors in the lab, we did not proceed with our pre-registered regression analyses for these variables.

Table 3.2

Correlations between PTSD symptoms, self-report PM, PM performance and all other comorbidity and mediator variables.

	PM err	TB err	EB err	PRMQ	PMQ	PCL tot	PCL B	PCL C	PCL D	PCL E	BAMQ Neg	BAMQ Pos	MCQ	PTCI Self	DASS D	DASS A	DASS S	CPS	WBS	B-IPF
PM err	-	.68***	.75***	-.01	-.05	-.01	.001	.01	-.03	-.01	.03	-.05	.05	.02	.003	-.06	-.07	-.07	-.04	-.01
TB err	-	-	.02	.03	.01	.03	.02	.05	.02	.04	.07	-.01	.07	.13*	.07	.01	<.001	-.03	.06	.06
EB err			-	-.04	-.08	-.04	-.02	-.04	-.05	-.04	-.03	-.07	.004	-.10	-.06	-.09	-.09	-.07	-.10	-.07
PRMQ				-	.69***	.32***	.32***	.28***	.30***	.25***	.24***	.15*	.62***	.34***	.35***	.46***	.46***	.17**	.39***	.38***
PMQ					-	.42***	.39***	.34***	.40***	.36***	.32***	.25***	.60***	.40***	.36***	.45***	.44***	.12	.39***	.29***
PCL Total						-	.90***	.73***	.94***	.93***	.37***	.35***	.33***	.45***	.29***	.34***	.36***	.12	.30***	.21***
PCL B							-	.61***	.74***	.75***	.34***	.33***	.31***	.35***	.26***	.32***	.32***	.08	.25***	.16*
PCL C								-	.64***	.57***	.31***	.22***	.26***	.28***	.17**	.22***	.22***	.03	.20***	.06
PCL D									-	.84***	.35***	.41***	.31***	.49***	.30***	.31***	.33***	.12*	.31***	.22***
PCL E										-	.31***	.32***	.29***	.40***	.25***	.32***	.35***	.15*	.26***	.22***
BAMQ Neg											-	.32***	.29***	.58***	.44***	.39***	.37***	.19**	.42***	.30***
BAMQ Pos												-	.15*	.43***	.32***	.31***	.34***	.05	.37***	.24***
MCQ													-	.35***	.32***	.32***	.29***	.19*	.28***	.25***
PTCI Self														-	.71***	.53***	.58***	.30***	.60***	.48***
DASS D															-	.63***	.70***	.36***	.60***	.50***
DASS A																-	.76***	.28***	.55***	.43***
DASS S																	-	.24***	.62***	.50***
CPS																		-	.30***	.25***
WBS																			-	.49***
B-IPF																				-

Note: *$p < .05$; **$p < .01$; ***$p < .001$

Next, we tested the idea that biased metamemory judgments (i.e., cognitive confidence, negative cognitions about the self, beliefs about memory, thought suppression tendency, and willingness to future plan) might underpin the PM-PTSD relationship. We first ran a series of simple correlations between our mediator and comorbidity variables and PM (self-report and lab-based). PM failures in the lab did not correlate with our mediator and comorbidity variables (rs = .001-.05, ps = .25-.99). Interestingly, only negative cognitions about the self (r = .13, p = .03, CI [.01, .25]) correlated with lab-based errors (specifically, time-based prospective memory errors). PM failures also did not correlate with functional impairment (rs = .007-.06, ps = .28-.91; see Table 3.2 for all correlational data). Then, we ran a series of mediated regressions for self-report PM only. We used a Bonferroni corrected alpha of 0.005 to correct for multiple tests (0.05/5). For the PMQ, PTSD symptom severity was a significant predictor of PM, explaining 17.7 % of the variance in PMQ scores, R^2 = .18, $F(1, 259) = 55.88$, $p < .001$. All mediators, except for tendency to future plan, partially explained the relationship between PM scores on the PMQ and PTSD symptoms, but PTSD symptoms also contributed unique variance to PMQ scores (see supplementary file for all regression statistics). For beliefs about memory, negative cognitions about the self and suppression tendency, PTSD symptoms contributed greater variance to PMQ scores. However, cognitive confidence was a greater predictor of PMQ scores than was PTSD symptom severity.

For the PRMQ, PTSD symptoms significantly predicted PM scores, explaining 10.1% of the variance, R^2 = .10, $F(1, 259) = 29.15$, $p < .001$. All variables partially mediated the relationship between PM scores on the PRMQ and PTSD symptoms, again except for tendency to future plan. As for the PMQ, PTSD was a better predictor of PRMQ scores than beliefs about memory. Conversely, negative cognitions about the self, suppression tendency and cognitive confidence were better predictors of PRMQ scores than were PTSD symptoms.

To address the possibility that the relationship between PTSD symptom severity and self-report PM arises because of historical or physical vulnerability factors as per Swain and Takarangi (2021), we regressed self-report PM on these variables. For the PMQ, we entered possible TBI (b = .19, p = .004), alcohol dependency (b = .09, p = .15), presence of a learning disorder (b = .08, p = .19) and childhood trauma (b = .18, p =.005) simultaneously in Step 1. Together, these variables explained 10.1% variance in PMQ scores, R^2 = .10, *Fchange*(4, 237) = 6.68, p < .001. In Step 2, we entered PTSD symptom severity (b = .37, p < .001), which explained an additional 12.5% of the variance in total failures, $R^2change$ = .13, F(5, 236) = 13.79, p < .001. We repeated the analysis with the PRMQ as the outcome variable. In Step 1, possible TBI (b = .19, p = .004), alcohol dependency (b = .12, p = .07), presence of a learning disorder (b = .11, p = .08) and childhood trauma (b = .08, p = .23) explained 8.0% of the variance in PRMQ scores, R^2 = .08, F(4, 237) = 5.18, p < .001. In Step 2, PTSD symptoms (b = .27, p < .001) explained an additional 14.8% of the variance, $R^2change$ = .15, *Fchange* (5, 236) = 18.67, p < .001; and PTSD symptom severity was the strongest predictor. These results mirror Swain and Takarangi (2021), however here, childhood trauma additionally contributed to PM. Both here and previously (i.e., Swain & Takarangi, 2021), PTSD symptom severity was the strongest predictor of self-report prospective memory.

To test the idea that depression, anxiety and stress might contribute to the relationship between self-report PM and PTSD symptoms, we ran hierarchical regressions controlling for these variables. For the PMQ, depression (b = .05, p = .51.), anxiety (b = .27, p = .002) and stress (b = .19, p = .04)—entered at Step 1—explained 22.7% of the variance in total prospective memory failures, R^2 = .23, F(3, 257) = 25.09, p < .001. At Step 2, PTSD symptoms explained a small but significant additional 6.9% of the variance in total failures, $R^2change$ = .07, *Fchange*(4, 256) = 25.26, p < .001, b = .28. Inconsistent with Swain and

Takarangi (2021) who found stress and anxiety were greater predictors of PMQ scores, here, at Step 2, PTSD was the strongest predictor.

We repeated this analysis for the PRMQ: depression (b = .01, p = .90), anxiety (b = .27, p = .002) and stress (b = .25, p < .008)—entered at Step 1—explained 23.7% of the variance in PRMQ scores, R^2 = .24, $F(3, 257) = 26.66$, p < .001. At Step 2, PTSD symptom severity (b = .16, p = .006) did explain additional variance in PRMQ scores, $R^2change$ = .02, $Fchange(4, 256) = 7.53$, p = .006. At Step 2, anxiety (b = .24) and stress (b = .21) were stronger predictors of PRMQ scores than PTSD symptom severity. Similar to Swain and Takarangi (2021), where stress predicted PRMQ scores but PTSD did not. However, here, PTSD did contribute unique variance. These findings suggest that although depression, anxiety and stress might contribute to the PTSD-PM relationship, PTSD symptoms alone independently contribute to self-report PM.

Because PM deficits might mirror the everyday impairment observed amongst people with PTSD, a new analysis here was exploring whether PTSD symptoms contribute to self-reported psychosocial functioning (IPF) via self-report prospective memory. Self-report prospective memory correlated with impairment on the PMQ (r = .29, p < .001, N = 261) and the PRMQ (r = .38, p < .001, N = 261) so we ran mediated regressions to explore this relationship. At Step 1, PTSD symptom severity explained 4.2% of the variance in functional impairment scores, R^2 = .04, $F(1, 259) = 11.47$, p < .001, b = 21. At Step 2, PMQ scores explained additional 4.8% variance in functional impairment, $R^2change$ = .05, $Fchange(2, 258) = 13.58$, p < .001. Interestingly, at Step 2, PMQ scores (b = .24, p < .001) were a stronger predictor of impairment than PTSD symptom severity (b = .10, p = .11). Similarly for the PRMQ, at Step 2, PRMQ scores explained an additional 11.1% variance in functioning, $R^2change$ = .11, $Fchange(2, 258) = 33.73$, p < .001. As for the PMQ, at Step 2, PRMQ scores

(b = .35, p < .001) were a greater predictor of functional impairment than PTSD symptoms (b = .09, p = .12).

Discussion

This study revealed three important findings. First, lab-based prospective memory (PM)—remembering to press a certain key at a certain time or when a certain word appeared—did not correlate with PTSD symptoms, or with our mediator or comorbidity variables—except for time-based errors and negative cognitions about the self. However, consistent with Swain and Takarangi (2021), self-report PM correlated with PTSD symptom severity. Second, self-report and behavioral PM measures did not correlate. Finally, participants made more event-based than time-based errors.

We turn to our primary findings that, contrary to predictions, lab-based PM did not correlate with symptom measures or with self-report PM. These findings suggest the PM-PTSD relationship may be tied exclusively to self-report assessment, and highlight that subjective and objective PM measures might measure different constructs, or map onto different components (Sugden et al., 2021). The dissociation between self-report and objective PM measures is consistent with prior research in adolescents (e.g., Arnold & Bayen, 2019), older adults (e.g., Hering et al., 2018), and people with schizophrenia (Chan et al., 2008). There are at least three possible explanations for this dissociation.

The first possibility is that self-report PM measures are a poor proxy for actual performance (Arnold & Bayen, 2019) because they are biased by people's existing negative self-beliefs, which might generalize to PM (i.e., metamemory judgments; "*I always forget to do things*"). We know that people with clinical disorders, including PTSD, are poor at predicting their memory performance (e.g., Cuttler & Graf, 2009; Carlozzi et al., 2010). Moreover, our finding that negative appraisals (e.g., cognitive confidence) partially mediate the relationship between self-report PM and PTSD symptom severity supports the idea that

negative appraisals contribute to this relationship. However, future research could test the idea that appraisals encourage poor PM *behaviors*—e.g., reduced effortful encoding of intentions. We also found that PTSD symptoms did *not* explain unique variance in psychosocial functioning after accounting for self-report PM. This finding might also arise from recall biases; when people perceive and subsequently report more PM errors, they might also perceive and report poorer everyday functioning.

A second explanation is that behavioral PM tasks (i.e., pressing a key at specified times or when particular words appear) are an inadequate proxy for everyday activities. Indeed, typical in-lab cognitive tasks use materials/paradigms that have few corresponding counterparts in everyday life (e.g., unrelated words/digits; Kvavilashvili & Ellis, 2004). Prior literature suggests that although some cognitive tasks have high ecological validity (e.g., free recall; Unsworth et al., 2012), lab-based PM tasks are relatively weak (e.g., Phillips et al., 2008), and naturalistic tasks are preferable (e.g., virtual week; Rendell & Craik, 2000).

A third possibility is that lab-based PM reflects people's "optimal" PM ability. These tasks require participants to divide their resources between *only* the ongoing task and the PM task, without other distractions. In everyday situations characterized by competing demands, people—particularly those with PTSD symptoms—may struggle to allocate sufficient cognitive resources towards PM. Indeed, we found that self-report PM better explains everyday impairment than PTSD symptoms, and existing data show that people with PTSD inefficiently allocate cognitive resources towards other tasks (e.g., working memory; Shaw et al., 2009). So, perhaps people with worse PTSD symptoms have the *ability* to complete PM tasks—under ideal conditions, e.g., the laboratory—but poor resource allocation strategies to successfully navigate everyday demands.

Our third key finding that, contrary to our hypothesis, participants made more event-based than time-based errors, is surprising given time-based tasks rely heavily on self-

initiated processes (Einstein & McDaniel, 1990). However, our results fit with research suggesting task *importance* affects time- but not event-based PM (Kliegel et al., 2001). Essentially, people allocate more resources to time-based monitoring when they perceive the task as important and/or difficult (e.g., Hicks et al., 2005). Perhaps our time-based task appeared difficult, leading participants to allocate additional resources. Alternatively, perhaps task differences led to inflated event-based errors. Our error criteria were stricter for event-based (i.e., "F6" had to be pressed *on* target words), than time-based tasks (i.e., within 10-seconds of 2-minutes), and—consistent with prior research (e.g., Hicks et al., 2005; Scullin & Bugg, 2013; Scullin et al., 2013)—we asked participants to remember two event-based cues ("bone", "theory") but only one time-based intention (every 2-minutes). Future research should equate performance criteria for time- and event-based tasks.

Our study is limited by using a general population to explore a clinical condition. Yet trauma exposure—events involving real or threatened death, serious injury, or sexual violence (i.e., Criterion A; APA, 2013), or other distressing events (e.g., marital separation, pet death, estrangement from a child—was ubiquitous in our sample (~85%; e.g., Nixon et al., 2007; Oulton & Takarangi, 2018). Moreover, 29.1% (n = 76) of our sample met the cut-off for a probable PTSD diagnosis (Ashbaugh et al., 2016). Indeed, although many trauma-exposed people do not meet the diagnostic threshold, they may still develop PTSD symptoms (Bonanno et al., 2010). Therefore, exploring measurement comparisons in these samples provides additional insight into the PTSD-PM relationship.

Overall, our results revealed that people with worse PTSD symptoms self-reported more everyday PM errors, but these errors were not reflected in in-lab performance. Interestingly, subjective and objective PM measures did not correlate. Our findings have methodological implications. They provide further insight into the difficulties with using subjective and objective measures interchangeably. Future research should use varied

measurement methods that represent everyday life tasks, minimize recall errors and/or maintain laboratory conditions (e.g., diary-measurement, Laughland & Kvavilashvili, 2018; actual-week, Rendell & Craik, 2000). Our clinical implications are twofold. First, greater *perceived* PM failures amongst people with worse PTSD symptoms provide insight into how negative beliefs in PTSD might generalize to cognition. Second, if *perceived* PM failures mediate PTSD symptom severity and psychosocial impairment, providing psychoeducation or interventions around recognizing and adjusting unhelpful beliefs, specifically related to PM, could improve biased thinking patterns for people with PTSD.

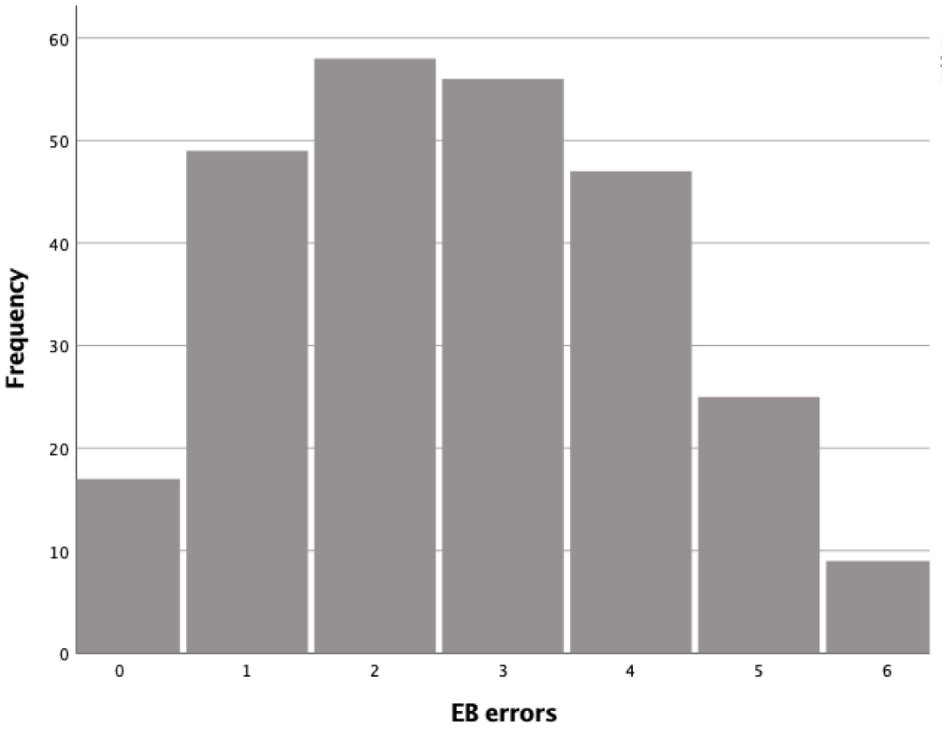
Supplementary Materials

Summary of previous literature (see also Piefke & Glienke, 2017)

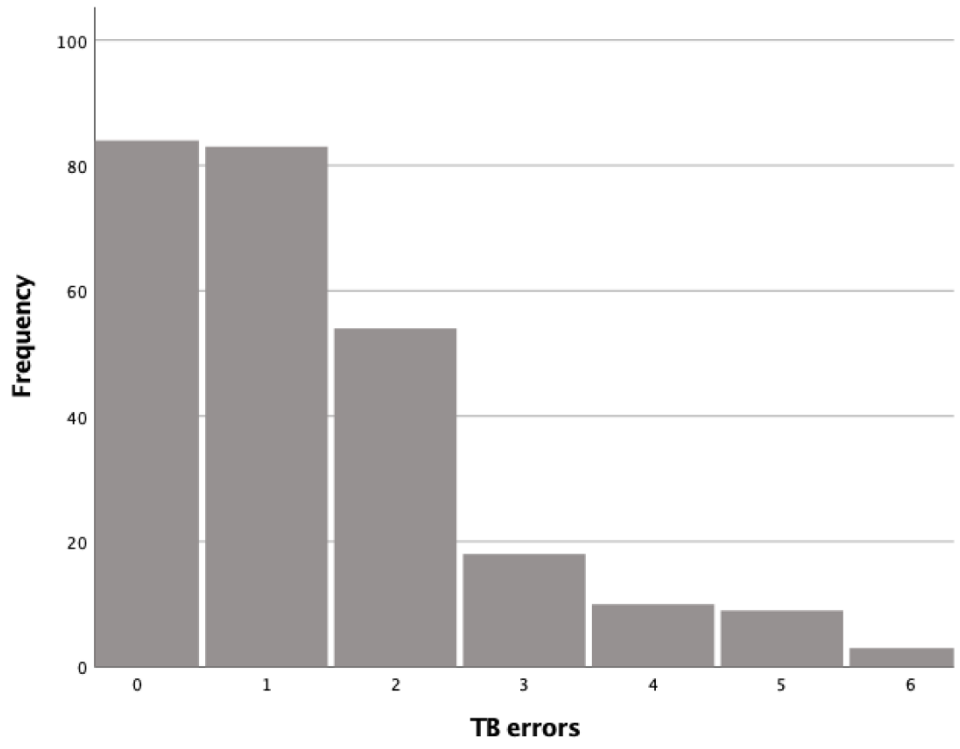
	Population	***Type of PM task***	***Type of ongoing task***	***Effect sizes***	***Key findings***
McFarland et al. (2016)	Combat veterans with PTSD (N = 40)	Event-based PM	Ongoing in lab task paradigm	Event-based PM, d = -.96	Elevated PTSD symptoms are associated with greater event-based PM failures.
Scott et al. (2016)	Combat veterans with PTSD (n = 40) and non-PTSD combat veterans (n = 38)	Time-based PM *and* event-based PM	Memory for intentions test (MIST)	PM performance overall, d = -.58 Event-based PM, d = -.39, Time-based PM, d = -.56	Participants with PTSD show poorer prospective memory performance, particularly for time-based tasks.
Glienke et al. (2017)	Veterans with PTSD (n = 13), veterans without PTSD (n = 12), and, non-military controls without PTSD (n = 21)	Time-based PM *and* event-based PM	"Plan a Holiday" – real-life related PM paradigm	PM performance overall: PTSD & non-military, U = -4.17 Event-based PM, PTSD & non-military, U = -4.02 Time-based PM, PTSD & non-military, U = -4.22	Combat-related stress has deteriorating effects on real-life related PM and other memory functions, even in the absence of a PTSD diagnosis.
Pagulayan et al. (2018)	Veterans with and without mTBI history (N = 61)	Time-based PM *and* event-based PM	Memory for intentions test (MIST)	TBI & PTSD positive vs control, PM total: d = -1.08, TBI & PTSD positive vs control, PM time-based: d = -1.02,	Veterans with TBI with current PTSD demonstrated significantly lower performance on the PM measure than Veterans in the control group.
Rau et al. (2018)	Veterans with and without mTBI history (N = 82)	Time-based PM *and* event-based PM	Memory for intentions test (MIST)	PM score overall and PTSD diagnosis, r = -.314	Fatigue is a greater contributor to prospective memory performance than PTSD symptoms. Fatigue fully mediates the relationship.
Korinek et al. (2021)	Veterans with PTSD (n = 26) and matched, combat-exposure controls without PTSD (n = 26)	Time-based PM *and* event-based PM	Memory for intentions test (MIST)	PM score overall and PTSD score, r = -.366, Event-based PM, r = -.37, Time-based PM, r = -.25	Although total PM performance and event-based PM correlated with PTSD symptoms, no significant differences between groups. Generalised anxiety better explained PM.
Swain & Takarangi (2021)	General population (N = 405)	Self-report PM	Prospective and Retrospective Memory Questionnaire (PRMQ) and Prospective Memory Questionnaire (PMQ)	Self-report PM and PTSD symptom severity, r = .42-.49	PTSD symptom severity positively correlated with self-report prospective memory failures. PTSD symptoms affected self-report prospective memory via their influence on negative appraisals and maladaptive strategies.

Histograms of key variables

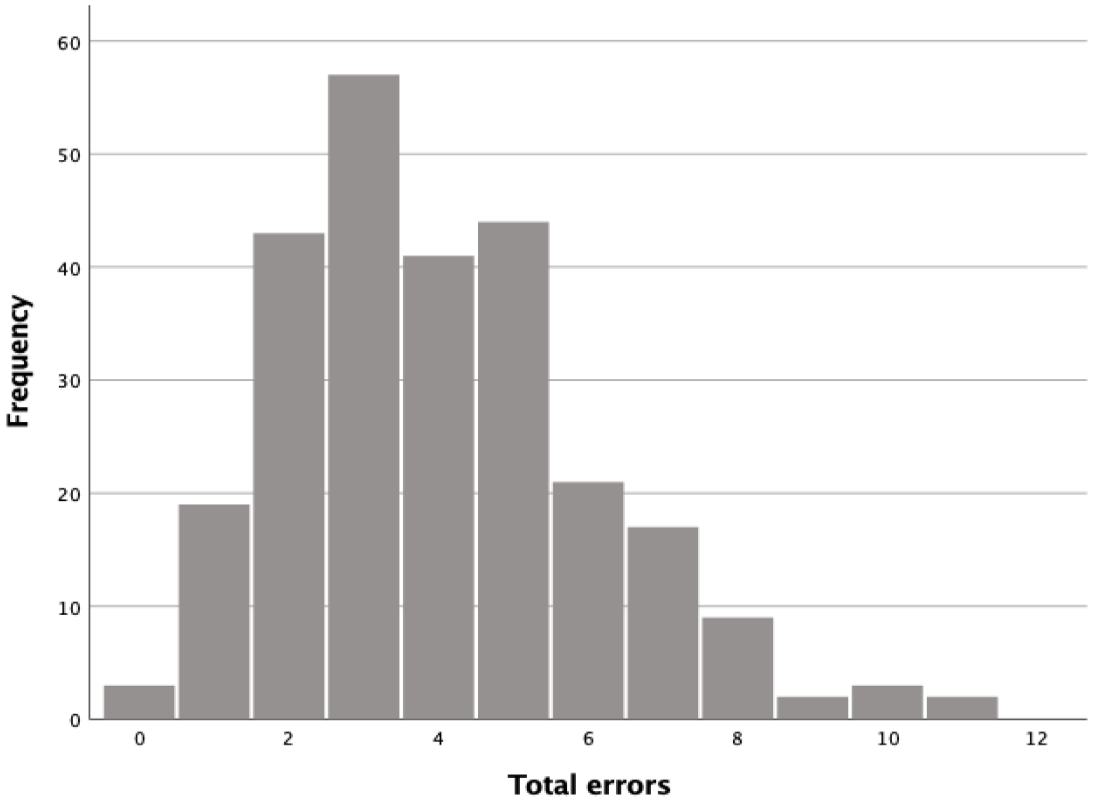
Supplementary figure 1: Histogram of event-based prospective memory errors across both task types



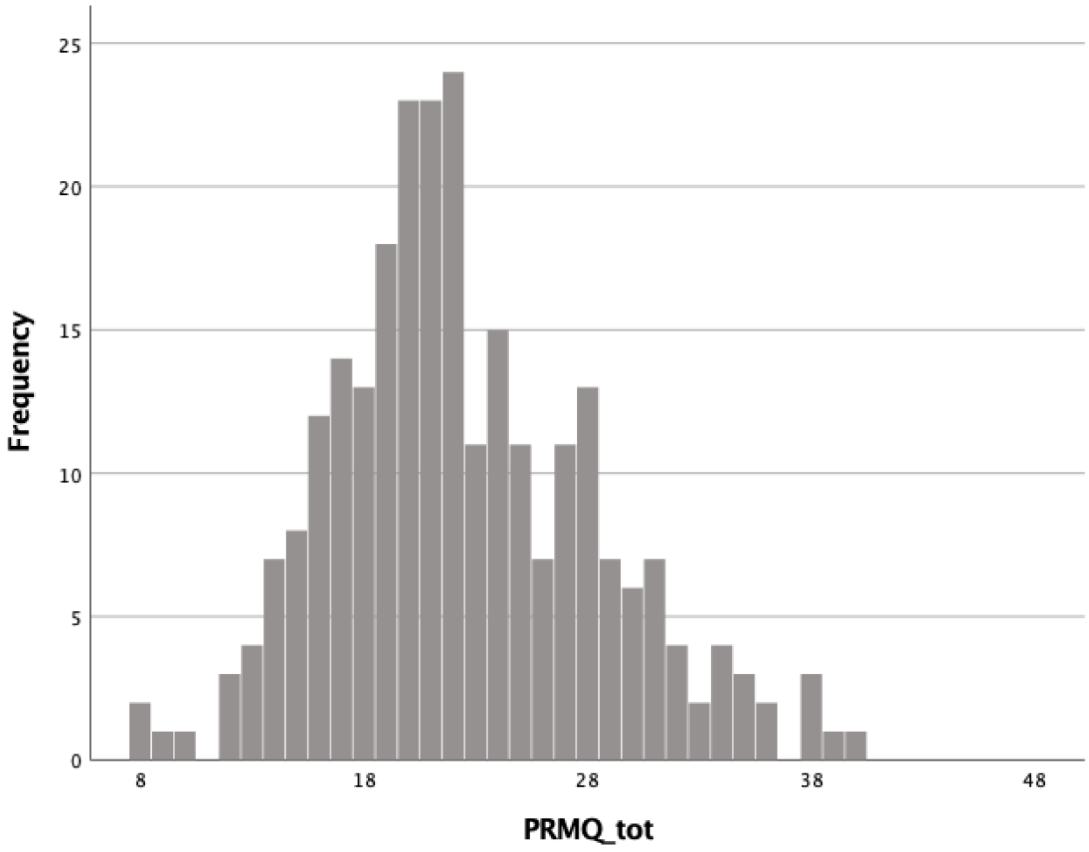
Supplementary figure 2: Histogram of time-based prospective memory errors across both task types



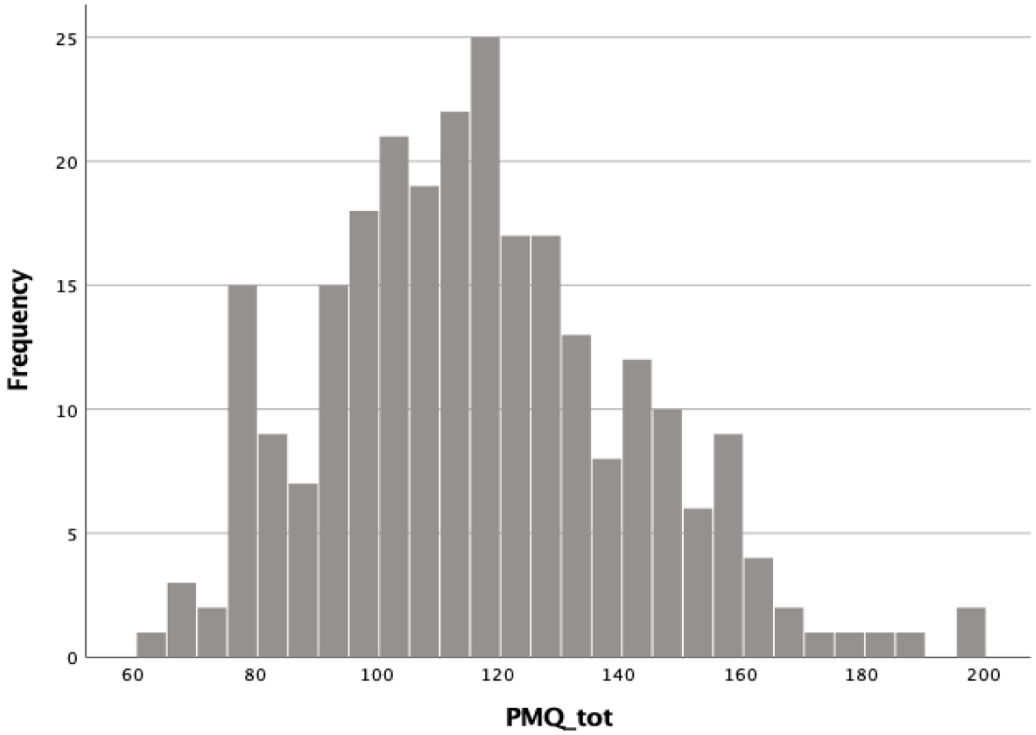
Supplementary figure 3: Histogram of total prospective memory errors across both task types



