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The Effect of State/Trait Rumination on a Prospective Memory Task Delivered Remotely Using a Real-Time and Repeated Approach

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By

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ABSTRACT

Background. Prospective memory (PM) refers to the intention to perform a future task held in memory that is executed without any explicit prompts. PM may be negatively impacted by depression, but the mechanisms that drive this association remain unclear. One idea is that rumination increases the frequency of task-irrelevant thoughts, depleting attentional capacity, and thereby reducing PM accuracy and increasing response times. To date, no studies have examined the effects of state and trait rumination on PM using online testing to collect real-time data over time. **Objectives**. To examine the effect of **(1)** state and **(2)** trait rumination on a computerized PM test across accuracy and response times among younger and older adults using a real-time and repeated approach. Age effects were explored. **Methods.** 139 younger (18-59 years) and 17 older adults (≥60 years) were recruited. Participants completed measures of state unpleasant mood and rumination, followed by a PM task twice per week for two weeks. Mixed-effects models were fit to examine state and trait rumination, and age on PM over time and Spearman correlations were generated to examine trait rumination on PM at baseline. **Results**. State rumination was associated with poorer PM accuracy in younger adults, after controlling for mood and trait rumination. Generally, younger adults became increasingly faster and accurate over time, while older adults became slower over time. Age was associated with better PM accuracy, but slower response times. **Significance.** Overall, rumination demonstrates promise as a variable of interest to examine in the context of PM and depression in younger and older adults.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

BMIS	Brief Mood Introspection Scale
BSRI	Brief State Rumination Inventory
DSM-5	Diagnostic and Statistical Manual of Mental Disorders
EF	Executive functioning
GAD-7	7-Item Generalized Anxiety Disorder
LTM	Long-term memory
M	Mean
MDD	Major Depressive Disorder
MLM	Multi-level modeling
MoCA	Montreal Cognitive Assessment
PAM	Preparatory Attentional and Memory Processes
PHQ-9	9-Item Patient Health Questionnaire
PM	Prospective memory
RRS	Ruminative Responses Scale
SD	Standard deviation
TICS	Telephone Interview for Cognitive Status
WM	Working memory

CHAPTER 1: LITERATURE REVIEW

1 Brief Thesis Overview

Prospective memory (PM) refers to the intention to recall executing a task at an appropriate timepoint in the near future, such as recalling to take medication, turn off home appliances, or hand in assignments (Cohen & Hicks, 2017; Henry, 2021; McDaniel & Einstein, 2007a). PM tasks are defined by several characteristics: (1) they require explicitly formed intentions, (2) they are smaller delayed events that are bound by a time in the future, and, (3) they do not require an extended timeframe for execution (McDaniel & Einstein, 2007a). PM is thus distinct from other types of memory, such as long-term memory (LTM) which instead involves the recollection of retrospective events and information (McDaniel & Einstein, 2007a). PM errors are frequent in daily life, with more than half of all reported memory errors involving this type of forgetting, as opposed to retrospective errors (Haas et al., 2020). Given that PM tasks are practical in nature, PM errors predict functional outcomes, and exhibit a larger negative impact on activities of daily living compared to LTM errors (Henry, 2021; Sheppard et al., 2020).

PM tasks are heterogenous and vary along several parameters. PM tasks differ by event- (i.e., viewing a coffee commercial and recalling to buy coffee beans) or time-based tasks (i.e., completing a task by 1:00PM) (McFarland & Vasterling, 2018); if the tasks are experimental or naturalistic (Blondelle et al., 2020; Rummel & Kvavilashvili, 2019); and if the designs are cross-sectional or repeated (Kim et al., 2020; McFarland & Vasterling, 2018). Experimental PM tasks are typically embedded in an ongoing task whereby individuals are required to interrupt the latter to execute the PM task. In such experiments, performance is measured by accuracy (i.e., completing the task or forgetting to initiate the task) and response times (McDaniel & Einstein, 2007a). In turn, naturalistic tasks involve participants carrying out tasks at prescribed times or after certain events in their daily life and are typically measured by the success or failure of the intended action (Koo et al., 2021).

Evidence suggests that PM performance is affected by several factors. For this thesis, the effects of mood and age-related changes in cognition are specifically examined (McFarland & Vasterling, 2018; Schnitzspahn et al., 2020). Firstly, the effect of depressive symptomatology on PM is an example of one poorly understood factor (McFarland & Vasterling, 2018). Although individuals with depression show poorer PM accuracy and slower reaction times, less is known on the specific mechanisms driving this effect (McFarland & Vasterling, 2018). Research on the effects of depression on PM to date has focused on negative affect as a mechanism for impacting PM, which has produced equivocal findings, suggesting other features of depression are central to explaining this poorer performance (Fredman Stein et al., 2018). Rumination has become a subsequent variable of interest as it may impact retrieval of intentions which, in turn, leads to poorer performance (McFarland & Vasterling, 2018). Specifically, state (i.e., ruminating in the moment) and trait rumination (i.e., the general tendency to ruminate) may contribute to poorer PM as postulated by the *resource allocation hypothesis* in that attentional capacity is reduced during rumination due to the presence of task-irrelevant thoughts (Ellis, 1990; Fredman Stein et al., 2018; Primosch, 2017). Secondly, studies examining age-related changes in cognition across PM tasks have produced mixed evidence (Schnitzspahn et al., 2020). As age increases, positive effects of aging occur in PM (i.e., greater accuracy) when examined in naturalistic settings but negative effects occur in PM (i.e., poorer accuracy) when examined in laboratory settings, leading to an *age-PM-paradox* (Schnitzspahn et al., 2020). The effects of mood and increasing age across PM remain unclear and necessitate further investigation given the importance of PM in daily functioning (Henry, 2021).

The present study examined the effects of state and trait rumination on accuracy and reaction times of a computerized PM task among younger and older adults in a real-time and repeated-measures design, which to date has not been examined and is novel in applied memory research. Participants completed demographic measures and measures of mood, rumination, and a PM task twice per week for two weeks. The first and second aims examined the effects of state and trait rumination on PM performance, respectively. Lastly, this study explored age effects of PM between younger and older adults. Overall, this study sought to elucidate mechanisms of depression on PM across younger and older adults, with specific examination of rumination.

2 Prospective Memory

Prospective memory (PM) refers to the intention to perform a future task retained in memory that is executed without any explicit prompts and during other ongoing tasks that require attention (Cohen & Hicks, 2017). Ubiquitous in daily life, examples of these tasks include remembering to pick up groceries on the way home, or remembering to take medication at a specific time (McDaniel & Einstein, 2007a). They also involve a prospective (i.e., recalling an intention that is to be completed) and a retrospective component (i.e., recalling the contents of that intention). Historically, studies have focused on other types of memory by challenging retrospective parts of memory, like long-term memory (LTM) to uncover its processes and properties, rather than the prospective parts. In LTM, specific processes include three main parts: encoding, retention, and retrieval (Ericsson & Kintsch, 1995). For example, participants in LTM research are instructed to encode and remember lists of words (i.e., testing the retrospective part), whereby the explicit instruction that the words will need to be subsequently recalled eliminates the need to remember to recall the list (i.e., minimizing the prospective component) (McDaniel & Einstein, 2007a). In contrast, PM research aims to isolate and test the prospective components of memory by challenging individuals to recall completing a task at some point in the near future, while minimizing the amount of information to recall (McDaniel & Einstein, 2007a).

Given the wide breadth of PM tasks, they are defined by several features (McDaniel & Einstein, 2007a). To illustrate these, an example of preparing a turkey in an oven is used throughout. Firstly, as outlined, execution of the intention should not be immediate, and there must be a prospective component (McDaniel & Einstein, 2007a). After waiting for the turkey to cook, an individual suddenly recalls that upon seeing a commercial for buying an oven, they disengage from watching television and instead, switch to removing the turkey from the oven. In this case, the individual is cued by a stimulus that is salient to the prospective task, and ultimately, signals the appropriate moment for the intention to be executed. Individuals can also be cued by time, such having to remove the turkey from the oven at 6:00PM. As such, the PM task is set in the immediate future, and does not occur immediately (McDaniel & Einstein, 2007a). Secondly, the delayed intention (i.e., removing the turkey out of the oven) requires interruption of some ongoing activity (i.e., watching television) (McDaniel & Einstein, 2007a). Thirdly, PM tasks are constrained within a window of opportunity, whereby an intention is formed to complete the action at a later time, and forgetting to execute that intention within the window constitutes an error or a failure in PM (McDaniel & Einstein, 2007a). As such, PM tasks are operationalized as successes or failures based on execution outcome (McDaniel & Einstein, 2007a). In naturalistic studies, the use of external aids are typically allowed and do not impact the success of the PM task (Au et al., 2018). The window of opportunity may range from several seconds to days depending on the PM tasks, but are no longer considered PM tasks if their completion could occur at any point (McDaniel & Einstein, 2007a). For example, an individual must remove the turkey out of the oven by an appropriate amount of time. Otherwise, they forget to execute the task and spoil the turkey. Fourth, PM tasks are circumscribed events that do not require an extended timeframe for execution, as opposed to more lengthier and open-ended tasks such as taking a trip or training for a job (McDaniel & Einstein, 2007a). Thus, the intention of removing the turkey is a PM task as it represents a small, delayed activity that must be completed by a specified time. In this case, failure would be described as burning the food, or other worse safety-related outcomes. This highlights one specific but potentially dangerous instance and ultimately, how instrumental PM is in daily life (Trawley et al., 2017).

2.1 Cognitive Bases of Prospective Memory

PM involves various cognitive processes that underlie planning future actions, such as undertaking other tasks while keeping the planned intention in mind, having the ability to retrieve the intention, and successfully switching tasks when appropriate

(Kliegel et al., 2002). One challenge has been specifying the precise processes underlying PM, for which, several models are proposed to explain these mechanisms and integrate these cognitive processes (Ellis, 1996; Kliegel et al., 2002; McFarland & Vasterling, 2018). In particular, a five-factor model is proposed with phases for (1) intention formation, (2) maintenance/monitoring, (3) retrieval, (4) inhibition, and (5) execution in PM that form a framework for conceptualizing PM (McFarland & Vasterling, 2018).

These five phases implicate multiple parts of the brain including the frontoparietal executive control system and the medial temporal lobes (McFarland & Vasterling, 2018). The frontoparietal executive control system is involved in executive functioning (EF) which is defined as a higher-order cognitive process that ultimately leads to decision-making and goal-oriented behaviours (McFarland & Vasterling, 2018). Namely, these skills promote adaptation to novel situations, creativity, planning, reasoning, problem-solving, and other functions that require effortful top-down processes (Diamond, 2013). EFs are typically broken down into three core parts. The first, inhibition, is the ability to interrupt an ongoing action or to ignore distracting information (Diamond, 2013). Cognitive flexibility is a second core EF, which involves the ability to shift attentional focus from one task to another (Diamond, 2013). Lastly, updating is the ability to manipulate and replace information currently in the mind, and is closely related to the notion of working memory (WM) (Diamond, 2013; Miyake et al., 2000). Although often used interchangeably with "short-term memory", WM implies additional functions of limited storage and mental manipulation of information, such as in mental calculations (Baddeley, 2000). The capacity stores in WM are separated into visuo-spatial and verbal information, in addition to parts that oversee transfer between these components, such the transfer of information from WM to LTM (Baddeley, 2000). In LTM, information is encoded when engaged in the initial learning of information, after which the information is stored and maintained over time. Retrieval occurs when that information is accessed from LTM and brought back into WM (Melton, 1963). The medial temporal lobes thus function as an explicit memory system and facilitate LTM for facts and events, connecting these processes together (McFarland & Vasterling, 2018). As such, prospective remembering is dynamic and includes EF, WM, and LTM components and their respective subcomponents.

2.1.1 Intention Formation

During the intention formation phase, EF is recruited to develop and plan an intention to be recalled in LTM (McFarland & Vasterling, 2018). As part of intention development, individuals plan how and when to execute the action which can be dependent on certain time- or event-related cues (i.e., at 6:00PM, remove the turkey from the oven). While this planning occurs in the frontoparietal executive control system, this episode (i.e., including the plan and contextual details present at the time) is encoded in the medial temporal lobes as an episodic LTM for later retrieval (McFarland & Vasterling, 2018).

2.1.2 Maintenance, Monitoring, and Retrieval

After intention formation, the relevant cues related to the consciously formed intention are maintained in LTM, while an individual is engaged in another unrelated ongoing task during the maintenance/monitoring phase (McFarland & Vasterling, 2018).

During cooking, an individual is typically engaged in other ongoing tasks such as watching television or washing the dishes while the intention of removing the turkey is planned and maintained as it bakes (Trawley et al., 2017). Attentional processes in EF are engaged during this stage. Thus, the executive frontoparietal system is critical for allocating resources for intention rehearsal, and monitoring the environment for cues as the ongoing task is occurring (McFarland & Vasterling, 2018).

There are two pathways by which a cue can elicit retrieval of the PM intention from LTM (McFarland & Vasterling, 2018). If a link between a cue and the intention is salient, retrieval is heavily dependent on the medial temporal lobes as the intention is more likely to be spontaneously retrieved from memory (i.e., in a "bottom-up" fashion), whereas a poorly recognized link between the two would engage the frontoparietal system for a more effortful and strategic "top-down" search, particularly if the cue is not salient or easily detected (McFarland & Vasterling, 2018). For example, watching an oven commercial on television is salient to cooking, prompting the individual in a bottom-up fashion to recall their turkey in the oven. Thus, existing strategies are separated into a reactive/bottom-up, or proactive/top-down approach. One characteristic of the top-down approach is that it is highly costly to be continually monitoring the environment for a cue (Einstein & McDaniel, 2005). Given these costs, individuals may only periodically evaluate if conditions are correct for performing a task (Einstein & McDaniel, 2005). In this case, associating a time with completing a task may require monitoring processes such as occasionally checking the clock for the time or relying on an internal estimate of the elapsed time when having to cook the turkey (Einstein & McDaniel, 2005; McDaniel & Einstein, 2007d). For tasks that are not time-based, attentional monitoring may still facilitate retrieval as proposed by the *preparatory attentional and memory processes* (PAM) theory (McDaniel & Einstein, 2007b; Smith, 2003). Intention retrieval thus involves a WM strategy to actively monitor the environment for an appropriate event to perform the task (Smith, 2003). If individuals are using a monitoring strategy, then their attentional capacity is allocated partially to this monitoring and, consequently, PM performance declines as a function of the difficulty of the ongoing task (Anderson et al., 2019). Conversely, the use of reactive or bottom-up strategies (i.e., spontaneous retrieval, such as having the intention “pop” into the mind) have also been posited (McDaniel & Einstein, 2007b; Scullin et al., 2013). In this case, the cost of monitoring is eliminated by a salient cue that triggers an involuntary retrieval process through automatic associative recall (Einstein & McDaniel, 2005). PM performance should thus not be impacted by the difficulty of the ongoing tasks since spontaneous retrieval involves automatic and non-effortful processes (Einstein & McDaniel, 2005).

Overall, the differential recruitment of these strategies have prompted the development of a multi-process theory where several processes support PM depending on task characteristics (Einstein et al., 2005). For example, younger adults completed two PM tasks that varied by saliency of its cue to the ongoing task (Anderson & McDaniel, 2019). When the cue related less to the task, participants engaged in more monitoring which led to task interference and reduced PM accuracy (Anderson & McDaniel, 2019). When the cue related more to the task, participants used less strategic monitoring which led to less task interference and higher PM accuracy (Anderson & McDaniel, 2019). As the associative link between an intention and its cue becomes more related, this reduces the likelihood to recruit the frontoparietal executive control system as the intention is spontaneously retrieved and less processing is required (McFarland & Vasterling, 2018). However, if the link is less related to the ongoing task, the frontoparietal system may be recruited as more effortful monitoring would occur (McFarland & Vasterling, 2018).

2.1.3 Inhibition and Execution

Once a cue is detected or the task is recalled, the frontoparietal executive control system is involved in disengaging and inhibiting from the ongoing activity, and switching to the PM task. Execution of the PM task occurs only when the ongoing task is inhibited, and attention is shifted to the PM task intention. A summary of this is found in Table 1.

Other PM models have emphasized similar concepts of multiple cognitive processes involved in execution of PM tasks (Ellis, 1996; Kliegel et al., 2002). For example, a previous model includes formation and encoding of an intention and action, retention, performance, and initiation/execution of an intended action, and evaluation of outcome (Ellis, 1996). In addition, the *process model of complex prospective memory* includes phases of intention formation, retention, initiation, and execution; and emphasizes cognitive processes of LTM and planning, cognitive flexibility, and inhibition (Kliegel et al., 2002). Despite these previous developments, the current model was chosen as it uniquely addresses cognitive processes (i.e., monitoring, inhibition, and switching) and neural correlates (i.e., involvement of the MTL and the executive control system) that underlie PM, and incorporates the multi-process theory, which builds upon previous models (Kliegel et al., 2002; McFarland & Vasterling, 2018).

Table 1

Functions of Networks Involved in Prospective Memory

Cognitive Process		Function	Phase of PM Model
Executive Functioning: Frontoparietal control system (i.e., involved in continuous monitoring)	Updating	• Ability to manipulate and replace information in the working memory.	• Development • Maintenance/ Monitoring
	Inhibition	• Mental process that overrides or deactivates another mental process. • Processes where individuals must ignore or disengage from task-irrelevant information.	• Inhibition
	Set shifting	• Switching attentional focus from one task to another.	• Execution
Long-term memory: Medial temporal lobe (i.e., involved in spontaneous retrieval)		• Develops and retains an associative link between the cue with the intention. • Spontaneously retrieves and recalls intention	• Maintenance/ Monitoring • Retrieval

3 The Measurement of Prospective Memory in Experimental Designs

PM tasks are classified according to various methodological characteristics (Blondelle et al., 2020). Experimental designs aim to capture PM performance by embedding a PM task in a specifically designed cognitive task in a well-controlled environment, where individuals must interrupt the latter to execute the former. A typical paradigm includes participating in a primary ongoing task, like an *n*-back WM task (i.e., pressing “M” if an image presented on one trial matches the image presented *n*th trials previously; and pressing “N” otherwise). This is operationalized as WM as individuals must retain in mind the image they saw previously while being presented new images (Nikolin et al., 2021). As part of the initial instructions, participants are also given a PM task, and are instructed to switch tasks (i.e., pressing the space bar) whenever a target image appears (McDaniel & Einstein, 2007a). Typically, there is a delay during the ongoing task before presenting the PM cues to decrease the likelihood that the participant is actively rehearsing the PM intention, thus making it more difficult to complete the PM task (McDaniel & Einstein, 2007a). Performance in these tasks are measured by the proportion of PM trials when participants execute the task correctly (i.e., “1” for success and “0” for failure) and reaction times of the correct trials (McDaniel & Einstein, 2007a).

3.1 PM Task Parameters

According to the multi-process theory, different strategies are employed based on task characteristics, like the type and focality of the cue (Anderson & McDaniel, 2019). These cues can be event- (i.e., the PM task is defined by a specific event that is distinct from the ongoing task) or time-based (i.e., the PM task is defined by completion by a specific time) (McDaniel & Einstein, 2007a). Cues can be focal or non-focal which is defined as the degree of processing overlap between the ongoing and PM task (Einstein et al., 2005). Based on the multi-process theory, focal cues encourage spontaneous retrieval based on an automatic associative process; while non-focal cues require extra processing (Anderson et al., 2019). In the example of the television commercial, this would represent a focal cue since the oven is directly related to the act of cooking itself. Lastly, experiments will typically include PM trials that appear rarely to increase task difficulty as lower accuracy and longer reaction times have been observed for these types of tasks. This is hypothesized to be due to the fact that participants are likely engaged in costly monitoring for PM trials that appear rarely (Wilson et al., 2013). In general, task development is important to consider to capture appropriate differences in PM performance (Einstein & McDaniel, 2005; Scullin et al., 2010).

3.2 Naturalistic vs. Laboratory-Based Tasks

Although laboratory-based PM tasks are advantageous in that there is a highly controlled and standardized environment, it is important to consider limitations of the their generalizability to real-life conditions, where naturalistic PM tasks may be more ecologically valid (Rummel & Kvavilashvili, 2019; Shiffman et al., 2008). Examples of naturalistic studies include those that require participants to recall to phone researchers at designated times, take their medication after breakfast, do exercises after dinner, etc. These naturalistic PM tasks are examples of performance-based measures of everyday PM (Rendell & Craik, 2000; Rendell & Henry, 2009; Rummel & Kvavilashvili, 2019).

Although not considered to be fully naturalistic, self-administered online neuropsychological assessments may be a close approximation to naturalistic PM tasks (Chaytor et al., 2020). These self-administered online assessments are perceived as less difficult and less distressing to participants, reduce costs of in-person assessment, and increase efficiency of testing (Chaytor et al., 2020). They provide opportunities to individuals who are homebound or living in rural communities to participate in research. In terms of validity, self-administered online assessments promote resemblance to daily cognitive performance conditions, as opposed to artificial testing conditions (Chaytor et al., 2020; Steinke et al., 2021). Limitations for naturalistic or online testing studies include variability in data due to uncontrolled conditions (e.g., living in a noisy/distracting house; testing at different times of the day; internet problems, etc.). Despite this, prior research demonstrates strong associations between lab and self-administered online assessment scores in some conditions, suggesting there is merit to continuing the use of these designs in research (Chaytor et al., 2020).

3.3 Cross-Sectional vs. Repeated Measures

Sampling PM repeatedly provides a unique opportunity to increase sensitivity and to monitor changes in cognition over time (Shiffman et al., 2008). PM tasks may result in relatively fewer data points to measure performance as these studies tend to be cross-sectional, and PM trials have dichotomous outcomes (i.e., succeed or fail) and appear rarely (Livner et al., 2008). As such, repeated measures designs of PM provide opportunities to increase frequency of PM trials while not compromising the difficulty the task itself (Wilson et al., 2013). To date, one study has examined PM using repeated measures where thirty-five community-dwelling older adults completed a PM task four times daily for one week (Schmitter-Edgecombe et al., 2020). Findings show daily fluctuations of cognition that were not captured cross-sectionally (Schmitter-Edgecombe et al., 2020). This is critical as monitoring cognition over time can reveal modifiable environmental factors and better clinical measurements of real-world competency (Gamaldo & Allaire, 2016).

There are many factors to designing an experimental design in PM which include considerations to PM task parameters, the setting the study is taking place in, and the design of the study that may all ultimately impact the validity of the results collected. It is thus critical to ensure that parameters are well established to rule out any confounding methodological factors that may explain results.

4 Depression in Prospective Memory

Major depressive disorder (MDD) is among one of the most prevalent mental health disorders, impacting approximately 350 million individuals worldwide (Dadi et al., 2020; Li et al., 2021). MDD is diagnosed by a medical doctor or clinical psychologist using the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) based on a two-week duration of at least one of depressed mood and/or diminished interest; and at least five or more of the following symptoms for diagnosis: irritability, changes to sleep and/or appetite, psychomotor agitation, feeling worthless/helpless, concentration difficulties, low energy, and/or suicidality (American Psychiatric Association, 2013). These symptoms must cause significant distress and functional impairment, and should not be attributed to any other condition for diagnosis (American Psychiatric Association, 2013). Functional impairment in MDD commonly includes memory deficits, and research in LTM has demonstrated that individuals with depression recall previous memories with fewer details and use an overly general negative view (Falco et al., 2015; Wilson & Gregory, 2018). Critical to daily functioning is carrying out future tasks which is especially relevant for individuals with depression (e.g., taking medication at an appropriate time, attending therapy, etc.) (McFarland & Vasterling, 2018). Indeed, across two meta-analyses, clinical depression and depressive symptoms are associated with reduced performance in PM (McFarland & Vasterling, 2018; Zhou et al., 2017). Event-based PM tasks with non-focal cues and time-based tasks were most strongly associated with poorer PM accuracy and slower reaction times in people with depression (McFarland & Vasterling, 2018). As individuals with depression may experience challenges with concentration and memory, they may also have difficulties with tasks that require greater self-initiation (i.e., tasks that employ monitoring strategies which are more effortful) (McFarland & Vasterling, 2018). Ultimately, challenges with PM in depression are common and can be associated with subsequent functional impairment.

Though recalling future intentions is suppressed in depression, the nature of how this impacts specific cognitive processes underlying PM remains unclear. Some depression-related impairments are found at the retrieval stage in PM (Lee et al., 2010; Li et al., 2013; McFarland & Vasterling, 2018). Poorer time-based PM performance occurs when tasks have longer delays between the ongoing task and the presentation of the PM cue (i.e., performance differences were greater at fifteen vs two minutes) in individuals with depression (Li et al., 2013). This suggests errors tend to occur in the retrieval phase as individuals must rely more on effortful LTM to recall the intention after fifteen minutes which ultimately led to their errors in PM (Li et al., 2013). Without this reliance on LTM in retrieval, similar performance would have occurred regardless of the delay time (Li et al., 2013). Depression-related cognitive deficits are associated with other reductions in planning and imagining future events (Shum et al., 2013), inhibition, and task switching, which are also heavily implicated processes in PM (Schnitzspahn et al., 2013). Although depression and PM share these cognitive processes, there is a limited understanding about their association (Cona & Rothen, 2019). Further, exact components of depression that most influence PM performance have not been specified (McFarland & Vasterling, 2018; Zhou et al., 2017). Beyond improving the understanding about associations between depression and PM, clarifying the contributions of these putative factors may provide opportunities for developing interventions that target PM and depression to improve functional outcomes (McFarland & Vasterling, 2018; Tsang et al., 2022).

4.1 Affective States in Prospective Memory

The specific impact of negative affect in depression has been examined to explain the impaired mechanisms in PM, though evidence has been inconclusive (Pupillo et al., 2020, 2022). One study shows that as participants' affective states change from negative to positive (i.e., away from their average), the likelihood of success in their naturalistic event- and time-based PM tasks increases; similarly, the effect of negative affect trends towards significantly reducing PM accuracy among younger and older adults (Pupillo et al., 2022). Similar associations between negative affect and reduced time- and event-based PM performance in younger, but not older adults are shown (Pupillo et al., 2020;

Schnitzspahn et al., 2014). As participants may experience alterations to the availability of their attentional resources due to their own negative affect, this may interfere with task processing and negatively influence their performance (Ellis, 1990). Mechanisms thus propose that negative affective states lead to increased amounts of task-unrelated thoughts that subsequently decrease attentional resources (Ellis, 1990; Pupillo et al., 2022). Despite these theories, negative affect can improve PM performance and positive affect can impair PM, in some cases (Kliegel & Jäger, 2006; Rummel et al., 2012). Underlying this alternative explanation, positive affect is thought to promote a broader processing style, compared to negative affect which promotes a more item-specific processing style (Storbeck & Clore, 2007). With such focus, negative affect alternatively may produce improved performance (Storbeck & Clore, 2007). Although these may provide explanations for the findings on the mixed effects, other studies have failed to provide evidence to suggest any impact of negative affect on PM (Kliegel et al., 2005). Inconclusive evidence may be related in part to various methodological limitations. For example, induction methods are typically used to induce affect in participants prior to the instruction of the PM task which may produce inadequate changes in negative affect (Gillies & Dozois, 2021; McFarland & Vasterling, 2018; Pupillo et al., 2020). More broadly, these inconclusive results in negative affect suggest that other factors within depressed mood can better explain poorer PM performance (McFarland & Vasterling, 2018; Zhou et al., 2017).

5 Rumination in Depression

Rumination is defined as the maladaptive tendency to repetitively focus on one's self, feelings, and negative experiences and feelings as a coping style (Nolen-Hoeksema et al., 2008; Watkins & Roberts, 2020). It can exist as a state (i.e., momentary rumination) or trait (i.e., an individual's general tendency to ruminate which is stable across time) (Fredman Stein et al., 2018; Nolen-Hoeksema, 2000). Rumination is robustly related to the onset and maintenance of depression (Watkins & Roberts, 2020). Namely, individuals who are trait and state ruminators experience higher levels of depressive symptoms over time due to a reciprocal relationship between depression and rumination (Watkins & Roberts, 2020; Whitmer & Gotlib, 2013). That is, individuals who ruminate are more likely to overgeneralize their past, present, and future situations as negative (Arditte Hall et al., 2019; Nolen-Hoeksema, 2000). Thus, as rumination increases self-focus, it magnifies the repetitive cycle between negative mood and negative thinking, wherein each increases the likelihood of the other (Watkins & Roberts, 2020). Importantly, rumination mediates the relationship between depression and EF. This suggests that ruminative thoughts that are difficult to control in the context of reduced EF can contribute to the development of clinical depression (von Hippel et al., 2008; Whitmer & Gotlib, 2012). As such, rumination is a critical feature to address in depression to prevent further decline (von Hippel et al., 2008).

5.1 Rumination on Cognitive Processes

One approach to clarifying the potential role of depression in PM is to examine theoretical relevant mechanisms that link the two constructs. The *analytical rumination* *hypothesis* attests that depression promotes the onset of rumination, which is an evolved function to analyze, and problem-solve solutions related to the triggering concern (Andrews & Thomson, 2009). In turn, this exhausts attentional resources and induces anhedonia which further causes less desire in the individual to engage in other activities (Andrews & Thomson, 2009). Rumination promotes a trade-off where an individual focuses on their negative feelings to prioritize concerns causing the depression rather than other goals (Andrews & Thomson, 2009). Likewise, rumination is posited to lead to a narrowed attentional scope, increasing the likelihood that these negative thoughts will be repetitive over time (Nolen-Hoeksema et al., 2008; Whitmer & Gotlib, 2013).

Rumination may thus be a key factor in reducing PM performance as it impairs cognitive phases involved in PM and interferes with attentional resources (McFarland & Vasterling, 2018). This thesis will primarily focus on the retrieval phase as a hypothesized stage at which PM is negatively impacted by rumination (McFarland & Vasterling, 2018). This is based on previous accounts whereby memory retrieval was negatively influenced by the content of repetitive and maladaptive thoughts (Andrews & Thomson, 2009; Ellis, 1990; van Vugt & van der Velde, 2018). Trait and state rumination also negatively impact WM performance at the level of retrieval (Curci et al., 2013; Nishimura et al., 2020; Whitmer & Gotlib, 2013). In one study, individuals who were trait ruminators were presented with two lists and were asked to forget words from one list. At testing, they were presented new words and asked if the words belonged to either list: individuals with higher levels of trait rumination had greater interference from the list that should have been forgotten (Whitmer & Gotlib, 2013). This greater recall of task-irrelevant information thus led to more interference during memory retrieval (Smith &

Hunt, 2000; Whitmer & Gotlib, 2013). Others hypothesize that rumination may create an additional challenge to subsequently remove the unwanted information from WM, negatively impacting retrieval of the intentions during rumination (van Vugt & van der Velde, 2018; Yang et al., 2017). In addition, individuals who were trait ruminators tend to be slower in WM tasks (Bernblum & Mor, 2010; Whitmer & Gotlib, 2013). In another study, rumination was correlated to scores in a retrieval task, independent of depressive symptoms (Colzato et al., 2020). Consistent with this, other studies have found that induced state rumination led to widespread deficits in various EFs (Philippot & Brutoux, 2008; Whitmer & Gotlib, 2013). In a similar vein, cognitive interventions targeting WM have shown promise for reducing repetitive negative thoughts (Roberts et al., 2021). In summary, rumination has a negative impact on WM ability by impacting the ability to retrieve, suggesting it may thus be associated with declines in PM performance at this stage (McFarland & Vasterling, 2018). Thus, rumination may serve as a variable of interest to examine in PM given overlapping cognitive processes.

5.2 Rumination in Prospective Memory

Despite the theoretical associations between rumination and PM discussed above, there are only two studies that have directly examined the effects of state and trait rumination on PM. One study was unable to detect any effect of induced state rumination on PM among eighty-eight young adults. Although trait rumination and poorer PM accuracy were correlated, this was only among participants with fewer depressive symptoms compared to their counterparts who were grouped into in moderate and severe groups (Primosch, 2017). Important to note is that rumination was induced through a response task that consisted of drawing participants' attention to their emotional states (Primosch, 2017). Evidence has shown that, similar to mood inductions, rumination inductions have little impact on individuals with no dysphoria as these individuals are less likely to ruminate if they are not in a negative mood or if they are able to recover easily by redirecting their attention (Whitmer & Gotlib, 2013). In addition, the PM task used may have required less effortful retrieval of intentions due to their use of focal cues in relation to the task (Primosch, 2017; Woods et al., 2007). In a non-clinical sample of sixty young adults, state rumination was associated with reduced PM accuracy and slower response times and trait rumination was associated with slower response times (Fredman Stein et al., 2018). Mood and rumination were sampled in real-time and participants completed an event-based PM task with non-focal cues (Fredman Stein et al., 2018). These findings emphasize that state and trait rumination may have dissociable effects in PM, but definitive evidence remains lacking (Fredman Stein et al., 2018).

In a related study, the effects of induced mood were examined in an event- and time-based PM task embedded in a WM task across younger and older adults (Pupillo et al., 2020). Intrusive thoughts were examined as a sub-aim, where younger adults (i.e., 18-27 years) reported significantly higher levels of intrusive thoughts compared to older adults (i.e., 59-85 years) (Pupillo et al., 2020). Despite this difference, no mediating effects of intrusive thoughts were found on PM (Pupillo et al., 2020). A limitation of this study is that intrusive thoughts were measured retrospectively by asking participants the extent to which they reflected on negative feelings caused by the mood induction, which may have limited their validity (Pupillo et al., 2020). Since ruminators may experience substantial fluctuations in state rumination, using repeated and real-time methods presents a valid approach to capturing these fluctuations, in addition to fluctuations in PM changes (Fredman Stein et al., 2018; Shiffman et al., 2008). To date, no studies have examined the effects of state and trait rumination on PM using a real-time and repeated-measures approach.