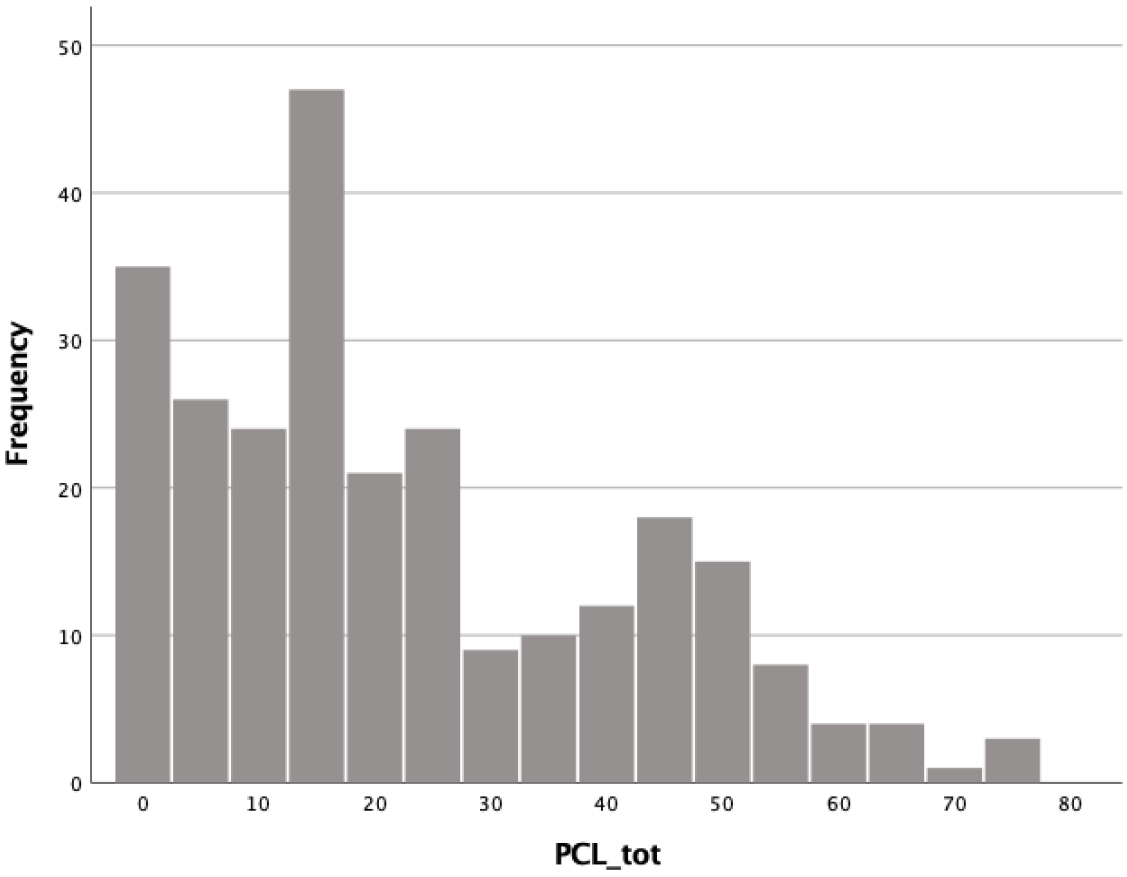
Supplementary figure 4: Histogram of PRMQ scores



Supplementary figure 5: Histogram of PMQ scores



Supplementary figure 6: Histogram of PCL-5 scores



Regression output and statistics

To test the idea that the relationship between PTSD and subjective PM might be explained by PTSD *causing* maladaptive appraisals and strategies, we ran a series of mediated regressions. We used a Bonferroni corrected alpha of 0.005 to correct for multiple tests (0.05/5). For the PMQ, PTSD symptom severity was a significant predictor of PM, explaining 17.7 % of the variance in PMQ scores, $R^2 = .18$, $F(1, 259) = 55.88$, $p < .001$ (please refer to Table 1 for all statistics). Beginning with cognitive confidence, at Step 1, this variable explained 35.5% of the variance in PMQ scores, but at Step 2, PTSD symptoms explained an additional 5.7% of the variance in PMQ scores. However, based on the beta values, cognitive confidence was a greater predictor of scores than PTSD symptoms. For beliefs about memory, these variables explained 10.9% of the variance in PMQ scores in Step 1. At Step 2, PTSD symptom severity explained an additional 10.0% variance in scores. Based on the beta values, PTSD symptom severity was a better predictor of PMQ scores than were negative beliefs about memory. For negative cognitions about the self, at Step 1, these beliefs explained 16.0% of the variance in PMQ scores. At Step 2, PTSD symptom severity explained an additional 7.3% variance in PMQ scores. Based on the beta scores, PTSD symptoms were a slightly better predictor of PMQ scores than were negative beliefs about the self. Finally for suppression tendency, at Step 1, this variable explained 15.0% of the variance in PMQ scores. At Step 2, PTSD symptom severity explained an additional 10.3% variance in PMQ scores. And, PTSD symptoms were indeed a greater predictor of PMQ scores than suppression tendency. We did not proceed with the tendency to future plan mediation due to the correlation being non-significant.

Supplementary table 1: Inferential statistics from regression analyses on PTSD and PMQ with maladaptive strategies and negative appraisals as mediators

Cognitive confidence	*b*	Variance explained (%)	R^2	R^2_{change}	*F*	F_{change}	*df*	*p*
1. MCQ-30	.60	35.5	.36		142.73		1, 259	< .001
2. MCQ-30	.51	41.2		.06		24.85	1, 258	< .001
PCL-5 (PTSD symptoms)	.25							
Beliefs about memory								
1. BAMQ - Positive	.11	10.9	.11		15.78		2, 258	< .001
BAMQ - Negative	.26							
2. BAMQ - Positive	.03	20.9		.10		32.47	1, 257	< .001
BAMQ - Negative	.17							
PCL-5 (PTSD symptoms)	.35							
Negative cognitions about the self								
1. PTCI – Negative cognitions about the self	.40	16.0	.16		49.47		1, 259	< .001
2. PTCI – Negative cognitions about the self	.26	23.3		.07		24.53	1, 258	< .001
PCL-5 (PTSD symptoms)	.30							
Willingness to future plan								
1. CPS		NA	-		-		-	.06
2. CPS		-		-		-	-	-
PCL-5 (PTSD symptoms)								
Suppression tendency								
1. WBSI	.39	15.0	.15		45.73		1, 259	< .001
2. WBSI	.29	25.3		.10		35.63	1, 258	< .001
PCL-5 (PTSD symptoms)	.34							

Note: numbers refer to the step of the hierarchical regression (i.e., 1. Means step 1, and 2. Means step 2).
PCL-5 = Posttraumatic Stress Disorder Checklist; BAMQ = Beliefs about Memory Questionnaire; MCQ = Metacognitions Questionnaire; cognitive confidence subscale; PTCI self = Posttraumatic Cognitions Inventory; negative cognitions about the self subscale; DASS = Depression, Anxiety and Stress Questionnaire, CPS = Continuous Planning Scale; WBS = White Bear Suppression; B-IPF = Brief Inventory of Psychosocial Functioning

For the PRMQ, PTSD symptom severity was a significant predictor of PM, explaining 17.7 % of the variance in PRMQ scores, $R^2 = .18$, $F(1, 259) = 55.88$, $p < .001$ (please refer to Table 2 for all statistics). Beginning with cognitive confidence, at Step 1, this variable explained 38.2% of the variance in PRMQ scores, but at Step 2, PTSD symptoms explained only an additional 1.5% of the variance in PMQ scores. Based on the beta values, and consistent with results for the PMQ, cognitive confidence was a greater predictor of PRMQ scores than PTSD symptoms. For beliefs about memory, these variables explained 5.9% of the variance in PRMQ scores in Step 1. At Step 2, PTSD symptom severity explained an additional 6.0% variance in scores. Based on the beta values, PTSD symptom severity was a better predictor of PRMQ scores than were negative beliefs about memory. For negative cognitions about the self, at Step 1, these beliefs explained 11.3% of the variance in PRMQ scores. At Step 2, PTSD symptom severity explained an additional 3.5% variance in PRMQ scores. Based on the beta scores, negative cognitions about the self were a slightly better predictor of PRMQ scores than PTSD symptoms. Finally for suppression tendency, at Step 1, this variable explained 15.4% of the variance in PRMQ scores. At Step 2, PTSD symptom severity explained an additional 4.5% variance in PRMQ scores. And, suppression tendency was actually a greater predictor of PRMQ scores than PTSD symptoms. We did not proceed with the tendency to future plan mediation due to the correlation being non-significant.

Supplementary table 2: Inferential statistics from regression analyses on PTSD and PRMQ with maladaptive strategies and negative appraisals as mediators

Cognitive confidence	*b*	Variance explained (%)	R^2	R^2_{change}	*F*	F_{change}	*df*	*p*
1. MCQ-30	.62	38.2	.38		160.21		1, 259	< .001
2. MCQ-30	.58	39.7		.02		6.26	1, 258	.01
PCL-5 (PTSD symptoms)	.13							
Beliefs about memory								
1. BAMQ - Positive	.03	5.9	.06		8.02		2, 258	< .001
BAMQ - Negative	.22							
2. BAMQ - Positive	-.03	11.9		.06		17.72	1, 257	< .001
BAMQ - Negative	.16							
PCL-5 (PTSD symptoms)	.27							
Negative cognitions about the self								
1. PTCI – Negative cognitions about the self	.34	11.3	.11		33.10		1, 259	< .001
2. PTCI – Negative cognitions about the self	.24	14.8		.04		10.54	1, 258	.001
PCL-5 (PTSD symptoms)	.21							
Willingness to future plan								
1. CPS		NA	-		-		-	.006
2. CPS		-		-		-	-	-
PCL-5 (PTSD symptoms)								
Suppression tendency								
1. WBSI	.39	15.4	.15		47.30		1, 259	< .001
2. WBSI	.33	19.9		.05		14.39	1, 258	< .001
PCL-5 (PTSD symptoms)	.22							

Note: numbers refer to the step of the hierarchical regression (i.e., 1. Means step 1, and 2. Means step 2).
PCL-5 = Posttraumatic Stress Disorder Checklist; BAMQ = Beliefs about Memory Questionnaire; MCQ = Metacognitions Questionnaire; cognitive confidence subscale; PTCI self = Posttraumatic Cognitions Inventory; negative cognitions about the self subscale; DASS = Depression, Anxiety and Stress Questionnaire, CPS = Continuous Planning Scale; WBS = White Bear Suppression; B-IPF = Brief Inventory of Psychosocial Functioning

Chapter 4: I forgot that I forgot: PTSD symptom severity in a general population correlates with everyday diary-recorded prospective memory failures[9]

Author contributions: I developed the study design with the guidance of CAK and MKTT. I, CAK and SL collected the data and cleaned the data for analysis. I performed the data analysis and interpretation. I drafted the manuscript and CAK, SL and MKTT provided critical revisions. All authors approved the final version of the manuscript for submission.

Abstract

Extant research suggests a complex relationship between prospective memory (PM) and Posttraumatic Stress Disorder symptom severity. In a general population, this relationship exists for self-report assessment but not objective, in-lab PM performance (e.g., pressing a certain key at a particular time, or when particular words appear; Swain & Takarangi 2021; 2022). However, both these measurement methods have limitations. Objective, in-lab PM tasks might not represent typical everyday performance, while self-report measurement might be biased by metacognitive beliefs. Thus, we used a naturalistic diary paradigm to answer the overarching question: are PTSD symptoms associated with PM failures in everyday life? We found a small positive correlation between diary-recorded PM errors and PTSD symptom severity (r = .21). Time-based tasks (i.e., intentions completed at a particular time, or after a specified time has elapsed; r = .29), but not event-based tasks (i.e., intentions completed in response to an environmental cue; r = .08), correlated with PTSD symptoms. Moreover, although diary-recorded and self-report PM correlated, we did not replicate the finding that metacognitive beliefs underpin the PM-PTSD relationship (Swain &

[9] Swain, T. L., Keeping, C. A., Lewitzka, S. & Takarangi, M. K. (2022). I forgot that I forgot: PTSD symptom severity in a general population correlates with everyday diary-recorded prospective memory failures. *Memory and Cognition*, Under Review.

Takarangi, 2021; 2022). These results suggest that metacognitive beliefs might be particularly important for self-report PM only.

Introduction

Imagine a person with Posttraumatic Stress Disorder (PTSD) forgets to: attend their therapy appointments, fill their medication prescription and subsequently to take that medication. Their symptoms worsen, so they then forget to: contact their social supports at agreed times and submit work tasks by agreed deadlines. These instances of forgetting to complete future intentions are all examples of prospective memory (PM) failures (Loftus, 1971). Such failures might occur in the everyday lives of people with PTSD, and consequently contribute to symptom maintenance or worsening. Existing research suggests a complex relationship between PM and PTSD symptom severity. In a general population, this relationship exists for self-report assessment but not in-lab, objective PM performance (e.g., pressing a certain key at a particular time, or when particular words appear; Swain & Takarangi, 2021; 2022). However, both these methods have limitations. Objective, in-lab PM tasks might not represent typical everyday performance, because the tasks (e.g., responding to unrelated digits) and the lab environments (i.e., free of competing demands) are unlike our everyday environments (Kvavilashvili & Ellis, 2004). And metacognitive beliefs (i.e., beliefs and appraisals about one's cognition and thinking; Papageorgiou & Wells, 2001) might bias self-report measurement. Thus, to increase the representativeness of the PM task, whilst reducing metacognitive biases in reporting, we used a naturalistic diary paradigm to answer the question: are PTSD symptoms associated with everyday PM failures?

Research exploring the PM-PTSD relationship is limited. In clinical populations, research relies specifically on in-lab, objective tasks. Some studies find a relationship for veterans with PTSD on time-based tasks; these tasks—e.g., asking the researcher when the session ends after 2-minutes, or attending a fictional breakfast at 10:30am in a holiday

simulation—capture intentions that occur at a particular time or after an elapsed time-period (e.g., equivalent to taking medication at 9am, or every 2-hours; Glienke et al., 2017; Pagulayan et al. 2018; Scott et al., 2016). Other studies find the PM-PTSD relationship exists for veterans with PTSD on event-based tasks; these tasks—e.g., attending a fictional medical appointment in response to leaving a simulated place (e.g., school), or self-addressing a postcard as it's presented—capture intentions that occur in response to environmental cues (e.g., equivalent to taking medication with breakfast; Glienke et al., 2017; McFarland et al., 2016; Pagulayan et al. 2018). Yet other work finds no difference between veterans with PTSD, and combat-exposed matched controls without PTSD, on either time- *or* event-based tasks (Korinek et al., 2021). But, symptom *severity* across the groups negatively correlates with overall PM performance (i.e., worse symptoms were related to more PM errors). In non-clinical, general population samples, participants who report worse PTSD symptom severity also *self-report* more PM errors (Mechanical Turk; Swain & Takarangi, 2021), but do not perform worse on in-lab, objective PM tasks (i.e., pressing a certain key after 2-minutes, or when certain words appear; undergraduates; Swain & Takarangi, 2022). Altogether, the nature of the PM-PTSD relationship seems to depend on: measurement type (e.g., in-lab computerised tasks vs. naturalistic tasks), task type (i.e., time- vs event-based) and sample type. Here, we focus on PM measurement and task types.

Lab-based PM tasks have two key limitations. First, they often have weak *ecological validity* (see Sugden et al., 2021, for review), because they do not investigate PM in a way that corresponds to everyday life, and thus cannot necessarily be *generalised* to everyday tasks (Kvavilashvili & Ellis, 2004). Lab environments are dissimilar to our everyday environments (Kvavilashvili & Ellis, 2004), and typically focus on one primary task. In fact, the absence of competing demands requiring cognitive resources—e.g., work demands, or social media—allows participants to allocate more resources to that primary in-lab task, than

they typically might in their everyday life. Second, and relatedly, lab-based cognitive assessments—like neuropsychological evaluations—typically measure a person's "peak" or "best" performance (Chaytor & Schmitter-Edgecombe, 2003), rather than their average performance. Objective PM measures—including the Einstein and McDaniel (1990) paradigm or the Memory for Intentions Screening Test (Raskin et al., 2010), where participants complete ongoing tasks while maintaining intentions—likely also capture maximal, rather than average, performance (e.g., Rummel & Kvavlishavili, 2019).

These two limitations of lab-based PM assessment may be particularly important for the PM-PTSD relationship. Ellis and Ashbrook (1988) propose that a person's emotional state regulates how they allocate cognitive resources. People in a more persistent negative emotional state, like PTSD, might allocate fewer resources to everyday PM tasks. Consistent with this idea, we know that people with PTSD inefficiently allocate cognitive resources towards other tasks (e.g., working memory; Shaw et al., 2009), likely because symptom management or other competing demands occupy these resources. But perhaps in-lab—i.e., without competing demands—they may allocate cognitive resources more efficiently. Additionally, the maladaptive strategies people with PTSD often use to control their environment for ongoing threat may be reduced in-lab, allowing for effective PM. For example, in everyday environments, people with worse PTSD symptoms may avoid trauma-related thoughts—e.g., by occupying their mind with other things (i.e., thought suppression)—resulting in fewer available resources for PM. They may also avoid making future plans—to avoid encountering any more stressful or traumatic experiences. However, in-lab (i.e., a controlled, predictable environment), people with worse PTSD symptoms may rely less on such strategies. Essentially, in-lab environments might mitigate the typical resource allocation difficulties people with PTSD experience.

Compared to lab-based tasks, self-report measures examine errors on everyday tasks (e.g., forgetting to post a letter, or contact a friend), that occur in typical everyday environments. However, because such tasks require participants to report their *perceived* error frequency over a specific period (e.g., the past month), without providing evidence for such errors (PMQ; Hannon et al., 1990; PRMQ; Smith et al., 2000), participants are likely vulnerable to recall biases (Kihlstrom et al., 1999). Thus, participants' reported errors may incorporate metacognitive concerns about PM (e.g., "I have a generally poor memory, so my PM is poor"), rather than reflecting only actual performance (e.g., Hainselin et al., 2021).

These metacognitive beliefs might be exaggerated among people with worse PTSD symptoms. We know that people with PTSD hold negative beliefs about themselves and their memory (Ehlers & Clark, 2000; Wells, 2000) and that these negative beliefs correlate with self-report PM errors (Swain & Takarangi, 2021; 2022). We also know people with PTSD demonstrate memory biases generally, including negative interpretation of ambiguous material (Bomyea et al., 2017), enhanced memory for negative content (Durand et al., 2019), and report their trauma memories as worse over time (i.e., memory amplification; e.g., Engelhard et al., 2008). Therefore, people with PTSD may be particularly susceptible to perception and memory biases when self-reporting PM.

Altogether, the limitations of these PM tasks likely obscure the PM-PTSD relationship. Thus, our aim here was to explore the relationship using a naturalistic assessment method; diary-recording. Researchers in the PM field have recently returned to diary-recording in assessing everyday failures. Some have used experience-sampling techniques; e.g., probing participants via text message or phone call over several days/weeks, to assess whether they were making an error, or thinking about an intention (Anderson & McDaniel, 2019; Gardner & Ascoli, 2015). Others have used retrospective questionnaires completed at the end of each day (for 5-14 days), where participants checked whether they

made specific errors (e.g., “to do an errand or chore”; Mogle et al., 2022), or free recalled errors they had made (Haas et al., 2020). Few have specifically asked participants to free record in a diary each time they made a PM error over a specified period (i.e., 1-7 days; Laughland & Kvavilashvili, 2018; Niedźwieńska et al., 2020). And, only one used *both* a free record diary *and* reminded participants via a watch vibration (Brazauskiene et al., 2020). Thus, here, we combined both free recall and experience-sampling to maximise the number of PM errors we captured. Importantly, this diary approach mitigates the limitations of *both* self-report and objective assessment methods by: 1) increasing the ecological validity of PM tasks and the task environment, 2) capturing participants’ “average” rather than peak performance, and 3) reducing memory biases in self-reporting (i.e., by requiring objective examples).

Our primary research question was: are PTSD symptoms correlated with *diary-recorded* everyday prospective memory failures? We asked participants to record their PM errors in a 4-day diary (including whether each error was time- or event-based). We prompted them three times per day to record any errors they might have forgotten. Prior to the diary, participants completed the same questionnaires (i.e., self-report PM, negative beliefs and strategies, PTSD symptom measures; and physical and mental health comorbidities that might account for a relationship between PM and PTSD symptoms: possible traumatic brain injury [TBI], alcohol dependency, learning/developmental disorder, childhood trauma, and depression, anxiety, and stress symptoms) as in Swain and Takarangi (2021; 2022).

We have two competing predictions. On the one hand, if diary reporting aligns with self-report measurement—due to the generalisable nature of everyday PM tasks and everyday environments—we predict that diary-reported PM failures will positively correlate with PTSD symptom severity. We expect that the correlation will be larger for time- than event-based failures, because time-based tasks rely heavily on executive functions (e.g.,

monitoring; e.g., Einstein & McDaniel, 1990) that are often impaired in PTSD. On the other hand, if PTSD symptoms are unrelated to actual PM performance—and only correlate with self-report PM because of metacognitive biases in reporting—we predict that diary-reported PM failures will *not* correlate with PTSD symptom severity.

Based on the idea that metacognitive beliefs and maladaptive strategies might underpin the relationship between PM and PTSD symptom severity—and the mediation results from our prior research—we also predict that cognitive confidence, negative cognitions about the self, beliefs about memory, thought suppression, and willingness to future plan, will partially mediate the relationship. We have two secondary interests. First, given self-reported but not lab-based PM errors correlate with everyday functioning (Swain & Takarangi, 2022), we examine the relationship between PTSD, PM and everyday functioning (e.g., social or occupational functioning). We predict that PTSD symptoms might contribute to greater PM errors, which then results in greater everyday impairment (i.e., a mediation). Second, stress may be an important predictor in the PM-PTSD relationship (Swain & Takarangi, 2021); thus, we examined the relationship between PTSD, PM and perceived everyday stress. We predict that PTSD symptoms might contribute to greater everyday stress, which then results in more PM errors (i.e., a mediation).

Method

Participants

We recruited 327 participants using varied methods: the Flinders University SONA system (credit: n = 108, paid: n = 22), social media (n = 136), flyers (n = 35), an online marketplace (i.e., Gumtree; n = 7), and other (e.g., referrals from others, n = 19). Twenty-one people completed only Phase 1 and were excluded from further participation (e.g., due to failing three attention checks embedded within that phase [Berinsky et al., 2014; Hauser & Schwarz, 2015], providing an invalid mobile number, or having already participated). Per our

pre-registration (see https://osf.io/pgw3u), we excluded a further 41 people who completed all study phases but recorded an insufficient number of PM errors (i.e., <2; *n* = 39), or completed the diary incorrectly (*n* = 2). We excluded one person who did not complete the surveys central to our research question (i.e., trauma history measures). Four participants chose to withdraw during the diary phase. Thus, our final sample was 260. This sample size was based on the idea that correlations stabilise as they approach 260 participants (Schonbrodt & Perugini, 2013; 2018). Our sample were aged 18-69 (*M* = 25.74, *SD* = 9.51) and identified as 15.0% male (*n* = 39), 80.8% female (*n* = 210), 3.8% non-binary (*n* = 10), and one person preferred not to identify their gender (0.4%). The majority of participants were Caucasian (73.8%, *n* = 192), followed by Asian (13.8%, *n* = 36), Mixed race (4.6%, *n* = 12), Middle Eastern (3.1%, *n* = 8), Indian (2.3%, *n* = 6) and Aboriginal, African, Hispanic, Pacific Islander and Serbian (each 0.4%, *n* = 1). Further, 1.5% completed doctoral studies as their highest qualification (*n* = 4), 7.3% master's studies (*n* = 19), 31.2% bachelor's degree (*n* = 81), 9.6% associate degree or certificate (*n* = 25), 49.5% senior high school or equivalent (*n* = 129), and two had only completed junior high school (0.8%). Participants were reimbursed $30 or course credit. All data can be found at: https://osf.io/wmvhb/

Measures

At-home prospective memory diary

Participants completed an at-home online PM diary based on Laughland and Kvavilashvili (2018). In the diary we asked participants to record: the time the error occurred, and the time they realised they had made the error. Participants described their error (i.e., what they were doing, what they forgot, where they were), and reported if the error was time-

or event-based, then were asked if they had any more instances to record, before finalising their response (see supplementary materials for full diary questions)[10].

Post-diary survey

To explore diary compliance and aid use, participants completed a brief survey after the diary-period. We asked participants if they carried their phone on every day of the study. If they responded "no", they reported the number of days they did not carry their phone. We then asked participants to estimate the percentage of errors they recorded over the diary-period (i.e., "*please indicate the % of forgetting instances you were able to record out of ALL your forgetting over the diary period*"). Participants reported the ease of: carrying their phone and recording their errors (*1 = very easy*, *4 = very difficult*). Finally, we asked participants if they used aids to help them remember, and asked them to indicate, on a list of potential aids (e.g., lists, electronic reminders) which they used, and if that aid use was typical of their behaviour.

Questionnaires

Historical/physical health comorbidities.

Learning/developmental disorder screening. We asked participants whether they had ever been: (a) diagnosed with a learning disorder (e.g., Attention-Deficit Hyperactivity Disorder [ADHD]), (b) placed in a learning/emotionally handicapped special class, or (c) told they had a learning disorder and by whom (e.g., teacher). We classified participants as having a learning disorder when they responded "yes" to questions (a) or (b), *and* listed doctor/other specialist or teacher on question (c) (Swain & Takarangi, 2021; 2022).

HELPS Screening Tool (HELPS; Picard et al., 1991). The HELPS is designed to screen for Traumatic Brain Injury (TBI). It includes five general questions about TBI events,

[10] This research was conducted as part of a larger study and therefore we report only the measures relevant to the current research question(s) here. Participants also reported their mood and stress level immediately prior to the error, and the seriousness of the error. Participants also predicted and post-dicted their diary-reported PM performance.

and the potential aftermath. “H” (Have you ever *H*it your *H*ead, or been *H*it on the *H*ead?); “E” (Were you ever seen in the *E*mergency room, hospital, or by a doctor because of an injury to your head?); “L” (Did you ever *L*ose consciousness or experience a period of being dazed or confused because of an injury to your head?); “P” (Do you experience any of these *P*roblems in your life daily since you hit your head? E.g., headaches and dizziness); “S” (Any significant *S*icknesses?). Participants are classified as having a potential TBI when they respond “yes” to at least one event, at least one medical assessment option, and report two or more chronic problems.

The Alcohol Use Disorders Identification Test (AUDIT; Babor et al., 1989). The AUDIT was developed by the World Health Organization (WHO) to identify people whose alcohol consumption has become harmful to their health. The AUDIT has 10-questions, here used in self-report form (e.g., ‘*how often do you have a drink containing alcohol?*’). These questions vary in format but typically use a Likert scale; higher scores indicate more harmful consumption (0, e.g., *never*, *1 or 2,* to 4, e.g., *4 or more times per week, daily or almost daily*). Internal consistency was good in the current study, ($\alpha = .80$).

Prospective Memory Questionnaires.

Prospective and Retrospective Memory Questionnaire (PRMQ; Smith et al., 2000). The PRMQ provides a self-report measure of prospective and retrospective memory slips in everyday life. Here, we used only the PM scale, containing eight items (e.g., “*Do you forget to buy something you planned to buy, like a birthday card, when you go to the shop?*”). Participants responded on a five-point Likert scale rating how often these occurrences happen to them (*1 = Never, 5 = Very Often*). The PM subscale had good internal consistency in the current study ($\alpha = .89$).

Prospective Memory Questionnaire (PMQ, revised version ; Hannon et al., 1990 ; 1995). We used a modified version of the PMQ (Cuttler et al., 2016) because participants

have difficulties understanding the original scale (Cuttler & Taylor, 2012; Uttl & Kibreab, 2010). Participants responded to 52-items (e.g., "*I missed appointments I had scheduled*") using a Likert scale (1 = *Never,* 5 = *Very often*). They can select "not applicable" if the task does not apply (e.g., "*I forget to return books to the library by the due date*" if they do not borrow books; scored as a '0'). The scale was reliable in the current study (α = .95).