6 Age Effects

6.1 Age Effects in Prospective Memory

Increasing age is generally associated with declining PM performance (i.e., poorer accuracy and slower reaction times), producing age-related changes in cognition among younger and older adults (Schnitzspahn et al., 2020). These aging effects are defined as general trends in PM that occur among all individuals, regardless of the time period as each group of individuals becomes older (Blanchard et al., 1977). With examination at the level of retrieval, higher self-initiated processing produces larger age effects between younger and older adults (McDaniel & Einstein, 2000; Sheppard et al., 2020; West et al., 2003). In other words, older adults demonstrate poorer performance in event-based PM compared to younger adults, with these differences becoming greater when retrieval demands increase (Cherry et al., 2001). Retrospective LTM recall measures accounted for 68% of the variance in PM performance among older adults, suggesting again that retrieval ability plays a prominent role in PM (Cherry et al., 2001). Overall, age differences are robust when task demands are higher at retrieval (Henry et al., 2004).

Despite these findings, there have been documented nuances in the literature related to differential age effects based on study setting. In the *age-PM-paradox*, older adults generally outperform younger adults in naturalistic settings (i.e., at home or daily life settings), but tend to be disadvantaged in experimental designs (i.e., laboratory-based settings) (Rendell & Craik, 2000; Schnitzspahn et al., 2020). For example, 81% of older adults remembered to call a researcher within ten minutes of the target time, compared to 61% of younger adults (Maillet & Schacter, 2016). In the study, older adult participants reported more intrinsic motivation and task engagement (Kvavilashvili & Fisher, 2007). In the laboratory, it is possible that although older adults have the same level of motivation, they are performing tasks that are unfamiliar and cognitively demanding (Kvavilashvili & Fisher, 2007). In general, enhanced planning ability and motivation among older adults in these settings compared to younger adults have been reasoned to explain positive findings (Haines et al., 2020; Kliegel et al., 2016; Schnitzspahn et al., 2011). A few studies have shown laboratory performance of older adults equal to that of younger adults and have attributed this to sampling older adults with higher WM abilities (McDaniel & Einstein, 2007c). However, certain methodological limitations may also explain the differences in the findings. For example, PM tasks are heterogenous across studies and few studies have tested the same samples of younger and older adults using within-persons designs (Henry et al., 2004). Most studies have only examined time-based PM events, where event-based PM events have not shown similar age benefits in naturalistic tasks, and thus, the paradox may have been overestimated (Schnitzspahn et al., 2020). Despite this, one study found that older adults were impaired in an event-based PM task with non-focal cues and suggested neural mechanisms involved the frontoparietal control network that would give rise to these age differences (Lamichhane et al., 2018). Overall, these limitations reduce the ability to compare age effects in studies and require further evaluation (Henry et al., 2004; Schnitzspahn et al., 2020).

6.2 Age Effects in Mood

Older adults typically demonstrate age-related benefits compared to younger adults which is again attributed to their enhanced emotional processing and emotional regulation (Scheibe & Carstensen, 2010). As individuals perceive time to be limited as they age, they are also more likely to prioritize emotional meaningfulness and functioning (Carstensen et al., 2003). Empirical findings have supported this view where older adults are more receptive to positive rather than negative information and generally have a reduced tendency to ruminate (Joubert et al., 2018; Ricarte et al., 2016). One study examines age differences in recall for emotional stimuli. Although older adults recall fewer images than younger adults, the images they recall are significantly more positive than the images the younger adults recall (Joubert et al., 2018). In a study examining the effects of mood on event-based PM across ages, younger adults' performance is impaired by negative mood, whereas older adults' performance is not influenced by mood (Pupillo et al., 2020). In the time-based PM task, older adults' performance improve under positive mood, whereas young adults' performance does not show similar improvements (Pupillo et al., 2020). Although enhanced emotional regulation among older adults is hypothesized to benefit performance, this variable did not account for the findings (Pupillo et al., 2020). Despite these positive findings, other studies have shown that older adults with lower EF (such as in depression) do not experience the positive effects in recall. Instead, they tend to recall and overgeneralize negative events (Knight et al., 2007; Mather & Knight, 2005). Overall, continued research is required to clarify these age effects across PM and mood.

7 Rationale and Objectives

Limited research has been devoted to the specific effects of depression on PM (McFarland & Vasterling, 2018). Although evidence suggests that depression has negative effects on PM, the mechanisms of its impact on PM are not yet clear. Researching rumination provides an important opportunity to examine effects of depression on PM, based on evidence of its negative impact on retrieval. There are also opportunities to enhance methods of previous studies that include optimizing the PM task to be more effortful by using an event-based and non-focal task (McFarland & Vasterling, 2018). Given the COVID-19 pandemic, study methodology was adapted for remote delivery which provided a novel opportunity to use real-time measures and employ a repeated measures design to enhance ecological validity. Although a few studies have demonstrated negative effects of rumination in PM, no studies have examined the effects of state and trait rumination on PM among younger and older adults using the proposed design. The present study thus sought to delineate the putative contributions of state and trait rumination on the performance of a computerized event-based PM task with non-focal cues delivered remotely using a repeated and real-time approach among younger and older adults. Specific aims were to examine the effect of (1) state and (2) trait rumination on PM test accuracy and response times over time and cross-sectionally for both groups. An exploratory aim was to examine age effects across groups: This aim was exploratory and preliminary given the small sample size of older adults. Overall, state and trait rumination were hypothesized to differentially impair PM performance (Fredman Stein et al., 2018). Specifically, (1) higher levels of state rumination would be associated with poorer accuracy and slower response times, and (2) trait rumination would be associated with slower response times on a PM task based on a previous study's findings (Fredman Stein et al., 2018).

CHAPTER 2: METHODS

1 Participants and Sample Size

1.1 Sample Size

Sample size guidelines and power analyses for repeated measures designs are complex as there are many parameters involved (Kerkhoff & Nussbeck, 2019). Between-persons sample sizes of $n > 50$ have been recommended for multi-level modeling (MLM) (Hoyle & Gottfredson, 2015; Lafit et al., 2020; Maas & Hox, 2005). Comparable sample sizes have yielded statistically significant results in other similar studies with moderate-large effect sizes (Cain et al., 2009; Kim et al., 2020; Nehrkorn-Bailey et al., 2018). Power analyses completed using effect size of .5 and a of .05 revealed that sample sizes of $n = 100$ would be required for power of .97 for Wilcoxon-rank sum tests (Faul et al., 2007). Samples sizes of $n = 100$ were thus proposed for older and younger adults, and $n = 56$ individuals were additionally recruited to account for potential dropouts. The within-persons sample size (i.e., number of observations per individual) proposed was $n = 4$ timepoints, similar to previous studies (Nehrkorn-Bailey et al., 2018). This number was determined to be feasible when occurring twice per week for two weeks following a pilot. In total, this study aimed to generate approximately $n = 400$ observations.

1.2 Younger Adult Participants

Younger adult participants were recruited from the University of Windsor and the Windsor community. Undergraduate students were recruited through the university's participant pool which is a large online database where researchers can upload studies and undergraduate students registered in eligible psychology courses can elect to participate (Buchanan et al., 2021). Students accessed advertised studies virtually and were compensated following their participation based on time spent completing the studies (i.e., half an hour would be equivalent to 0.5 bonus points, one hour would be one bonus point, and so on). Younger adults were also recruited through the community to ensure equivalency of recruitment methods. Community advertisement (i.e., posters) and social media (i.e., Twitter, Instagram, and the lab website) were used.

To be eligible as a younger adult participant, individuals must have been aged between 18-59 years, were required to understand English, have normal or normal-to-corrected vision to be able to see and complete the computerized task, and have access to a computer and internet. This age cut-off was chosen as it replicates previous studies that examined age affects in PM (Henry et al., 2004; Pupillo et al., 2020). Additionally, participants must have been cognitively intact based on a Montreal Cognitive Assessment (MoCA) score of >26 to ensure any deficits in PM were not related to cognitive impairments (Nasreddine et al., 2005). Due to the restrictions of the COVID-19 pandemic and given no existing validated remote cognitive screening tools for younger adults, we were not able to screen for cognitive impairment in person or over the telephone in younger adults. To account for this limitation and to ensure findings were not confounded by any other disorders, participants were excluded based on a reported previous history of severe neurodevelopmental/neurological/psychiatric disorder.

1.3 Older Adult Participants

Community-dwelling older adults were recruited through community sampling. Study advertisement occurred on social media via the University of Windsor's and our lab's websites; Twitter, and Instagram; and in the community by distributing posters and contacting community organizations (i.e., Life After Fifty, the Multicultural Council, the Filipino Community Center, Elder College, and Essex-County Chinese Canadian Association).

Inclusion criteria included participants aged 60 years or older, the ability to communicate in English, have eyesight proficient enough to complete tasks on a computer, and have access to a computer and internet. There is no existing prescribed criteria for age cut-offs for older adults, though our cut-off is considered acceptable and similar to previous studies (Henry et al., 2004; Shenkin et al., 2017). Additionally, participants must have been cognitively intact based on remote screening using the Telephone Interview for Cognitive Status (TICS) with a score of >28 or an in-person screening using the MoCA with a score of >26 (Desmond et al., 1994; Nasreddine et al., 2005) to ensure differences in PM performance were not attributed to any cognitive impairments. Due to the COVID-19 pandemic, only telephone screening was completed. Participants were excluded based on a reported previous history of severe neurodevelopmental/neurological/psychiatric disorder to ensure the findings were not being confounded by any other disorders.

2 Procedure and Study Design

This study received clearance by the Research Ethics Board (REB#: 21-017) at the University of Windsor and employed a prospective observational and repeated measures design with four separate timepoints. The initial pilot ensured that each timepoint was not prolonged and did not cause fatigue for participants. The study thus elapsed approximately half an hour for the first session (i.e., the shortest possible timepoint to be credited for in the University of Windsor participant pool), and 5-10 minutes for subsequent sessions.

Younger adult participants who attended the University of Windsor signed up through the university's participant pool. The participant pool has numerous pre-screening questions to ensure students who sign up are already eligible to participate. Any additional exclusion criteria not available as pre-screeners were added into the demographic survey for additional screening. Once signed up, they were emailed the link to review and provide consent. Once consent was given, participants were sent the study link along with their anonymized code to access the first part of the study. All younger and older adult participants recruited from the community emailed the research assistant or the master's student to express interest in participating in the study after viewing study advertisements. A research assistant or the master's student set up a time to screen participants for eligibility criteria and to obtain informed telephone consent. If eligible, the first study link and anonymized code was emailed to participants. All participants were provided an option for the research assistant or the master's student to guide them through the first session via telephone or videoconferencing to enhance accessibility should they have requested it.

Using a computer, participants accessed the study link to complete demographic measures, measures of depression, anxiety, state and trait rumination, and momentary mood. Next, they completed the PM task which occurred during the ongoing task. Lastly, participants completed feasibility questions. Participants repeated this process twice per week for two weeks and links were scheduled to be sent at the appropriate time via email reminders. Email reminders were particularly important to provide given this would eliminate the confounding variable of poor LTM to recall to access and complete the study. All participants were provided with mental health resources at the end of each session. Community participants were redirected to a link to receive their compensation (i.e., entering a draw for an Amazon gift card). Undergraduate student participants were compensated with student bonus points required for their classes which included half a bonus point for the first three sessions and one full bonus point for the last session. The full bonus point was implemented to promote compliancy until the final timepoint. A schematic table of the study procedure is found in Appendix 1.

3 Measures

3.1 Descriptor Measurements

3.1.1 Demographic Variables

Collected variables at first session included age, gender, and reported race/ethnicity. These variables are typically collected as typical demographic information in cognitive studies (Medina et al., 2021). Additionally, vision status (i.e., normal, or corrected-to-normal and if the latter, if wearing glasses/contact lenses), and prior neurodevelopmental/neurological/psychiatric history were collected to further ensure participants met inclusion criteria.

3.1.2 Anxiety Symptoms

Participants completed the seven-item General Anxiety Disorder (GAD-7) at first session to assess anxiety symptoms (Spitzer et al., 2006) (Appendix 2). It has shown acceptable psychometric properties (i.e., high sensitivity and specificity) among younger and older adults (Byrd-Bredbenner et al., 2020; Wild et al., 2014). Anxiety symptoms were measured to ensure these symptoms would not confound findings, as previous research has demonstrated that anxiety can impact PM performance. Anxiety symptoms are also highly comorbid with depressive symptoms (Bowman et al., 2019; Yapan et al., 2020). The GAD-7 is scored out of seven items, where scores between 0-4 represent minimal, 5-9 represent mild, 10-14 represent moderate, and 15-21 represent severe anxiety (Spitzer et al., 2006).

3.1.3 Depressive Symptoms

Participants completed the nine-item Patient Health Questionnaire (PHQ-9) at first session to assess depressive symptoms (Kroenke et al., 2001) (Appendix 3). The PHQ-9 has excellent sensitivity and specificity in younger and older adults (Katz et al., 2020; Levis et al., 2019). It also has a high internal reliability with an alpha's Cronbach value of 0.89 and excellent test/re-test reliability (Kroenke et al., 2001). Given mixed findings the effects of depressive symptoms related to PM performance, these symptoms were collected to ensure that depressive symptoms were not confounding findings (McFarland & Vasterling, 2018). The PHQ-9 is scored out of nine items where 0-4 indicates none to minimal, 5-9 indicates mild, 10-14 indicates moderate, 15-19 indicates moderately severe, and 20-27 indicates severe depression (Kroenke et al., 2001).

3.1.4 Cognitive Functioning

Older adults were screened for cognitive impairment using the TICS via the telephone (Brandt et al., 1988). The TICS has been validated as a screening tool for dementia and has good reliability and validity (Desmond et al., 1994; Knopman et al., 2010). It has demonstrated greatest evidence for test accuracy for cognitive screening when in-person screening is not possible (Elliott et al., 2020; Watt et al., 2021).

3.1.5 State Rumination

Participants completed the 8-item Brief State Rumination Inventory (BRSI) every session to measure momentary state rumination (Appendix 5) (Marchetti et al., 2018). Items range from “completely disagree” = 0 to “completely agree” = 100, and the total score was calculated by summing the items. The BSRI was developed from trait rumination scales and adapted for momentary assessment (Marchetti et al., 2018). It has good convergence with negative affect scales, trait rumination and symptoms of depression and anxiety, and is a sensitive tool to detect state rumination (Dondzilo et al., 2020; Lopes et al., 2020; Marchetti et al., 2018).

3.1.6 Trait Rumination

Participants completed the 22-item Ruminative Responses Scale (RRS) only on the first testing session to measure trait rumination (Appendix 6) (Nolen-Hoeksema & Morrow, 1991). The RRS includes items that report individuals’ reactions to depressed mood related to the self or reflecting on possible consequences and causes of their own negative mood. Items range from “almost never” = 1 to “almost always” = 4 (Fredman

Stein et al., 2018). Total scores were calculated by summing all the items. The Cronbach's alpha was high, and moderate correlations were shown between responses on this scale to ruminative responses in a 30-day diary (Moberly & Watkins, 2008b; Nolen-Hoeksema, 2000).

3.1.7 Momentary Mood

Participants completed the Brief Mood Introspection Scale (BMIS) every session to measure momentary mood experience. The BMIS is based on adjectives including happy, lively, loving, caring, calm, content, active, peppy, jittery, nervous, grouchy, fed up, tired, drowsy, gloomy or sad (Appendix 7) (Mayer & Gaschke, 1988). This scale has good validity and reliability (Cavallaro et al., 2019; Mayer & Gaschke, 1988). A total score of pleasantness/unpleasantness incorporating all items was calculated by adding the sum of the negative items that were reverse scored (i.e., jittery, nervous, grouchy, fed up, tired, drowsy, sad, and gloomy) and the sum of the positive items (i.e., happy, loving, calm, content, lively, caring, active, and peppy) together.

3.1.8 Feasibility Data

At the end of each study session, participants were asked if they experienced any issues during the study (i.e., "distracted by something", "internet connectivity issues", "computer malfunction", and "accidentally closed browser"). They were asked to what extent did these issues impact performance on the tasks on a five-point Likert scale ranging from "not at all" to "very much". Participants had the option to provide their own open-ended answer. These questions provide insightful information related to preliminary methods to enhance similar future studies.

3.2 Outcome Measurements

3.2.1 Prospective Memory and Ongoing Working Memory Task

The computerized task included a PM task embedded within a WM task (*n*-back). The development of this task followed guidelines from an event-based PM paradigm, (McDaniel & Einstein, 2007a). For the *n*-back, participants were shown images of single everyday objects (i.e., chair, table, fire hydrant, cat, etc.), one at a time, and instructed to indicate when a presented image matched the image from one trial prior in the sequence by pressing “M”. If the image did not match the image from one step earlier, they were told to press “N”. During the *n*-back instructions, participants were told to press the space bar if a dog appeared: this served as the intention that participants had to encode into LTM, and subsequently recall with the presentation of the cue (i.e., dog). They began the ongoing task and throughout this task, the PM cue appeared approximately every 20 trials, and participants had to recall to switch tasks and press the space bar to accurately perform the PM task (Jáger & Kliegel, 2008) (Appendix 7). Performance was measured by accuracy out of four PM trials and response times of the correct PM trials (Jáger & Kliegel, 2008; McFarland & Vasterling, 2018; Schnitzspahn et al., 2020). Accuracy was calculated as the frequency of correct hits. Response times were defined as the time taken to initiate a reaction (i.e., reaction times) to the stimulus as well as the movement time (i.e., time it takes to complete the response) for correct trials (Kyllonen & Zu, 2016). In addition, ongoing task performance for the *n*-back task was measured by computing accuracy out of 160 trials and response times of the correct trials. A previous study using an *n*-back task four times daily for one week as the ongoing task did not show any practice effects (Schmitter-Edgecombe et al., 2020). Regardless, task stimuli were randomized across the four different timepoints to further minimize practice effects. Participants were instructed to complete this task only using a desktop or laptop computer as research has shown differences in scores based on the interface used (Passell et al., 2021).

4 Statistical Analyses

Descriptive analyses were conducted by generating frequency counts for categorical data and means and standard deviations for the continuous data. The number of timepoints completed, and missing data were reported. Shapiro-Wilk tests of normality were conducted to assess normality of the variables. Differences between younger and older adults were conducted using mean tests of differences and Cohen's *d* effect sizes were generated, where d = .15 indicated a small; d = .40 indicated moderate; and d = .75 indicated a large effect size (Brydges, 2019). Determining how many timepoints would be included in the models involved considerations of robustness of data, but overall, including at least two timepoints was proposed. Main analyses were repeated with participants who completed all timepoints to examine differences between participants included in the analyses and the total sample. Descriptive statistics regarding data related to feasibility was provided for context but was not included in any analyses.

4.1 Effects of State Rumination on Prospective Memory

The first aim examined the effect of state rumination on PM accuracy and response times. To address this, MLM were fit as they account for hierarchical and missing data which are characteristic of repeated measures designs (Bolger & Laurenceau, 2013). Other analyses, such as a repeated-measures ANOVA, are limited in that they are limited in accounting for missing data or handling nested data (Quené & Van Den Bergh, 2004). In addition, the assumptions of MLM include assumptions of normality of residuals, heterogeneity of variances, linearity, collinearity, and adequate sample sizes. Despite these, violations to errors in these assumptions are typically robust, highlighting the benefits of the use of these models (Schielzeth et al., 2020). Specifically, level-2 MLM was fit where time data represented the level-2 grouping variable nested within the level-1 variable of participants (Nezlek, 2012). One model was fit the participant variable as a random effect as this data aimed to generalize to a larger population of individuals experiencing rumination. Time (i.e., the week number) was fit as a fixed effect as the timepoints were specific and chosen in time. For both BSRI and BMIS data, the total scores were each separated into two terms representing person mean-centered data and average data; these two terms were included in the models as fixed effects. This allowed disaggregation of within- and between-person differences in rumination (BSRI) and mood (BMIS) (Bolger & Laurenceau, 2013). Spearman-rank correlations were run between the unpleasant mood and rumination variables to ensure no collinearity between these variables. Correlation coefficient values of $r < .30$ were considered negligible, $r = .30$-$.50$ were low, $r = .50$-$.70$ were moderate, $r = .70$-$.90$ were high and $r > .90$ were very high (Mukaka, 2012). Accuracy and response time data for separate age groups were each inserted as the dependent variables to generate four main models. Full information maximum likelihood estimation was used. Analyses were also repeated to examine any effects of state rumination on ongoing WM task performance in younger and older adults. Once models were run, statistically significant effects were reported using $p < .05$. Effect sizes and their confidence intervals were reported by converting *t*-scores into pseudo partial-ETA (η^2) squared values, with $\eta^2 = .01$ (small); $\eta^2 = .06$ (moderate); $\eta^2 = .14$ (large) and replicate similar studies that have conducted these effect size calculations (Goldstein et al., 1976; Tribolet et al., 2021). Additionally, pseudo partial-ETA values are typically used when standardized effect sizes are not easily computed, such as in linear mixed models. They are computed by dividing the squared *t*-values produced by the models by the sum of the squared *t*-value and the degrees of error (Mordkoff, 2019).

4.2 Effects of Trait Rumination on Prospective Memory

The second aim examined the effect of trait rumination on PM accuracy and response times. To address this, Spearman's rank two-tailed correlations with Bonferroni corrections were generated to examine the association between trait rumination to each mean accuracy and mean response times on the PM task for each age group as data was non-parametric. Analyses were also repeated to examine any effects of trait rumination on ongoing WM task performance in younger and older adults. Correlation coefficient values of $r < .30$ were considered negligible, $r = .30$-$.50$ were low, $r = .50$-$.70$ were moderate, $r = .70$-$.90$ were high and $r > .90$ were very high (Mukaka, 2012).

4.3 Age Effects on Prospective Memory

The exploratory aim examined age effects on PM accuracy and response times. For this aim, another MLM was generated by adding age as a fixed effect into the MLM models from Aim 1. Similarly, participants were fit as a random effect, time was fit as a fixed effect, BSRI and BMIS data were each separated into centered data and aggregated average data and these terms entered as fixed effects, and accuracy and response time data were each inserted as the dependent variables to generate two models. Analyses were also repeated to examine any effects of state rumination on ongoing WM task performance in younger and older adults. Partial-ETA squared scores and their confidence intervals were calculated (Goldstein et al., 1976). Analyses were performed in R software using *rms* for MLM (Harrell & Frank, 2018) and analyzed using $p < .05$.

CHAPTER 3: RESULTS

3.1 Descriptive Analysis on Participants

In total, 156 participants were recruited. Of these participants, 139 were younger adults and 17 were older adults. Of the younger adults, 131 were younger adults from the University of Windsor and 8 were younger adults from the community. As it was proposed that participants that completed at least two timepoints throughout the entire study would be included in the final analysis, only these individuals were included. Ultimately, this resulted in a total of 110 participants that were included in the subsequent analyses (Table 2). Crucially, there were no demographic differences in participants between those who completed at least two timepoints, and those who completed all four timepoints (Appendix 8). Demographic data related to the total original sample (n = 156), and younger (n = 139) and older adults (n = 17) are reported in Appendix 9.

Shapiro-Wilk tests of normality revealed that all variables were non-normal with exception to PM response times in older adults (W = .97, p = .21). Given the non-normal distributions, group differences on demographic variables were determined using non-parametric statistics (i.e., Wilcoxon Rank-Sum Tests). Younger adults' scores were significantly different than older adults' scores on the PHQ-9 (W = 1731, $p < .05$, d = .46), GAD-7 (W = 1788, $p < .001$, d = .51), and RRS (W = 1683, $p < .01$, d = .42). This suggests that younger adults were experiencing higher levels of depressive and anxious symptoms, and higher trait rumination than older adults with moderate effect sizes.

Table 2

Demographic Data from Participants Who Completed At Least Two Timepoints

	Total Sample (*n* = 110)	Younger Adults (*n* = 95)	Older Adults (*n* = 15)
Age (M years, SD years)	27.84 (16.07)*	21.78 (4.61)	66.20 (6.39)
Age Ranges (years)	18-80	8-53	60-80
Gender (%F)	87%	95%	4%
Race/Ethnicity (n)			
White	77	61	14
Black	8	8	0
Latin American	2	2	0
South Asian	8	7	1
West Asian	3	3	0
Southeast Asian	2	2	0
Arab	12	12	0
Filipino	0	0	0
Chinese	0	0	0
Indigenous	1	1	0
PHQ-9 (M, SD)	6.54 (4.82)*	7.01 (4.69)	3.53 (3.46)
GAD-7 (M, SD)	6.69 (5.33)*	7.29 (5.74)	2.87 (4.17)
RRS (M, SD)	43.68 (13.85)*	45.15 (14.33)	34.40 (9.19)
TICS (M, SD)	-	-	35.57 (4.02)

Note. PHQ-9: 9-Item Patient Health Questionnaire; GAD-7: 7-Item Generalized Anxiety Disorder; RRS: Ruminative Responses Scale; F: Female; M = mean; SD = Standard deviation. *$p < .05$.

3.1.1 Preliminary Feasibility Analysis

In terms of the descriptive data on feasibility, the most common concern listed was feeling distracted which was endorsed by 32% of the entire sample. Sixty per cent of the sample did not endorse any concerns related to finishing the study (Table 3).

Table 3

Feasibility Outcomes Listed by Participants in PM Study

Concerns listed	Frequency (*n*)
Distracted by something	119
Internet connectivity issues	12
Computer malfunction	6
Accidentally closed browser	2
No, I did not experience any issues	225
Other concerns reported:	
Clicked wrong key due to keyboard	4
Cognitive test did not appear	1
Hit “submit” before the task appeared	2
Overwhelmed by task/hard to keep up	3
Participating while sick	1
Confused about instructions	1
Had to retrieve charger while participating	1

When considering all four timepoints, 389 observations were collected in the total sample where younger adults constituted 87% of the observations collected (Table 4). Out of all observations from recruited individuals, this represents a compliance rate of 70% (389/556). In the younger adults, 170 observations were missing which represented a compliance rate of 67% (338/508) (Table 5). In the older adults, 5 observations were missing, representing a compliance rate of 91% (51/56) (Table 6). Generally, missing data was more likely to occur as participants progressed through the study. However, some missing data from the older adults occurred at the beginning, leading to greater sample sizes near the end. The sample size of observations decreased from the first to second timeslot by 27%. Subsequently, from the second to third timeslot, the sample size decreased by 22%. From the third to last timepoint, the sample size decreased by 11%. Overall, the entire sample size decreased by 50% from time 1 to time 4 (Table 4).

3.2 Descriptive Analysis on Cognitive Performance, Rumination and Mood

Prior to the main analyses, descriptive data and comparisons of mood and cognitive performance across groups and across timepoints are presented. These results are given to provide an overview of performance for the primary variables of interest (Table 4). Observations were separated by younger (Table 5) and older adults (Table 6) across time with several differences between younger and older adults.

3.2.1 Analysis of PM Performance Across Groups

Group differences in PM accuracy were found at the second ($W = 355.5$, $p < .05$, $d = -.52$) and third timeslots ($W = 218$, $p < .05$, $d = -.62$), with younger adults performing more poorly, compared to older adults with moderate effect sizes (Tables 5 & 6). In contrast, younger adults were significantly faster on all PM trials compared to the older adults with moderate to large effect sizes (Timeslot 1: $W = 246$, $d = -.76$; Timeslot 2: $W = 254$, $d = -.64$; Timeslot 3: $W = 140$, $d = -.75$; Timeslot 4: $W = 150$, $d = -.68$; $p < .05$) (Tables 5 & 6).

Table 4

Means and Standard Deviations of Performance Outcomes Collected at Each Timepoint for the Total Sample

	Timepoints			
	1 (*n* = 139)	2 (*n* = 101)	3 (*n* = 79)	4 (*n* = 70)
PM Accuracy (%)	.69 (0.3)	.71 (.29)	.79 (.25)	.78 (.26)
PM Response Times (s)	.82 (.16)	.77 (.18)	.75 (.16)	.74 (.19)
WM Accuracy (%)	.87 (.21)	.90 (.18)	.89 (.19)	.91 (.19)
WM Response Times (s)	.60 (.13)	.57 (.13)	.54 (.12)	.54 (.14)
BSRI Total Score	328 (177)	284 (179)	295 (192)	276 (193)
BMIS Total Score	41 (8)	42 (9)	41(9)	41 (10)

Note. PM: Prospective memory; WM: Working memory; BSRI: Brief State Rumination Inventory; BMIS: Brief Mood Introspection Scale.

3.2.2 Analysis of WM Performance Across Groups

Older adults performed significantly better in WM trials at the third timeslot compared to younger adults, demonstrating higher accuracy with a small effect size ($W =$

288, $d = -.6$, $p < .05$) (Tables 5 & 6). Younger adults were significantly faster on the WM trials compared to the older adults with moderate to large effect sizes (Timeslot 1: $W = 482$, $d = -.55$; Timeslot 2: $W = 147$, $d = -.80$; Timeslot 3: $W = 94$, $d = -.83$; Timeslot 4: 93, $d = -.80$; $p < .05$) (Tables 5 & 6).

3.2.3 Analysis of Rumination and Mood Outcomes Across Groups

Younger adults had significantly higher state rumination as measured by the BSRI in the first ($W = 1088$, $d = .01$, $p < .05$) and last ($W = 570$, $d = .20$, $p < .05$) timepoints compared to older adults with small effect sizes (Tables 5 & 6).

Table 5

Means and Standard Deviations of Performance Outcomes Collected at Each Timepoint in Younger Adults

	Timepoints			
	1 (*n* = 127)	2 (*n* = 88)	3 (*n* = 67)	4 (*n* = 56)
PM Accuracy (%)	.70 (.29)	.68 (.30)	.76 (.25)	.75 (.27)
PM Response Times (s)	.80 (.14)	.74 (.16)	.72 (.12)	.69 (.12)
WM Accuracy (%)	.88 (.20)	.89 (.19)	.88 (.20)	.92 (.17)
WM Response Times (s)	.59 (.12)	.55 (.11)	.51 (.10)	.49 (.11)
BSRI Total Score	340 (171)	288 (179)	306 (182)	300 (187)
BMIS Total Score	40 (7)	51 (9)	39 (8)	39 (9)

Note. PM: Prospective memory; WM: Working memory; BSRI: Brief State Rumination Inventory; BMIS: Brief Mood Introspection Scale.

Younger adults had significantly lower scores on the unpleasantness/pleasantness scale on the BMIS compared to older adults at all timepoints with moderate to large effect sizes (Timeslot 1: W = 485, d = -.58; Timeslot 2: W = 194, d = -.73; Timeslot 3: W = 192, d = -.70; Timeslot 4: W = 162, d = -.71; $p < .05$) (Tables 5 & 6).

Table 6

Means and Standard Deviations of Performance Outcomes Collected at Each Timepoint in Older Adults

	Timepoints			
	1 (*n* = 12)	2 (*n* = 13)	3 (*n* = 12)	4 (*n* = 14)
PM Accuracy (%)	.58 (.37)	.87 (.24)	.96 (.10)	.88 (.16)
PM Response Times (s)	1.06 (.26)	.95 (.22)	.95 (.21)	.94 (.25)
WM Accuracy (%)	.79 (.26)	.93 (.12)	.94 (.14)	.90 (.26)
WM Response Times (s)	.69 (.16)	.73 (.15)	.69 (.12)	.71 (.14)
BSRI Total Score	210 (208)	255 (178)	231 (240)	188 (198)
BMIS Total Score	47 (9)	51 (7)	49 (9)	49 (9)

Note. PM: Prospective memory; WM: Working memory; BSRI: Brief State Rumination Inventory; BMIS: Brief Mood Introspection Scale.

3.3 Mixed-Linear Modeling

To address the first aim, MLM models were fit to examine associations between rumination and PM. These models were run separately in younger and older adults and repeated in the full sample. Intercorrelations between mood and rumination variables are presented in Table 7. Significant correlations were low between trait rumination and average state rumination values (*r* = .40), suggesting that higher state rumination is associated with higher trait rumination; higher state rumination was associated with lower pleasant mood (*r* = -.46); and higher pleasant mood was associated with lower trait rumination (*r* = -.49). One significant correlation was found between change in unpleasant mood and change in state rumination.

Table 7

Inter-correlations Between Mood and Rumination Variables in Mixed-Linear Models

	BSRI_A	BSRI_C	RRS	BMIS_A	BMIS_C
BSRI_A	-	-.04	.40*	-.46*	.07
BSRI_C		-	.09	.15	-.18*
RRS			-	-.49*	.07
BMIS_A				-	-.002
BMIS_C					-

Note. RRS: Ruminative Responses Scale; BSRI_C: Change in Brief State Ruminative Inventory Scores; BSRI_A: Average Brief State Ruminative Inventory Scores; BMIS_A: Average in Brief Mood Introspection Scores; BMIS_C: Change in Brief Mood Introspection Scores; *$p < .05$.

3.3.1 Mixed-Linear Modeling Analysis in Younger Adults for State Rumination and PM

The association between state rumination and PM was examined in younger adults. The average BSRI values across participants was significantly associated to PM accuracy, after controlling for all other variables, with a large effect size (t = -2.95, p < .05, η^2 = .90) (Table 8). This suggests that as the average state rumination increases between younger adults per day, PM accuracy is significantly more likely to decrease. Trait rumination, average mood between individuals, and daily changes in mood and rumination within individuals were not significantly related to PM accuracy (p > .05). Time was also not related to any significant changes in PM accuracy (p > .05) (Table 8).