Mediator Variables.

Beliefs About Memory Questionnaire (BAMQ; Bennett & Wells, 2010). The BAMQ is used to measure metacognitive beliefs about participants' trauma memory; here we used it to measure maladaptive beliefs about memory. Participants respond to 15-statements (e.g., "*having memory blanks means there is something seriously wrong with me*") on a Likert scale (*1 = Do not agree, 4 = Agree very much*). The subscales had good internal consistency in the current study (α = .78-.89).

Cognitive Confidence Subscale of the Metacognitions Questionnaire (MCQ; Cartwright-Hatton & Wells, 1997). The MCQ consists of five subscales designed to measure beliefs about worry and intrusive thoughts. Here we used the cognitive confidence subscale to measure confidence in memory ability. Participants responded to a series of six statements (e.g., "*I have a poor memory*") on a Likert scale (*1 = Do not agree, 4 = Agree very much*). Higher scores indicate greater maladaptive beliefs (i.e., lower cognitive confidence). The cognitive confidence subscale had good reliability in the current study (α = .85).

Negative Cognitions About the Self Subscale from the Posttraumatic Cognitions Inventory (PTCI; Foa et al., 1999). The PTCI contains 36-items used to measure beliefs related to a traumatic experience. Here, we used only the negative cognitions about the self subscale. Participants rated a series of 26-statements that potentially represent their thinking (e.g., '*the event happened because of the way I reacted'*; *1 = Totally disagree, 7 = Totally agree).* This subscale had excellent reliability in the current study (α = .96).

White Bear Suppression Inventory (WBSI; Muris et al., 1996; Wegner & Zanakos, 1994). The WBSI is a self-report questionnaire used to measure people's tendency to suppress negative thoughts. Here, we used the scale to measure the maladaptive strategy of not thinking about their nominated most traumatic/stressful event. Participants responded on a 5-point scale demonstrating their agreement (*1 = Strongly disagree, 5 = Strongly agree*) with 15-statements (e.g., "*There are things I prefer not to think about*"). Thus, higher scores indicate greater suppression. The scale had good internal validity in the current study (α = .94).

Continuous Planning Scale (CPS; Prenda & Lachman, 2001). We used the CPS to measure willingness to future plan. Participants responded to five statements (e.g., "*I find it helpful to set goals for the near future*") describing how much each statement is representative of themselves (4 = *A lot*, 1 = *Not at all*). Internal validity was acceptable in the current study (α = .67).

PTSD Symptoms and Current Mental Health Comorbidity Variables.

Trauma History Screen (THS; Carlson et al., 2011) and PTSD Checklist-5 (PCL-5; Blevins et al., 2015). Participants responded Yes/No to traumatic events they may have experienced (e.g., "a really bad car, boat, train or airplane accident"). If they responded yes, they reported: how many times each event(s) occurred, if any event bothered them emotionally, and described their most traumatic experience. Participants who did not endorse any of the listed events described their "most stressful event". We used the PCL to measure self-reported PTSD symptom severity over the last month in reference to their most traumatic/stressful event. Participants rated their symptoms (e.g., "*repeated, disturbing, and unwanted memories of the stressful experience*?") on a 5-point scale (0 = *Not at all,* 4 = *Extremely*). The PCL-5 has excellent internal consistency (α = .95 in the current study).

Depression and Anxiety Symptoms (DASS-21; Lovibond & Lovibond, 1995). The DASS-21 is a 21-item measure of depression, anxiety and stress. Participants rated the degree to which each statement (e.g., "*I found it hard to wind down*") applied to them over the past week (0 = *Did not apply to me at all*, 3 = *Applied to me very much or most of the time*). Scores are totalled for each subscale and place participants in ranges of severity from normal to extremely severe. The DASS-21 had excellent internal consistency in the current study (depression, $\alpha = .92$; anxiety, $\alpha = .88$; stress, $\alpha = .88$).

Brief Inventory of Psychosocial Functioning (B-IPF; Bovin et al., 2018). The B-IPF measures everyday functioning through seven questions; one for each impairment domain in everyday life (e.g., social activities, work and education). Participants responded to how much (*0 = Not at all, 6 = Very much*) trouble they experience in each domain of functioning over the past 30 days (e.g., "*I had trouble with my family relationships*"). The B-IPF had high internal consistency in the current study ($\alpha = .72$).

Perceived Stress Scale (PSS-10; Cohen & Williamson, 1988). The PSS-10 is a shortened version of the PSS, designed to measure the degree to which an individual perceives situations in their life as stressful, over the past month. Participants responded how often (*0 = Never*, *4 = Very Often*) they felt or thought a certain way (e.g., In the last month, how often have you felt nervous and "stressed"?). The PSS-10 had good internal consistency in the current study ($\alpha = .85$).

Procedure

Participation occurred in three phases.

Phase 1. Participants first completed an online battery of questionnaires (~30-40 minutes to complete). Participants reported demographics (i.e., age, gender, highest level of education, history of developmental disorder), then responded to the historical/physical health comorbidity questionnaires (i.e., HELPS and AUDIT) presented in a randomised

order. We then presented the prospective memory questionnaires (PMQ; PRMQ) and the cognitive confidence scale (MCQ-30) as one block, in a randomised order. We presented these measures before participants completed questionnaires related to trauma because they are ostensibly unrelated to trauma and reporting a trauma could have influenced scores on these measures. Next, participants completed the trauma-related questionnaires, with trauma history and PTSD symptoms (THS and PCL-5) presented before the negative cognitions about the self and beliefs about trauma memory scales (PTCI, BAMQ in a randomised order). Finally, we presented the remaining mediator variables (i.e., continuous planning; CPS, suppression tendency; WBSI) and current mental health comorbidity variables (i.e., psychosocial functioning; B-IPF, and depression, anxiety and stress; DASS, PSS-10) as a block, in a randomised order. Participants finished by indicating the date they wanted to begin the diary phase within the next 7-days (i.e., Phase 2).

Phase 2. Participants received emailed diary instructions at 5pm the day prior to their requested start date (see supplementary materials for details). On average, participants began the diary 2.07 days after they completed Phase 1. They received the automated text message reminders three times per day (i.e., 8am, 2pm and 8pm), for four days. Participants could also self-initiate diary completion any time they realised they made an error, by clicking on the same link they received via the reminders.

Phase 3. At 9am on the day after diary completion (i.e., the fifth day), participants received a link to the post-diary survey (~5 minutes). Participants completed the compliance questions, ease of diary compliance and questions about aid use, respectively. Participants were then debriefed.

Data sorting and analysis

We began data analysis by compiling the list of errors for each participant. A coder (the third author) checked all errors to ensure that: 1) they met the definition of a PM error

(i.e., an action or task to-be-completed in the future at a designated time or in the presence of a specific cue; removed 132 total errors), 2) participants had correctly coded their errors as time- or event-based (29 errors changed; two errors not entered as time- or event-based by the participants had enough information to be coded), and, 3) all recorded errors occurred during the 4-day diary period (19 errors removed). Missing data were minimal in our Phase 1 questionnaires, but were addressed using mean replacement. One participant did not answer enough items from the BAMQ to calculate an accurate total score, so we excluded their score on this scale. One participant completed <20% of Phase 3 therefore we excluded their data from questions in this phase. In Phase 3, participants were asked to estimate the percentage of errors they recorded, out of the total errors they *actually* made; responses listing a range (e.g., 50-60%) were changed to the middle of that range so there was one data point for analysis (e.g., 55%).

Results

Population and diary characteristics

To examine the clinical prevalence of our sample and to explore the descriptive nature of participants' PM errors we first report descriptive statistics for our self-report scales (Table 4.1) and diary data. Overall, participants reported subthreshold PTSD symptoms, but 38.5% (n = 100) of participants met the cut-off score for probable PTSD (>= 31; Ashbaugh et al., 2016). Additionally, 31.5% (n = 82) of participants were in the severe or extremely severe range for depression, 46.2% (n = 120) for anxiety, and 33.8% (n = 88) for stress (Lovibond & Lovibond, 1995). On average, participants made 4.82 errors over the 4-days (SD = 2.74). We conducted some exploratory t-tests that were not pre-registered, finding that participants reported more event- (M = 3.59, SD = 2.24) than time-based errors (M = 1.23, SD = 1.36; $t(259) = -15.31$, $p < .001$, $d = -0.95$), and recorded more errors after a reminder (M = 2.48, SD = 2.04), than freely recalled errors (M = 1.80, SD = 2.04; $t(259) = 3.36$, $p < .001$, $d = 0.21$).

We next explored whether the frequency of diary-recorded errors correlated with self-report PM (see Table 4.2 for all correlations); there was a small positive correlation for both the PMQ (r = .14, 95% CI [0.02, .0.26], p = .02) and PRMQ (r = .14 [0.02, .0.26], p = .02). Time-based errors correlated with the PMQ (r = .14, [0.020, .0.26], p = .02), but not the PRMQ (r = .08, [-0.04, 0.20], p = .20); event-based errors correlated with the PRMQ (r = .13, [0.01, 0.25], p = .04) but not the PMQ (r = .09, [-0.03, 0.21], p = .17).

Table 4.1

Descriptive Statistics for All Variables

	Scale	Mean (SD)
PRMQ	8-40	23.09 (6.43)
PMQ	52-260	119.86 (28.13)
PCL Total	0-80	27.18 (18.78)
PCL Re-experiencing	0-20	6.45 (5.23)
PCL Avoidance	0-8	3.52 (2.61)
PCL Alterations in cog/mood	0-12	9.88 (7.31)
PCL Alterations in arousal	0-16	7.33 (6.15)
BAMQ Positive	8-32	14.50 (6.05)
BAMQ Negative	7-28	10.27 (3.69)
MCQ	6-24	12.29 (4.15)
PTCI Self	1-7	2.59 (1.37)
DASS Depression	0-21	7.78 (5.85)
DASS Anxiety	0-21	7.18 (5.50)
DASS Stress	0-21	9.77 (5.52)
CPS	5-20	13.55 (2.46)
WBSI	15-75	53.97 (14.71)
B-IPF	0-48	29.62 (10.41)
PSS-10	0-40	21.56 (6.71)

PRMQ = Prospective and Retrospective Memory Questionnaire; PMQ = Prospective Memory Questionnaire; PCL = Posttraumatic Stress Disorder Checklist; BAMQ = Beliefs about Memory Questionnaire; MCQ = Metacognitions Questionnaire; cognitive confidence subscale; PTCI self = Posttraumatic Cognitions Inventory; negative cognitions about the self subscale; DASS = Depression, Anxiety and Stress Questionnaire, CPS = Continuous Planning Scale; WBS = White Bear Suppression; B-IPF = Brief Inventory of Psychosocial Functioning, PSS-10 = Perceived Stress Scale.

Table 4.2. *Correlations between PTSD symptoms, self-report PM, diary-recorded PM and all other comorbidity and mediator variables.*
Note: *$p < .05$

	PM err	TB err	EB err	PRMQ	PMQ	PCL tot	PCL B	PCL C	PCL D	PCL E	BAMQ Neg	BAM Q Pos	MCQ	PTCI Self	DASS D	DASS A	DASS S	CPS	WBS	B-IPF	PSS-10
PM err	-	.58*	.87*	.14*	.14*	.21*	.25*	.18*	.16*	.16*	.20*	.06	.14*	.13*	.08	.09	.15*	-.03	.10	.08	.07
TB err	-	-	.10	.08	.14*	.29*	.32*	.22*	.23*	.24*	.20*	.07	.11	.14*	.14*	.14*	.19*	<.001	.14*	.07	.12
EB err			-	.13*	.09	.08	.11	.09	.05	.05	.13*	.03	.11	.07	.01	.03	.07	-.03	.04	.05	.02
PRMQ				-	.77*	.34*	.20*	.21*	.33*	.38*	.20*	.18*	.62*	.38*	.41*	.37*	.42*	.34*	.39*	.40*	.45*
PMQ					-	.34*	.25*	.27*	.31*	.35*	.27*	.16*	.61*	.30*	.29*	.39*	.39*	.17*	.35*	.28*	.38*
PCL Total						-	.86*	.75*	.92*	.91*	.47*	.35*	.27*	.64*	.60*	.57*	.60*	.17*	.55*	.46*	.53*
PCL B							-	.67*	.67*	.69*	.37*	.29*	.13*	.42*	.40*	.42*	.43*	.04	.40*	.28*	.37*
PCL C								-	.61*	.56*	.36*	.30*	.15*	.37*	.37*	.37*	.38*	.08	.46*	.29*	.38*
PCL D									-	.80*	.46*	.35*	.30*	.68*	.61*	.57*	.57*	.21*	.55*	.46*	.49*
PCL E										-	.42*	.29*	.28*	.62*	.61*	.56*	.61*	.20*	.49*	.48*	.55*
BAMQ Neg											-	.47*	.23*	.54*	.28*	.32*	.33*	.12*	.32*	.27*	.30*
BAMQ Pos												-	.18*	.44*	.27*	.23*	.23*	.09	.24*	.23*	.24*
MCQ													-	.35*	.35*	.35*	.36*	.23*	.30*	.32*	.36*
PTCI Self														-	.62*	.53*	.56*	.33*	.56*	.54*	.59*
DASS D															-	.70*	.71*	.38*	.59*	.58*	.70*
DASS A																-	.78*	.26*	.57*	.40*	.64*
DASS S																	-	.27*	.59*	.51*	.74*
CPS																		-	.28*	.21*	.33*
WBS																			-	.40*	.66*
B-IPF																				-	.55*
PSS-10																					-

PTSD symptoms and prospective memory failures

Now we turn to our primary research question: are PTSD symptoms correlated with everyday *diary-recorded* PM failures? Simple correlational analyses revealed that total diary-recorded PM failures positively correlated with PTSD symptom severity, with a small effect size (r = .21, 95% CI [0.09, 0.32], p < .001). Consistent with our hypothesis that the relationship would be larger for time- than event-based failures—because time-based tasks rely more on executive functions often impaired in PTSD—time-based PM failures were correlated with PTSD symptom severity (r = .29, [0.18, 0.40], p < .001), but event-based PM failures were not (r = .08, [-0.04, 0.20], p = .18); this difference was statistically significant, $t(257) = 3.52$, p = .001. Total failures also correlated with each PTSD symptom subscale (Table 4.2)[11]

To address the possibility that the PM-PTSD relationship arises because of pre-existing vulnerability factors, we pre-registered to regress diary-recorded PM failures on these variables. However, alcohol dependency (r = -.11, 95% CI [-0.012, -.229], p = .08) and childhood trauma (r = .05, [-0.07, 0.17], p = .45) did not correlate with diary-recorded PM failures, therefore we ran the regression controlling only for possible TBI and presence of a learning disorder. We entered possible TBI (b = .13, p = .04) and presence of a learning disorder (b = .18, p = .06) simultaneously in Step 1. Together, these variables explained 5.0% variance in diary-recorded PM errors, R^2 = .05, $F(2, 257) = 6.69$, p = .001. In Step 2, we entered PTSD symptoms (b = .16, p =.01), which explained a significant additional 2.5% of the variance in diary-recorded failures, $R^2change$ = .03, $Fchange(1, 256) = 7.02$, p =.01. Therefore, even after controlling for physical comorbidities that might account for the PM-PTSD relationship, PTSD symptoms were a significant predictor of diary-recorded PM errors

[11] For all following analyses we report only total diary-recorded PM errors as the main outcome variable. Separate analyses for time- and event-based PM appear in our supplementary materials.

Next, to test the idea that depression, anxiety and stress might contribute to the PM-PTSD relationship, we pre-registered hierarchical regressions controlling for these variables, and diary-recorded failures. However, depression (r = .08, 95% CI [-0.04, 0.20], p = .22), and anxiety (r = .09, [-0.03, 0.21], p = .14) did not correlate with diary-recorded PM errors, therefore we ran the regression only for stress. Stress, over the past week (i.e., DASS stress scores; b = .04, p = .64)—entered at Step 1—explained 2.2% of the variance in diary-recorded PM failures, R^2 = .02, $F(1, 258) = 5.79$, p = .02. At Step 2, PTSD symptoms explained a small but significant additional 2.3% of the variance in failures, $R^2change$ = .02, $Fchange(1, 257) = 7.21$, p = .01, b = .19. Therefore, PTSD symptoms remained the strongest predictor of diary-recorded PM failures. Previous research (Swain & Takarangi, 2021; 2022) suggests that stress (i.e., measured by the DASS) might be a key mediator in the PM-PTSD relationship.

We next explored our two secondary interests. First, we aimed to explore whether PTSD symptoms affect everyday functioning via PM performance[12]. However, psychosocial functioning did *not* correlate with diary-recorded PM failures (r = .08, [-0.04, 0.20], p = .20), therefore we did not proceed with this analysis. Second, to explore whether PTSD symptoms explain unique variance in PM errors when controlling for chronic everyday stress over the past month (i.e., the PSS-10), we pre-registered another hierarchical regression. However, everyday stress did not correlate with diary-recorded PM failures (r = .07, [-0.05, 0.19], p = .12), so we did not proceed with this analysis.

To test the idea—based on previous research (Swain & Takarangi, 2021; 2022)—that the PM-PTSD relationship might be explained via metacognitive beliefs and maladaptive strategies, we planned a series of mediated regressions with diary-recorded errors as the outcome variable. However, diary-recorded PM errors did not correlate with positive beliefs

[12] For the analyses with psychosocial functioning and *self-report* prospective memory, please see supplementary file.

about memory, willingness to future plan, or suppression tendency; therefore we ran these regressions for only cognitive confidence, negative beliefs about memory, and negative cognitions about the self. We used a Bonferroni-corrected alpha of 0.017 to correct for multiple tests (0.05/3). PTSD symptom severity was a significant predictor of diary-recorded PM at Step 1, explaining 4.4% of the variance in errors, $R^2 = .05$, $F(1, 258) = 11.81$, $p < .001$. Beginning with cognitive confidence, at Step 1, this variable explained a non-significant 2.0% of the variance in diary-recorded errors, $R^2 = .02$, $F(1, 258) = 5.30$, $p = .02$, therefore we did not proceed with Step 2. For negative beliefs about memory, at Step 1, this variable explained 4.1% of the variance in diary-recorded errors, $R^2 = .04$, $F(1, 258) = 11.06$, $p = .001$. At Step 2, PTSD symptoms explained a non-significant additional 1.7% variance in diary-recorded errors, $R^2change = .02$, $Fchange(1, 257) = 4.55$, $p = .03$. When entering these variables together, neither beta value was significant in predicting diary-recorded errors (negative beliefs about memory, $b = .13$, $p = .05$; PTSD symptoms, $b = .15$, $p = .03$). For negative cognitions about the self, at Step 1, this variable explained a non-significant 1.7% of the variance in diary-recorded errors, $R^2 = .02$, $F(1, 258) = 4.40$, $p = .037$, therefore we did not proceed with Step 2. Altogether, we did *not* find that maladaptive appraisals and strategies mediated the PM-PTSD relationship when PM was measured via diary-recording.

However, we did replicate our findings that negative metacognitive beliefs and maladaptive strategies mediated the relationship between *self-report* prospective memory and PTSD symptoms (see supplementary file for full statistical analyses). For both the PMQ and the PRMQ, all mediators significantly explained additional variance in scores. Cognitive confidence, negative cognitions about the self and suppression tendency seemed to be the most important mediators for *self-report* PM. In summary then, although prior research and our findings here suggest that the *self-report* PM-PTSD relationship is mediated by maladaptive appraisals and strategies (Swain & Takarangi, 2021; 2022), we did not find this

relationship for diary-recorded PM errors. In fact, diary-recorded errors correlated only with the self-related variables (i.e., negative cognitions about the self, cognitive confidence). Negative beliefs about trauma memory was the only variable that mediated the PM-PTSD relationship for diary-recorded PM, but neither these beliefs nor PTSD symptoms uniquely predicted diary-recorded PM failures. Thus, the PM-PTSD relationship, when measured via diary-recording is *not* explained by metacognitive beliefs and maladaptive strategies.

Diary compliance

Because we found that people with worse PTSD symptom severity also reported more everyday PM errors, we wondered if they also complied more poorly with the diary-recording task (i.e., reported recording a lower % of forgetting out of ALL their forgetting over the diary-period)[13]—a PM task. Indeed, people with worse PTSD symptoms estimated they recorded *fewer* errors than they actually made, indicating poorer compliance with the diary-recording task. Put differently, the percentage of errors participants believed they successfully recorded negatively correlated with PTSD symptoms (r = -.19, 95% CI [0.070, 0.31], p = .003). To explore whether worse PM performance was attributed to lesser use of memory aids, we correlated the frequency that people reported using aids, with PTSD symptom severity. Aid use in the whole sample did not correlate with PTSD symptoms (r = -.05, [-0.07, 0.17], p = .39). Of those who *did* report using aids, (i.e., n = 111), *frequency* of their aid use was also not correlated with diary-recorded errors (r = .07, [-0.05, 0.19], p = .47), or PTSD symptoms (r = .06, [-0.06, 0.18], p = .55).

Discussion

Overall, our key finding was replication of the PM-PTSD relationship, for both self-report PM—as measured by the PMQ and the PRMQ—*and* using naturalistic diary-recording; participants who recorded more PM errors over a 4-day period also reported worse

[13] We excluded one person who recorded their percentage as "I have no idea", thus, N = 259.

PTSD symptom severity. Interestingly, the correlation was significantly smaller for diary-recorded errors (r = .21), than for self-report questionnaires (i.e., PMQ and PRMQ; rs = .34), $t(257) = -2.21$, $p = .03$. Participants made more event-based than time-based PM errors, but only time-based errors significantly correlated with PTSD symptom severity. *Inconsistent* with our prior research (Swain & Takarangi, 2021; 2022), metacognitive beliefs and maladaptive strategies did *not* contribute to the relationship between PTSD symptoms and *diary-recorded* PM, though they continued to explain the relationship with *self-report* PM. Thus, perhaps there is a true, albeit small, relationship between PTSD symptoms and everyday PM, but on self-report measures, people's negative beliefs about themselves and their memory *exaggerate* the size of this relationship.

Our first key finding was that PTSD symptom severity correlated with diary-recorded PM errors, in addition to self-report PM, in a general population. By contrast, the PM-PTSD relationship does not exist when PM is measured via objective, in-lab tasks (i.e., pressing a certain key after a specified time-period, or when particular words appear). Two lines of thought might explain this pattern.

First, perhaps lab-based PM tasks measure a "peak" or "best" performance (e.g., Chaytor & Schmitter-Edgecombe, 2003), rather than typical, everyday performance. Instead, more naturalistic measurement—that captures everyday errors (e.g., forgetting to stop at the shops, or phone a friend), and reflects everyday environments, such as *both* self-report or diary-recording—may be more representative and generalisable.

Second, both self-report measurement and diary-recording likely reflect biased beliefs, in addition to actual PM performance. However, although both our analyses here, and in prior research (Swain & Takarangi, 2021; 2022), demonstrate that the self-report PM-PTSD relationship is mediated by maladaptive beliefs and appraisals—specifically cognitive confidence, negative beliefs about memory, suppression tendency and negative cognitions

about the self—these same beliefs did *not* contribute to diary-recorded errors. Thus, despite diary-recording and self-report measures overlapping in their relevance to everyday PM tasks and task environments, negative metacognitive beliefs seem tied specifically to *self-report* PM questionnaires. However, an interesting alternative possibility is that diary-recording is biased by metacognitive judgements (e.g., of emotion) that occur in real-time, as participants experience and/or report on their PM errors, rather than by *existing* and more general beliefs, which we measured *before* the diary-period. To explore this possibility, we examined whether participants with worse PTSD symptoms judged the characteristics of their diary-recorded errors—specifically, judgments of their mood, and stress, and the seriousness of their lapses—differently to participants with less severe symptoms. Indeed, participants reporting worse PTSD symptom severity reported more negative mood (r = -.15, 95% CI [-0.27, -0.03], p = .01), and greater stress (r = .28, [0.16, 0.39], p < .001), and reported that their errors were more serious (r = .22, [0.10, 0.33], p < .001). Of course, we cannot verify whether people with worse PTSD symptoms truly experienced higher stress, poorer mood, and/or greater seriousness of their errors, but we could hypothesise that these people *judged* these experiences as worse in real-time. Future research could manipulate and measure mood, or stress (see Piefke & Glienke, 2017 for review), before a PM task or diary-recording period to examine whether people with worse PTSD symptoms are in a more negative mood, or more stressed, or just *judge* that they are. Thus, it seems likely diary-recording might be biased by real-time metacognitive judgments (e.g., of emotion)—but not by general metacognitive beliefs (e.g., "I am a weak person")—instead of reflecting actual PM performance alone.

Another way diary-recording might be biased is by participants' *perception* of their reported errors. Diary-recording requires participants to *notice* the error, *acknowledge* it was an error, and subsequently to *record* that error. In the same way that people with PTSD pay

greater attention to, and have enhanced memory for, negative stimuli (e.g., Durand et al., 2019), perhaps for diary-recording, people with worse PTSD symptoms pay more attention to their PM *failures* and therefore report more errors. This increased attention might work as a confirmation bias—seeking or interpreting evidence that confirms pre-existing beliefs/expectations (e.g., Nickerson, 1998). That is, if people with worse PTSD symptoms perceive they are in a more negative mood, or are more stressed, as our data suggest, they might misinterpret or pay greater attention to PM errors that confirm these perceptions. Our data support this idea; people with worse PTSD symptoms estimated recording fewer of their total errors over the diary-period, judging they made a high number of errors, even without evidence. Future research could use a type of cognitive bias modification (e.g., Hoppitt et al., 2010) to educate participants about negative metacognitive biases, to eliminate biases in reporting. Altogether then, it is possible a small relationship exists between PM and PTSD when PM is measured by everyday tasks but not lab-based tasks, because lab-based tasks are not ecologically valid. Alternatively, it is also possible that lab-based tasks are a "pure" assessment of PM and both diary-recording and self-report PM incorporate metacognitive beliefs and biases in how people perceive their errors.

Our next key finding is that only time-, not event-based PM errors, correlated with PTSD symptom severity. This finding is consistent with Scott et al. (2016), who found that veterans with combat-exposure, regardless of PTSD status, performed similarly on event-based tasks, but those with PTSD demonstrated impaired time-based PM. Yet, other research finds combat-exposed veterans with PTSD perform worse on event-based *and* time-based tasks when compared to non-veteran (Glienke et al., 2017), or non-combat, veteran control groups (Pagulayan et al. 2018), without PTSD. Perhaps then combat-stress specifically impairs *both* time- and event-based tasks (e.g., via brain injury or general cognitive deficits), whereas, PTSD symptoms impair time-based PM (e.g., due to cognitive resources occupied

in symptom management, e.g., Aupperele et al., 2012; Scott et al., 2016). Therefore, trauma type (i.e., combat-stress) likely complicates the PM-PTSD relationship resulting in inconsistent findings.

The finding that time-based, but not event-based failures correlated with PTSD symptom severity provides insight into which PM processes might be impaired amongst people with worse PTSD symptoms. According to the multiprocess framework (McDaniel & Einstein, 2000), PM tasks involve automatic (i.e., a bottom-up process involving spontaneous retrieval without ongoing monitoring) or controlled (i.e., a top-down memory function involving active maintenance, while scanning for cues; McDaniel & Einstein, 2000; Piefke & Glienke, 2017) cognitive processes. Typically, time-based tasks rely more on controlled processes which rely heavily on executive function (Yang et al., 2015). Thus, these controlled or higher-order executive functioning processes seem impaired in the everyday life of people with PTSD, compared to their automatic counterparts.

We reported the exploratory finding that participants reported more event-based, than time-based, PM errors. In the general PM literature, time-based tasks are considered more difficult—they require people to monitor and self-initiate performance without external cues (e.g., McDaniel & Einstein, 2002)—than event-based tasks. Therefore, in-lab, event-based PM typically appears superior to time-based performance (e.g., Haines et al., 2020, Jäger & Kliegel, 2008). However, recent research suggests this event-based superiority reverses in real-life situations; people perform time-based tasks better (Wojcik et al., 2021). In everyday life, time-based tasks allow for greater aid use—e.g., assigning an electronic reminder to take medication at 9am, or a calendar event for a 4pm meeting. And, a time of day (e.g., 9am) is a more distinct reminder than ambiguous time periods for lab-based tasks (e.g., every 2-minutes; Kliegel et al., 2008). There are also a number of alternative explanations for higher event-based errors resulting from us measuring only intention *execution*, not planned

intentions. Perhaps people: complete more everyday event-based, rather than time-based tasks, leaving greater opportunity for errors, or, were more likely to forget to record, or fail to realise time-based errors, compared to event-based errors. Thus, future research should aim to measure planned *and* executed intentions (e.g., actual week; Rendell & Craik, 2000).