Table 8

Mixed-Linear Modeling for Prospective Memory Accuracy in Younger Adults

					95% CI	
	Estimate	SE	*t*	*p*	Lower	Upper
Intercept	1.05	.18	5.83	<.001*	.70	1.41
Time2	-.05	.04	-1.39	.17	-.12	.02
Time3	.03	.04	.86	.39	-.04	.11
Time4	-.02	.05	-.40	.69	-.12	.08
RRS	.001	.002	.56	.58	-.002	.004
BSRI_C	-.0001	.0001	-1.30	.20	-.0004	.0001
BSRI_A	-.0004	.0002	-2.95	.004*	-.0007	-.0001
BMIS_A	-.006	.0032	-1.81	.07	-.012	.001
BMIS_C	-.003	.0035	-.88	.38	-.01	.004

Note. RRS: Ruminative Responses Scale; BSRI_C: Change in Brief State Ruminative Inventory Scores; BSRI_A: Average Brief State Ruminative Inventory Scores; BMIS_A: Average in Brief Mood Introspection Scores; BMIS_C: Change in Brief Mood Introspection Scores; SE: Standard errors; CI: Confidence interval. *p < .05.

Younger adults' PM response times were significantly related to times two (t = -3.06, $p < .05$, $\eta^2 = .90$), three (t = -4.02, $p < .05$, $\eta^2 = .94$), and four (t = -3.53, $p < .05$, $\eta^2 = .93$) with the first timepoint as the reference category (Table 9). This suggests that younger adults' PM response times were significantly faster at each timeslot with the first timeslot as a reference category (Table 9).

Table 9

Mixed-Linear Modeling for Prospective Memory Response Times in Younger Adults

					95% CI	
	Estimate	SE	*t*	*p*	Lower	Upper
Intercept	.77	.10	7.95	<.001*	.58	.96
Time2	-.05	.02	-3.06	.003*	-.08	-.02
Time3	-.07	.02	-4.02	.0001*	-.11	-.04
Time4	-.09	.02	-3.53	.001*	-.13	-.04
RRS	-.001	.001	-.94	.35	-.003	.0009
BSRI_C	.00001	.0001	-0.12	.91	-.0001	.0001
BSRI_A	.0001	.0001	1.62	.11	-.00002	.0003
BMIS_A	.0004	.002	.21	.83	-.003	.0038
BMIS_C	-.003	.002	-1.9	.05	-.006	-.0001

Note. RRS: Ruminative Responses Scale; BSRI_C: Change in Brief State Ruminative Inventory Scores; BSRI_A: Average Brief State Ruminative Inventory Scores; BMIS_A: Average in Brief Mood Introspection Scores; BMIS_C: Change in Brief Mood Introspection Scores; SE: Standard errors; CI: Confidence interval. *$p < .05$.

It is important to note that the association between the day-to-day changes in BMIS scores and PM response times was at the conventional threshold of statistical significance (t = -1.9, p = .05). Although not technically significant, this could suggest that daily mood changes of unpleasantness may be weakly related to slower response times. Trait rumination, average mood between individuals, and daily changes in mood and rumination within individuals were not significantly related to PM response times ($p > .05$) (Table 9).

3.3.2 Mixed-Linear Modeling Analysis in Younger Adults for State Rumination and WM

In younger adults, average BSRI was at threshold for significance as a predictor of WM accuracy ($t = -2.30$, $p = .05$, $\eta^2 = .84$) (Table 10). As mean BSRI increased between individuals, there was a decrease in WM accuracy with a large effect size. Trait rumination, average unpleasant mood per day, and changes in unpleasant mood and state rumination were not significantly related to WM accuracy ($p > .05$) (Table 10).

Time was significantly associated to WM response times at all timepoints with the first as the reference category with large effect sizes (Timepoint 2: $t = -3.95$, $\eta^2 = .94$; Timepoint 3: $t = -5.90$, $\eta^2 = .97$; Timepoint 4: $t = -4.90$, $\eta^2 = .96$, $p < .05$) (Table 11).

Table 10

Mixed-Linear Modeling for Working Memory Accuracy in Younger Adults

					95% CI	
	Estimate	SE	*t*	*p*	Lower	Upper
Intercept	.98	.14	7.00	<.001*	.71	1.26
Time2	.001	.02	.04	.97	-.04	.04
Time3	-.01	.02	-.4	.67	-.06	.04
Time4	-.003	.03	-.1	.92	-.07	.06
RRS	.001	.001	.54	.59	-.002	.003
BSRI_C	-.0001	.0001	-1.55	.12	-.0003	.00003
BSRI_A	-.0002	.0001	-2.03	.05	-.0004	-.00001
BMIS_A	-.001	.003	-0.55	.57	-.006	.0036
BMIS_C	.003	.002	1.40	.16	-.001	.0073

Note. RRS: Ruminative Responses Scale; BSRI_C: Change in Brief State Ruminative Inventory Scores; BSRI_A: Average Brief State Ruminative Inventory Scores; BMIS_A: Average in Brief Mood Introspection Scores; BMIS_C: Change in Brief Mood Introspection Scores; SE: Standard errors; CI: Confidence interval. *$p < .05$.

This suggests that younger adults' WM response times were faster at each time with the first time as a reference category. Trait rumination, average mood and state rumination between individuals, and daily changes in mood and rumination within individuals were not significantly related to PM accuracy or WM response times ($p > .05$).

Table 11

Mixed-Linear Modeling for Working Memory Response Times in Younger Adults

					95% CI	
	Estimate	SE	*t*	*p*	Lower	Upper
Intercept	.61	.08	8.14	<.001*	.46	.76
Time2	-.06	.01	-3.95	.0001*	-.08	-.03
Time3	-.08	.01	-5.41	<.001*	-.11	-.05
Time4	-.10	.02	-4.90	.000001*	-.14	-.06
RRS	-.0001	.001	-.11	.92	-.001	.001
BSRI_C	-.00001	.0001	-.16	.88	-.0001	.0001
BSRI_A	.000001	.0001	.03	.98	-.0001	.0001
BMIS_A	-.0003	.001	-.02	.81	-.003	.002
BMIS_C	.001	.001	.85	.40	-.002	.004

Note. RRS: Ruminative Responses Scale; BSRI_C: Change in Brief State Ruminative Inventory Scores; BSRI_A: Average Brief State Ruminative Inventory Scores; BMIS_A: Average in Brief Mood Introspection Scores; BMIS_C: Change in Brief Mood Introspection Scores; SE: Standard errors; CI: Confidence interval. *$p < .05$.

3.3.3 Mixed-Linear Modeling in Older Adults for State Rumination and PM

Two of the models could not converge, and thus, the random effects were removed from the models (Table 12a & 14a) (Brown, 2021). After omitting the random effects, all timepoints were associated with PM accuracy in older adults (Timepoint 2: t = 3.30, η^2 = .92; Timepoint 3: t = 4.40, η^2 = .95; Timepoint 4: t = 2.79, η^2 = .89, p < .05). This suggests that older adults' PM accuracy increased at each timeslot with the first timeslot as a reference category (Table 12b). Trait rumination, average mood and state rumination between individuals, and daily changes in mood and rumination within individuals were not significantly related to PM accuracy ($p > .05$) (Table 12b). These effects were reflected in the non-converging model output (Table 12a).

Table 12a

Mixed-Linear Modeling for Prospective Memory Accuracy in Older Adults

					95% CI	
	Estimate	SE	*t*	*p*	Lower	Upper
Intercept	.60	.54	1.11	.27	-.48	1.69
Time2	.30	.09	3.43	.001*	.12	.47
Time3	.40	.09	4.57	.00003*	.22	.57
Time4	.32	.1	3.32	.002*	.13	.51
RRS	.005	.005	.91	.36	-.01	.02
BSRI_C	-.0001	.0003	-.50	.62	-.001	.0004
BSRI_A	.0001	.0003	.33	.75	-.0004	.001
BMIS_A	-.004	.008	-.54	.59	-.02	.01
BMIS_C	.001	.004	.30	.77	-.01	.09

Note. RRS: Ruminative Responses Scale; BSRI_C: Change in Brief State Ruminative Inventory Scores; BSRI_A: Average Brief State Ruminative Inventory Scores; BMIS_A: Average in Brief Mood Introspection Scores; BMIS_C: Change in Brief Mood Introspection Scores; SE: Standard errors; CI: Confidence interval. *$p < .05$.

Table 12b

Linear Modeling for Prospective Memory Accuracy in Older Adults

					95% CI	
	Estimate	SE	*t*	*p*	Lower	Upper
Intercept	.60	.60	1.01	.32	-.61	1.82
Time2	.30	.10	3.10	.004*	.10	.49
Time3	.40	.10	4.13	.0001*	.20	.59
Time4	.32	.11	3.00	.005*	.11	.53
RRS	.005	.006	.83	.41	-.01	.02
BSRI_C	-.0001	.0003	-.46	.65	-.001	.0004
BSRI_A	.0001	.0003	.30	.77	-.0005	.001
BMIS_A	-.004	.009	-.49	.62	-.023	.013
BMIS_C	.001	.004	.27	.79	-.01	.01

Note. RRS: Ruminative Responses Scale; BSRI_C: Change in Brief State Ruminative Inventory Scores; BSRI_A: Average Brief State Ruminative Inventory Scores; BMIS_A: Average in Brief Mood Introspection Scores; BMIS_C: Change in Brief Mood Introspection Scores; SE: Standard errors; CI: Confidence interval. $*p < .05$.

Time was significant for predicting PM response times with large effect sizes (Timepoint 2: $t = -2.80$, $\eta^2 = .81$; Timepoint 3: $t = -2.80$, $\eta^2 = .89$; Timepoint 4: $t = -4.03$, $\eta^2 = .94$, $p < .05$). This suggests that older adults were faster at each timeslot with the first timeslot as a reference category (Table 13). Trait rumination, average mood between individuals, and daily changes in mood and rumination within individuals were not significantly related to PM response times ($p > .05$) (Table 13).

Table 13

Mixed-Linear Modeling for Prospective Memory Response Times in Older Adults

					95% CI	
	Estimate	SE	*t*	*p*	Lower	Upper
Intercept	.82	.78	1.05	.31	-.15	2.06
Time2	-.10	.05	-2.08	.05	.01	-.33
Time3	-.13	.05	-2.80	.01*	-.01	.31
Time4	-.20	.05	-4.03	.0003*	-.02	.25
RRS	-.001	.008	-.14	.89	-.18	.004
BSRI_C	-.0002	.0001	-1.47	.15	-.001	.0003
BSRI_A	-.000003	.0004	-.01	1.0	-.0002	.0008
BMIS_A	.01	.01	-.50	.63	-.02	.02
BMIS_C	.0001	.002	.06	.96	-.005	.01

Note. RRS: Ruminative Responses Scale; BSRI_C: Change in Brief State Ruminative Inventory Scores; BSRI_A: Average Brief State Ruminative Inventory Scores; BMIS_A: Average in Brief Mood Introspection Scores; BMIS_C: Change in Brief Mood Introspection Scores; SE: Standard errors; CI: Confidence interval. *$p < .05$.

3.3.4 Mixed-Linear Modeling Analysis in Older Adults for State Rumination and WM

The model assessing state rumination and WM could not converge (Table 14a). Thus, the random effects were subsequently removed and fit as a linear model (Table 14b). Only the second timeslot was significantly associated with WM accuracy in older adults (t = 2.13, η^2 = .81) (Table 14b). This suggests that at the second timeslot, older adults were significantly more likely to be more accurate during this time with the first timeslot as a reference.

Table 14a

Mixed-Linear Modeling for Working Memory Accuracy in Older Adults

					95% CI	
	Estimate	SE	*t*	*p*	Lower	Upper
Intercept	1.10	.50	2.14	.04*	-.15	2.06
Time2	.17	.08	2.13	.04*	.01	-.33
Time3	.15	.08	1.87	.07	-.01	.31
Time4	.07	.09	.85	.40	-.02	.25
RRS	-.01	.005	-1.66	.10	-.18	.004
BSRI_C	-.0003	.0002	-1.03	.31	-.001	.0003
BSRI_A	.0003	.0002	1.11	.27	-.0002	.0008
BMIS_A	-.001	.007	-.16	.87	-.02	.02
BMIS_C	.002	.004	.66	.51	-.005	.01

Note. RRS: Ruminative Responses Scale; BSRI_C: Change in Brief State Ruminative Inventory Scores; BSRI_A: Average Brief State Ruminative Inventory Scores; BMIS_A: Average in Brief Mood Introspection Scores; BMIS_C: Change in Brief Mood Introspection Scores; SE: Standard errors; CI: Confidence interval. *$p < .05$.

Trait rumination, average mood and state rumination between individuals, and changes in mood and state rumination within individuals were not significantly related to WM accuracy ($p > .05$) (Table 14b). In addition, neither of the remaining timeslots were significantly associated with WM accuracy ($p > .05$) (Table 14b). These effects were reflected in the non-converging model output (Table 14a).

Table 14b

Linear Modeling for Working Memory Accuracy in Older Adults

					95% CI	
	Estimate	SE	*t*	*p*	Lower	Upper
Intercept	1.06	.55	1.94	.06	-.05	2.17
Time2	.17	.09	1.92	.06	-.01	.35
Time3	.15	.09	1.69	.10	-.03	.27
Time4	.07	.10	.77	.45	-.12	.003
RRS	-.008	.005	-1.50	.14	-.02	.0003
BSRI_C	-.0003	.0003	-.93	.36	-.0001	.003
BSRI_A	.0003	.0003	1.00	.32	-.0003	.001
BMIS_A	-.0012	.008	-.15	.88	-.018	.02
BMIS_C	.002	.004	.60	.56	-.01	.01

Note. RRS: Ruminative Responses Scale; BSRI_C: Change in Brief State Ruminative Inventory Scores; BSRI_A: Average Brief State Ruminative Inventory Scores; BMIS_A: Average in Brief Mood Introspection Scores; BMIS_C: Change in Brief Mood Introspection Scores; SE: Standard errors; CI: Confidence interval. *$p < .05$.

Trait rumination, average mood and state rumination between individuals, and changes in mood and state rumination within individuals were not significantly related to WM response times ($p > .05$) (Table 15). In addition, none of the timeslots were significantly associated with WM response times ($p > .05$) (Table 15).

Table 15

Mixed-Linear Modeling for Working Memory Response Times in Older Adults

					95% CI	
	Estimate	SE	*t*	*p*	Lower	Upper
Intercept	.53	.47	1.15	.26	-.41	1.51
Time2	.045	.03	1.40	.15	-.02	.11
Time3	.003	.03	.08	.94	-.06	.06
Time4	-.02	.03	-.57	.57	-.09	.05
RRS	-.0003	.005	-.06	.95	-.01	.01
BSRI_C	-.0001	.0001	-1.15	.26	-.0003	.0001
BSRI_A	.0003	.0002	1.10	.28	-.0002	.0001
BMIS_A	.002	.01	.33	.75	-.013	.016
BMIS_C	.002	.002	.97	.34	-.02	.005

Note. RRS: Ruminative Responses Scale; BSRI_C: Change in Brief State Ruminative Inventory Scores; BSRI_A: Average Brief State Ruminative Inventory Scores; BMIS_A: Average in Brief Mood Introspection Scores; BMIS_C: Change in Brief Mood Introspection Scores; SE: Standard errors; CI: Confidence interval. **p* < .05.

3.3.5 Mixed-Linear Modeling in Entire Sample for State Rumination and PM

In the total sample, age was significantly associated with PM accuracy ($t = 2.39$, $\eta^2 = .85$, $p < .05$) (Table 16). This suggests that as age increases, PM accuracy was significantly higher, with a large effect size. Average state rumination scores remained significantly associated to PM accuracy ($t = -2.14$, $\eta^2 = .84$, $p < .05$), where higher state rumination as measured by the BSRI was associated with poorer PM accuracy in the full sample with a large effect size (Table 16).

Table 16

Mixed-Linear Modeling for Prospective Memory Accuracy in Full Sample

					95% CI	
	Estimate	SE	*t*	*p*	Lower	Upper
Intercept	.90	.17	5.31	.000002*	.56	1.23
Age	.003	.001	2.40	.02*	.0005	.006
Time2	-.008	.034	-.25	.8	-.08	.06
Time3	.08	.036	2.26	.02*	.010	.15
Time4	.04	.05	.92	.36	-.05	.14
RRS	.001	.002	.65	.51	-.002	.0004
BSRI_C	-.0001	.0001	-.76	.45	-.0003	.0002
BSRI_A	-.0003	.0001	-2.29	.02*	-.001	-.00004
BMIS_A	-.005	.003	-1.81	.07	-.01	.0005
BMIS_C	-.002	.003	-.68	.50	-.007	.003

Note. RRS: Ruminative Responses Scale; BSRI_C: Change in Brief State Ruminative Inventory Scores; BSRI_A: Average Brief State Ruminative Inventory Scores; BMIS_A: Average in Brief Mood Introspection Scores; BMIS_C: Change in Brief Mood Introspection Scores; SE: Standard errors; CI: Confidence interval. $*p < .05$.

The third timeslot was significantly associated with PM accuracy relative to the first timepoint ($t = 2.27$, $\eta^2 = .84$, $p < .05$). This suggests that at the third timeslot, participants were more accurate compared to the first timeslot (Table 16). Trait rumination, average mood between individuals, and changes in mood and state rumination within individuals were not significantly related to PM accuracy ($p > .05$) (Table 16). In addition, neither of the remaining timeslots were significantly associated with PM accuracy ($p > .05$) (Table 16).

Table 17

Mixed-Linear Modeling for Prospective Memory Response Times in Full Sample

	Estimate	SE	*t*	*p*	95% CI Lower	95% CI Upper
Intercept	.63	.10	6.12	<.001*	.46	.87
Age	.005	.0008	7.17	<.001*	.004	.07
Time2	-.064	.016	-4.04	.0001*	-.09	-.03
Time3	-.082	.022	-4.93	<.001*	-.05	-.02
Time4	-.11	.001	-5.02	<.001*	-.15	-.07
RRS	-.0005	.001	-.50	.62	-.002	.001
BSRI_C	-.00004	.0001	-.74	.46	-.0002	.00005
BSRI_A	.0001	.0001	1.42	.16	-.00005	.0003
BMIS_A	.0008	.002	.41	.68	-.003	.004
BMIS_C	-.002	.001	-1.55	.12	-.004	.001

Note. RRS: Ruminative Responses Scale; BSRI_C: Change in Brief State Ruminative Inventory Scores; BSRI_A: Average Brief State Ruminative Inventory Scores; BMIS_A: Average in Brief Mood Introspection Scores; BMIS_C: Change in Brief Mood Introspection Scores; SE: Standard errors; CI: Confidence interval. *$p < .05$.

Age was significantly associated to PM response times ($t = 7.17$, $\eta^2 = .98$, $p < .05$) (Table 17). This suggests that with increasing age, individuals were taking longer to respond with large effect sizes (Table 17). Time was a significant effect across PM accuracy (Timepoint 2: $t = -4.04$, $\eta^2 = .81$; Timepoint 3: $t = -4.93$, $\eta^2 = .96$; Timepoint 4: $t = -5.02$, $\eta^2 = .96$, $p < .05$). This suggests that individuals were more likely to become faster at each timeslot with the first timeslot as a reference category with large effect sizes (Table 17). Trait rumination, average mood and state rumination between individuals, and changes in mood and state rumination within individuals were not significantly related to PM response times ($p > .05$). In addition, neither of the remaining timeslots were significantly associated with PM response times ($p > .05$) (Table 17).

3.3.6 Mixed-Linear Modeling in Entire Sample for State Rumination and WM

There were no significant effects found in the model output examining state rumination and WM accuracy ($p > .05$) (Table 18).

Table 18

Mixed-Linear Modeling for Working Memory Accuracy in Full Sample

					95% CI	
	Estimate	SE	*t*	*p*	Lower	Upper
Intercept	.96	.13	7.13	<0.01*	.69	1.23
Age	-.001	.001	-1.09	.28	-.003	.001
Time2	.02	.02	0.76	.44	-.03	.06
Time3	.01	.02	.47	.64	-.04	.06
Time4	.05	.03	.16	.87	-.06	.07
RRS	.0002	.001	.16	.88	-.002	.002
BSRI_C	-.0001	.0001	-1.72	.09	-.0003	.00002
BSRI_A	-.0002	.0001	-1.50	.14	-.0004	.0001
BMIS_A	-.0004	.0024	-.15	.88	-.005	.004
BMIS_C	.001	.002	.71	.48	-.002	.005

Note. RRS: Ruminative Responses Scale; BSRI_C: Change in Brief State Ruminative Inventory Scores; BSRI_A: Average Brief State Ruminative Inventory Scores; BMIS_A: Average in Brief Mood Introspection Scores; BMIS_C: Change in Brief Mood Introspection Scores; SE: Standard errors; CI: Confidence interval. *$p < .05$.

Age was significantly related to WM response times (t = 7.30, η^2 = .94, p < .05), suggesting that as age increased, participants were significantly slower on WM. Time was also significantly related to WM response times (Timepoint 2: t = -3.50, η^2 = .92; Timepoint 3: t = -5.28, η^2 = .97; Timepoint 4: t = -4.85, η^2 = .96, p < .05) (Table 19).

Table 19

Mixed-Linear Modeling for Working Memory Response Times in Full Sample

					95% CI	
	Estimate	SE	*t*	*p*	Lower	Upper
Intercept	.47	.07	6.30	<.001*	.32	.62
Age	.004	.001	7.30	<.001*	.003	.005
Time2	-.05	.013	-3.50	.001*	-.07	-.02
Time3	-.07	.013	-5.28	<.001*	-.10	-.05
Time4	-.09	.018	-4.85	<.001*	-.12	-.05
RRS	.0001	.007	.16	.85	-.001	.001
BSRI_C	-.00001	.00004	-.18	.52	-.0001	.0001
BSRI_A	.0001	.0001	1.04	.32	-.0001	.0002
BMIS_A	.0001	.001	.10	.90	-.002	.003
BMIS_C	.001	.001	.95	.37	-.001	.003

Note. RRS: Ruminative Responses Scale; BSRI_C: Change in Brief State Ruminative Inventory Scores; BSRI_A: Average Brief State Ruminative Inventory Scores; BMIS_A: Average in Brief Mood Introspection Scores; BMIS_C: Change in Brief Mood Introspection Scores; SE: Standard errors; CI: Confidence interval. *p < .05.

This suggests that over time, participants performed faster on WM trials with the first timeslot as a reference category (Table 19). Trait rumination, average mood and state rumination between individuals, and changes in mood and state rumination within individuals were not significantly related to WM response times ($p > .05$) (Table 19).

3.4 Correlations Between Trait Rumination and PM

There were no significant correlations between trait rumination with any of the PM and WM accuracy and response times in younger and older adults (Table 20). Of note, there were also no significant effects of trait rumination (i.e., RRS) in any of the model outputs that explain PM or WM performance.

Table 20

Spearman Correlations Between Trait Rumination and Prospective Memory Accuracy and Response Times and Working Memory Accuracy and Response Times in Younger and Older Adults

	Trait Rumination		
	Younger Adults	Older Adults	Full Sample
PM Accuracy	-.06	.45	.01
PM Response Times	-.02	.03	-.08
WM Accuracy	.16	-.47	-.08
WM Response Times	-.04	.34	-.05

Note. PM: Prospective memory; WM: Working memory; BSRI: Brief State Rumination Inventory; BMIS: Brief Mood Introspection Scale.

CHAPTER 3: GENERAL DISCUSSION AND CONCLUSIONS

1 Summary of Findings and Interpretations

The present study examined the effects of state and trait rumination on a computerized PM task in younger and older adults using a repeated and real-time approach. The findings suggest that (1) state rumination is associated with poorer PM accuracy in younger adults, even after controlling for momentary mood and trait rumination, (2) generally, younger adults tend to become faster and more accurate over time while older adults tend to become slower over time, and (3) trait rumination may be less related to PM accuracy and response times. Exploratory findings suggest that age may be associated with better PM accuracy, but slower response times on PM and WM trials over time. Overall, rumination shows promise as a variable of interest to examine in the context of PM and depression in younger and older adults.

1.1 Aim 1: State Rumination on Prospective Memory

The first aim sought to examine the effect of state rumination on PM accuracy and response times among younger and older adults, and the full sample. This was assessed through MLM modeling which demonstrated a significant effect of mean state rumination between individuals (i.e., as measured by BSRI) on PM accuracy in younger adults with large effect sizes. Findings confirm that state rumination exhibits a negative effect on PM accuracy over time in younger adults. In the full sample, state rumination was also associated with poorer PM accuracy, although this interpretation is limited due to the small number of older adults included in the full sample. Ultimately, this identifies rumination as an important mechanism in depression that negatively impacts PM accuracy and reinforces rumination as a promising candidate for future examination.

1.1.1 State Rumination on Prospective and Working Memory in Young Adults

These results provide novel evidence to suggest that state rumination exhibits a negative effect on PM accuracy in younger adults, and some evidence to suggest there may be a similar effect across age. This is in line with previous findings of associations between state rumination and PM accuracy in younger adults, found independently of mood and trait rumination (Fredman Stein et al., 2018). State rumination was also previously associated with slower response times on PM trials, however, only when viewing negative stimuli in the PM task (Fredman Stein et al., 2018). That is, individuals were required to complete an ongoing sentence-rating task, where they had to rate the valence (i.e., if the sentences were positive, neural, or negative) of ninety sentences. The PM task involved responding differently (i.e., pressing the “t” key) if the sentence contained their target category before making their valence rating (Fredman Stein et al., 2018). Thus, more nuanced relationships with response times may exist with valanced cues in the context of rumination that were not specifically examined in the present study. When shifting attention away from negative stimuli (i.e., rather than positive or neutral), individuals may have difficulties inhibiting negative material specifically and thus, may take longer time (de Lissnyder et al., 2010; Fredman Stein et al., 2018). For individuals who ruminate and perceive negative stimuli, this may additionally provoke ruminative thoughts due to the nature of the stimuli typically found in previous studies that use negative stimuli (Fredman Stein et al., 2018; Smallwood & Schooler, 2015; Werner-

Seidler et al., 2020). However, since every-day stimuli were presented in the current PM task, this may be in line with previous null findings related to response times and there may have been less sensitivity in detecting these impairments at the level of response times (Fredman Stein et al., 2018). Thus, individuals who ruminate should still exhibit slower response times as they compete for attentional capacity, though perhaps to a lesser extent than if they were viewing negative stimuli (Ellis, 1990). In a previous eye-tracking study, individuals with depression demonstrated poorer accuracy, slower response times and longer fixation durations in ongoing and PM conditions (Chen et al., 2013). This provides behavioural evidence to show that individuals with depression demonstrate impairments in PM tasks as measured by slower response times and poorer accuracy (Chen et al., 2013). The authors explained the devotion of attentional resources on ruminative thoughts led to this impaired performance (Chen et al., 2013). Despite this explanation, authors did not directly examine the presence of ruminative thoughts (Chen et al., 2013; Ellis, 1990). Future studies can replicate findings by using measures that could show behavioural evidence for faster response times and direct measures of rumination concurrently.

Other studies were not able to ascertain effects of state rumination on PM (Primosch, 2017; Pupillo et al., 2020). These studies have cited limitations that the present study attempted to address. As stated by the multi-process theory, different strategies are recruited based on numerous parameters of a PM task (Einstein et al., 2005). Tasks that have non-focal cues encourage higher processing due to reduced saliency of the cue to the task which leads to greater effortful monitoring on the individual’s part. This greater effort has led to greater performance deficits as individuals are engaged in costly monitoring (Einstein et al., 2005; Primosch, 2017). Previously, the effects of state and trait rumination on PM was examined across in a non-clinical sample of individuals with low, moderate, and higher depressive symptoms (Primosch, 2017). Participants completed the Memory for Intentions Test, a standardized test of event- and time-based PM. When handed a red pen, participants had to recall to sign their name. However, this focal cue likely prompted individuals to use spontaneous retrieval which requires less effortful intention retrieval (Primosch, 2017). As such, no main effects of state rumination on event-based PM were found (Primosch, 2017). The present study was thus strengthened by its use of a non-focal and event-based task which likely encouraged more effortful processing, and was better suited to detect the negative effect of state rumination (Fredman Stein et al., 2018; Primosch, 2017). Studies have also cited the use of induction procedures that may have limited their ability to detect any effects (Primosch, 2017; Pupillo et al., 2020). One induction involved participants viewing videos clips of varying emotional valences. Following the PM task, participants were asked to what extent they thought about the contents of the clips while performing the PM tasks to explore if the effects of mood were mediated by intrusive thoughts (Pupillo et al., 2020). However, intrusive thoughts could not explain any additional variance on PM performance, though this may have been due to the retrospective measurement of these thoughts and poor induction methods (Pupillo et al., 2020). Other authors using a rumination induction reported it to be less effective as participants may have already been in a state of rumination when they entered the study (Primosch, 2017). This would cause less of a change in their ruminative state from their baseline (Primosch, 2017). In the current study, daily variation in rumination was measured in real-time prior to completing the PM task and likely represented a more valid estimate of individuals' state rumination, eliminating concerns related to the limited effectiveness of experimentally-inducing rumination and recall biases (Fredman Stein et al., 2018). Other studies have suggested that their lack of findings are due to recruitment of non-clinical samples of individuals who may not have been experiencing high enough levels of distress (Primosch, 2017). Despite this, significant and robust effects in a non-clinical sample were found in the current study.

These findings provide a potential mechanism for how depression may negatively impact PM, and a potential stage at which the impairment occurs. State rumination may deplete attentional resources that are critical to certain PM stages, namely at the level of retrieval. Ultimately, this provides support for the *resource allocation hypothesis* (Ellis, 1990; Fredman Stein et al., 2018). Individuals who are ruminating in the moment are more likely to retrieve task-irrelevant information in the form of negative thoughts which ultimately interferes with the retrieval of task-relevant information required for the PM task (Primosch, 2017; Whitmer & Banich, 2010). As individuals ruminate, they further enter a negative feedback loop, increasing the likelihood they will continue to retrieve negative thoughts (van Vugt & van der Velde, 2018). The impairment in retrieval is also reflected in the WM task, where state rumination trended towards a negative effect on WM. In general, individuals who ruminate have difficulty updating their WM (Whitmer & Gotlib, 2013). During the ongoing WM task, participants are engaged in a retrieval where, on their own, they must recall the previous object to compare to the current object, while also recalling whether or not to perform the PM task at the appropriate moment (Kvavilashvili & Rummel, 2020). Given that WM capacity is limited, it is critical that this updating is efficient. Otherwise, difficulties with updating WM can lead to an inability to remove negative thoughts and attend to and process new information, thereby contributing to negatively impacting PM ability (Joormann & Gotlib, 2008). This may have also contributed to the content of task-irrelevant thoughts that interfered with the monitoring process and impacted PM accuracy (Palit et al., 2022). Given overlapping functions in retrieval required in both PM and WM, this emphasizes the robust negative effect state rumination has on both types of memory tasks.

Interestingly, this study identified an association between a specific type of measured state rumination on PM. State rumination is defined as a state episode triggered by momentary discrepancies between an individual's goals and current state that fluctuates over the day (Moberly & Watkins, 2008b). This is otherwise different from self-reported traits as individuals may rely on varying information to report on states rather than traits (Moberly & Watkins, 2008b). In the current study, individual differences in the variation of state rumination were separated from their average values between individuals, and only the latter disaggregated variable was significant. One potential interpretation is that state rumination as measured by the BSRI in real-time may be a valid and sensitive way to measure state rumination and does not require as frequent timepoints for measurement that were used in this study design. It is thus possible that examining state rumination variation produced noise in the data whereas the average scores between individuals were a more valid measure (Oleson et al., 2022). Overall, present findings contribute to the growing body of literature on the effects of state rumination on PM and are strengthened by its methodology.

1.1.2 State Rumination on Prospective and Working Memory in Older Adults

As part of the first aim, the effect of state rumination on PM accuracy and response times in older adults was also examined which represents a novel aim that has not been examined in the literature to date. Unlike younger adults, there were no significant effects of state rumination on PM or WM, although the study was limited by its small sample size of older adults which may have impacted the power to detect effects. In addition, the sample may have limited generalizability in that a more emotionally resilient and tech-savvy group of older adults may have been recruited.

Nevertheless, the lack of significant findings is comparable to past studies that have examined negative effects of similar variables on PM in older adults (Pupillo et al., 2020; Schnitzspahn et al., 2014, 2022). For example, significant negative effects of psychosocial stress and negative moods in younger, but not older adults on event-based PM have been found (Pupillo et al., 2020; Schnitzspahn et al., 2022). One potential explanation for this may be attributed to older adults' level of emotional regulation which leads them to place greater focus on the positive, rather than the negative information (Carstensen et al., 2003). In the present study, there were significant differences between rumination among older and younger adults. Documented age differences in rumination have also been large and robust between the two age groups, even in smaller sample sizes, where older adults show significantly less rumination (Emery et al., 2020). Studies examining intrusive thoughts in older adults have shown that on days with stressors, older adults experienced increased intrusive thoughts and negative affect (Maillet & Schacter, 2016). However, this association between stressful days and intrusive thoughts was attenuated in older adults compared to younger adults (Maillet & Schacter, 2016). Thus, older adults experience a reduction in affective reactivity to intrusive thoughts (Erskine et al., 2007; Maillet & Schacter, 2016). There were also no significant findings for any effects of state rumination on WM in older adults. The fact that WM was not impacted by state rumination also highlights a protective moderating factor for older adults, that has also been previously established. That is, high WM capacity has shown to moderate the relationship between repetitive negative thinking and depression in older adults (Sohtorik İlkmen, 2020).