Our research has limitations. First, we used a general population to explore a clinical issue. However, this sample compared to similar research using a general population (i.e., Swain & Takarangi, 2021; 2022) reported higher scores on clinical symptom scales. In fact, 38.5% of our sample met the cut-off score for a probable PTSD diagnosis[14], 31.5% were in the severe/extremely severe ranges for depression, 46.2% for anxiety, and 33.8% for stress. Therefore, we believe this sample presents with a meaningful level of mood and stress symptoms to explore different symptom severity levels and PM, but future research could explore this relationship among clinical populations. Second, and importantly, the diary task here was in itself a PM task. Generally, without a cue to trigger participants they forgot—e.g., realising you forgot to buy milk when making cereal—they might not realise, and subsequently not record such errors. If people with PTSD symptoms have PM difficulties, as our findings suggest, our methodology might not have captured all errors among participants with worse symptoms. To mitigate this issue, we used diary reminders and found that the relationship with PTSD symptom severity and errors recorded after a reminder (r = .14, p = .02) or after recording a prior error (r = .18, p = .004) was larger than for freely recalled errors (i.e., not after prompting, r = .06, p = .37), which was not statistically significant. These results suggest that without prompting, people with worse PTSD symptoms may not have noticed all their errors. Thus, due to using only three reminders per day we may still have underestimated total errors. Third, this methodology relied on participants engaging effortfully and understanding definitions we provided (e.g., of PM). To mitigate these issues,

[14] Compared to 22.8% (Swain & Takarangi, 2021) and 29.1% (Swain & Takarangi, 2022).

we: removed participants who recalled less than two errors over the 4-days (Laughland & Kvavilashvili, 2018), and removed errors that did not fit the definition of a PM error. This strategy resulted in removing 132 recorded errors (9.5% of all recorded errors), suggesting some confusion regarding definitions of PM. Future research would benefit from exploring researcher-dictated PM tasks that are consistent with participants' daily life and priorities, in real-life environments (e.g., actual week; Rendell & Craik, 2000), to preserve experimental control whilst maintaining the representativeness and generalisability of PM tasks, and the experimental environment.

Conclusions

Overall, our data suggest that self-reported and diary-recorded PM errors—specifically *time-based,* not event-based—correlate with PTSD symptom severity. It seems likely a small correlation exists between everyday PM failures and PTSD symptoms, and this relationship is *exaggerated* for self-report PM. This exaggeration might arise from metacognitive beliefs—e.g., cognitive confidence—that contribute to the relationship with self-report, but not diary-recorded, PM. Therefore, given the different findings based on measurement type, future research should combine different assessment methods to better understand PM impairment for people with PTSD, and generally within the PM field. Continued research would allow us to ultimately assist people with PTSD in attending appointments, taking their medication, connecting with social supports, or simply altering negative beliefs, to avoid symptom maintenance or worsening.

Supplementary Materials

Diary instructions

Thank you for your participation so far in our study *Forgetting in everyday life.*
As you would be aware, the next phase of the study involves keeping an at-home diary for 4 consecutive days. You are starting your diary XXXXX. The diary for you to complete is **online** and is collected via two methods:

1. You will be reminded at three time points each day via a **text message** to record any forgetting instances you might have had since your last recording. Each text message will include the link to the online diary.
2. You can also self-initiate the recording of your forgetting when you realise either by clicking the **link in this email** (below) yourself. Or by clicking the link in any one of the text messages at any time.

Each time you forget to do a task you had previously planned, we would like you to record the details in this diary. It is important you complete this diary ***as soon as possible*** after the forgetting happened, or when you get your closest reminder message. The details you must record include the day, time, what happened, any consequences as a result of your forgetting and some questions about your mood before and after. We would also like you to record whether your instance of forgetting was "time-based" or "event-based".

Time-based errors involve forgetting to complete a task at a specified time, or after a given period of time. Examples include:

- Forgetting to feed your pet at 6pm
- Forgetting to attend a meeting at 11am
- Forget to take medication every 2 hours
- Forgetting to take your dinner out the oven after 30 minutes

Event-based errors involve forgetting to complete a task when a specific event occurs in your environment, or when a specific cue appears. Examples include:

- Forget to take medication with breakfast
- Forget to turn the heater off when you go to bed
- Forgetting to stop at the shops and pick up milk on your way home
- Forget to message your friend on their birthday

The link to your survey is: XXXXXX

You can click on this link at any point when you realise you have forgotten to do something, or it will be sent to you at three time points to remind you to complete it.

It's important you do not change your performance for the purpose of this study. We want an accurate picture of your *typical* forgetting behaviours. That is, avoid using any extra reminders, alarms or lists, just go about your normal behaviour.
At the end of the 4-days you will be sent a final survey to complete.

If you have any questions along the way, please contact XXXX.

Diary Questions

When did you have a memory error? Date: _____ Time: _____ AM/PM
Or when did you realise you made an error?

When did you record it here? Date: _____ Time: _____ AM/PM

Describe your memory error:
What it was:

What you were doing:

Where you were:

As a reminder:
Time-based errors involve forgetting to complete a task at a specified time, or after a given period of time. Examples include:
- Forgetting to feed your pet at 6pm
- Forgetting to attend a meeting at 11am
- Forget to take medication every 2 hours
- Forgetting to take your dinner out the oven after 30 minutes

Event-based errors involve forgetting to complete a task when a specific event occurs in your environment, or when a specific cue appears. Examples include:
- Forget to take medication with breakfast
- Forget to turn the heater off when you go to bed
- Forgetting to stop at the shops and pick up milk on your way home
- Forget to message your friend on their birthday

Was the error: **time-based ☐** **or** **event-based ☐?**

What was your mood immediately before the error?

☐	☐	☐	☐	☐	☐
Very unhappy		Neutral		Very happy	Don't Know

How relaxed or stressed were you immediately before the error?

☐	☐	☐	☐	☐	☐
Very relaxed		Neutral		Very stressed	Don't Know

How serious was the memory lapse?

☐	☐	☐	☐	☐
Insignificant	Minor	Somewhat significant	Significant	Very significant / potentially dangerous

Time-based and event-based PM analyses for key variables

We pre-registered to run our key analyses separately for both time- and event-based diary recorded prospective memory. However, because event-based prospective memory did not correlate with PTSD symptoms (r = .08, 95% CI [-0.04, 0.20], p = .19) we proceeded only with the analyses for *time-based* diary-recorded prospective memory failures. To address the possibility that the relationship between PTSD symptom severity and prospective memory arises because of pre-existing vulnerability factors, we pre-registered to regress *time-based* diary-recorded prospective memory failures on these variables. However, alcohol dependency (r = .02, [-0.01, 0.14], p = .79) childhood trauma (r = .08, [-0.04, 0.20], p = .17), and possible TBI (r = .07, [-0.05, 0.19], p = .25) did not correlate with *time-based* diary-recorded prospective memory failures, therefore we ran the regression controlling only for possible presence of a learning disorder. We entered presence of a learning disorder (b = .09, p = .13) in Step 1. This variable explained 2.1% variance in *time-based* diary-recorded prospective memory errors, R^2 = .02, $F(2, 257) = 5.42$, p = .02. In Step 2, we entered PTSD symptom severity (b = .27, $p < .001$), which explained a significant additional 7.0% of the variance in total failures, $R^2change$ = .07, $Fchange(1, 256) = 19.82$, $p < .001$. Therefore, even after controlling for physical comorbidities that might account for the relationship between prospective memory and PTSD symptoms, PTSD symptom severity was a significant predictor of *time-based* diary-recorded prospective memory errors.

Next, to test the idea that depression, anxiety and stress might contribute to the relationship between *time-based* prospective memory and PTSD symptoms, we ran hierarchical regressions controlling for these variables. Depression (b = -.08, p = .38), anxiety (b = -.06, p = .54), and stress (b = .11, p = .30), over the past week—entered at Step 1—explained 3.5% of the variance in *time-based* diary-recorded prospective memory failures, R^2 = .04, $F(3, 256) = 3.07$, p = .03. At Step 2, PTSD symptoms explained a significant

additional 5.4% of the variance in *time-based* failures, $R^2change$ = .05, *Fchange*(1, 255) = 15.03, $p < .001$, $b = .31$. Therefore, PTSD symptoms remained the strongest predictor of *time-based* diary-recorded prospective memory failures. Previous research (Swain & Takarangi, 2021; 2022) suggested that stress (i.e., over the past week) might be a key mediator in the relationship between prospective memory and PTSD symptoms. To explore whether PTSD symptoms explain unique variance in prospective memory errors when controlling for chronic everyday stress over the past month (i.e., scores on the PSS-10), we pre-registered another hierarchical regression controlling specifically for this variable. However, everyday stress did not correlate with *time-based* diary-recorded prospective memory failures ($r = .12$, [-0.002, 0.24], $p = .06$), so we did not proceed with this analysis.

As a secondary interest, we wanted to explore whether PTSD symptoms affect everyday functioning via prospective memory performance. However, psychosocial functioning did *not* correlate with *time-based* diary-recorded prospective memory failures ($r = .07$, [-0.05, 0.19], $p = .23$), therefore we did not proceed with this analysis.

To test the idea—based on previous research (Swain & Takarangi, 2021; 2022)—that the relationship between PTSD and prospective memory might be explained via metacognitive beliefs and maladaptive strategies, we planned to run a series of mediated regressions with *time-based* diary-recorded errors as the outcome variable. However, *time-based* diary-recorded prospective memory errors did not correlate with cognitive confidence, positive beliefs about memory or tendency to future plan therefore we continued the regression controlling only for negative beliefs about memory, negative cognitions about the self and suppression tendency. We used a Bonferroni corrected alpha of 0.017 to correct for multiple tests (0.05/3). PTSD symptom severity was a significant predictor of *time-based* diary-recorded prospective memory at Step 1, explaining 8.3% of the variance in errors, $R^2 = .08$, $F(1, 258) = 23.20$, $p < .001$. At Step 2, negative beliefs about memory (0.5% variance,

$R^2change$ = .005, $Fchange$(1, 257) = 1.29, p =.26, b = .08), negative cognitions about the self (0.3% variance, $R^2change$ = .003, $Fchange$(1, 257) = 0.88, p = .35, b = -.07), and suppression tendency (<0.01% variance, $R^2change$ < .001, $Fchange$(1, 257) = .09, p = .76, b = -.02) did not explain significant additional variance.

Self-report PM, PTSD and mediator variables

To test the idea that the relationship between PTSD and self-report PM might be explained by PTSD *causing* maladaptive appraisals and strategies, and to replicate the finding that negative metacognitive beliefs and maladaptive strategies mediated the relationship between *self-report* prospective memory and PTSD symptoms. we ran a series of mediated regressions. We used a Bonferroni corrected alpha of 0.005 to correct for multiple tests (0.05/5). For the PMQ, PTSD symptom severity was a significant predictor of scores, explaining 11.7% of the variance in PMQ scores, $R^2 = .12$, $F(1, 258) = 34.12$, $p < .001$ (refer to Table 1 for all statistics). Beginning with cognitive confidence, at Step 1, this variable explained 37.3% of the variance in PMQ scores, but at Step 2, PTSD symptoms explained an additional 3.5% of the variance in PMQ scores. However, based on the beta values, cognitive confidence was a greater predictor of scores than PTSD symptoms. For beliefs about memory, these variables explained 7.3% of the variance in PMQ scores in Step 1. At Step 2, PTSD symptom severity explained an additional 5.8% variance in scores. Based on the beta values, PTSD symptom severity was a better predictor of PMQ scores than were positive and negative beliefs about memory. For negative cognitions about the self, at Step 1, these beliefs explained 9.3% of the variance in PMQ scores. At Step 2, PTSD symptom severity explained an additional 3.6% variance in PMQ scores. Based on the beta scores, PTSD symptoms were a better predictor of PMQ scores than were negative beliefs about the self. For willingness to future plan, at Step 1, this variable explained 2.8% of the variance in PMQ scores. At Step 2, PTSD symptom severity explained an additional 10.1% variance in PMQ scores. Based on the beta scores, PTSD symptoms were a greater predictor of PMQ scores than willingness to future plan. Finally, for suppression tendency, at Step 1, this variable explained 12.1% of the variance in PMQ scores. At Step 2, PTSD symptom severity explained an additional 3.3%

variance in PMQ scores. Based on the beta scores, suppression tendency and PTSD symptoms were similar predictors of PMQ scores.

Supplementary table 1: Inferential statistics from regression analyses on PTSD and PMQ with maladaptive strategies and negative appraisals as mediators

Cognitive confidence	*b*	Variance explained (%)	R^2	R^2_{change}	*F*	F_{change}	*df*	*p*
1. MCQ-30	.61	37.3	.37		153.38		1, 258	< .001
2. MCQ-30	.56	40.8		.04		15.09	1, 257	< .001
PCL-5 (PTSD symptoms)	.19							
Beliefs about memory								
1. BAMQ - Positive	.05	7.3	.07		10.18		2, 257	< .001
BAMQ - Negative	.25							
2. BAMQ - Positive	-	13.2		.06		17.17	1, 256	< .001
BAMQ - Negative	.003							
PCL-5 (PTSD symptoms)	.14							
	.28							
Negative cognitions about the self								
1. PTCI – Negative cognitions about the self	.30	9.3	.09		26.22		1, 257	< .001
2. PTCI – Negative cognitions about the self	.15	12.8		.04		10.47	1, 256	.001
PCL-5 (PTSD symptoms)	.25							
Willingness to future plan								
1. CPS	.17	2.8	.03		7.49		1, 258	.007
2. CPS	.11	12.9		.10		29.84	1, 257	< .001
PCL-5 (PTSD symptoms)	.32							
Suppression tendency								
1. WBSI	.35	12.1	.12		35.56		1, 258	< .001
2. WBSI	.23	15.4		.03		9.88	1, 257	.002
PCL-5 (PTSD symptoms)	.22							

Note: numbers refer to the step of the hierarchical regression (i.e., 1. Means step 1, and 2. Means step 2).
PCL-5 = Posttraumatic Stress Disorder Checklist; BAMQ = Beliefs about Memory Questionnaire; MCQ = Metacognitions Questionnaire; cognitive confidence subscale; PTCI self = Posttraumatic Cognitions Inventory; negative cognitions about the self subscale; DASS = Depression, Anxiety and Stress Questionnaire, CPS = Continuous Planning Scale; WBS = White Bear Suppression

For the PRMQ, PTSD symptom severity was a significant predictor of PM, explaining 11.5% of the variance in PRMQ scores, $R^2 = .12$, $F(1, 258) = 33.67$, $p < .001$ (refer to Table 2 for all statistics). Beginning with cognitive confidence, at Step 1, this variable explained 38.2% of the variance in PRMQ scores, but at Step 2, PTSD symptoms explained an additional 3.3% of the variance in PRMQ scores. Based on the beta values, and consistent with results for the PMQ, cognitive confidence was a greater predictor of PRMQ scores than PTSD symptoms. For beliefs about memory, these variables explained 4.9% of the variance in PRMQ scores in Step 1. At Step 2, PTSD symptom severity explained an additional 7.1% variance in scores. Based on the beta values, PTSD symptom severity was a better predictor of PRMQ scores than were negative beliefs about memory. For negative cognitions about the self, at Step 1, these beliefs explained 14.3% of the variance in PRMQ scores. At Step 2, PTSD symptom severity explained a small but additional 1.6% variance in PRMQ scores. Based on the beta scores, negative cognitions about the self were a better predictor of PRMQ scores than PTSD symptoms. For willingness to future plan, at Step 1, this variable explained 11.7% of the variance in PRMQ scores. At Step 2, PTSD symptom severity explained an additional 8.2% variance in PRMQ scores. Based on the beta scores, PTSD symptoms and willingness to future plan were equal predictors of PRMQ scores. Finally for suppression tendency, at Step 1, this variable explained 14.9% of the variance in PRMQ scores. At Step 2, PTSD symptom severity explained an additional 2.3% variance in PRMQ scores. And, suppression tendency was actually a greater predictor of PRMQ scores than PTSD symptoms.

Supplementary table 2: Inferential statistics from regression analyses on PTSD and PRMQ with maladaptive strategies and negative appraisals as mediators

Cognitive confidence	*b*	Variance explained (%)	R^2	R^2_{change}	*F*	F_{change}	*df*	*p*
1. MCQ-30	.62	38.2	.38		159.15		1, 258	< .001
2. MCQ-30	.57	41.5		.03		14.63	1, 257	< .001
PCL-5 (PTSD symptoms)	.19							
Beliefs about memory								
1. BAMQ - Positive	.11	4.9	.05		6.59		2, 257	.002
BAMQ - Negative	.14							
2. BAMQ - Positive	.06	12.0		.07		120.73	1, 256	< .001
BAMQ - Negative	.02							
PCL-5 (PTSD symptoms)	.31							
Negative cognitions about the self								
1. PTCI – Negative cognitions about the self	.38	14.3	.14		43.00		1, 257	< .001
2. PTCI – Negative cognitions about the self	.27	15.9		.02		4.81	1, 256	.029
PCL-5 (PTSD symptoms)	.16							
Willingness to future plan								
1. CPS	.34	11.7	.12		34.07		1, 258	< .001
2. CPS	.29	19.9		.08		26.27	1, 257	< .001
PCL-5 (PTSD symptoms)	.29							
Suppression tendency								
1. WBSI	.39	14.9	.15		45.33		1, 258	< .001
2. WBSI	.29	17.3		.02		7.25	1, 257	.008
PCL-5 (PTSD symptoms)	.18							

Note: numbers refer to the step of the hierarchical regression (i.e., 1. Means step 1, and 2. Means step 2).
PCL-5 = Posttraumatic Stress Disorder Checklist; BAMQ = Beliefs about Memory Questionnaire; MCQ = Metacognitions Questionnaire; cognitive confidence subscale; PTCI self = Posttraumatic Cognitions Inventory; negative cognitions about the self subscale; DASS = Depression, Anxiety and Stress Questionnaire, CPS = Continuous Planning Scale; WBS = White Bear Suppression

Self-report PM, PTSD and psychosocial functioning

Regarding our secondary interest in psychosocial functioning, we repeated correlational and regression analyses but with *self-report* prospective memory as the outcome variable. Impairment did correlate with self-report prospective memory (PMQ: $r = .14$, 95% CI [0.020, .0.26], $p = .02$, PRMQ: $r = .14$, [0.020, .0.26], $p = .02$). Therefore, we ran a mediated regression to explore whether PTSD symptoms contribute to greater prospective memory errors, which then result in greater everyday impairment. At Step 1, PTSD symptom severity explained 20.7% of the variance in functional impairment scores, $R^2 = .21$, $F(1, 258) = 67.24$, $p < .001$, $b = .41$. At Step 2, PMQ scores ($b = .14$, $p = .02$) uniquely predicted impairment and explained a small but additional 1.7% of the variance in everyday impairment, $R^2change = .02$, $Fchange(1, 257) = 5.63$, $p = .02$. Similarly for the PRMQ, at Step 2, PRMQ scores explained an additional 6.7% variance in functioning, $R^2change = .07$, $Fchange(1, 257) = 23.80$, $p < .001$. As for the PMQ, at Step 2, PRMQ scores ($b = .28$, $p < .001$) were a lesser predictor of impairment than PTSD symptoms ($b = .36$, $p < .001$). Therefore, although self-report prospective memory seems related to self-report impairment, PTSD symptom severity remained a greater predictor of impairment scores.

Chapter 5: Self-report prospective memory is malleable based on negative appraisals of ability[15]

Author contributions: I developed the study design with the guidance of MKTT. I collected the data, cleaned the data for analysis, and performed the data analysis and interpretation. I drafted the manuscript and MKTT provided critical revisions. MKTT approved the final version of the manuscript for submission.

Abstract

Research finds a general dissociation between people's predictions of *prospective memory*—memory for future intentions (Loftus, 1971)—and their actual prospective memory performance (e.g., remembering to press a specific key when certain words appear; e.g., Uttl & Kibreab, 2011). This dissociation suggests that self-report prospective memory measures might be biased in some way (e.g., by metacognitive beliefs). Therefore, we wondered whether we could manipulate the way people self-report on their prospective memory, based on how they *appraise* their ability. Across two experiments, we used a variation on an Ease of Retrieval paradigm (e.g., Schwarz, 1988): participants recalled either two, or 10, instances of forgetting (i.e., prospective memory failures) over the past week. Participants recalling two instances self-reported making fewer prospective memory errors (on a self-report prospective memory questionnaire), compared to those recalling 10. As a secondary interest—given research suggests negative metacognitive beliefs in Posttraumatic Stress Disorder (PTSD) contribute to the relationship between PTSD and prospective memory (Swain & Takarangi, 2021; 2022)—we wondered if PTSD symptom severity might contribute to this relationship. In Experiment 2, PTSD symptom severity moderated the relationship between recall condition and self-report prospective memory; the difference between the recall conditions on

[15] Swain, T. L., & Takarangi, M. K. (2022). Self-report prospective memory is malleable based on negative appraisals of ability. *Journal of Experimental Psychology: Learning, Memory and Cognition*, Under Review.

self-reported prospective memory was strongest at lower levels of symptom severity, with the pattern reversing at high symptom levels. These findings suggest that we can manipulate how people self-report on their prospective memory, and that self-report methods of assessment are vulnerable to metacognitive biases (e.g., negative beliefs about memory).

Introduction

"I'm so sorry, I'm such a bad friend!" you say, after forgetting to message happy birthday to your friend for the third year in a row. Remembering to message your friend is an example of prospective memory—memory for actions to be completed in the future (Loftus, 1971)—which is often measured by asking people how often they make these sorts of everyday errors: forgetting to message a friend on special occasions, or forgetting to attend scheduled appointments (e.g., Prospective Memory Questionnaire; Hannon et al., 1990). But what if such measures, requiring retrospective and subjective judgment, capture not only what people recall about their memory errors (e.g., forgetting to say happy birthday three years in a row), but *also* the metacognitive beliefs—beliefs and appraisals about cognition and thinking (Papageorgiou & Wells, 2001)—that accompany those errors (e.g., that you are a useless friend and a bad person). Indeed, perhaps self-report prospective memory measures reflect people's beliefs about their memory *in addition* to how often they *actually* forget to do things. This possibility fits with evidence demonstrating a general dissociation between people's predictions of their prospective memory performance and their actual performance on objective tasks (e.g., press a specific key when certain words appear; Arnold & Bayen, 2019; Meeks et al., 2007; see Uttl & Kibreab, 2011 for review) but has not, to our knowledge, been directly tested. Therefore, we wondered whether we could manipulate the way people self-report on their prospective memory errors simply by altering their experience of retrieving recent prospective memory errors from their everyday life. As a secondary interest—given research suggests the negative metacognitive beliefs that often arise with

Posttraumatic Stress Disorder (PTSD) contribute to the relationship between PTSD and prospective memory (Swain & Takarangi 2021; 2022)—we wondered if the effect of our manipulation might differ for people with worse PTSD symptom severity.

Self-report methods of assessment have long been scrutinized in the psychological literature. Their first flaw is that they are more vulnerable to measurement errors than their objective counterparts (e.g., cognitive tests in the lab). For example, the order or wording of the questions, or social desirability (i.e., participants providing responses consistent with what they believe is the desirable response; Chan, 2010) could contribute to responding. Second, there is a general "widespread belief" amongst researchers that self-reported variables are "inherently flawed" at measuring what they were designed to measure (i.e., construct validity; Chan, 2010). In fact, researchers query the validity of self-report methods across a huge range of fields including cognitive ageing (e.g., Rabbitt & Abson, 1990), occupational stress (e.g., Razavi, 2001), physical activity (e.g., Sallis & Saelens, 2000) and even self-reported physical characteristics such as height, weight and Body Mass Index (e.g., Gorber et al., 2007).

There is also specific evidence that self-report *prospective memory* measures have poor validity. For example, self-report prospective memory questionnaires correlate poorly with, or explain minimal variance in, actual prospective memory performance on objective methods of assessment (e.g., write your initials on paper, or press a particular key in response to target cues; e.g., Chan et al., 2008; Hannon et al., 1995; Kliegel & Jager, 2006, Swain & Takarangi, 2022; see Uttl & Kibreab, 2011 for review). Instead, these self-report measures tend to correlate with measures of *retrospective* memory, thus also demonstrating poor divergent validity (i.e., the ability to discriminate between prospective memory and other types of memory; Uttl & Kibreab, 2011).

One explanation for these validity issues is that people's responses to self-report prospective memory questions reflect metacognitive beliefs about their memory (e.g., "I have a poor memory") in general and/or at the time they are responding. Indeed, self-report measures of prospective memory require people to retrospectively reflect on their recent errors, leaving their responses open to such metacognitive biases, and potentially providing an inaccurate representation of people's actual everyday performance. If this explanation is true, then people's self-reported prospective memory must be malleable and vulnerable to momentary change, based on how people *appraise* their prospective memory ability at the time of responding. To test this idea experimentally, we used a variation on the Ease of Retrieval paradigm (e.g., Schwarz, 1988). Participants recalled either two, or 10, instances of forgetting (i.e., prospective memory failures) over the past week. Typically, an ease of retrieval manipulation is designed so participants base their judgments on the ease of the task (i.e., how easy/difficult it is to bring information to mind), rather than the content they recall (i.e., the number or detail of their examples). However, because recalling prospective memory errors is highly self-relevant and therefore participants are motivated to engage with the task—which we confirmed with pilot testing—we predicted judgments would be based on the content of recall, rather than the ease of the task (e.g., Grayson & Schwarz, 1999; Rothman & Schwarz, 1998; Schwarz, 1998). Therefore, we hypothesized that participants recalling two instances of forgetting would self-report better prospective memory performance (i.e., lower scores on the self-report prospective memory questionnaire), than those recalling 10.

As a secondary interest, we explored the role of PTSD in the malleability of self-report prospective memory. We know that negative beliefs—such as appraisals of trauma and/or trauma symptoms (e.g., forgetting means I am broken)—contribute to the development and maintenance of PTSD symptoms (Ehlers & Clark, 2000). We also know

that negative beliefs about the self, and specifically about one's own memory, contribute to the relationship between prospective memory and PTSD (Swain & Takarangi, 2021; 2022). So, if self-report methods of prospective memory measurement are vulnerable to momentary change, they might also be influenced by such beliefs. Regarding this secondary interest, we predicted that PTSD symptom severity would positively correlate with self-report prospective memory (i.e., scores on the PRMQ). We also predicted that PTSD symptom severity would moderate the relationship between number of details recalled and self-report prospective memory (i.e., scores on the PRMQ). That is, we expected that participants who recalled two items would have lower scores on the PRMQ (i.e., report making prospective memory errors less often) than those who recalled 10, but this effect will be greater for people with worse PTSD symptom severity.

Experiment 1

Method

Design

We used a between-subjects experimental design, randomly allocating participants to the easy (recall two) or the hard condition (recall 10). The independent variable was the number of instances of forgetting recalled, and our key dependent variables were: self-reported prospective memory errors (i.e., scores on the PRMQ), a single-item measure of perceived memory ability, and subjective task ratings (i.e., motivation and relevance). We also used a single-item task difficulty question as a manipulation check, and collected current PTSD symptom severity as a moderator variable.

Participants

We recruited 229 participants through Mechanical Turk (MTurk). We excluded one participant for failing three embedded attention checks (Berinsky et al., 2014; Hauser & Schwarz, 2015), two for guessing the hypothesis accurately (e.g., they predicted a

relationship between their "mindset" after the recall task and their prospective memory reporting), one for recalling only three instances of forgetting (in the hard condition), and six whose responding suggested Bot or server farmer responses (i.e., one word answers to open ended questions, e.g., "perception"). Therefore, our final sample was 219 (for further information on our sample please see: https://osf.io/vxnpr). We based our target sample size on Brysbaert's (2019) suggestion that a between-groups design with two levels—with an effect size of $d = 0.4$ as the most reasonable estimate for a useful or theoretically meaningful effect—should include 200 participants (i.e., 100 per condition). Our sample is also close to the size at which correlations stabilize (260; Schonbrodt & Perugini, 2013; 2018).

Participants were predominately female (58.9%, $n = 129$; male: 38.4%, $n = 84$, non-binary: 2.3% , $n = 5$; preferred not to say: $n = 1$). Participants were aged 21 to 80 years ($M = 41.25$, $SD = 12.76$), and were mostly Caucasian (72.6%, $n = 159$), followed by African-American (10.0%, $n = 22$), Asian (7.3%, $n = 16$), Mixed (4.1%, $n = 9$); one person preferred not to say. Further, 3.2% of our sample had completed doctoral studies as their highest qualification ($n = 7$), 10.0% master's studies ($n = 22$), 41.1% bachelor's degree ($n = 90$), 20.5% associate degree or certificate ($n = 45$), and 25.1% senior high school or equivalent ($n = 55$). Participants were reimbursed $1USD for their time.

Materials / Questionnaires

Recall task. As per a typical ease of retrieval paradigm (e.g., Schwarz, 1988), participants recalled either two (easy) or 10 (hard) instances of forgetting. Participants saw the following instructions, which were identical in each condition, except for the number of instances participants were asked to recall:

"*We are interested in the types of tasks you might have forgotten that you planned to do, over the past week. There are a number of things you might have forgotten to do but examples might include:*

- Forgetting to stop at the shops for milk,

- Forgetting to call your friend on their birthday,

- Forgetting to take medication at the appropriate time,

- Forgetting to take baking out of the oven on time, or,

- Forgetting to book or attend an appointment.

Below, please recall 2 / 10 specific instances when you have forgotten to do things over the past week including where you were, and what you were doing when you forgot."

Manipulation check. To check the effectiveness of the manipulation (e.g., Schwarz et al., 1991), we asked participants about task difficulty: "*Now we want you to think about the task where you had to recall several instances of forgetting over the past week, how difficult was this task for you?"* (1 = "*Very Easy"*, 7 = "*Very Hard"*).