Further, the range of rumination and depressive and anxious symptoms were restricted, as most older adults in this study experienced lower levels of negative mood. Of those that were experiencing relatively higher distressing symptoms, the difficulty of the PM task may have prompted them to more adequately regulate their emotions and contribute more effort into task processing, thus distracting them from their ruminative thoughts (Pupillo et al., 2022). Thus, they may also have been more highly motivated to complete the study, which has also shown to be associated with positive mood (Pupillo et al., 2022). Specifically, positive affect in daily life coupled with higher motivational states may have fostered enhanced task engagement, and thus, higher performance in the older adults (Brose et al., 2014; Pupillo et al., 2022). These emotional variables will be further discussed in the age-related changes in PM section that appears below. Future studies should thus aim to recruit larger samples of older adults with greater variability in ruminative thoughts.

1.2 Aim 2: Trait Rumination on Prospective and Working Memory in Younger and Older Adults

For the second aim, the effect of trait rumination on PM was examined in younger and older adults. This was assessed with Spearman correlations which did not demonstrate any significant effects of trait rumination (i.e., as measured by RRS values) on any performance outcomes among younger or older adults. Likewise, the MLM models did not demonstrate any significant effects of trait rumination. Although this suggests that trait rumination may have had less of a role in negatively impacting PM and WM, limitations related to the use of the RRS as a measure of trait rumination may have impacted findings.

Whereas state rumination is associated with momentary thoughts and is more likely to impact the task at hand directly, trait rumination is conceptualized as the ability to habitually ruminate which is associated more with a slower processing speed over time (Fredman Stein et al., 2018). Indeed, trait rumination has shown to be associated with slower PM and WM reaction times in younger adults (Bernblum & Mor, 2010; Fredman Stein et al., 2018; Joormann et al., 2011) and with poorer memory for contextual details during a task (Forner-Phillips et al., 2020). Despite this, there were no significant findings associated with trait rumination and performance in the cognitive tasks.

Given that trait rumination is a broad construct, its impact on PM might differ based on the type of trait rumination (Primosch, 2017). The lack of current findings may thus be related to the use of a total trait rumination score, rather than calculating brooding and reflective pondering subscores (Griffith & Raes, 2015). Some studies have additionally examined brooding (i.e., defined as maladaptive focus on depressive symptoms) and reflective pondering (i.e., defined as reflective thinking for problem-solving) (Treynor et al., 2003). Previously, brooding was associated with slower reaction times in younger adults which is typically associated with impairments in cognitive processes (Fredman Stein et al., 2018). In contrast, brooding was correlated with better PM performance in a group experiencing moderate depressive symptoms (Primosch, 2017). However, these associations were found among small sample sizes and accumulating evidence remains mixed despite the use of these more specific scores (Fredman Stein et al., 2018; Primosch, 2017). Other evidence has suggested that trait rumination may confer positive effects, such as in the case of reflective pondering (Bartoskova et al., 2018). Despite this, reflective pondering has also been associated with deficits in PM and may not always be beneficial (Primosch, 2017). Although pondering is defined as a purposeful turning inward to engage in cognitive problem-solving, its items are still focused on understanding causes of feelings (i.e., as items in brooding) (Bartoskova et al., 2018). In fact, brooding and reflective pondering have been correlated together despite these differences (Bartoskova et al., 2018). Both pondering and brooding thus share a focus on understanding causation, making problem-solving a lacking and misleading feature on the RRS, perhaps limiting the validity of these two subscores (Bartoskova et al., 2018).

Another related possibility is that using the RRS as measure of trait rumination may not adequately measure its proposed construct as theorized given its multifaceted nature (Bernstein et al., 2019). A previous network analysis that examined the items of the RRS found that the strongest items that emerged were more related to brooding about feelings of sadness, loneliness, and repetitive self-criticism (Bernstein et al., 2019).

However, these emerging items did not correlate to the other items in the questionnaire, suggesting that relying on a single sum score for the RRS can also be misleading as individuals may achieve the same scores despite the endorsement of items in different patterns (Bernstein et al., 2019). Although the study did find clusters related to reflection and brooding, results suggested that dwelling on feelings of sadness were highly interrelated to factors typically viewed as adaptive, like reflection (Bernstein et al., 2019). Further, this factor structure did not hold in clinical samples (Bernstein et al., 2019; Whitmer & Gotlib, 2011). Recommendations have included weighting questionnaire items, such as those more central items, rather than summing a total score (Bernstein et al., 2019). Other important considerations are related to the fact that the RRS measures largely depressive rumination, and no other forms of repetitive thought (Bernstein et al., 2019). In addition, the RRS is a retrospective measure of rumination that may pose a challenge for individuals to provide reliable ratings (Robinson & Clore, 2002). Further, it does not specify a timeframe in which to base ratings off, leaving individuals to rely on generalized beliefs about themselves.

In contrast, the BSRI focuses more on general repetitive and ruminative thoughts in the moment, and is less focused on depressive-rumination specifically (Marchetti et al., 2018). Its development was based on multiple scales of trait rumination with the assumption that state rumination would not show the same variety of features as trait rumination (Marchetti et al., 2018). Indeed, state rumination has not always been found to be associated with trait rumination, and other variables have better explained this relationship (LeMoult et al., 2013). For example, one study investigated the effects of state and trait rumination, and depressive symptoms on attentional biases. After controlling for other variables, only state rumination was associated with difficult disengaging from negative stimuli (LeMoult et al., 2013). Other studies have found that state rumination could predict variance in ratings of negative affect independent of trait rumination (Moberly & Watkins, 2008b) and state rumination modified the relationship between trait rumination and physiological recovery (Fang et al., 2019; Key et al., 2008). Likewise, average state rumination was also weakly correlated to trait rumination in the study. An interesting implication of the significance of the average state rumination between individuals as measured by the BSRI could potentially suggest its utility as a trait-like measure as its variation within individuals was not significant. In addition, its focus on momentary assessment may have higher validity than a retrospective measure of trait rumination (Moberly & Watkins, 2008a). Overall, current findings related to effects of trait rumination may have been limited and appropriate modifications to methodology related to the measurement of rumination in the future are warranted.

1.3 Exploratory Aim: Age Effects on Prospective Memory

For the final and exploratory aim, age-related changes in PM performance were examined. Interestingly, increasing age was significantly related to enhanced PM accuracy. This reflects findings where older adults were performing significantly better than younger adults at specific timepoints. These findings relate to the mixed evidence that underlie the *age-PM-paradox*. That is, typically, younger adults tend to outperform older adults in experimental PM studies, but the reverse occurs in naturalistic studies (Koo et al., 2021). However, the current study represents a unique situation whereby an experimental PM task was completed in a naturalistic setting and may thus strongly bear resemblance instead to a self-administered online tool. Despite this, older adults using such tools to self-assess PM have also shown age-related declines in PM (Zuber et al., 2022). As such, more research is required to elucidate the mechanisms of the age-PM-paradox in this context.

Previous studies have found generally poorer performance in event-based, non-focal experimental PM in older adults when compared to younger adults, but a reversed effect in naturalistic settings (Ballhausen et al., 2019; Schnitzspahn et al., 2020). However, a few studies have shown a pattern like the one found here. For example, younger adults in a negative mood were more likely to perform poorly in a PM task compared to older adults in a negative mood (Pupillo et al., 2020). Other studies have found differences between intrinsic motivation between older and younger adults, where older adults reported more motivation and perceived the tasks to be more important and enjoyable when set in a naturalistic setting, such as in the home which can help explain these findings (Aberle et al., 2010). Older adults may also be engaged in more habitual daily activities which resemble naturalistic PM approaches, even when they perceive them as demanding (Peter & Kliegel, 2018). Namely, age differences between younger and older adults were smaller when tasks occurred more regularly. In contrast, irregular tasks (i.e., those resembling experimental PM tasks, also with fewer PM cues) led to larger age differences (Schnitzspahn et al., 2011). Positive effects of motivation among older adults have been found across laboratory studies (Peter & Kliegel, 2018). Older adults also tend to outperform younger adults when they perceived tasks with low and medium levels of importance. At the highest level of perceived importance, there were no differences between younger and older adult performance in naturalistic settings (Aberle et al., 2010; Peter & Kliegel, 2018). As such, one possibility is that motivation and familiarity to the task may have moderated older adult performance in the present study given that efforts were made to increase these variables. Older adults also had higher WM performance at the third timeslot compared to younger adults. This may suggest that older adults also perceived the ongoing task to be less difficult, allowing for their attentional resources to be focused on the PM task. Such an effect was also found in a previous study, where older adults outperformed younger adults on a PM task (Hering et al., 2020; Rendell & Henry, 2009). Others have similarly argued that age differences emerge when there are larger differences between available attentional capacity and the level of difficulty of the ongoing task (Ballhausen et al., 2019; Kliegel et al., 2011). In addition, older adults were significantly more likely to be slower compared to younger adults. As such, they may have been using a trade-off strategy whereby recalling the intention may have taken them longer but resulted in more accurate responding (Ball & Aschenbrenner, 2018). Thus, it could be possible that older adults were perceiving the tasks as more important, were more motivated, or were less likely to ruminate as their WM capacity likely focused on task-relevant thoughts in the context of a slower and more cautious responding style.

1.4 Effects of Time on Prospective and Working Memory Performance

There were several other significant effects found other than those related to the main aims that should be addressed. Firstly, the association between unpleasant mood and slower PM response times was at the significance threshold of $p = .05$. There were also many significant effects associated with time, underscoring the potential use of such designs to monitor changes in PM over time. These significant changes over time, along with preliminary data related to feasibility of completing remote studies provide promise into the use of remote monitoring for cognitive changes.

Methods used in this study thus provide promise into the use of repeated and real-time sampling for better understanding about cognitive strategies that individuals use when completing PM tasks (Pupillo et al., 2022; Schmitter-Edgecombe et al., 2020). Previous longitudinal studies have found that older adults may experience declines in their PM performance over several years (Sullivan et al., 2020). Despite this, current findings showed that older adults were becoming significantly more accurate over time, perhaps highlighting potential practice effects and a trade-off between slower response time costs and accuracy (Anderson et al., 2019). Older adults were more likely to become slower over time, which is in line with well-established age-related changes in cognition related to slowed processing speed over time (Kerchner et al., 2012). In contrast, younger adults were more likely to become faster over time, perhaps also reflecting a trade-off with being faster but having poorer PM accuracy (Anderson et al., 2019).

1.5 Effects of Mood on Prospective and Working Memory Performance

There have been a plethora of studies demonstrating mixed evidence for the effect of negative mood in depression on PM performance (McFarland & Vasterling, 2018). These studies have provided the rationale for the current thesis given inconsistent findings related to the effect of negative mood, despite strong evidence that depression confers negative effects on PM (McFarland & Vasterling, 2018). For example, studies have found beneficial effects of negative mood on event-based PM (Altgassen et al., 2010; Rummel et al., 2012). These studies have purported that their results are in line with a processing style account where negative emotions are theorized to produce a more analytic processing style, while positive emotions produce a broader and less detailed style (Rummel et al., 2012). Studies that have examined negative effects of mood have not examined rumination, despite it being a confounding factor that could potentially explain findings over and above mood. In fact, most studies that outline mechanisms of mood suggest that negative mood increase the likelihood of mood-related, task-irrelevant thoughts (i.e., in other words, ruminative thoughts) that compete for cognitive capacity (Ellis, 1990; Kliegel et al., 2005; Kliegel & Jäger, 2006). In addition, effects of mood on PM have shown to be short-lived, with interference effects decreasing over time (Kliegel et al., 2005; Kliegel & Jäger, 2006). Other theories have emphasized that individuals may be engaged in a task of restoring their moods to become more positive that may interfere with the task only in the initial stages of the PM task (Kliegel et al., 2005). This has been specifically shown with a study involving older adults, who reported a planning task to be enjoyable and who reported more positive moods by the end of the study (Phillips et al., 2002). The lack of findings of any effects of unpleasant mood on accuracy once rumination is examined underscore the likelihood that negative affect may play less of a role in inhibiting PM and may be better accounted for by ruminative thoughts.

However, there were some indications of a possible effect of mood on PM response times as it was at the threshold of significance. Previous theories have attested that individuals may be more likely to ruminate in response to a negative mood. For example, momentary fluctuations in mood were prospectively associated with greater rumination levels in subsequent assessment periods (Hjartarson et al., 2021). However, this relationship was moderated by habitual characteristics (i.e., repetition, lack of control, etc.) (Hjartarson et al., 2021). Despite the close relation between negative mood and rumination, these findings should be interpreted with caution (Moberly & Watkins, 2008b). There were few PM trials, owing to the nature of PM, and thus the response time data were specifically limited. Typically, response time data require 20 trials or more to produce stable estimates, and the few PM trials likely resulted unstable estimates of participant response time (Draheim et al., 2019). The current data thus suggests that the act of ruminating (i.e., rather than the negative feelings associated with these thoughts) lead to poorer PM and WM. Our study is thus strengthened by the fact that robust effects of state rumination were found on PM accuracy, even after accounting for average and daily fluctuations in mood. Despite this, future studies can continue to clarify the mechanisms between mood and rumination.

2 Limitations

This study has several limitations that required to be addressed. Firstly, this study was completed in participants' homes which may have introduced confounding variables due to limited experimental control. As evidenced by the preliminary feasibility data, approximately one quarter of participants reported that they were distracted during the task and numerous other concerns. It was unknown if these distractions/concerns had any impact on the validity of the data, the content of the distractions (i.e., things in the environment, ruminative thoughts, other thoughts, etc.), or if any individuals omitted any specific concerns. It is also unknown if participants were completing the experiments appropriately. Although efforts were made to exclude any data that resembled random completion of the experiments, it is difficult to conclude if the data were completed with valid effort. Future studies should continue to pilot data and aim to improve feasibility and validity of remote studies. In addition, participants were able to pick when they would complete the study. Some findings suggest that PM performance may improve at different times of the day (Barner et al., 2019). Despite this limitation, data contribute to a novel understanding of delivering studies in participants' homes.

As this study involves many timepoints, dropouts were common. Dropping out or forgetting to complete a study may be a consequence of poorer PM and can lead to a sample with relatively higher PM (Sullivan et al., 2020). Attempts were made to account for this by providing reminder emails to serve as external cues to remember to complete the study, an optional training session to all participants to enhance task familiarity, and compensation to participants to encourage extrinsic motivation. Although the sample size for younger adults was considered adequate, the sample size for older adults was particularly limited which led to two multi-level models that could not converge and more difficulty with interpreting older adult data. Future studies should aim to recruit equal amounts of younger and older adults.

Thirdly, the samples recruited have limited generalizability to a larger group of individuals due to numerous factors. For example, participants were less ethnically diverse and more tech-savvy since this study required individuals to have emails and own computer devices (Schnitzspahn et al., 2020). In addition, the sample of younger adults were predominantly women which may also impact generalizability of findings. Previous studies in gender differences have shown that women tend to have higher PM performance than men in event-based tasks (Palermo et al., 2016) and report more PM problems and higher depressive symptoms compared to men (Huber et al., 2022).

Critically, this study occurred during the COVID-19 pandemic which may present unique cohort effects. For example, this period has been associated with increased emotional distress, as well as poorer objective WM and PM performance in younger adults (Pisano et al., 2021). In the current study, younger adults also experienced higher levels of depressive and anxious symptoms, and poorer performance. Older adults have also showed greater ability to use adaptive strategies to overcome emotional distress during the pandemic, compared to younger adults (Aizpurua et al., 2021; Dworakowski et al., 2021). Secondly, the pandemic may have also impacted recruitment. For participants recruited from the community, they may have been increasingly motivated to participate in research and likely represented a sample of individuals who were of a higher socio-economic status, more tech-savvy, and higher in motivation (Sharma et al., 2022). There were also some challenges with recruitment from community organizations given reduced services and in-person participation which may have also led to decreased access to venues serving more racial and ethnic minority populations (Sharma et al., 2022). Among others, these effects have the potential to impact the validity of the results uniquely compared to past studies.

There are also some methodological limitations that may have limited the ability to draw conclusions. The number of PM trials included may have restricted the range of performance that was captured. The inclusion of few trials was done intentionally to increase task difficulty as lower accuracy and slower response times have been observed for experiments with few PM cue trials as individuals are typically engaged in monitoring for low frequency PM cues (Wilson et al., 2013). This was circumvented by including multiple observations of the trials, but future studies can continue to collect PM more frequently to increase the accuracy of PM performance estimates. Another example is that although inferences can be made that individuals were using a monitoring strategy by the tasks implemented, the study would have benefitted from participants first completing an ongoing task without a PM task. This would allow comparisons between the ongoing task and the ongoing task with the PM to provide direct evidence that there were cognitive costs to completing both the PM and WM tasks simultaneously (Maillet & Schacter, 2016). Further, it would have been helpful to measure ruminative thoughts pre- and post-task completion to better ascertain if the task had distracted individuals from their ruminative thoughts or had little effect. Qualitative data could have also supplemented this by asking participants if they were distracted during the task if this was due to their own thoughts or due to other external factors.