Subjective task ratings. When participants are particularly motivated to engage in an ease-of-retrieval recall task, and perceive the task as relevant to them, the typical effect is reversed, such that participants rely on the content they recalled, rather than the ease of the recall experience (e.g., Grayson & Schwarz, 1999; Rothman & Schwarz, 1998; Schwarz, 1998). Therefore, to assess participants' perceptions of our recall task, we asked them to report their motivation; "*How motivated were you to complete the recall task?*", and how relevant they felt the task was to their life; "*How relevant did you feel the recall task was to your life?*" (1 = "*Not at all Motivated / Relevant"*, 7 = "*Very Motivated / Relevant"*).

Perceived memory ability (Cuttler et al., 2013). To explore the influence of the task on general judgments of memory, participants also completed a single-item question related to their own general memory ability: "*Following this task I believe my memory is…*" (1 = "*Excellent"*, 5 = "*Poor"*).

Prospective and Retrospective Memory Questionnaire (PRMQ; Smith et al., 2000). The PRMQ is a self-report measure of prospective and retrospective memory lapses in

everyday life. Here, we used only the prospective memory scale, which has eight items (e.g., "*Do you forget to buy something you planned to buy, like a birthday card, when you go to the shop?*"). We chose this brief questionnaire rather than other self-report PM measures (i.e., PMQ) to maximize the impact of the recall manipulation. Participants responded on a 5-point Likert scale rating how often these occurrences happen to them (1 = "*Never"*, 5 = "*Very Often"*). The prospective memory subscale of the PRMQ had good internal consistency (Experiment 1, $\alpha = .87$; Experiment 2, $\alpha = .86$).

Single item trauma question and Posttraumatic Stress Disorder Checklist (PCL-5; Weathers et al., 2013). When completing the PCL-5, participants must index their Posttraumatic Stress symptoms to a reported event. Therefore, we asked participants to recall their worst experienced stressful or traumatic event: *"Please bring to mind the event in your life that was the most traumatic or stressful. Briefly describe [in one or two sentences] the event that bothered you the most [i.e., your most stressful or traumatic experience] in the box below. We are going to ask you a number of questions about this event".* The PCL measures self-reported PTSD symptom severity over the last month in reference to this event. Participants rated their symptoms (e.g., "*repeated, disturbing, and unwanted memories of the stressful experience*?") on a 5-point scale (0 = "*Not at all"*, 4 = "*Extremely"*). The PCL-5 had excellent internal consistency (Experiments 1 and 2: $\alpha = .95$).

Procedure

To prevent bots/server farmers completing the experiment (Bai, 2018; Stokel-Walker, 2018), participants had to: pass a captcha question, score at least 8/10 on an English proficiency test, and pass a "cultural check" (i.e., asked to identify the American name for a particular vegetable; see Moeck et al., 2022). Then, following consent procedures, participants completed demographic questions followed by the recall task. They completed the difficulty and perceived memory ability items, then the self-report prospective memory

questionnaire (i.e., PRMQ). Next, participants completed the other subjective task ratings (i.e., motivation then relevance), followed by the single-item trauma question, then reported on their PTSD symptoms (i.e., PCL-5). Finally, we asked participants to guess the hypothesis of the study, before providing debriefing information. The Flinders University Human Research Ethics Committee approved this research. We preregistered the experiment (https://osf.io/vxnpr) and provide all data on the Open Science Framework (OSF; https://osf.io/7zm29/).

Results and Discussion

We first confirmed that participants recalling two (i.e., easy condition) instances of forgetting found the recall task easier than those recalling 10 (i.e., hard condition), using an independent samples *t*-test. Indeed, participants in the easy condition reported the task was significantly easier ($M = 2.88$, $SD = 1.63$), than participants in the hard condition ($M = 4.07$, $SD = 1.78$), $t(217) = -5.67$, $p < .001$, $d = -0.70$, *95% CI* [-0.97, -0.43].

We next assessed whether participants were motivated to complete the task and found the task self-relevant. Both conditions were highly motivated, but participants in the easy condition were significantly *more* motivated to complete the task ($M = 5.89$, $SD = 1.42$) than those in the hard condition ($M = 5.54$, $SD = 1.52$), $t(217) = 1.75$, $p = .04$, $d = 0.24$, *95% CI* [-0.03, 0.50]. This finding was unsurprising given that recalling two instances of forgetting was quicker and less effortful. Participants in both the easy condition ($M = 5.19$, $SD = 1.63$) and the hard condition ($M = 5.04$, $SD = 1.75$), reported the that task was highly relevant to them, $t(217) = 0.69$, $p = .25$, $d = 0.09$, [-0.17, .36], suggesting this high self-relevance likely also increased their motivation to engage. Additionally, we used strict recruitment criteria on MTurk (i.e., Cloud Research's high-quality participant selection pool) that likely resulted in participants who were conscientious and motivated. Taken together, these data suggest participants would rely on the *content* they recalled, rather than the ease of the recall

experience (e.g., Grayson & Schwarz, 1999; Rothman & Schwarz, 1998; Schwarz, 1998), in judging their prospective memory.

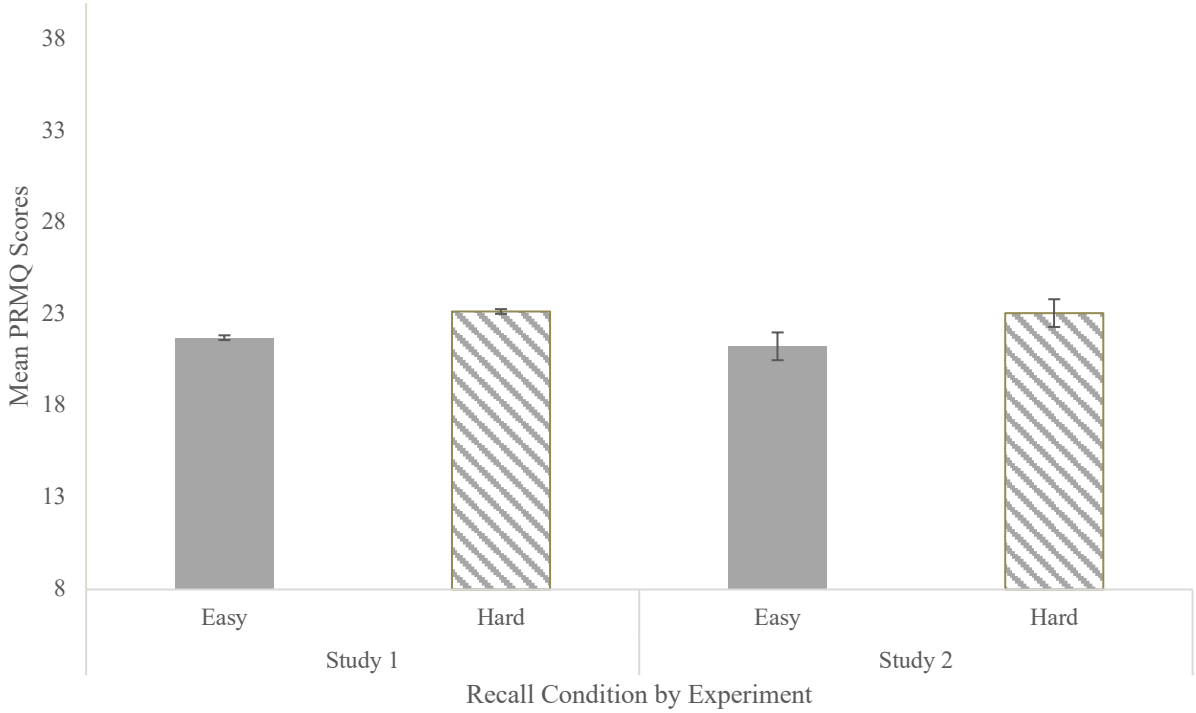
Next, we explored our main research question—are self-report methods of prospective memory sensitive to momentary change, based on how people currently *appraise* their prospective memory ability? To address this question, we used two measures. First, because prior research manipulating people's beliefs about their memory ability has typically used a general single-item subjective memory judgment (e.g., Alcolado & Radomsky, 2011; Cuttler et al., 2013), we asked people to report how they were feeling about their memory generally, after completing the recall task. Participants' perceived memory ability was lower in the easy condition (M = 2.81, SD = 1.02) compared to the hard condition (M = 3.00, SD = 0.99) but the difference was not statistically significant, $t(217) = -1.37$, $p = .09$, and the effect size was small, d = -0.19, *95% CI* [-0.45, 0.08]. Second, we examined scores on the PRMQ. In line with our predictions, participants in the easy condition reported making significantly fewer prospective memory errors over the past week (M = 21.74, SD = 5.81) compared to the hard condition (M = 23.17, SD = 5.90), $t(217) = -1.81$, $p = .036$ (see Figure 5.1). However this effect was again small, d = -0.24 [-0.51, 0.02]. Because we initially powered for a medium effect size (d = 0.4) but found a small effect, we ran a Bayesian independent samples t-test[16] to assess evidence for the alternative hypothesis—our prediction—that participants recalling fewer instances of forgetting (i.e., the easy condition) would report lower PRMQ scores, compared to those recalling more details (i.e., the hard condition; Rouder method; Rouder et al., 2009). According to the ranges suggested by Wetzels et al. (2011), we had anecdotal evidence against this alternative hypothesis (BF_{10} = 0.68). These data therefore

[16] We acknowledge that this analysis was not pre-registered and therefore is only exploratory. Bayesian analyses were run using JASP (2021).

suggest that self-report methods of prospective memory are not necessarily sensitive to momentary change.

Figure 5.1

Average PRMQ scores after recall task by condition (for both experiments – with 95% confidence interval error bars)



Recall our secondary interest in the relationship between PTSD symptom severity and prospective memory; specifically, the possibility that PTSD symptom severity might change how participants responded to the retrieval experience manipulation. To explore this possibility, we first correlated PTSD symptom severity and scores on the PRMQ. Consistent with prior research finding that PTSD symptoms and self-report prospective memory are related (Swain & Takarangi, 2021; 2022), we found a medium correlation: people who reported making more prospective memory errors in their everyday life also reported worse PTSD symptoms, $r = .54$, $p < .001$, *95% CI* [0.44, 0.63]. To test the idea that PTSD symptom

severity might influence the strength of the relationship between the number of forgetting instances participants recalled and self-report prospective memory, we ran a moderated regression. Although PTSD symptom severity contributed to PRMQ scores (b = .54), there was no interaction between recall condition and PTSD on self-report prospective memory (ps > .19).

Overall, in line with our predictions, people who reported 10 instances of forgetting reported worse self-report prospective memory compared to those who only recalled two instances. However, this effect was small (d = 0.24) and Bayesian analyses revealed anecdotal evidence against the alternative hypothesis that there was a difference between the easy and hard conditions on self-report PM scores. However, since we initially powered for an effect of d = 0.40, we decided to replicate the experiment with an appropriately powered sample size to detect a small effect. We believe—given the simplicity of this manipulation—that a small effect might still be meaningful and indicate that self-report prospective memory is malleable to change in some way, based on people's present appraisals about their ability.

Experiment 2

Method

We used the same design, procedure and materials as in Experiment 1, but collected a larger sample. We preregistered this replication on the OSF (https://osf.io/45ntf).

Participants

G*Power analyses revealed that for a one tailed[17] t-test comparing two groups, we should collect 216 participants (total N = 432) per group to detect a small effect (i.e., d = 0.24), with 80% power. Therefore, we collected 445 participants through Mechanical Turk (MTurk). We excluded two participants for failing three embedded attention checks

[17] We used a one-tailed t-test because our pilot data and data from Experiment 1 meant we had a directional prediction.

(Berinsky et al., 2014; Hauser & Schwarz, 2015), four for guessing the hypothesis accurately (e.g., they predicted a relationship between rating themselves negatively and the number of details they recalled), five for recalling fewer than 50% of the required instances of forgetting[18] (i.e., <5 in the recall 10 condition), and two whose responding suggested bot/server farmer or fake responses. Therefore, our final sample was 432 (for further information please see our OSF; https://osf.io/45ntf).

Participants were predominately 61.1% female (n = 264), 37.3% males (n = 161), 1.4% non-binary (n = 6) and one person who preferred not to report gender. Participants were aged 20 to 84 years (M = 42.79, SD = 13.12), and were mostly Caucasian (81.0%, n = 350), followed by African-American (7.2%, n = 31), Asian (6.0%, n = 26), Mixed (3.0%, n = 13) and Hispanic (2.8%, n = 12). Further, 4.6% of our sample had completed doctoral studies as their highest qualification (n = 20), 16.4% master's studies (n = 71), 41.4% bachelor's degree (n = 179), 17.6% associate degree or certificate (n = 76), 19.4% senior high school or equivalent (n = 84), and two people who completed only junior high school (0.5%). Participants were reimbursed $1USD for their time.

Results and Discussion

For Experiment 2, we again began by confirming that participants in the recall two condition (i.e., easy condition) found this task easier than those recalling 10 (i.e., hard condition). Indeed, participants in the easy condition reported the task was significantly easier (M = 2.89, SD = 1.62) than participants in the hard condition (M = 4.33, SD = 1.77), $t(430) = -8.81$, $p < .001$, $d = -0.85$, *95% CI* [-1.04, -0.65].

As in Experiment 1, we again wanted to confirm participants were motivated to complete the task and found the task self-relevant (e.g., Grayson & Schwarz, 1999; Rothman

[18] Because recalling 5 or fewer instances of forgetting was more similar to the task of recalling two instances of forgetting, than recalling 10.

& Schwarz, 1998; Schwarz, 1998). Participants in the easy condition (M = 5.90, SD = 1.23) and the hard condition[19] (M = 5.96, SD = 1.26), $t(428) = -.45$, $p = .33$, $d = -0.04$, *95% CI* [-0.23, 0.15] were similarly and highly motivated to complete the task; this pattern was the same for judgments of task relevance (Easy: M = 5.09, SD = 1.64; Hard: M = 4.97, SD = 1.72), $t(430) = .72$, $p = .24$, $d = 0.07$, [-0.12, 0.26].

Next, we explored our main research question—are self-report methods of prospective memory sensitive to momentary change, based on how people currently *appraise* their prospective memory ability? Like Experiment 1, we used two measures to explore post-manipulation reports on memory ability. First, as in Experiment 1, those in the easy condition reported their general memory ability was better (M = 2.74, SD = 0.94), compared to those in the hard condition (M = 2.93, SD = 1.01), but here this effect reached statistical significance, $t(430) = -1.96$, $p = .025$. Consistent with the effect size in Experiment 1, this effect was small, $d = -0.19$, *95% CI* [-0.38, 6.79]. Next, participants in the easy condition reported making fewer prospective memory errors (i.e., lower PRMQ scores) over the past week (M = 21.27, SD = 5.72) compared to the hard condition (M = 23.08, SD = 5.40), $t(430) = -3.38$, $p < .001$, $d = 0.33$, [-0.52, -0.14]; see Figure 5.1). We confirmed this finding using a Bayesian independent samples *t*-test (Rouder method; Rouder et al., 2009). According to the ranges suggested by Wetzels et al. (2011), we have strong evidence for the alternative hypothesis that those in the easy condition self-reported lower scores on the PRMQ, compared to those in the hard condition ($BF_{10} = 25.67$). Therefore, importantly, self-report prospective memory appears sensitive to momentary change and can be altered by a simple task highlighting participants' recent prospective memory errors.

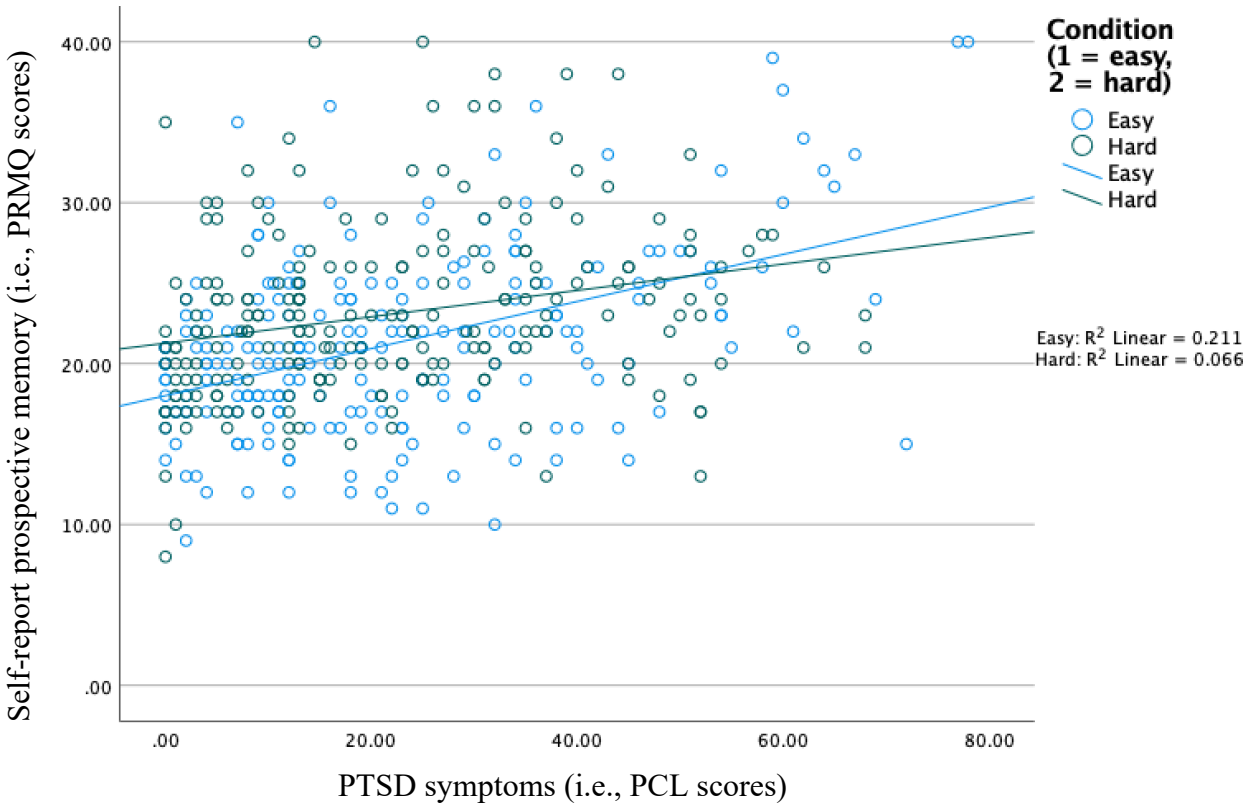
To investigate our secondary interest regarding the relationship between prospective memory and PTSD, as in Experiment 1, we correlated PTSD symptom severity and scores on

[19] Note two participants in the hard condition did not complete the motivation question, therefore n = 213.

the PRMQ. People who reported making more errors in their everyday life (i.e., PRMQ scores) also reported worse symptoms, a medium correlation, $r = .36$, $p < .001$, *95% CI* [0.28, 0.44]. This effect size is similar to other research using similar populations (e.g., Swain & Takarangi, 2021; 2022), but smaller than the effect we found in Experiment 1. Our effect size in Experiment 2 is likely a more stable estimate given the increased sample size (Schonbrodt & Perugini, 2013; 2018). To test the idea that PTSD symptom severity might influence the strength of the relationship between the number of details recalled and self-report prospective memory, we ran a moderated regression. PTSD symptom severity ($b = .36$) and condition (i.e., hard or easy; $b = .16$) entered at Step 1 explained 15.5% of the variance in PRMQ scores, $R^2 = .16$, $F(2, 429) = 39.44$, $p < .001$. At Step 2, there was a significant interaction between PTSD symptom severity and condition (explaining an additional 1.0% of the variance). Inconsistent with our hypothesis, this interaction suggests that the influence of condition (i.e., recalling two or 10 instances of forgetting) on self-report PRMQ changed as PCL scores increased, $R^2change = .01$, $Fchange(1, 428) = 5.09$, $p = .025$. More specifically, the difference between the hard and easy conditions on self-reported PM was strongest at lower levels of symptom severity, with the pattern reversing at high symptom levels. Indeed, at very high levels of symptom severity, those in the *easy* condition reported worse scores on the PRMQ (see Figure 5.2). However, at Step 2, PTSD symptom severity was still the greatest predictor of PRMQ scores ($b = .65$), compared to condition ($b = .29$) and the interaction term ($b = -.33$). Therefore, in addition to the number of details recalled, and the relationship between that recall condition and PTSD symptoms, PTSD symptom severity—and possibly the negative beliefs that accompany these symptoms—was the primary factor in determining how people self-report on their prospective memory.

Figure 5.2

Moderation Between Condition (Easy vs Hard) and PTSD Symptom Severity on Self-report Prospective Memory (PRMQ)



As a new analysis here in Experiment 2, we wondered—given the malleability of self-report prospective memory—is self-report PTSD symptom severity also vulnerable to momentary change? We ran an independent samples *t*-test to explore whether participants' PTSD symptom severity differed by condition (i.e., recall two, or recall 10). However, we found no significant difference in PTSD symptom scores between participants in the easy (M = 22.27, SD = 17.95), vs. hard condition (M = 22.04, SD = 1.16), $t(430) = .14$, $p = .45$, d = 0.01, *95% CI* [-0.18, 0.20]. We confirmed this finding using a Bayesian independent samples *t*-test, finding substantial evidence against the alternative hypothesis that those in the easy condition self-reported their PTSD symptoms differently to those in the hard condition (BF_{10}

= 0.11). This finding suggests that our manipulation was specific to self-report prospective memory only, that PTSD symptom severity reporting might not be vulnerable to momentary change, or that the manipulation did not last long enough to influence PTSD symptoms (which participants reported last).

General Discussion

In line with our predictions, our key finding was that participants who recalled only two recent instances of forgetting self-reported making fewer prospective memory errors in their everyday life (i.e., lower scores on the PRMQ), compared to participants recalling 10. This finding suggests that self-report prospective memory might be malleable and vulnerable to momentary change, based on how people presently *appraise* their ability. Similarly, participants who recalled two instances of forgetting reported their general memory ability as better, compared to those reporting 10. Regarding our secondary interest exploring the relationship between prospective memory and PTSD symptom severity, we replicated the positive correlation between PTSD symptoms and self-reporting more everyday prospective memory errors (Swain & Takarangi, 2021; 2022). Interestingly, in Experiment 2 only, PTSD symptom severity moderated the relationship between recall condition (i.e., recall two vs 10) and self-report prospective memory such that the difference between the recall conditions on self-reported prospective memory was strongest at lower levels of symptom severity, with the pattern reversing at high symptom levels.

We first highlight that overall, scores on our key variables of interest (i.e., self-report prospective memory; PRMQ, PTSD symptom severity; PCL-5) were higher than in previous research using the same population (i.e., Mechanical Turk; Swain & Takarangi, 2021)[20]. These small, non-statistical differences in mean scores on both measures might be attributed

[20] PRMQ: Swain & Takarangi, 2021 (M = 18.28), current experiment (1: M = 22.47, 2: M = 22.17), PCL-5: Swain & Takarangi, 2021 (M = 18.41), current experiment (1: M = 22.38, 2: M = 22.16).

to the manipulation we used here. Perhaps even recalling two recent instances of forgetting was enough to change the way people reported on their prospective memory ability and this relationship was simply *stronger* for people recalling more instances (i.e., 10). To explore this possibility, future research could compare the recall conditions to a control group who do not complete any prospective memory recall task. For PTSD symptoms, although there was no difference between the conditions on symptom scores, the manipulation potentially increased symptom reporting equally across conditions. This difference again might arise from negative metacognitive beliefs. Perhaps our manipulation successfully targeted beliefs about prospective memory, but recalling any number of instances of "forgetting" highlighted negative beliefs about the self (e.g., feelings of failure), resulting in overall heightened symptom reporting. Future research could seek to manipulate beliefs about PTSD symptom severity in a similar way to our manipulation here, to explore whether PTSD symptoms—or other self-report psychopathology—are similarly malleable based on present negative appraisals.

An alternative explanation lies in the fact that the prior research (i.e., Swain & Takarangi, 2021) was conducted *before* the COVID-19 pandemic. Indeed, we know that people might perceive events occurring as part of the pandemic (e.g., lockdowns, media coverage, virus exposure) as traumatic stressors, and that generally people report increased anxiety, depression and stress symptoms associated with the pandemic (e.g., Bridgland et al., 2021; Brivio et al., 2021; Salari et al., 2020; Sanchez-Gomez et al., 2021; Shevlin et al., 2020). Given the extended effects of the pandemic, perhaps symptom reporting here remained high. In terms of prospective memory reporting, we know that stress, anxiety, PTSD symptoms and depression are all positively related to prospective memory (e.g., Kliegel & Jager, 2006; Piefke & Glienke, 2017; Zhou et al., 2017). Therefore, perhaps self-reporting of prospective memory failures simultaneously increased over the pandemic—due

to actual impairment, or even just increasing negative appraisals of errors—consistent with worse psychopathology. Because of our brief manipulation, we did not take baseline measures of these variables, thus we cannot rule out these explanations. Future research could include baseline measurement of key variables to determine whether scores were generally higher at the time of the research, or whether the manipulation affected all subsequent self-reporting.

We next discuss our key finding that self-report prospective memory is malleable and sensitive to momentary change, based on how people currently appraise their prospective memory ability. We acknowledge that the effect sizes here were small (*d*s = 0.24-0.33), but we argue this effect is nonetheless meaningful. We used a brief, simple manipulation that, to our knowledge, has not yet been applied to the field of prospective memory. If this manipulation can change the way people self-report on their everyday prospective memory performance, perhaps other, stronger manipulations—e.g., providing specific feedback about memory ability compared to a normative population (e.g., Alcolado & Radomsky, 2011, Cuttler et al., 2013)—or real-life events—e.g., exposure to stressful or traumatic events that might actually increase negative beliefs—might influence prospective memory reporting to a greater extent. Future research could use an analogue trauma paradigm to explore whether exposure to a traumatic event leads to differences in prospective memory reporting via negative beliefs. Additionally, future research could explore whether our manipulation, or other similar manipulations, might be cumulative—over time and/or with repetition—in the same way that negative beliefs persist and are rehearsed over time (see Funder & Ozer, 2019).

In terms of our secondary interest, we found an interesting interaction between recall condition, PTSD symptom severity and self-report prospective memory, where the pattern—i.e., that those recalling two instances of forgetting reported less prospective memory errors

in their everyday life compared to those recalling 10—reversed at higher symptom levels. At higher symptom levels, the pattern reflected a typical ease-of-retrieval effect, suggesting that participants with PTSD, or worse PTSD symptoms, relied on the *ease* of the recall experience, rather than the *content* they recalled to judge how often they make prospective memory errors in their everyday life. This ease-of-retrieval effect typically arises from the *availability heuristic* (Tversky & Kahneman, 1973), where people tend to use easy, non-content cues—specifically, the ease of the recall experience (e.g., Bohner et al., 1988; Schwarz et al., 1991)—to inform their judgments. Such heuristics generally help us make decisions quickly and with ease (e.g., Shah & Oppenheimer, 2008). We know that people with PTSD or worse PTSD symptom severity often have limited cognitive resources, due to the resources symptom management consumes. Having fewer resources for higher-order functions like decision making may result in greater reliance on heuristics. Alternatively, difficulty concentrating is also a symptom of PTSD (American Psychiatric Association; 2013). Perhaps people with PTSD or worse PTSD symptoms rely on heuristic processing because they are unable to maintain concentration to effortfully process the information they recall to inform their judgments. Future research could use a clinical population with PTSD diagnoses to explore these possibilities.

We believe our findings have important implications not only for research specifically on prospective memory, but also more generally in the cognitive psychology field, particularly for clinical cognition. Researchers often rely on self-report questionnaires to measure variables including everyday cognitive failures (Broadbent et al., 1982), divided attention (Tun & Wingfield, 1995), suppression tendency (Wegner & Zanakos, 1994), and responses to trauma intrusions (Clohessy & Ehlers, 1999). Although we only manipulated prospective memory judgments here, we wonder if—consistent with the idea that self-report questionnaires might be biased in some way—these questionnaires might too be malleable

and sensitive to momentary change. These findings are important for considering methodological choices like the use of questionnaires without objective counterparts, or the placement of self-report measures amongst batteries of other questionnaires/tasks.

Our study has limitations. First, as we have already acknowledged, we did not collect baseline measures of our key variables. We made this methodological choice because of the brief nature of the manipulation and the possibility that participants might remember and recall how they previously responded, rather than responding consistent with their present beliefs post-manipulation, ultimately eliminating any effect of the manipulation. Future research could seek to collect baseline measures on a separate occasion *prior* to the manipulation (e.g., 24-hours) and/or could embed these questionnaires in a larger study where participants are less likely to remember specific responses to key variables. Second, we have assumed that the mechanism explaining the malleability of self-report prospective memory is biased beliefs, but we did not collect any data on beliefs about the self or about memory specifically. Again, we wanted to avoid participants relying on their reporting or feelings from completing other questionnaires to inform their subsequent reporting, therefore reducing the effectiveness of the manipulation. Future research could specifically examine these beliefs before, and after, a manipulation to identify any changes in reporting over time (e.g., negative beliefs about the self, confidence in cognitive abilities). Third, we used only one self-report prospective memory measure, the PRMQ. Prior research suggests that this measure might be the least valid of the options available (Uttl & Kibreab, 2011). But we chose it because of its brief nature—e.g., compared to the Prospective Memory Questionnaire with 52-items—again to maximize the effect of the manipulation. Future research could replicate our methodology using an alternative measure such as the Prospective Memory Questionnaire (PMQ; Hannon et al., 1990) or the Comprehensive Assessment of Prospective Memory (CAPM; Chau et al., 2007). Similarly, we asked participants to self-report their

motivation and self-relevance of the recall task to determine whether participants were more likely to rely on the content or the ease of their retrieval. However, given these questions were also self-report, participants may have exaggerated or over-reported these ratings in order to appear as "responsible" or "ideal" participants.

Overall, our results suggest that people's self-report prospective memory is malleable to momentary change. We found that a simple manipulation requiring participants to bring prospective memory errors to mind changed the way they self-reported their everyday prospective memory failures. That is, people recalling fewer instances of forgetting similarly reported making less everyday prospective memory errors compared to those recalling more. We also found that PTSD symptom severity moderated this relationship, such that at higher levels of symptom severity, participants recalling fewer instances reported making *more* everyday prospective memory errors, compared to those recalling more instances—i.e., a classic ease-of-retrieval effect. Since these findings might generalize to self-report measurement of other, metacognitive variables, further research should explore this possibility.

Chapter 6: General discussion

My thesis aims were threefold: 1) to explore the relationship between PTSD symptoms and prospective memory in *general population* samples, 2) to use a variety of *prospective memory measurement methods* to investigate the generalisability of the relationship between PTSD and prospective memory, across different prospective memory tasks and experimental environments, and, 3) to explore one particular mechanism that might underpin the relationship between PTSD symptoms and prospective memory—*metacognitive beliefs*. This final chapter aims to summarise the findings from my four empirical chapters and discuss these findings in the context of prior research and theories I introduced in Chapter 1. This chapter also identifies clinical, methodological and theoretical implications of my research, acknowledges limitations of the current investigation and suggests future directions.

Nature of the PTSD and PM relationship in the general population

In Study 1 (Chapter 2), I began exploring preliminary evidence for a relationship between PTSD symptom severity and self-report prospective memory in a general population sample. Prior research using clinical populations—specifically veterans—has reported mixed evidence for the PM-PTSD relationship when using objective, in-lab tasks (e.g., Glienke et al., 2017; Korinek et al., 2021; McFarland et al., 2016; Pagulayan et al. 2018; Scott et al., 2016). However, this prior work was limited by small sample sizes and exclusive use of veteran participants. Such participants likely present with comorbidities (e.g., traumatic brain injury) that might contribute to prospective memory impairment, in addition to PTSD symptoms. Therefore, I aimed to examine the presence, and size, of any relationship between PTSD symptom severity and self-report prospective memory in a general, non-veteran sample, whilst also controlling for these comorbidities. I found that indeed, people who reported worse PTSD symptom severity also reported making more prospective memory

errors in their everyday life (i.e., higher scores on prospective memory self-report questionnaires). Importantly, PTSD symptom severity uniquely contributed to self-report prospective memory, even when controlling for other physical and mental health comorbidities (e.g., TBI, depression). This study was the first to confirm that a relationship between PTSD symptom severity and prospective memory exists uniquely because of *PTSD symptoms* themselves, not only because of comorbidities that often co-occur with PTSD—such as poor physical health (in particular traumatic brain injury, e.g., Shum et al., 2011), substance use and depression severity—and directly impair executive functions, including prospective memory Crean et al., 2011; Hultsch et al., 1993; McDermott et al., 1998).

I then continued to explore the PM-PTSD relationship in different general population samples—while still controlling for comorbidities (Studies 1-3). I found a consistent correlational relationship between self-report prospective memory and PTSD symptoms across three different general population samples; online (i.e., Mechanical Turk; Study 1; *r*s = .42-.49), undergraduate student (Study 2; *r*s = .32-.42), and community (Study 3; *r*s = .34) participants. However, there were small inconsistencies in the descriptive data across these samples. Specifically, undergraduate participants' (i.e., Study 2) scores on key mental health and related measures (i.e., PTSD symptoms, depression, anxiety and stress scores, self-reported prospective memory errors, metacognitive variables and psychosocial functioning) were higher than those for Mechanical Turk (MTurk) participants (Study 1), and community participants' (Study 3) means on these measures were higher than both MTurk and undergraduate participants. For example, MTurk participants reported lower PTSD (M = 18.41) and mood symptoms (depression, M = 5.18; anxiety, M = 3.76; stress, M = 5.87), compared to undergraduate participants (PTSD, M = 23.17; depression, M = 5.62; anxiety, M = 5.55; stress, M = 7.65) and community participants (PTSD, M = 27.18; depression, M =

7.78; anxiety, $M = 7.18$; stress, $M = 9.77$)[21]. There are at least two explanations for this increase over time from Study 1 through to Study 3. The first is that these key variables all increased with the COVID-19 pandemic. Study 1 was conducted before the pandemic (i.e., January-March, 2019), Study 2 was conducted before and during (May 2019-May 2021), and Study 3 was conducted only during the pandemic (April-November 2021). To explore the possibility that these key variables increased due to the pandemic, I split the Study 2 data into participants who completed the study before vs. after the onset of COVID-19 (i.e., March, 2020). However, there were no significant differences in scores (ps > 0.06, ds = 0.009-0.19), except for psychosocial functioning (B-IPF); participants who completed the study *after* the pandemic began reported worse everyday functioning ($M = 24.52$, $SD = 10.91$) compared to participants who completed the study before ($M = 18.85$, $SD = 11.36$), $t(259) = -4.08$, $p < .001$, $d = -0.51$. Therefore, while it is possible that everyday impairment worsened from Study 1 to Study 3 due to COVID-related difficulties, it seems unlikely the pandemic caused change in other psychopathology (e.g., Bridgland et al., 2021; Brivio et al., 2021; Salari et al., 2020; Sanchez-Gomez et al., 2021; Shevlin et al., 2020).

A second explanation for the differing descriptive statistics relates to where we sourced our samples. We know that MTurk participants have similar *prevalence* rates of PTSD and depression compared to undergraduate and community samples, but report overall lower symptom scores compared to these same groups (Engle et al., 2020). This finding is consistent with my finding that MTurk participants reported lower scores than did participants in the other general population samples I used (i.e., undergraduate and community participants). I also used strict recruitment criteria on MTurk (i.e., Cloud Research's high-quality participant selection pool) to increase data quality, but this choice might have resulted in participants who were particularly conscientious—compared to my

[21] Refer to pages 61 (Study 1), 98 (Study 2) and 132 (Study 3) for the full descriptive data for each study.

undergraduate and community samples who perhaps had lower levels of, or more varied levels of conscientiousness (despite using the same attention checks across all three studies). Given conscientiousness predicts greater recovery from negative emotions (Javaras et al., 2012), perhaps my MTurk sample had lower psychopathology—compared to other MTurk workers, and the other participant groups I used, particularly the community sample—due to their increased ability to cope with, and recover from, stressors. Specifically regarding the difference between my non-online samples, undergraduate participants were mentally well enough to complete their current university courses, potentially resulting in overall lower psychopathology, compared to the community sample where study status was unknown. However, the differences between these two non-online samples were small and likely not clinically meaningful. Overall, despite each general population sample being clinically representative, it seems likely the recruitment process resulted in mildly differing psychopathology within each sample.

In addition to the varied general population samples, in Study 1, I examined the relationship between PTSD and prospective memory among only those participants reporting a Criterion A trauma (i.e., exposure to real or threatened death or serious injury); representative of a clinical population. However, the size and nature of the relationship in the Criterion A subsample was similar in size to that in the whole sample[22]. This finding suggests it is not necessarily the *presence* of a PTSD diagnosis, but rather the *severity* of symptoms that relate to self-report prospective memory.

However, it is difficult to directly compare any differences in symptom severity between my studies and prior literature because of differences in symptom measurement (i.e.,

[22] Even though I did not collect sufficient participant numbers (i.e., $N = 260$; Schonbrodt & Perugini, 2013; 2018) to calculate a stable correlation among participants reporting a Criterion A trauma in Studies 2 ($n = 173$) and 3 ($n = 179$), the correlation was similar as for the whole population: Study 2 (Criterion A: PMQ; $r = .44$, $p < .001$, PRMQ; $r = .30$, $p < .001$, whole population: PMQ; $r = .42$, $p < .001$, PRMQ; $r = .32$, $p < .001$), Study 3 (Criterion A: PMQ; $r = .29$, $p < .001$, PRMQ; $r = .24$, $p = .001$, whole population: PMQ; $r = .34$, $p < .001$, PRMQ; $r = .34$, $p < .001$).

prior versions of the Posttraumatic Symptom Checklist [McFarland et al., 2016; Pagulyan et al., 2018], or the use of only semi-structured clinical interview tools; i.e., Clinical Administered PTSD Scale [Glienke et al., 2017; Scott et al., 2016]). Despite using a clinical veteran population, Korinek et al. (2022) used the Posttraumatic Checklist for DSM-5—in addition to the Clinical Administered PTSD Scale—as I did here, and thus provides a useful comparison. Among veterans without PTSD, PCL scores were higher on average (M = 22.31) than the MTurk participant scores I report in Study 1 (M = 18.41), closely aligned with the undergraduate participant scores I report in Study 2 (M = 23.17), and were lower than the community participant scores I report in Study 3 (M = 27.18). Thus, in terms of clinical representativeness, on average, my general population samples appear similar to a veteran population, without PTSD diagnoses.

In addition to scores on clinical scales, the size of the relationship between PTSD symptom severity and PM in my studies was similar to prior research using the PTSD checklist. Korinek et al. (2022) reported similar sized correlations between actual prospective memory performance in the lab, for total (r = -.37) and event-based prospective memory performance (r = -.37), as I report across Studies 1-3 between PTSD symptom severity and self-report prospective memory scores (rs = .32-.49). These comparisons further support the idea that the relationship with prospective memory appears tied to *severity* of symptoms rather than the presence of a PTSD diagnosis. Indeed, for someone to receive a PTSD diagnosis, they must meet thresholds within each symptom category, in addition to having experienced an event involving real or threatened death, serious injury, or sexual violence (American Psychiatric Association [APA], 2013). Prospective memory impairment might result from symptoms in any of these categories, or a combination of a number of, or all of these symptoms.

First, for intrusion symptoms (Criterion B), people with worse PTSD symptoms exhibit poor attentional control (e.g., Esterman et al., 2013; Schoorl et al., 2014). That is, cognitive resources are typically occupied by task-irrelevant internal (e.g., intrusive thoughts) or external (e.g., threat monitoring) stimuli, leaving fewer resources for prospective memory tasks. This symptom cluster would likely result in impaired *planning* and *maintenance* in the PM process. That is, because of poor attentional control people with worse PTSD symptoms may have difficulty finding the available resources to plan and maintain PM tasks, resulting in impaired *performance*.

Second, avoidance symptoms (Criterion C) may similarly occupy cognitive resources. People with avoidance symptoms may actively suppress or occupy their mind (e.g. with thoughts unrelated to the trauma) to avoid feeling or thinking about their traumatic event, or to avoid situations in which they might encounter reminders of the event (APA, 2013). In support of this idea, McFarland et al. (2016), reported that the avoidance symptom cluster was particularly associated with more prospective memory errors, more so than the other symptom clusters. Similarly, in Studies 1 and 2, I also found that suppression tendency and avoidance of future planning both mediated the relationship between self-report prospective memory, and PTSD symptom severity. That is, people who reported worse PTSD symptoms also reported they were less likely to make future plans and more likely to suppress negative thoughts, and consequently self-reported making more everyday prospective memory errors. Symptoms in this cluster may similarly impair the *planning* and *maintenance* stages of the PM process. People with worse PTSD symptoms may avoid making future plans and therefore not properly *plan* any PM intentions, or they may accidentally suppress to-be-completed intentions as part of their attempts to suppress other unwanted thoughts resulting in failed *maintenance*.

Third, negative alterations in cognition and mood (Criterion D) might impair prospective memory in several ways. This criterion includes negative beliefs about the self, other people and the world, which we know significantly contribute to the relationship between self-report prospective memory and PTSD symptoms (i.e., negative beliefs about memory, cognitive confidence, and negative cognitions about the self; Studies 1-3). This symptom cluster is particularly important in Study 1 where I relied *only* on self-report assessment of prospective memory, which might also be affected by changes in mood and cognition. For example participants might use their negative beliefs or mood state as a lens through which to self-report their PM. Similarly, we know that persistent negative mood states (i.e., ongoing feelings of fear, horror, anger, guilt or shame) make it difficult to efficiently allocate cognitive resources (e.g., Ellis & Ashbrook, 1988), again likely impairing prospective memory. And, diminished interest or participation in everyday or pleasurable activities might reduce overall motivation in everyday life, therefore reducing motivation to *plan*, *maintain* and successfully *perform* prospective memory tasks. In support of the idea that alterations in cognition and mood might be particularly important to understanding the relationship between PTSD and PM, in Studies 1 and 3, the correlations between self-report prospective memory and negative alterations in cognition and mood (subscale D on the PCL) were statistically larger than the correlations with re-experiencing and avoidance (subscales B and C; ps < .04, only PRMQ in Study 3).

Finally, in Chapter 1 I suggested that hyperarousal might be particularly important for the PM-PTSD relationship. We know that a state of hyperarousal—or alterations in arousal and reactivity (Criterion E)—restricts resources available for other cognitive tasks such as prospective memory. Instead, these resources are consumed in monitoring the environment for threat (e.g., McFarland et al., 2016; Scott et al., 2017). Specifically, prior literature investigating the PM-PTSD relationship reports that hyperarousal is particularly associated

with time-based tasks that rely heavily on higher-order functions to monitor the environment and self-initiate intentions (Scott et al., 2017). Heightened arousal also sometimes results in difficulty concentrating and difficulty sleeping, both of which could also directly impair prospective memory (see also Rau et al., 2017). I also found—in Studies 1 and 3—that alterations in arousal and reactivity seemed particularly important; the correlations between self-report prospective memory and subscale E on the PCL were statistically greater than the correlations with re-experiencing and avoidance (subscales B and C; *p*s < .008, only PRMQ in study 3). This finding aligns with the idea that hyperarousal might be a mechanism that explains the relationship between PTSD and prospective memory. Indeed, I acknowledge and agree with prior research suggesting that hyperarousal symptoms are particularly important in the PM-PTSD relationship (e.g., Rau et al., 2017; Scott et al., 2017). However, my findings suggest that *all* PTSD symptom clusters likely contribute to the relationship in some way.

In sum, Studies 1-3 add to prior literature finding that indeed we see a relationship with prospective memory and PTSD symptom severity in the general population, not just in clinical populations. We know that PTSD symptoms independently contribute to self-report prospective memory over and above other physical and mental health comorbidities that commonly arise with PTSD. And, that any level of symptoms within any cluster might impair prospective memory, rather than impairment resulting only when people's overall PTSD symptoms cross the diagnostic threshold.

Nature of the relationship using different measurement methods

In Studies 1-3 (Chapters 2-4) I addressed my second thesis aim, to explore the relationship between PTSD symptom severity and prospective memory using a variety of measurement methods, and across different empirical environments. We know that each measurement method has limitations, and that the existing literature in clinical PTSD

populations has relied solely on a variety of in-lab objective tasks (e.g., Glienke et al., 2017; Korinek et al., 2021; McFarland et al., 2016; Pagulayan et al. 2018; Scott et al., 2016). In Study 1, I used self-report questionnaires and found medium-sized correlations between scores on these measures and PTSD symptom severity (*r*s = .42-.49). In Study 2, I replicated this pattern with self-report questionnaires (*r*s = .32-.42), but additionally used objective lab-based prospective memory tasks. I found no relationship between PTSD symptom severity and PM performance on these lab-based tasks, nor were the self-report and lab-based assessment methods related. In Study 3, I again replicated the relationship between PTSD symptom severity and self-report questionnaires (*r*s = .34), and additionally found a small correlation between symptom severity and diary-recorded prospective memory errors (*r* = .21). Therefore, the size and presence of the relationship between PTSD symptom severity in the general population and prospective memory seems dependant on measurement type. That is, the relationship is absent for in-lab, objective assessment, but exists for subjective assessment (i.e., self-report), and to a lesser extent for naturalistic tasks (i.e., diary recording). One interpretation of this pattern of results is that prospective memory impairment does exist amongst people with worse PTSD symptom severity, and this impairment is simply *exaggerated* on self-report questionnaires.

Comparison of current findings and prior research: PM and PTSD

My finding that lab-based objective tasks do not correlate with PTSD symptom severity is inconsistent with prior literature (e.g., Korinek et al., 2021; McFarland et al., 2016; Pagulayan et al., 2018; Rau et al., 2017; Scott et al., 2016). This prior literature used similar, lab-based tasks such as the Memory For Intentions Test (MIST; Korinek et al., 2021; Pagulayan et al., 2018; Rau et al., 2017; Scott et al., 2016), and computerised multiple-choice trivia tasks (McFarland et al., 2016). Using such tasks, these studies report that: PTSD symptom severity predicts event-based PM performance amongst veterans (McFarland et al.,

2016), veterans with PTSD perform worse on time-based tasks but not event-based tasks, compared to veterans without PTSD (Scott et al., 2016), overall PM performance (i.e., time- and event-based performance) correlates with PTSD symptoms (Korinek et al., 2022; Rau et al., 2017), and veterans with self-report history of blast-related TBI and PTSD perform worse on overall PM (i.e., time- and event-based PM), than a non-combat control group (Pagulayan et al., 2018). Yet here, using similar in-lab computerised tasks, I found no correlation between overall, time-based, or event-based PM performance and PTSD symptoms, in a general population.

There are several potential explanations for the absence of a relationship with lab-based prospective memory in a general population sample, compared to prior literature using veterans. First, exposure to combat-stress in particular might result in neurological changes that impair prospective memory specifically in the lab environment. We know that combat exposure results in functional and structural changes in frontal and mid-regions of the brain (E.g., Elder, 2015; van Wingen, Geuze, Caan, & Fernandez, 2012) that consequently impairs general cognitive performance (e.g., Liberman et al., 2005). These frontal and mid-regions are important for prospective memory and thus exposure to combat specifically could impair PM (see also Glienke et al., 2017). Therefore, given the prior literature has relied exclusively on veteran samples (i.e., that have been exposed to combat), the type of comparison group is particularly important. The studies that reported prospective memory impairment among veterans with PTSD using in-lab computerised PM tasks (i.e., Korinek et al., 2021; McFarland et al., 2016; Pagulayan et al., 2018; Rau et al., 2017; Scott et al., 2016) specifically compared veteran groups to control groups that had been exposed to combat in some way, therefore relying on *combat-stress* specifically. This idea that combat-stress specifically impairs PM might also apply to ecologically valid PM tasks, not just tasks in the lab. Glienke et al. (2017) used an ecologically valid in-lab task—where they asked

participants to plan and complete both time- and event-based prospective memory tasks in a virtual, fictional holiday week—and both combat *and* non-combat control groups. They concluded that—given veterans with and without PTSD performed similarly on PM, but both veteran groups performed worse compared to the non-combat controls—exposure to combat-related stress specifically impaired prospective memory. Altogether then, it seems likely that exposure to combat-stress impairs prospective memory in addition to PTSD symptoms themselves (e.g., via brain injury or deficits in cognitive functioning).

A second explanation for the absence of a relationship between lab-based prospective memory in the general population—compared to the presence of the relationship amongst veteran samples—relates to the presence and level of negative beliefs. Among general population samples, the belief structure after a traumatic event involves three factors; negative beliefs about the self, negative beliefs about the world, and self-blame (Foa et al., 1999). However, for veteran samples, this belief structure has a fourth component; beliefs about coping competence (Sexton et al., 2018) and includes ideas of moral injury (i.e., witnessing or contributing to transgressions that violate moral beliefs; Frankfurt & Frazier, 2016). Thus, the belief structure for veterans compared to general population samples is different and therefore may affect lab-based PM specifically (e.g., less motivation or engagement in cognitive tasks due to moral beliefs such as "the world is a bad place"). Similarly, veterans are typically male, yet females tend to hold greater negative beliefs about the self, higher self-blame and view the world as more dangerous (e.g., Tolin & Foa, 2002). Thus, samples relying on veterans might have lower, or different, negative beliefs related to the self, and therefore veterans' PM reporting may be less biased by such beliefs.

A third explanation relates to the statistical power in my thesis. The prior literature relied heavily on smaller sample sizes (Ns < 100) therefore the presence or size of the effects might arise from outliers in the population, or a small number of people scoring in a

particular way (e.g., excessively high prospective memory failures, and/or PTSD symptom severity). In addition to these small sample sizes, any difference between groups might arise from a spurious relationship that exists because of other variables not controlled for (e.g., traumatic brain injury, other mental health or substances use disorders), rather than specifically from PTSD symptoms.

Comparison of current findings and prior research: PM and other clinical disorders

Interestingly, for other clinical disorders, the relationship between symptoms and prospective memory seems mostly consistent across measurement types. For schizophrenia, impairments are observed across all measurement types and different population samples (see Zhou et al., 2019) and for depression and bipolar disorders, the relationship has only been investigated using lab-based objective tasks (e.g., Au et al., 2013; Chan et al., 2013; Zhou et al., 2013; see Zhou et al., 2017). For OCD, the relationship appears particularly complex (i.e., depending on the symptom profile, e.g., checking behaviours), but there is evidence for a relationship between symptoms and every type of measurement method. The objective tasks I used in Study 2 were similar to those used in other clinical groups (e.g., Cao et al., 2016; Cuttler & Graf, 2007; Rude et al., 1999). Therefore, the *sample type* might be important in addition to measurement type. Interestingly, studies exploring schizophrenia and depression have relied only on clinical comparison groups, rather than subclinical, or general populations with varying levels of symptoms. Yet for OCD, the literature has included subclinical (e.g., Cuttler & Graf, 2007) and general populations (e.g., Palmer et al., 2015). Thus, the use of different populations with varying symptomology might complicate the relationship, as we see for PTSD. In a similar way to PTSD, perhaps OCD symptoms themselves, at sub-clinical levels, can impair prospective memory. Put differently, for a clinical diagnosis, symptoms must meet a certain threshold. However—paralleling the way that symptoms can impair our everyday functioning (e.g., social, occupational) without

meeting a certain threshold—symptoms likely do not need to reach such a threshold for PM difficulties to arise. Specifically, checking compulsions are common in the general population and can exist without an OCD diagnosis (Stein et al., 1997). Indeed, within this specific sub-group of OCD symptoms, dysfunctional beliefs (e.g., overestimation of threat) and general metamemory deficits (Woods et al., 2002) play an important role in the maintenance of compulsions (Rachman, 2002). Thus, likewise for PTSD then, perhaps the presence of metamemory deficits, even at lower levels of symptom severity not necessarily resulting in a diagnosis, contribute to a relationship with prospective memory.

PTSD is unique

PTSD is different to these other clinical disorders in several ways that might contribute to the nature of the relationship with prospective memory. First, we know that PTSD is commonly identified as a "disorder of memory" (e.g., McNally, 2006), or a "disorder of forgetting" (e.g., Ursano et al., 2007). Although difficulties with cognition and/or memory may present with other clinical symptoms (e.g., depression; APA, 2013), people with PTSD present with numerous unique memory-related issues (e.g., memory amplification; e.g., Engelhard et al., 2008; Oulton et al., 2016). And, difficulties with memory in a number of ways form part of the diagnostic criteria; e.g., nightmares, flashbacks, inability to recall key features of the traumatic event (APA, 2013). These multifaceted memory problems therefore might complicate the relationship that appears mostly straightforward in other clinical disorders. For example, the presence and/or severity of intrusive thoughts might result in impaired functioning in everyday life, but not in the laboratory.

Second, and along similar lines, changes in beliefs are a key diagnostic criterion for PTSD (APA, 2013). As I have mentioned, Foa and colleagues (1999) propose that three core belief systems arise after a traumatic event: 1) beliefs about the world, 2) beliefs about the

self, and 3) self-blame. Here, the most relevant belief—given that prospective memory is related to *self*-abilities rather than the world or other people—is the second; negative beliefs about the self. In Cognitive Processing Therapy (Resick et al., 2016), people with PTSD often present with unhelpful, unrealistic beliefs regarding *trust* and *esteem*—related to the way we value ourselves as worthy—and these are two of the target belief groups for re-appraising during therapy. These specific changes in core beliefs around self-trust and self-esteem are particularly important for prospective memory. For example, someone with PTSD might begin to believe their memory is untrustworthy, or that they are useless and a failure. These specific beliefs likely then contribute to the way people with worse PTSD symptom severity self-report on their prospective memory failures, and/or the way they engage in PM behaviours in their everyday life (e.g., less effortful encoding if they believe they are already a failure). Overall, these negative beliefs—related to trust and esteem—are unique to PTSD, and therefore might specifically affect PM in a different way, compared to beliefs in other disorders that also have a relationship with PM (e.g., feelings of hopelessness in depression, or overestimation of threat in OCD).

In sum, Studies 1-3 highlight the importance of measurement in the field of prospective memory, particularly when investigating the relationship with PTSD symptoms. There are specific components of PTSD (i.e., the nature of the traumatic event, the complex memory dysfunction, and the presence of negative beliefs relating to trust and esteem) that may explain why we see an inconsistent relationship across measurement types, particularly compared to other, similar clinical disorders. Given such complexities, future research in the prospective memory field, and specifically investigating the PM-PTSD relationship, should seek to include a variety of measurement methods.

Nature of the mechanisms that might underpin the relationship—metacognitive beliefs

In all my empirical chapters, I addressed the third aim of my thesis; to explore one particular mechanism that might underpin the relationship between PTSD symptoms and prospective memory—metacognitive beliefs (e.g., negative beliefs about the self, and about memory). In Studies 1-3 I used mediations to test the idea that PTSD symptoms cause greater metacognitive beliefs, that may then contribute to prospective memory. I found that indeed, in all three studies, metacognitive beliefs mediated the relationship between self-report prospective memory, and PTSD symptom severity. That is, people with worse PTSD symptoms reported holding more negative beliefs about themselves and their memory, that resulted in greater self-reporting of everyday prospective memory failures. This finding is consistent with the idea that changes in core beliefs (e.g., trust and esteem) might contribute to prospective memory, specifically in the case of self-report measurement. However, these metacognitive variables did *not* contribute to the relationship when prospective memory was measured using a naturalistic diary (Study 3). Therefore, these metacognitive beliefs seem tied to self-report questionnaire assessment specifically. Interestingly, these findings are also in line with research in the PTSD field suggesting that several other phenomena only exist when using *self-report* assessment and not when using objective-type tasks (e.g., memory fragmentation or disorganisation; e.g., Byrne et al., 2001, Koss et al., 1996, Tromp et al., 1995, van der Kolk & Fisler, 1995). Thus altogether, it seems likely PTSD is a disorder of memory *and* a disorder of metacognition (i.e., beliefs about memory).

In Study 4, I empirically tested the idea that self-report prospective memory is vulnerable to momentary change based on current appraisals (e.g., “I have a poor memory”, or “I have no confidence in my memory”). Across two experiments, I found that participants recalling two instances of forgetting self-reported making fewer prospective memory errors (on a self-report prospective memory questionnaire), compared to participants recalling 10,

suggesting that self-report assessment of prospective memory *is* vulnerable to current appraisals of ability. In the case of PTSD, in Study 4 (Experiment 2) I also found the difference between the recall conditions on self-reported prospective memory was strongest at lower levels of symptom severity, with the pattern reversing at high symptom levels. That is, at higher levels of PTSD symptoms, these participants tended to rely on the *ease* of the retrieval experience, rather than the *content* they recalled. This finding is consistent with the idea that people with worse PTSD symptom severity rely on easier cognitive processing (i.e., heuristics) because they may not have the available cognitive resources to deeply analyse, and therefore make complex decisions. Indeed, the finding that people with worse symptoms relied on heuristics rather than content also aligns with the evidence that suggests people with worse PTSD symptoms demonstrate poor resource allocation because their cognitive resources are consumed in symptom management. Altogether then, recall one interpretation of my findings is that actual prospective memory impairment does exist amongst people with worse PTSD symptom severity, and that this impairment is just *exaggerated* on self-report questionnaires. However, these findings related to metacognitive beliefs suggest another possibility; that prospective memory is *not* impaired amongst people with worse PTSD symptoms and instead this relationship arises entirely because of negative metacognitive beliefs.

As I discussed in Chapter 1, metacognitive processes likely play a particular role in the fourth stage of the prospective memory framework—evaluation. This final stage requires judgement and reinforcement of the planning, retention and performance stages (e.g., "I did, or did not, perform all those tasks successfully") leaving this judgment open to biases. Beliefs, for example that I am a failure, or that I am useless, likely result in incorrect reinforcement at the evaluation stage, particularly among people with worse PTSD symptoms. For example, someone with less severe PTSD symptoms who forgot take their

medication might evaluate this failure as, “I made a mistake and will try to remember next time” compared to someone with worse PTSD symptoms who might instead appraise this mistake as “I am a total failure and will never remember”. The person in the former scenario has more accurately appraised their failure as a mistake and reinforced that they can improve next time. However, the person with the worse symptoms has internalised this negative appraisal; blaming themselves for the failure and instead expressing a sense of learned helplessness—the belief that after repeated exposure to adverse events we are unable to avoid or deal with these adverse events therefore they are uncontrollable (e.g., Seligman, 1972; Seligman & Teasdale, 1978). This learned helplessness may then maintain negative beliefs and inaccurately reinforce PM behaviours. Specifically, this negative reinforcement in the *evaluation* stage may result in failures at the other PM stages for future PM tasks.

My findings therefore suggest impairment at the planning, retention and performance stages, in addition to evaluation. After the evaluation stage, people engage in “behavioural adaptation” to learn from their prior success or failures, and therefore adapt their behaviour to improve future performance. However, if people with worse PTSD symptoms evaluate their failures consistent with negative beliefs about themselves (e.g., interpreting success and failures) or with ideas of learned helplessness (e.g., I will never remember), this evaluation may impair their future planning. Indeed, my findings also suggest that when PM is measured via self-report questionnaires, tendency to future plan mediates the PM-PTSD relationship; people with worse PTSD symptoms are less likely to make plans for the future, and therefore report more PM errors. If these people then believe they will never remember or avoid making future plans altogether, they may contribute less effort to future *encoding* and *maintaining* intentions. Failed or impaired performance at these stages would then result in difficulties with *performance.* Thus, a second way metacognitive beliefs might impair PM performance in the *encoding, maintenance* and *performance* stages is via a self-fulfilling

prophecy—a situation where false beliefs eventually come true (Merton, 1948). This idea might be yet another explanation for the absent relationship I found for in-lab prospective memory tasks. That is, when participants with worse PTSD symptoms are given the opportunity to perform at their "peak" free of other distractions, these behaviours arising initially from their false beliefs are reduced, or entirely eliminated.

Clinical Implications

My thesis has several clinical implications, regardless of whether prospective memory is actually impaired, or if impairment arises only from metacognitive beliefs. First regarding actual impairment, poor engagement in therapy might result from poor prospective memory, rather than poor motivation (e.g., nonadherence to homework; Cook et al., 2014, see also Murphy et al., 2002). Indeed, session attendance and practice assignment (i.e., homework) completion is key in therapy success (Resick et al., 2006). But, we know that avoidance is a key contributor to poor therapeutic engagement (e.g., changing the subject, showing up late for sessions; Resick et al., 2006), and consequently this avoidance and/or lack of engagement maintains PTSD symptoms. Thus, if PM is actually impaired in everyday life (as Study 3 suggests), for example via a self-fulfilling prophecy or learned helplessness, then meaningful therapeutic engagement might be challenging.

Second regarding metacognitive beliefs, my findings provide insight into the breadth of maladaptive beliefs in PTSD. As I have mentioned, we know that changes in cognition (e.g., negative beliefs about the self, other people and the world, or distorted views of blame; APA, 2013) are essential to a PTSD diagnosis, and are key targets for change in PTSD interventions (e.g., Resick et al., 2016). We also know that people with PTSD might also hold negative beliefs about their *memory,* specifically (e.g., Woud et al., 2018; see Bennett & Wells, 2010) and that metacognitive features might be more important than *actual* features of

memory (e.g., memory disorganisation) in causing PTSD (Wells, 2000, Wells & Sembi, 2004). That is, beliefs about what these memory features might *mean* (i.e., "gaps in my memory mean I am broken"), likely contribute to the development of PTSD, rather than the memory features themselves (i.e., the memory gaps for the traumatic event). However, these extant findings relate mainly to beliefs about the trauma memory (i.e., retrospective memory) and interpretation of these difficulties (e.g., "having memory blanks for the incident means I can't cope with stress"; Bennett & Wells, 2010). Yet here, I found that these negative beliefs about memory perhaps generalise to other memory functions, like prospective memory, in addition to retrospective memory. It is possible that people with PTSD feel so poorly about themselves generally, that they might mis-appraise all cognitive functions, consistent with the negative appraisals about themselves. For example, if people believe they are a failure, or are useless, they may similarly believe they are "dumb", "stupid" or "incapable" (i.e., of cognitive tasks like remembering or concentrating). Thus, people with worse PTSD symptom severity, self-report worse prospective memory, not just worse memory for their trauma.

Altogether, if the relationship between PTSD symptom severity and prospective memory arises even in-part because of metacognitive beliefs and subsequent biases in reporting, these beliefs should be targeted in therapy. Indeed, in common interventions like Cognitive Processing Therapy (CPT; Resick et al., 2016), therapists provide psychoeducation regarding beliefs about the self, other people, and the world, but this psychoeducation does not highlight metacognitive disruption. My findings suggest that psychoeducation and cognitive re-appraisal should also target metacognitive beliefs, and specifically those about prospective memory. These reappraisals should then assist in changing negative beliefs about the self and consequently reducing overall PTSD symptoms. And, if education and intervention specifically to re-adjust such inaccurate beliefs results in changing PM

behaviours (e.g., reduction in aid use, or less effortful encoding or retrieval) this too could improve overall functioning.

An additional avenue for future research is to use metacognitive intervention strategies for negative beliefs about memory. Indeed, the findings from Chapter 5 suggest that self-report prospective memory is malleable. If we can make people feel worse about their everyday prospective memory with a simple manipulation (i.e., recall 2 or 10 instances of forgetting), we may also be able to make people feel *better* about their prospective memory. Indeed, people feel *better* about their prospective memory and engage in fewer compensatory strategies after simply being told they performed above average (i.e., in the 85th to 90th percentile; Alcolado & Radomsky, 2011). Clinically then, metacognitive intervention strategies could be applied to improve beliefs about prospective memory, specifically. One strategy for intervention is cognitive bias modification—educating participants about negative metacognitive beliefs and their tendency to pay greater attention to their errors—which successfully reduces attention to threat and instead promotes positive interpretation of stimuli (e.g., ambiguous words or images; e.g., Brosan et al., 2011; Hoppitt et al., 2010). In a similar way, perhaps this training could be tailored to prospective memory (e.g., to reduce attention to errors, or to positively interpret errors). A second strategy is reinforced self-affirmation—boosting self-confidence to rely on your own memory, instead of external cues (e.g., Szpitalak & Polczyk, 2019). This strategy is typically used in the case of misinformation (i.e., to increase reliance on participants' own memory for an event rather than inaccurate information from other sources), but could be applied to prospective memory. For example, participants could be provided with false feedback that their prospective memory performance was better than the average to encourage positive future PM behaviours.

Methodological Implications

My thesis has significant methodological implications, both in the prospective memory field specifically, and for wider cognition research. I found more evidence to support the demonstrated finding that subjective and objective measures of the same construct likely do not capture the whole construct, and instead map onto different components (see Dang et al., 2020). Therefore, researchers should carefully select measures based on the type of population, and the research question, to tap into these different components of prospective memory. For example, among clinical populations like people with PTSD or OCD—i.e., disorders with metacognitive theoretical underpinnings and/or characterised by problematic beliefs about memory but where ecological validity is important—research should use ecologically valid, but unbiased measurement (e.g., virtual week; Rendell & Craik, 2000). However, self-report questionnaires are similarly useful in the case of specifically exploring *beliefs* or *judgments* of performance, including for such biases in reporting. And, in-lab assessment may serve a purpose to examine a population's "peak" or best performance, or if this performance might be equal to performance in everyday life. More generally, in the field of prospective memory, researchers should seek to use a combination of both subjective and objective measurement methods, or provide explanation as to why only one was included (e.g., exploring self-report biases specifically).

In addition to prospective memory specifically then, the broader literature supports the idea that subjective and objective measurement tools should not be used independently or interchangeably, and instead likely answer different research questions. In the applied cognitive field, there are discrepancies between subjective and objective measurement for cognitive function amongst, for example: cancer survivors post-chemotherapy (see Hutchinson et al., 2012, for review), people with affective disorders (e.g., Svendsen et al., 2012), patients following electroconvulsive therapy (e.g., Hammershøj et al., 2022), and ICU

survivors (e.g., Brück et al., 2019). And, in the general memory literature, there are discrepancies between subjective and objective measurement amongst, for example: older adults (see Crumley et al., 2014 for review), women during the menopausal transition (Weber et al., 2012), and people with chronic fatigue syndrome (e.g., Cockshell & Mathias, 2014). Altogether then, across a variety of samples, there appears ongoing discrepancies between objective and subjective measurement types. Thus, measurement choice should be made carefully both in prospective memory research and within the broader applied cognitive field.

Theoretical Implications

My thesis has theoretical implications both for prospective memory theory, and PTSD theories.

PTSD and the multiprocess framework

As I discussed in Chapter 1, McDaniel and Einstein (2000) proposed a multiprocess framework to explain the cognitive processes underpinning PM. Specifically they argue that PM involves both automatic—spontaneous retrieval that relies less on self-initiated processes—and controlled processes—strategic resource monitoring that relies heavily on executive functions. My thesis supports the idea that PTSD symptoms might be another individual difference factor that affects how likely people are to engage in either automatic or controlled prospective memory processes. McDaniel and Einstein (2000) suggest there is likely a general bias towards using automatic processes, rather than controlled processes, to reduce the cognitive demands of PM tasks and any subsequent impact on other ongoing tasks. Given my findings that there was no relationship between PTSD and prospective memory in the lab, but a relationship for everyday, diary-recorded errors, perhaps people with PTSD have even greater bias towards automatic processes, because their resources are otherwise occupied in symptom management (e.g., controlling intrusive thoughts). Yet, in the lab

environment, people with PTSD are able to appropriately prioritise the prospective memory task and therefore engage both controlled and automatic processes. My findings from Study 3—that *time-based* diary-recorded prospective memory errors correlated with PTSD symptom severity, but event-based errors did not—also support this idea. Time-based tasks require more controlled processes to strategically monitor the environment for time-based cues, therefore likely these controlled processes are the ones that are impaired in PTSD. Yet, automatic processes seem to remain intact, similarly supporting a bias towards these processes. In Study 4, I also found that people at higher levels of PTSD symptoms relied on the ease of processing, rather than the content they recalled, suggesting reliance on automatic, rather than controlled processes that may be impaired. Altogether then, amongst people with worse PTSD symptoms, PM impairment might arise only for controlled processes because these processes rely heavily on executive resources that are otherwise occupied in symptom monitoring. Yet, automatic processes may remain relatively intact both in the lab, and for event-based tasks.

PTSD theories

Finally, my thesis adds to what we know about PTSD as a "disorder of memory" (e.g., McNally, 2006), or a "disorder of forgetting" (e.g., Ursano et al., 2007). Not only is PTSD characterised by intrusive thoughts, nightmares and vivid sensory flashbacks (APA, 2013; McNally, 2006), but significant research reports memory disturbances including delayed processing for trauma-related material (i.e., longer to respond to the word "firefight" than other negative, positive, or neutral words, e.g., McNally et al., 1990), learning and memory difficulties for verbal material (e.g., Vasterling & Brailey, 2005), deficits on tests of sustained attention, working memory, initial learning (e.g., Vasterling et al., 1988), and overgeneral memory (i.e., difficulty recalling specific personal memories in response to cues, e.g., McNally et al., 1994). This prior research examines memory for the past (i.e., retrospective

memory), both personally (i.e., autobiographical memory) and for new learned content (i.e., word lists). Thus, typically PTSD is thought to be a disorder related to the past. But some studies of episodic memory find PTSD has deteriorating effects on imagining future events (Brown et al., 2014; Kliem et al., 2014). Along similar lines, more recent literature suggests that people may have traumatic stress reactions for events that have not yet happened—including deployment to Afghanistan (Berntsen & Rubin, 2015), childbirth (Goutaudier et al., 2019), and the COVID-19 pandemic (Bridgland et al., 2021). In fact, some literature even reports that people have *worse* traumatic stress-like reactions for future events, compared to events that have already happened (e.g., Rubin, 2013). This body of work, in addition to the findings from my thesis, suggests that theoretical models of PTSD likely need to consider PTSD not as a disorder strictly of memory for the past, and instead include components related to memory for the future, including prospective memory.

My thesis findings also support the metacognitive model of PTSD (Wells, 2000), suggesting that several memory difficulties reported in PTSD do only present subjectively—as I have found for prospective memory in the general population. One long-standing theory of PTSD suggests that memory fragmentation (i.e., gaps in the trauma memory), or disorganisation (i.e., poor integration into existing schemas) contributes to the development and maintenance of symptoms (Brewin & Holmes, 2003; Foa & Riggs, 1993; Horowitz, 1976). However, despite some objective evidence for memory disorganisation or fragmentation (see Bennett & Wells, 2010, for review), most evidence suggests trauma memories are only *self-reported* as more disorganised or fragmented, when compared to non-trauma memories (e.g., Byrne et al., 2001, Koss et al., 1996, Tromp et al., 1995, van der Kolk & Fisler, 1995). When examined experimentally (i.e., via a trauma film paradigm), participants who saw disorganised scenes in a random sequence, compared to those who saw the scenes in the correct temporal sequence, reported no difference *objectively* on analogue

symptoms, number of reported intrusions or the degree of memory distortion (Segovia et al., 2016, see also Taylor et al., 2021). However, participants who *self-reported* greater memory disorganisation reported more avoidance symptoms specifically, and greater memory distortion (Segovia et al., 2016). Altogether, these findings suggest specific impairment in metacognition, which consequently resulted in worse symptoms and perceived memory coherence, as opposed to an actual objective memory impairment.

Wells (2000) suggests that memory disorganisation is only important when it is the focus of maladaptive thinking and coping strategies. For example, if someone with PTSD perceives they are "broken" because there are gaps in their memory, or that they must have a whole memory for the event to recover, both these beliefs are unhelpful to recovery. My thesis findings might work in a similar way. Perhaps there is some degree of prospective memory impairment in everyday life (e.g., Chapter 4), but this impairment becomes problematic only when it is the focus of maladaptive thinking and coping strategies. In fact, we know that prospective memory errors are common in the general population (e.g., Crovitz & Daniel, 1984; Einstein & McDaniel, 1996; Kliegel & Martin, 2003; West, 1984), and therefore these errors could be considered "normal". Thus, it is the interpretation of these errors amongst people at increasingly high PTSD symptom severity that might become problematic. Moreover, people with worse PTSD symptoms might interpret PM errors in a way that suggests they have failed, or that they are a bad person, but it is in fact these beliefs—rather than the actual impairment—that could contribute to the maintenance and worsening of PTSD symptoms (e.g., Bennett & Wells, 2010; Wells 2000).

Limitations and future directions

My thesis has important limitations. First, I recruited non-clinical samples to investigate a clinical issue. However, as I acknowledge throughout this thesis, my primary aim was to explore the nature of the relationship between PTSD symptom severity and

prospective memory within general population samples, because prior literature had relied on veterans only. I therefore strategically recruited non-clinical participants—from differing populations; online (Mechanical Turk), community, and undergraduates—to attain a wide range of PTSD symptom scores, and to control for comorbidities that might explain the relationship in clinical veteran populations. Despite using non-clinical populations, a meaningful proportion of participants in each study (22.8-38.5%) met the cut off for a likely PTSD diagnosis (>31; Ashbaugh et al., 2016). But, although our PTSD symptom checklist demonstrates good convergent validity with semi-structured diagnostic interviews for PTSD (e.g., Clinical Administered PTSD Scale; CAPS, Weathers et al., 2013), we did not use such clinical tools here. Therefore, we were not able to formally diagnose or clinically—and more importantly, objectively—examine the presence or severity of PTSD symptoms for each participant. Similarly, of course—and especially because I have extensively noted the limitations of using self-report measurement—these self-report symptom questionnaires (e.g., the PTSD checklist) might be biased in some way. Using the CAPS instead of, or in addition to the PTSD checklist, would allow for clinical judgment of symptoms (i.e., objective scoring; e.g., nightmares occurring 3-4 times per week), rather than relying only on participants' self-reported symptoms, which might too be biased. Given I successfully manipulated people's self-report prospective memory in Study 4, I also explored the difference between groups on the PTSD checklist to determine if current appraisals similarly affected symptom reporting. However, I found no difference between groups on PTSD symptom severity, after the manipulation. This null finding suggests that perhaps PTSD symptom reporting is more robust than questionnaires focusing on cognitive constructs (e.g., prospective memory). Despite this finding, it is possible that the PTSD checklist is also vulnerable to biases in reporting and was simply not affected by this manipulation specifically. In fact, we know that PTSD symptom severity appears malleable and may

sometimes inaccurately reflect actual symptom experiences (e.g., Merkelbach et al., 2019; Nahleen et al., 2019, but see also Greene et al., 2022). Future research could use a semi-structured interview to examine the severity of PTSD symptoms using a more objective assessment (i.e., the CAPS). Given we don't know whether something about exposure to specific types of events (e.g., combat-stress) might contribute directly to impaired PM, future research could also aim to recruit specific clinical populations across a range of traumatic events, and could compare between event-type (e.g., interpersonal vs not).

Second, I acknowledge that Studies 1-3 rely specifically on correlational data and therefore we cannot attribute causation. I hypothesise that PTSD symptom severity *causes* or contributes to deficits in prospective memory in some way, but cannot conclude that these symptoms are solely responsible for any observed impairment. I also hypothesised that other variables that commonly co-exist with PTSD might similarly impair prospective memory (i.e., traumatic brain injury, childhood trauma, alcohol use, presence of a learning/developmental disorder; depression, anxiety and stress), and therefore measured and statistically controlled for these variables. This statistical control allowed me to examine the unique contribution of PTSD symptoms to prospective memory. Similarly, I proposed and statistically examined (i.e., via mediation) mechanisms that might underpin the PM-PTSD relationship, and used an experimental manipulation in Study 4 to support these correlational ideas. But, despite this control, we cannot experimentally manipulate PTSD symptoms and therefore cannot attribute direct causality.

Third, two key variables I did not explore that might contribute to the nature of the relationship, in addition to PTSD symptoms, are age[23] and baseline intellectual functioning. Beginning with age, there is a significant amount of literature exploring the prospective

[23] However note that across studies 1-3, PM performance and self-report PM measures did not correlate with age (*p*s > .05).

memory paradox—that age-related deficits are observed in laboratory-based prospective memory tasks, but age-related *benefits* are observed in naturalistic designs (e.g., Henry et al., 2004 for review). We also know that younger adults tend to report a greater number of negative life events (e.g., Hatch & Dohrenwend, 2007) and might report lesser symptom severity than in veteran samples (e.g., Konnert & Wong, 2015). In terms of cognitive functioning, we know that childhood traumatic events can impair cognitive functioning over the lifespan (e.g., Majer et al., 2010; McGuire & Jackson, 2020) and that cognitive functioning (i.e., measured by IQ) generally predicts the development of PTSD symptoms following a traumatic event (e.g., Buckley et al., 2000). Therefore, it is possible that both age and intellectual functioning might be additional contributing factors to the PM-PTSD relationship and future research should explore and control for these variables.

A fourth limitation is that although I place great emphasis on the importance of the type of prospective memory assessment method in the relationship with PTSD, there are several assessment methods not included in the scope of this thesis. Specifically, numerous self-report questionnaires (e.g., CAPM; Chau et al., 2007, see also Brief Assessment of Prospective Memory; BAPM; Man, Fleming, Hohaus, & Shum, 2011) and objective assessment tools (e.g., Memory for Intentions Test; Raskin & Buckheit, 2000; Raskin, 2004; Raskin, Buckheit, & Sherrod, 2010) remain untested in the current population, to explore the same research questions. Specifically, Sections B and C of the CAPM (Chau et al., 2007) explore how much each of participants' failures concerns them, and why these failures might have occurred (e.g., "the more things I have to do, the more likely I am to forget to do them"). Thus, despite this measure being designed for TBI populations, these sections might provide additional insight into people's metacognitive judgments of their PM performance in everyday life. Specifically, this measure would assist in understanding *why* (e.g., because they are useless, or a failure) people believe they make errors, and their level of *concern,*

rather than just reporting on the frequency people believe they make errors. Additionally, since the inception of this thesis, researchers have devised a self-report measure examining people's *concerns* about their prospective memory ability (Sugden et al., 2021; see also Metacognitive Prospective Memory Inventory; Rummel et al., 2019). This assessment tool could help provide additional insight into not only self-report judgments of performance, but concerns about this performance (i.e., metacognition). Given my findings that negative metacognitive beliefs about memory are important in the PM-PTSD relationship, these measures might have revealed that people with worse PTSD symptom severity similarly report greater *concerns* about their prospective memory, in addition to greater frequency of errors. Moreover, three particularly promising assessment methods are those that maintain high experimental control whilst maintaining good ecological validity of the tasks; virtual week (Rendell & Craik, 2000), actual week (Rendell & Craik, 2000), and the use of virtual reality (e.g., Virtual Reality Prospective Memory Test, Man et al., 2016; Virtual Reality Shopping Test, Canty et al., 2014). These assessment tools allow researchers to explore planned intentions that are consistent with participants' daily lives and priorities. These tasks remove subjectivity whilst maintaining the representative nature and generalisability of the prospective memory tasks, and the experimental environment. Given the high variability between populations and types of assessment, we cannot be sure that the same outcome would arise for all assessment tools. On the one hand, if diary-recording is biased by metacognitive beliefs, we might find no relationship between PTSD symptoms and prospective memory performance on these objective but naturalistic tasks (i.e., virtual reality; actual week). On the other hand, if self-report measurement is just *exaggerated* by beliefs and everyday impairment does exist, we would predict a small relationship between PTSD symptoms and performance on these tasks. Therefore, future research should seek to replicate

the relationship between PTSD symptom severity in a general population and prospective memory performance on these different assessment tools.

Fifth, I acknowledge that measurement type and sample type are somewhat confounded throughout my thesis studies. That is, although I replicated the self-report relationship in each study with a different general population sample, I did not seek to replicate the objective tasks in online, or community participants, nor the diary-recording task in undergraduate or online participants. Thus, although I am assuming these differences in findings between the studies arise because of measurement type, population variables might change the nature of the PM-PTSD relationship. Future research should seek to further tease apart the specific role of sample and measurement type in the PM-PTSD relationship.

Additionally, multiple self-report measures also have informant-report versions of their questionnaires (i.e., relatives and/or carers complete the questionnaires on behalf of someone else; PRMQ and CAPM; see Sugden et al., 2021) that I did not use in this thesis. Despite less use of informant-report tools in the prospective memory literature (Sugden et al., 2021) some evidence finds these questionnaires more strongly correlate with performance-based PM measures, than their self-report counterparts (e.g., Chi et al., 2014; Fleming et al., 2009). Yet, there is limited evidence on the validity of informant-reports (Sugden et al., 2021). Future research should seek to first validate these questionnaires, then they could provide a useful supplement to measuring the PM-PTSD relationship in everyday life. Researchers could use these questionnaires in addition to self-report questionnaires *and* performance-based tasks (either in the lab, or naturalistic assessment) to explore their utility. Informant-report measures likely would *not* be biased by metacognitive beliefs in the same way as self-report measures and therefore provide a more objective assessment tool, representative of everyday life. If self-report questionnaires are biased because of metacognitive beliefs, we may see a smaller relationship between PTSD symptom severity

and informant-report questionnaires. Or, if the relationship exists entirely because of subjective bias, then we may see no relationship at all. Correlating the self-report and the informant-report measures would also provide further insight into how closely reports on performance align, and therefore the veracity of metacognitive biases for self-report components.

Sixth, I focused on metacognitive biases as an explanation for the relationship between prospective memory and PTSD symptoms—but acknowledge that several additional mechanisms remain untested. In Chapter 1, I proposed that neurocognitive impairment (i.e., dysfunction in the prefrontal, frontal and mediotemporal regions), the presence of other memory difficulties, and hyperarousal might be important for the PM-PTSD relationship, yet these are untested here. To further eliminate these explanations and explore the reasons for the PM-PTSD relationship, future research could use a comprehensive battery of neuropsychological testing (e.g., Neuropsychological Assessment Battery; Stern & White, 2003, Repeatable Battery for the Assessment of Neuropsychological Status; Randolph, 1998) to explore both neurocognitive impairment, and the presence of other memory difficulties. Ideally, future research could also use neuroimaging to explore neurological deterioration in brain regions or neural networks important for prospective memory (i.e., prefrontal, frontal and mediotemporal regions). In terms of hyperarousal, although I explored Criterion E on the PTSD checklist as a measure of alterations in arousal—and found that this symptom cluster was more important than re-experiencing and avoidance symptom clusters—future research could also use physiological measures of arousal like cortisol or heart rate. Additionally, prospective memory researchers propose other mechanisms including fatigue and stressor characteristics (e.g., level of cortisol; Glienke et al., 2017; Piefke & Glienke, 2017; Rau et al., 2017) that are similarly untested here. To test these ideas, future research could take measures of fatigue (e.g., Pittsburgh Sleep Quality Index; Buysse et al., 1989, see also Rau et

al., 2017), but I acknowledge these too might be biased by metacognitive beliefs. Indeed, people with insomnia (e.g., Manconi et al., 2010) and people with depression (e.g., Tsuchiyama et al., 2003) tend to underestimate their sleep time and quality. Therefore, objective assessments of fatigue or wakefulness would also be useful.

Finally, as I discussed earlier, I did not specifically examine prospective memory impairment at certain stages of the prospective memory process (e.g., planning, retention, performance). Impairment at each of these stages likely indicates a different type of cognitive function and therefore provides insight into specific difficulties for people with PTSD. For example; impairment in the planning stage would suggest difficulties with higher-order complex cognitive processes, impairment in the retention stage would suggest difficulties with working memory, and impairment in the performance stage would suggest difficulties with both retrospective memory and cognitive control. My findings suggest likely impairment during the *evaluation* stage of the PM process, but investigating impairment at each stage—for example, using a method like that from Glienke et al. (2017) examining the stages in a naturalistic task—would provide further insight into exactly where the deficits may lie for people with PTSD. This exploration could further assist with explaining the measurement discrepancies in the PM-PTSD relationship.

Conclusion

Previous investigations into a relationship between PTSD symptom severity and prospective memory relied only on veteran populations, and reported mixed findings. Overall, my findings provide evidence for a relationship between PTSD symptom severity and self-report prospective memory in the general population, and to a lesser extent diary-recorded prospective memory errors in everyday life, but not for objective, in-lab prospective memory tasks. I argue these mixed findings likely arise, primarily, from metacognitive beliefs underpinning the relationship between PTSD and prospective memory. These findings

support metacognitive theories of PTSD and provide further insight into the breadth of unhelpful beliefs in PTSD. Future PTSD models should seek to incorporate the idea that people with PTSD likely also experience difficulties with memory for the future, in addition to difficulty with memory for the past. Given the mixed findings across different measurement methods, future research should avoid relying on one assessment tool (i.e., subjective *or* objective measurement) in assessing prospective memory, or other cognitive variables. And, given the malleability of self-report prospective memory, intervention strategies could seek to specifically improve metacognitive beliefs about prospective memory. Alternatively, perhaps we could just find our way to the wizarding world and bring back some rememberalls!

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Appendices

Appendix A – Learning/Developmental Disorder Screening

Have you ever been diagnosed with any of the following learning/developmental disorders? Please tick as many that apply to you.

- Attention Deficit Hyperactivity Disorder (ADHD)
- Conduct Problems
- Learning Disorder/Developmental Delay
- Autism/Autism Spectrum Disorder
- I have never been diagnosed with learning or developmental disorder

Have you ever been placed in a resource class or an emotionally handicapped (EH), learning handicapped (LH), learning disorder (LD) special class?

- Yes
- No

Have you ever been told you had a learning disorder?

- Yes
- No

If yes, who told you you had a learning disorder? Please tick as many that apply to you.

- Doctor/other specialist
- Teacher
- Parent
- Other _____
- I have never been told I had a learning disorder

Appendix B – The Alcohol Use Disorders Identification Test (AUDIT; Babor et al., 1989)

1. How often do you have a drink containing alcohol?
   - Never
   - Monthly or less
   - 2-4 times per month
   - 2-3 times per week
   - 4 or more times per week

2. How many standard drinks containing alcohol do you have on a typical day when drinking?
   - 1 or 2
   - 3 or 4
   - 5 or 6
   - 7 to 9
   - 10 or more

3. How often do you have six or more drinks on one occasion?
   - Never
   - Less than monthly
   - Monthly
   - Weekly
   - Daily or almost daily

4. During the past year, how often have you found that you were not able to stop drinking once you had started?
   - Never
   - Less than monthly
   - Monthly
   - Weekly
   - Daily or almost daily

5. During the past year, how often have you failed to do what was normally expected of you because of drinking?
   - Never
   - Less than monthly
   - Monthly
   - Weekly
   - Daily or almost daily

6. During the past year, how often have you needed a drink in the morning to get yourself going after a heavy drinking session?
   - Never
   - Less than monthly
   - Monthly
   - Weekly
   - Daily or almost daily

7. During the past year, how often have you had a feeling of guilt or remorse after drinking?
   - Never
   - Less than monthly
   - Monthly
   - Weekly
   - Daily or almost daily

8. During the past year, have you been unable to remember what happened the night before because you had been drinking?
   - Never
   - Less than monthly
   - Monthly
   - Weekly
   - Daily or almost daily

9. Have you or someone else been injured as a result of your drinking?
   - No
   - Yes, but not in the past year
   - Yes, during the past year

10. Has a relative or friend, doctor or other health worker, been concerned about your drinking or suggested you cut down?
   - No
   - Yes, but not in the past year
   - Yes, during the past year

Appendix C - HELPS Screening Tool (Picard et al., 1991)

Have you ever hit your head or been hit on the head?
Think of incidents that could have occurred at any age, even those that did not seem serious (e.g., car accidents, falls, sport, abuse, assault etc). These incidents could also result from being violently shaken (e.g., as a child).

- Yes
- No

Were you ever seen in the emergency room, hospital or by a doctor because of an injury to your head? This also includes times when you may have thought you required medical attention but did not have access, or could not afford it.

- Yes
- No

Did you ever lose consciousness or experience a period of being dazed and confused because of an injury to your head?
Note: you may have not lost consciousness entirely, but could have experienced "altered consciousness". This includes feeling dazed, confused, or disoriented at the time of injury, or being unable to remember the events surrounding the injury.

- Yes
- No

Any significant sicknesses?
Brain injuries can occur not only from physical injury, but from illnesses such as: brain tumour, meningitis, stroke, seizures etc. They can also occur from significant loss of oxygen, for example, near suffocation, near drowning or following a heart attack.

- Yes
- No

Do you experience any of these problems in your daily life since you hit your head?
Note: these issues must only have arisen after the injury occurred.

- Headaches
- Dizziness
- Anxiety
- Depression
- Difficulty concentrating
- Difficulty remembering
- Difficulty reading, writing, calculating
- Poor problem solving
- Difficulty performing your job/school work
- Change in relationships with others
- Poor judgment (being fired from jobs, arrests, fights)
- I do not experience any of these problems in my daily life

Appendix D – Prospective Memory Questionnaire (PMQ, Hannon et al., 1990; 1995; revised version; Cuttler et al., 2016)

The following questionnaire has been developed to test how well you remember to do things. Please answer each question to the best of your knowledge. For each item, select the rating below that best describes the frequency you have the experience.

n/a = this item does not apply to me because I never perform the task
1 = never
2 = rarely
3 = sometimes
4 = often
5 = very often

n/a	1	2	3	4	5	I miss appointments I have scheduled.
n/a	1	2	3	4	5	I forget to follow a change in my usual routine.
n/a	1	2	3	4	5	I forget to send a card for a birthday or anniversary.
n/a	1	2	3	4	5	I forget to make an important phone call.
n/a	1	2	3	4	5	I tell someone something that I do not mean to tell.
n/a	1	2	3	4	5	I forget to return something I borrowed.
n/a	1	2	3	4	5	I forget to pick up items I need when shopping.
n/a	1	2	3	4	5	I forget to meet a friend on time.
n/a	1	2	3	4	5	I forget to pass on a message to someone.
n/a	1	2	3	4	5	I forget to run an errand I meant to do.
n/a	1	2	3	4	5	I forget to return a phone call.
n/a	1	2	3	4	5	I forget to make an appointment I need to make (e.g., doctor or dentist).
n/a	1	2	3	4	5	I forget to write an important letter.
n/a	1	2	3	4	5	I forget to return books to the library by the due date.
n/a	1	2	3	4	5	I forget to tip when I finish dinner at a restaurant.
n/a	1	2	3	4	5	I forget to turn my alarm clock off when I get up in the morning.
n/a	1	2	3	4	5	I forget to lock the door when leaving my apartment or house.
n/a	1	2	3	4	5	I forget to take my keys out of my car before locking the doors.
n/a	1	2	3	4	5	I forget to button or zip some part of my clothing as I am dressing.
n/a	1	2	3	4	5	I forget to pay the bill when I finish a meal at a restaurant.
n/a	1	2	3	4	5	I forget to put a stamp on a letter before mailing it.
n/a	1	2	3	4	5	I forget to comb my hair in the morning.
n/a	1	2	3	4	5	I forget to put on deodorant after showering or bathing.
n/a	1	2	3	4	5	I forget to flush the toilet.
n/a	1	2	3	4	5	I forget to get the groceries out of the car when I get home from the grocery store.
n/a	1	2	3	4	5	I forget to lock up my house, bike, or car.
n/a	1	2	3	4	5	I forget to shower or bathe.

n/a	1	2	3	4	5	I forget to cash or deposit my paycheck before my account runs out of money.
n/a	1	2	3	4	5	I forget what I want to say in the middle of a sentence.
n/a	1	2	3	4	5	I forget to say something important I had in mind at the beginning of a conversation.
n/a	1	2	3	4	5	I forget what I came into a room to get.
n/a	1	2	3	4	5	I start to do something, and then forget what it is I want to do.
n/a	1	2	3	4	5	I forget to bring something I mean to take with me when leaving the house.
n/a	1	2	3	4	5	I get part way through a chore and forget to finish it.
n/a	1	2	3	4	5	When I am driving I temporarily forget where I am going.
n/a	1	2	3	4	5	I dial someone on the phone and forget who I called by the time they answer.
n/a	1	2	3	4	5	I start writing a note or letter and forget what I want to say.
n/a	1	2	3	4	5	I start to write a check and forget to whom it is to be paid.
n/a	1	2	3	4	5	I make lists of things I need to do.
n/a	1	2	3	4	5	I write myself reminder notes.
n/a	1	2	3	4	5	I make a grocery list whenever I go shopping for food.
n/a	1	2	3	4	5	I plan my daily schedule in advance so I will not forget things.
n/a	1	2	3	4	5	I repeat things I need to do several times to myself in order to remember.
n/a	1	2	3	4	5	I use external reminders like tying a string around my finger to help me remember to do things.
n/a	1	2	3	4	5	I rehearse things in my mind so I will not forget to do them.
n/a	1	2	3	4	5	I lay things I need to take with me by the door so I will not forget them.
n/a	1	2	3	4	5	I make Post-It (sticky notes) reminders and place them in obvious places.
n/a	1	2	3	4	5	I create mental picture to help me remember to do things.
n/a	1	2	3	4	5	I put things in piles so I know which ones to do first and which can wait.
n/a	1	2	3	4	5	I lie in bed at night and think of things I need to do the next day so I won't forget to do them.
n/a	1	2	3	4	5	I try to do things at a regular time so I will remember to do them.
n/a	1	2	3	4	5	I keep an appointment book updated in order to remember to do things.

Scoring:
Episodic PM: Items 1-14
Habitual PM: Items 15-28
Internally Cued PM: Items 29-38
Memory Aids: 39-52

Appendix D – Prospective and Retrospective Memory Questionnaire (PRMQ; Smith et al., 2000 – prospective items only)

Below is a set of questions about minor memory mistakes that everyone makes from time to time. Please rate how often these things happen to you on a 5-point scale:

1 = Never,
2 = Rarely,
3 = Sometimes,
4 = Quite Often,
5 = Very Often.

	1 Never	2 Rarely	3 Sometimes	4 Quite Often	5 Very Often
Do you decide to do something in a few minutes' time then forget to do it?					
Do you fail to do something you were supposed to do a few minutes later even though it's there in front of you, like take a pill or turn off the kettle?					
Do you forget appointments if you are not prompted by someone else or by a reminder such as a calendar or diary?					
Do you forget to buy something you planned to buy, like a birthday card, even when you get to the shop?					
Do you intend to take something with you, before leaving a room or going out, but minutes later, leave it behind, even though it's there in front of you?					
Do you fail to mention or give something to a visitor you were asked to pass on?					
If you tried to contact a friend or relative who was out, would you forget to try again later?					
Do you forget to tell someone something you had meant to mention a few minutes ago?					

Appendix E – Metacognitions Questionnaire (MCQ-30; Cartwright-Hatton & Wells, 1997): cognitive confidence subscale.

We are concerned with beliefs people have about their thinking. Listed below are a number of beliefs that people have expressed.
Please read each item and indicate how much you generally agree with it by selecting the appropriate number.
Please respond to all of the items, there are no right or wrong answers.

	1 Do not agree	2 Slightly agree	3 Agree moderately	4 Agree very much
1. I have a poor memory				
2. I have little confidence in my memory for places				
3. I do not trust my memory				
4. I have little confidence in my memory for words and names				
5. I have little confidence in my memory for actions				
6. My memory can mislead me at times				

Appendix F – Beliefs About Memory Questionnaire (BAMQ; Bennett & Wells, 2010).

This questionnaire is about the attitudes and beliefs people have concerning their memory for traumatic or stressful events. Below are a number of beliefs people have about their memories for events. Please read each one and select how much you agree or disagree with the belief in relation to your memory for the event that has caused you most discomfort both at the time of the event and since the event. There are no right or wrong answers to this questionnaire.

	1 Do not agree	2 Slightly agree	3 Agree moderately	4 Agree very much
1. Gaps in my memory for the event are preventing me from getting over it.				
2. Having memory blanks means something is seriously wrong with me.				
3. If I have gaps in my memory of the event it means that I did something wrong.				
4. Having gaps in my memory of the event means I am not normal.				
5. If I have gaps in my memory of the event it means I lost control during the incident.				
6. If I can't remember everything about the event it is because something really bad happened.				
7. I shouldn't have gaps in my memory for such a serious incident.				
8. Having memory blanks for the incident means I can't cope with stress.				
9. I need to have a clear memory of all the events that happened during the stressful event to prevent it from happening again.				

	1 Do not agree	2 Slightly agree	3 Agree moderately	4 Agree very much
10. I need to go over the event to work out whether I did anything wrong or whether I could have done something differently.				
11. I need to remember the event perfectly to work out who was to blame.				
12. I need to have a perfect memory of the event because I need to find answers.				
13. I must try to remember all of the details of the event so that I can understand why it happened.				
14. It is important for me to fill in any gaps in my memory.				
15. I need to have a complete memory for what happened so that I can learn from the incident.				
16. I need to complete my memory for the incident before I can really get over it.				
17. I should be able to remember everything that happens to me in detail.				

Appendix G – Posttraumatic Cognitions Inventory (PTCI; Foa et al., 1999): negative cognitions about the self subscale.

We are interested in the kind of thoughts you may have had after your traumatic or stressful experience. Below are a number of statements that may or may not be representative of your thinking. Please read each statement carefully and tell us how much you AGREE or DISAGREE with each statement, keeping in mind your specific traumatic or stressful experience. People react to traumatic events in many different ways, there are no right or wrong answers to these statements.

1 = Totally disagree
2 = Disagree very much
3 = Disagree slightly
4 = Neutral
5 = Agree slightly
6 = Agree very much
7 = Totally agree

1. I can't trust that I will do the right thing.
2. I am a weak person.
3. I will not be able to control my anger and will do something terrible.
4. I can't deal with even the slightest upset.
5. I used to be a happy person but now I am always miserable.
6. I feel dead inside.
7. I am inadequate.
8. If I think about the event, I will not be able to handle it.
9. My reactions since the event mean that I am going crazy.
10. I will never be able to feel normal emotions again.
11. I have permanently changed for the worse,
12. I feel like an object, not like a person.
13. I feel isolated and set apart from others.
14. I have no future.
15. I can't stop bad things from happening to me.
16. My life has been destroyed by the trauma.
17. There is something wrong with me as a person.
18. My reactions since the event show that I am a lousy coper.
19. I feel like I don't know myself anymore.
20. I can't rely on myself.
21. Nothing good can happen to me anymore.

Appendix H - Continuous Planning Scale (CPS; Prenda & Lachman, 2001).

The next few questions are about your tendency to make plans in the future. Please respond to these questions by rating how much each statement applies to you from 1 (not at all) to 4 (a lot).

	1 Not at all	2 A little	3 Some	4 A lot
a) I like to make plans for the future.				
b) I find it helpful to set goals for the near future.				
c) I live one day at a time.				
d) I have too many things to think about today, to think about tomorrow.				
e) I believe there is no sense planning too far ahead because so many things can change.				

Appendix I - White Bear Suppression Inventory (WBSI; Muris et al., 1996; Wegner & Zanakos, 1994).

Please select the number for each item below that best describes how you generally deal with your thoughts, where: 1 = 'strongly disagree' and 5 = 'strongly agree'.

	1 Strongly disagree	2	3	4	5 Strongly agree
There are things I prefer not to think about.					
Sometimes I wonder why I have the thoughts I do.					
I have thoughts that I cannot stop.					
There are images that come to mind that I cannot erase.					
My thoughts frequently return to one idea.					
I wish I could stop thinking of certain things.					
Sometimes my mind races so fast I wish I could stop it.					
I always try to put problems out of my mind.					
There are thoughts that keep jumping into my head.					
Sometimes I stay busy just to keep thoughts from intruding on my mind.					
There are things I try not to think about.					
Sometimes I really wish I could stop thinking.					
I often do things to distract myself from my thoughts.					
There are many thoughts that I have that I don't tell anyone.					
My thoughts frequently return to one idea.					

Appendix J - Trauma History Screen (THS; Carlson et al., 2011).

The events below may or may not have happened to you. Circle "YES" if that kind of thing has happened to you or circle "NO" if that kind of thing has not happened to you. If you select any events, put a number in the blank box below it indicating the number of times something like that happened.

			Number of times something like this happened
A. A really bad car, boat, train, or airplane accident	NO	YES	
B. A really bad accident at work or home	NO	YES	
C. A hurricane, flood, earthquake, tornado, or fire	NO	YES	
D. Hit or kicked hard enough to injure - as a child	NO	YES	
E. Hit or kicked hard enough to injure - as an adult	NO	YES	
F. Forced or made to have sexual contact - as a child	NO	YES	
G. Forced or made to have sexual contact - as an adult	NO	YES	
H. Attack with a gun, knife, or weapon	NO	YES	
I. During military service - seeing something horrible or being badly scared	NO	YES	
J. Sudden death of close family or friend	NO	YES	
K. Seeing someone die suddenly or get badly hurt or killed	NO	YES	
L. Some other sudden event that made you feel very scared, helpless, or horrified.	NO	YES	
M. Sudden move or loss of home and possessions.	NO	YES	
N. Suddenly abandoned by spouse, partner, parent, or family.	NO	YES	

If you selected any of the events above, did any of these happen when you were a child? (i.e., under 18 years).

YES NO

If so, please list the letters that correspond with the traumatic event you experienced aged under 18.

_____

If you selected any of the events above, did any of these things really bother you emotionally (including those that may have occurred when you were a child)?

YES NO I did not experience any of the events above

Regardless of what you selected on the previous page, briefly describe (in one or two sentences) the event that bothered you the most (i.e., your most stressful or traumatic experience) in the box below. We are going to ask you a number of questions about this event.

_____
_____
_____
_____

Regardless of what you selected on the previous page, briefly describe (in one or two sentences) the most stressful experience of your life in the box below. We are going to ask you a number of questions about this event.

_____
_____
_____
_____

How old were you when this event happened?

_____

When this happened did anyone get hurt or killed?

YES NO

When this happened, were you afraid that you or someone else might get hurt or killed?

YES NO

When this happened, did you feel very afraid, hopeless, or horrified?

YES NO

After this happened, how long were you bothered by it?

- Not at all
- One week
- 2-3 weeks
- A month or more

How much did it bother you emotionally?

- Not at all
- A little
- Somewhat
- Much
- Very much

Appendix H – The Posttraumatic Stress Disorder Checklist (PCL-5; Weathers et al., 2013).

Below is a list of problems that people sometimes have in response to a very stressful experience. Keeping your most stressful or traumatic experience in mind (i.e., the one you just described), please read each problem carefully and then select the number that best indicates how much you have been bothered by that problem **in the past month**.

1. Repeated, disturbing, and unwanted memories of the stressful experience?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

2. Repeated, disturbing dreams of the stressful experience?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

3. Suddenly feeling or acting as if the stressful experience were actually happening again (as if you were actually back there reliving it)?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

4. Feeling very upset when something reminded you of the stressful experience?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

5. Having strong physical reactions when something reminded you of the stressful experience (for example, heart pounding, trouble breathing, sweating)?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

6. Avoiding memories, thoughts, or feelings related to the stressful experience?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

7. Avoiding external reminders of the stressful experience (for example, people, places, conversations, activities, objects, or situations)?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

8. Trouble remembering important parts of the stressful experience?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

9. Having strong negative beliefs about yourself, other people, or the world (for example, having thoughts such as: l am bad, there is something seriously wrong with me, no one can be trusted, the world is completely dangerous)?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

10. Blaming yourself or someone else for the stressful experience or what happened after it?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

11. Having strong negative feelings such as fear, horror, anger, guilt, or shame?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

12. Loss of interest in activities that you used to enjoy?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

13. Feeling distant or cut off from other people?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

14. Trouble experiencing positive feelings (for example, being unable to feel happiness or have loving feelings for people close to you)?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

15. Irritable behavior, angry outbursts, or acting aggressively?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

16. Taking too many risks or doing things that could cause you harm?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

17. Being "superalert" or watchful or on guard?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

18. Feeling jumpy, or easily startled?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

19. Having difficulty concentrating?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

20. Trouble falling or staying asleep?

1	2	3	4	5
Not at all	A little bit	Moderately	Quite a bit	Extremely

Appendix I - Depression, Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995)

Please read each statement and circle a number 0, 1, 2 or 3 which indicates how much the statement applied to you **over the past week**. There are no right or wrong answers. Do not spend too much time on any statement.

		Never	Sometimes	Often	Almost always
1.	I found it hard to wind down	0	1	2	3
2.	I was aware of dryness of my mouth	0	1	2	3
3.	I couldn't seem to experience any positive feeling at all	0	1	2	3
4.	I experienced breathing difficulty (e.g., excessively rapid breathing, breathlessness in the absence of physical exertion)	0	1	2	3
5.	I found it difficult to work up the initiative to do things	0	1	2	3
6.	I tended to over-react to situations	0	1	2	3
7.	I experienced trembling (e.g., in the hands)	0	1	2	3
8.	I felt that I was using a lot of nervous energy	0	1	2	3
9.	I was worried about situations in which I might panic and make a fool of myself	0	1	2	3
10.	I felt that I had nothing to look forward to	0	1	2	3
11.	I found myself getting agitated	0	1	2	3
12.	I found it difficult to relax	0	1	2	3
13.	I felt down-hearted and blue	0	1	2	3
14.	I was intolerant of anything that kept me from getting on with what I was doing	0	1	2	3
15.	I felt I was close to panic	0	1	2	3
16.	I was unable to become enthusiastic about anything	0	1	2	3
17.	I felt I wasn't worth much as a person	0	1	2	3
18.	I felt that I was rather touchy	0	1	2	3
19.	I was aware of the action of my heart in the absence of physical exertion (e.g., sense of heart rate increase, heart missing a beat)	0	1	2	3
20.	I felt scared without any good reason	0	1	2	3
21.	I felt that life was meaningless	0	1	2	3

Appendix J – Lexical Decision Task Example Stimuli

reverted	jain
shrewd	flearing
flit	mourse
culprits	adacia
scooter	crisker
rodeo	cosses
turbine	boneybee
stealthy	bronies
trapdoor	centeps
matinee	rining
laird	nastards
misfit	befoud
jabs	boneybee
falconry	hubbled
endanger	sheerio
penance	ralleon
lied	phasm
paid	banf
tipper	payou
canons	centeps
dusted	flearing
abrasion	thawl
blot	porough
setter	elic
rousing	sheerio
penance	jain
trapdoor	clared
zebra	elic
belted	dosks
tipper	bempors
codex	selped
belted	conjoink
doctored	rastest
zooms	nastards
lunged	adacia
laird	fasket

Appendix K – Multiple Choice Trivia Example Questions

Question	Correct Answer	Answer options
The Greek goddess of love is _____.	Aphrodite	Aphrodite, Athena, Isis, Venus
From what classic movie comes the line, 'Frankly my dear, I don't give a damn'?	Gone with the Wind	All about Eve, Casablanca, Gone with the Wind, Sunset Blvd
In the tales of King Arthur, who was the young knight whose exceptional purity and virtue enabled him to see the Holy Grail in all its splendor, while many other knights who sought it could not see it at all?	Sir Galahad	Sir Galahad, Robin Hood, Sir Lancelot, William Tell
Brave New World is a novel written by _____.	Aldous Huxley	Aldous Huxley, George Orwell, Jonathan Swift, Kurt Vonnegut
_____ was a Spanish painter of the twentieth century, well known for cubism and his painting Guernica.	Pablo Picasso	Diego Rivera, Francisco Goya, Pablo Picasso, Salvador Dali
The capital of Kenya is _____.	Nairobi	Kampala, Addis Ababa, Lagos, Nairobi
In the 16th century, the ____ empire was overthrown by the Spanish Conquistadores under Hernando Cortes.	Aztec	Aztec, Mayan, Incan, Yanomam
What chemical weapon (developed in 1943 by Louis Fieser) is used in bombs and flamethrowers, burns intensely, and sticks to its target?	napalm	Epoxy, Gasohol, DDT, Napalm
The Roman Goddess of Love is _____.	Venus.	Aprodite, Athena, Isis, Venus
In which continent did the ostrich originate?	Africa	Australia, Africa, Asia, America
Which pop duo was the first western band to play in The Peoples Republic of China?	Wham	Wham, Simon and Garfunkel, Chas and Dave, Duran Duran
What are Lanthanides?	Elements on the periodic table	Elements on the periodic table, mountains on the moon, a class of bacterium, a family from Game of Thrones
What part of the body does a turtle use to breathe?	Anus	Anus, Mouth, Shell, Nose
Who won the AFL grand final in 1998?	Adelaide	North Melbourne, Adelaide, Essendon, Carlton
Who wrote the song "Time to Pretend"?	MGMT	MGMT, Birds of Tokyo, San Cisco, Muse
Hypermetropic people are what?	Far sighted	Diabetic, Obese, Far sighted, Anxious
Anemophobia is the fear of what?	Wind	Wind, The dark, Beards, Bone

Who was the Prime Minister of Australia in 2005?	John Howard	John Howard, Paul Keating, John Brown, Tony Abbott
Which Disney film is set in China?	Mulan	The Jungle Book, Mulan, Pinnochio, The Aristocats
What was the original name of Sir Francis Drake's Ship?	Pelican	Puffin, Pigeon, Plover, Pelican
Who discovered Penicillin in 1928?	Alexander Fleming	Joseph Lister, James Lind, William Harvey, Alexander Fleming
At which famous sports venue are the Edrich Stand and Compton Stand?	Wimbledon	Centre court; Wimbledon, Lord's, Silverstone, Old Trafford
Which poisonous gas has the formula CO?	Carbon Monoxide	Cobalt tetroxide, chlorine oxide, carbon monoxide, calcium trioxide
Which of these words mean a street entertainer?	Busker	Bluster, Bolster, Boulder, Busker
Prime Minister Edward Heath took part in which sailing event in 1971?	Admiral's Cup	Admiral’s Cup, Jules Verne Trophy, America’s Cup, Tall Ships Challenge
With which sporting event is Jonathan Edwards most associated?	Triple jump	100 metres, Triple jump, Marathon, Javelin
One of the world’s best-known operas is George Bizet’s what?	Carmen	Caramel, Cameron, Carmel, Carmen

Appendix L - Brief Inventory of Psychosocial Functioning (B-IPF; Bovin et al., 2018)

Please indicate how much each of these statements applied to you over the past 30-days. If these items do not apply to you please select the not applicable option.

Overall, in the past 30 days:	Not at Much All			Somewhat			Very	Not applicable
1. I had trouble in my romantic relationship with my spouse or partner.	0	1	2	3	4	5	6	7
2. I had trouble in my relationship with my children.	0	1	2	3	4	5	6	7
3. I had trouble with my family relationships.	0	1	2	3	4	5	6	7
4. I had trouble with my friendships and socializing.	0	1	2	3	4	5	6	7
5. I had trouble at work.	0	1	2	3	4	5	6	7
6. I had trouble with my training and education.	0	1	2	3	4	5	6	7
7. I had trouble with day to day activities, such as doing household chores, running errands and managing my medical care.	0	1	2	3	4	5	6	7

Appendix M - At-home prospective memory diary instructions

Thank you for agreeing to participate in our study *Forgetting in everyday life.*
As you would be aware, the next phase of the study involves keeping an at-home diary for 4 consecutive days. The paper diary for you to complete is contained in this pack. For the next 4-days, you should keep this diary on you at all times.

Each time you forget to do a task you had previously planned, we would like you to record the details in this diary. It is important you complete this diary ***as soon as possible*** after the forgetting happened. The details you must record include the day, time, what happened, any consequences as a result of your forgetting and some questions about your mood before and after. We would also like you to record whether your instance of forgetting was "time-based" or "event-based".

Time-based errors involve forgetting to complete a task at a specified time, or after a given period of time. Examples include:

- Forgetting to feed your pet at 6pm
- Forgetting to attend a meeting at 11am
- Forget to take medication every 2 hours
- Forgetting to take your dinner out the oven after 30 minutes

Event-based errors involve forgetting to complete a task when a specific event occurs in your environment, or when a specific cue appears. Examples include:

- Forget to take medication with breakfast
- Forget to turn the heater off when you go to bed
- Forgetting to stop at the shops and pick up milk on your way home
- Forget to message your friend on their birthday

At the end of each day, we would like you to enter your forgetting in an online version of the diary found here: XXXX (link here) XXXX.
The questions are exactly the same as in your paper diary.

It's important you do not change your performance for the purpose of this study. We want an accurate picture of your *typical* forgetting behaviours. That is, avoid using any extra reminders, alarms or lists, just go about your normal behaviour.
At the end of the 4-days you can either post your diary back with the return label. Or, you can take photos of each page, or you can scan the document and send to applcoglab@flinders.edu.au
If you have any questions along the way, please contact taylor.swain@flinders.edu.au

Appendix N - At-home prospective memory diary (adapted from Laughland & Kvavilashvili, 2018)

Are you completing this entry after a text reminder?
- o Yes
- o No

When did you have a memory error? Or when did you realise you made an error?

Date: _____
Time (AM/PM): _____

When did you record it in your diary?

Date: _____
Time (AM/PM): _____

Describe your memory error:

What it was: _____
What were you doing? _____
Where were you? _____

As a reminder:

Time-based errors involve forgetting to complete a task at a specified time, or after a given period of time. Examples include:
- Forgetting to feed your pet at 6pm
- Forgetting to attend a meeting at 11am
- Forget to take medication every 2 hours
- Forgetting to take your dinner out the oven after 30 minutes

Event-based errors involve forgetting to complete a task when a specific event occurs in your environment, or when a specific cue appears. Examples include:
- Forget to take medication with breakfast
- Forget to turn the heater off when you go to bed
- Forgetting to stop at the shops and pick up milk on your way home
- Forget to message your friend on their birthday

Was the error:
- o Time-based
- o Event-based

What was your mood immediately before the error?
- o Very unhappy
- o Unhappy

- Neutral
- Happy
- Very happy
- Don’t know

How relaxed or stress were you immediately before the error?

- Very relaxed
- Relaxed
- Neutral
- Stressed
- Very stressed
- Don’t know

How serious was the memory lapse?

- Insignificant
- Minor
- Somewhat significant
- Significant
- Very significant / potentially dangerous

Do you have any other instances of forgetting to record?

- Yes
- No

Appendix O - Percieved Stress Scale (PSS-10; Cohen & Williamson, 1988)

The questions in this scale ask you about your feelings and thoughts during the last month. In each case, you will be asked to indicate by circling how often you felt or thought a certain way.

	0 Never	1 Almost never	2 Sometimes	3 Fairly Often	5 Very Often
1. In the last month, how often have you been upset because of something that happened unexpectedly?					
2. In the last month, how often have you felt that you were unable to control the important things in your life?					
3. In the last month, how often have you felt nervous and "stressed"?					
4. In the last month, how often have you felt confident about your ability to handle your personal problems?					
5. In the last month, how often have you felt that things were going your way?					
6. In the last month, how often have you found that you could not cope with all the things that you had to do?					
7. In the last month, how often have you been able to control irritations in your life?					
8. In the last month, how often have you felt that you were on top of things?					
9. In the last month, how often have you been angered because of things that were outside of your control?					
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?					

Appendix P – Post-diary questionnaire (Study 3)

Did you carry your phone with you on every day of the study?
- Yes
- No

(If no) Please indicate the number of days you did not carry your phone with you: _____

How easy did you find it to keep your phone with you at all times?
- Very easy
- Somewhat easy
- Somewhat difficult
- Very difficult

How easy did you find it to record your forgetting instances in the diary?
- Very easy
- Somewhat easy
- Somewhat difficult
- Very difficult

Please estimate the % of forgetting instances you were able to record out of ALL your forgetting over the diary period? _____

Please indicate why you didn't/were unable to record ALL your instances of forgetting over the 4-day diary period
- I just forgot to record some forgetting instances
- I forgot what the memory errors were or other details of the memory errors
- It was too much effort to record all forgetting instances
- I was unable to record all forgetting instances (e.g., because I didn't have my phone/device with me)
- I was too busy to record all forgetting instances
- I just didn't record all forgetting instances
- Other (please specify) _____
- I did record ALL my forgetting instances

Did you use memory aids to help you remember?
- Yes
- No

Was your use of any memory aids typical of your everyday behaviour?
- Yes, I normally use/don’t use these aids
- No, I changed my behaviour for the study

Which memory aids did you use? Please tick all those that apply:
- Lists
- Reminder notes (e.g., sticky notes, notes on paper)
- Repetition/rehearsal
- Calendar reminders/Electronic alerts
- External reminders (e.g., tying a string around your finger)

- Other (please specify) _____

How often did you use memory aids?

- Never
- Sometimes
- About half the time
- Most of the time
- Always