Lastly, associations found can only suggest correlation, and not causation. Although it is plausible that state rumination can negatively impact PM, it is unclear if the relationship can also be reversed. As such, it is possible that individuals with poorer PM are more likely to ruminate. For example, poorer EF has predicted higher baseline levels of rumination (Ng et al., 2022).

3 Future Directions

This study provides timely findings related to the effect of rumination on PM given the paucity of research in this area. Though the present study has produced promising results, much remains to be investigated and examined.

The impact of state and trait rumination at other PM stages can be investigated. Previous studies have found significant effects of rumination at stages other than retrieval which have included inhibition and attentional switching (Grant et al., 2021; Vălenaș &

Szentágotai-Tătar, 2017). Although deficits have been defined in stages of retrieval, there is merit to continue investigations in other parts of PM given that other studies have also found differential effects of rumination at different stages (Hostler et al., 2018).

Although this study was a first step towards enhancing ecological validity by sampling participants' real-time mood and rumination, PM in daily life is dynamic and future studies can seek to design studies with increasingly naturalistic PM tasks. For example, the Actual Week is a validated naturalistic PM task that involves both time- and event-based PM tasks in daily life with strong psychometric properties in older adults (Au et al., 2018). This provides a good opportunity to examine relationships of rumination in PM in daily life, which would further enhance ecological validity. Other avenues of research should also involve examining the effects of valanced cues, given that daily life is rife with the experience of internal emotional states, as well as external emotional cues that subsequently impact these experiences. The impact of emotional stimuli on PM represents a large and inconsistent literature. Typically, studies suggest that emotional stimuli (i.e., both negative and positive) should improve PM performance over neutral stimuli (Hostler et al., 2018). However, other studies have shown individuals with and without depression experience the poorest performance with negative stimuli (Altgassen et al., 2011), while others have shown no costs to performance when stimuli were negative. This represents an important opportunity for future research to pursue.

Other variables are known to impact PM and can be subsequently studied as they may moderate performance and account for variability not captured in the present study. These can include methodological variables in experimental PM studies such as PM trial frequency, focality of PM cues, and the delay between the presentation of the PM cues and the beginning of the ongoing task (Anderson et al., 2019). Other variables include examining emotional regulation strategies (Pupillo et al., 2020), personality (Uttl et al., 2018), perceived task importance, stress (Ihle et al., 2012), and sleep (Leong et al., 2019).

Enhanced methods also can provide an important opportunity to contribute to the growing body of research on real-time and valid monitoring of cognitive function over time which has implications for remote healthcare delivery and neuropsychological testing (Mioni et al., 2020; Wadsworth et al., 2018). In addition, incorporating behavioural methods to enhance our understanding can also be of interest in future studies, such as eye tracking and/or neuroimaging (fMRI, EEG) studies to provide more objectives methods of measuring PM (Ballhausen et al., 2019; Forner-Phillips et al., 2020; Hering et al., 2018). For example, previous studies using eye-tracking methods have been able to objectively quantify monitoring behaviours, demonstrating that older adults do not have deficits in this ability (Ballhausen et al., 2019).

Understanding how rumination can impact PM may also stimulate further research on training programs. Thus far, PM interventions have shown promise among older adults with and without cognitive impairment (Bowman et al., 2019; Farzin et al., 2018; Shelton et al., 2016). Overall, benefits of improving PM include increasing independence and well-being in older adults (Farzin et al., 2018). Some of these interventions have also shown promise by being delivered through smartphone technology (Scullin et al., 2022). Future studies can seek to recruit clinical populations, as we recruited non-clinical groups of individuals with ruminative symptoms.

4 Final Conclusions

To conclude, this thesis provides several novel findings to contribute to the literature on the effects of state and trait rumination on an event-based, computerized, and experimental PM task with non-focal cues among younger and older adults. The first aim addressed the effect of state rumination on PM accuracy and response times in younger and older adults. Results for this aim revealed a significant effect of average state rumination as measured by the BSRI values on PM accuracy in younger adults. This suggests that as state rumination increases, PM accuracy decreases. Given that average mood ratings were approaching significance, (i.e., as unpleasant meta-mood increases, WM response times were slower) this could also potentially suggest that mood does play a role on WM, but this relationship remains equivocal. Other relevant and significant findings include that younger adults tend to become faster on PM and WM trials over time. In older adults, only time was significantly associated with PM accuracy and response times in that over time, older adults were significantly more likely to become slower and more accurate. In the overall sample, the average state rumination values were significant in that increased state rumination in the full sample was significantly associated with reduced PM accuracy. In addition, increased age was significantly associated with improved PM accuracy. These findings have important implications for shaping our early understanding about the mechanisms of depression in PM in that state rumination had effects on PM accuracy that may be impacting individuals at the level of retrieval. Overall, this can have future implications for improving PM assessments and interventions for individuals which can lead to enhanced outcomes of independence and autonomy, and completion of daily life tasks (Kinsella et al., 2018; Lee et al., 2018).

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APPENDICES

Appendix 1

Table 21

Schematic Diagram of Study Design

Timeline	Study stage	Procedure
Pre-study	Enrolment	• Obtaining informed consent from undergraduate students via uWindsor Participant Pool. • Obtaining informed consent from older adults via online recruitment and email (i.e., cognitive screening using the TICS).
Week 1	Baseline period	• Demographic measures • GAD-7 • PHQ-9 • RRS
	Momentary measures	• BMIS • BSRI • Ongoing working memory and PM task • Feasibility questions
Week 2	Participant reassessment and final assessment	• BMIS • BSRI • Ongoing working memory and PM task • Feasibility questions

Appendix 2

Table 22

The 7-Item Generalized Anxiety Disorder Scale

GAD-7 Over the last two weeks how often have you been bothered by the following problems?	0 Not at all	1 Several days	2 More than half the days	3 Nearly everyday
Feeling nervous, anxious, or on edge				
Not being able to stop or control worrying				
Worrying too much about different things				
Trouble relaxing				
Being so restless that it's hard to sit still				
Becoming easily annoyed or irritable				
Feeling afraid as if something awful might happen				
Total Score (add your column scores)				
If you checked off any problems, how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people?	Not difficult Somewhat difficult Very difficult Extremely at all difficult			

Appendix 3

Table 23

The Nine-Item Patient Health Questionnaire

PHQ-9 Over the last two weeks how often have you been bothered by the following problems?		0 Not at all	1 Several days	2 More than half the days	3 Nearly everyday
A	Little interest or pleasure in doing things				
B	Feeling down, depressed, or hopeless				
C	Trouble falling or staying asleep, sleeping too much				
D	Feeling tired or having little energy				
E	Poor appetite or overeating				
F	Feeling bad about yourself – or that you are a failure or have let yourself or your family down				
G	Trouble concentrating on things, such as reading the newspaper or watching television				
H	Moving or speaking so slowly that other people could have noticed. Or the opposite – being so fidgety or restless that you have been moving around a lot more than usual				
I	Thoughts that you would be better off dead or of hurting yourself in some way				
Severity Score	Mild depression = 5 – 10 Moderate depression = 10 – 18 Severe depression = 19 – 27	Total Score:			
If you checked off any problems, how difficult have these problems made it for you to do your work, take care of things at home or get along with other people?		Not difficult Somewhat difficult Very difficult Extremely at all difficult			

Appendix 4

Table 24

Brief State Rumination Inventory

Items	Scale
1. Right now, I am reflecting about my mood.	0 – 100
2. Right now, I wonder why I react the way I do.	0 – 100
3. Right now, I wonder why I always feel the way I do.	0 – 100
4. Right now, I am thinking, “Why do I have problems other people don’t have?”	0 – 100
5. Right now, I am rehashing in my mind recent things I’ve said or done.	0 – 100
6. Right now, I am thinking, “Why can’t I handle things better?”	0 – 100
7. Right now, it is hard for me to shut off negative thoughts about myself.	0 – 100
8. Right now, I wonder why I can’t respond in a better way.	0 – 100

Note. Participants are required to place on their response on a sliding scale from 0-100 on the online survey.

Appendix 5

Table 25

The Ruminative Responses Scale

People think and do many different things when they feel depressed. Please read each of the items below and indicate whether you almost never, sometimes, often, or almost always think or do each one when you feel down, sad, or depressed. Please indicate what you generally do, not what you think you should do.

Items	Scaling			
1. Think about how alone you feel.	0	1	2	3
2. Think “I won’t be able to do my job if I don’t snap out of this.”	0	1	2	3
3. Think about your feelings of fatigue and achiness	0	1	2	3
4. Think about how hard it is to concentrate	0	1	2	3
5. Think “What am I doing to deserve this?”	0	1	2	3
6. Think about how passive and unmotivated you feel.	0	1	2	3
7. Analyze recent events to try to understand why you are depressed	0	1	2	3
8. Think about how you don’t seem to feel anything anymore	0	1	2	3
9. Think “Why can’t I get going?”	0	1	2	3
10. Think “Why do I always react this way?”	0	1	2	3
11. Go away by yourself and think about why you feel this way	0	1	2	3
12. Write down what you are thinking about and analyze it	0	1	2	3
13. Think about a recent situation, wishing it had gone better	0	1	2	3
14. Think “I won’t be able to concentrate if I keep feeling this way.”	0	1	2	3
15. Think “Why do I have problems other people don’t have?”	0	1	2	3
16. Think “Why can’t I handle things better?”	0	1	2	3
17. Think about how sad you feel.	0	1	2	3
18. Think about all your shortcomings, failings, faults, mistakes	0	1	2	3
19. Think about how you don’t feel up to doing anything	0	1	2	3
20. Analyze your personality to try to understand why you are depressed	0	1	2	3
21. Go someplace alone to think about your feelings	0	1	2	3
22. Think about how angry you are with yourself	0	1	2	3

Appendix 6

Table 26

The Brief Mood Introspection Scale

Circle the response on the scale below that indicates how well each adjective or phrase describes your present mood, where XX = "definitely do not feel", X = "do not feel", V = "slightly feel", VV = "definitely feel".

Lively	XX	X	V	VV	Drowsy	XX	X	V	VV
Happy	XX	X	V	VV	Grouchy	XX	X	V	VV
Sad	XX	X	V	VV	Peppy	XX	X	V	VV
Tired	XX	X	V	VV	Nervous	XX	X	V	VV
Caring	XX	X	V	VV	Calm	XX	X	V	VV
Content	XX	X	V	VV	Loving	XX	X	V	VV
Gloomy	XX	X	V	VV	Fed Up	XX	X	V	VV
Jittery	XX	X	V	VV	Active	XX	X	V	VV

Overall, my mood is:

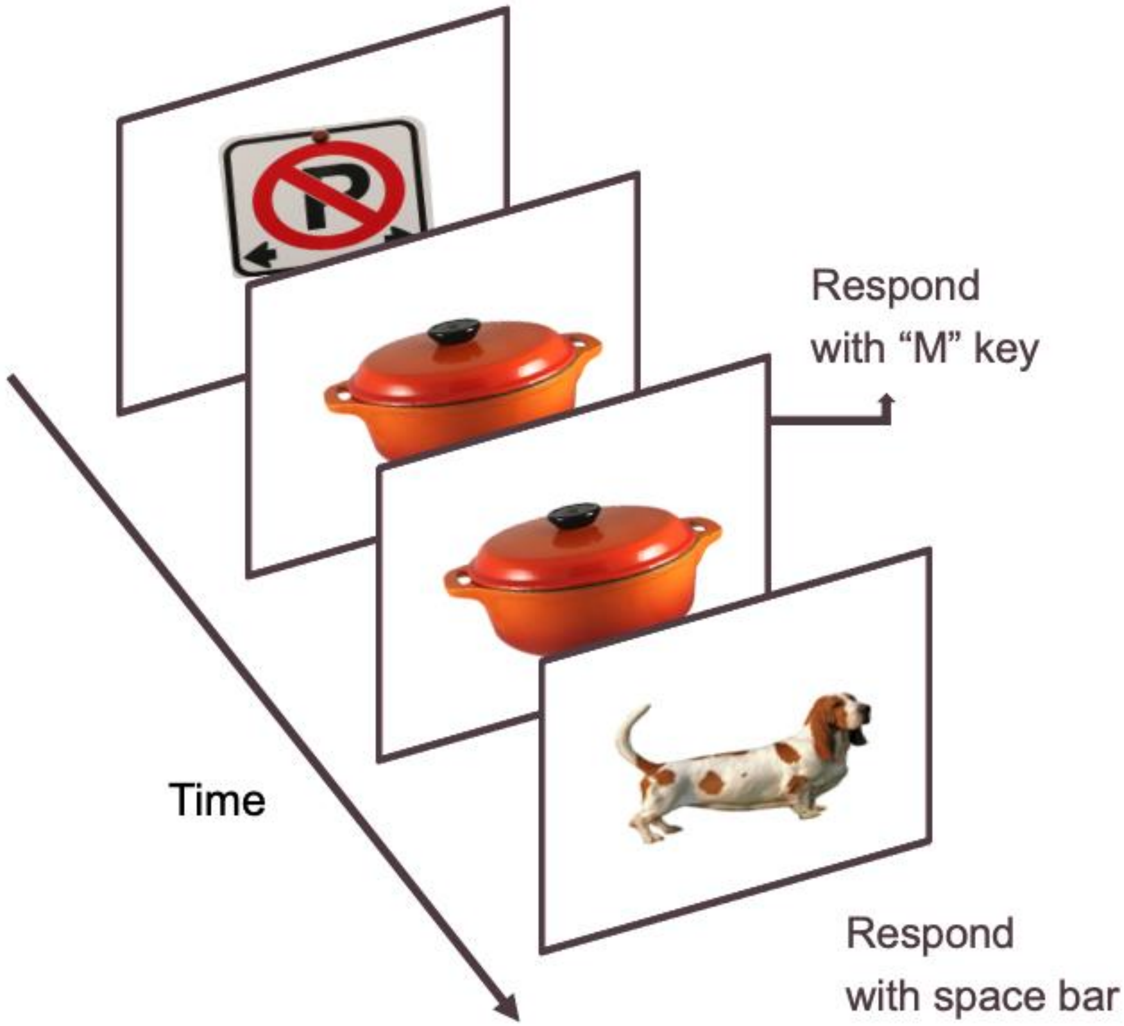
Very Unpleasant ... Very Pleasant

-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10

Appendix 7

Figure 1

Schematic Diagram of the PM Task



Note. Participants are required to press "M" if they see an image that matches the one presented previously, "N" if they see an image that does not match the one presented previously, and press the "space bar" if they see an image of a dog.

Appendix 8

Table 27

Sample Demographic and Baseline Data

	Participants with Four Timepoints (*n* = 156)	Participants with Two Timepoints (*n* = 95)	*p*
Age (M, SD)	26.36 (14.84)	27.84 (16.07)	.22
Gender (%F)	87%	87%	-
Race/Ethnicity (n)			
White	116	77	
Black	7	8	
Latin American	3	2	
South Asian	12	8	
West Asian	3	3	
Southeast Asian	2	2	
Arab	14	12	
Filipino	1	0	
Chinese	2	0	
Aboriginal	1	1	
PHQ-9 (M, SD)	6.43 (4.82)	6.54 (4.82)	.72
GAD-7 (M, SD)	6.46 (5.33)	6.69 (5.33)	.86
RRS (M, SD)	42.33 (13.85)	43.68 (13.85)	.48

Note. PHQ-9: 9-Item Patient Health Questionnaire; GAD-7: 7-Item Generalized Anxiety Disorder; RRS: Ruminative Responses Scale; F: Female; M = mean; SD = Standard deviation. *$p < .05$.

Appendix 9

Table 28

Sample Demographic and Baseline Data of the Total Data

	Total Sample (*n* = 156)	Younger Adults (*n* = 139)	Older Adults (*n* = 17)
Age (M, SD)	26.36 (14.84)*	21.45 (4.42)	66.47 (6.74)
Gender (%F)	87%	92%	41%
Race/Ethnicity (n)			
White	116	100	16
Black	7	5	0
Latin American	3	3	0
South Asian	12	11	1
West Asian	3	3	0
Southeast Asian	2	2	0
Arab	14	14	0
Filipino	1	1	0
Chinese	2	2	0
Aboriginal	1	1	0
PHQ-9 (M, SD)	6.43 (4.82)*	6.81 (4.85)	3.35 (3.28)
GAD-7 (M, SD)	6.46 (5.33)*	6.90 (5.32)	2.88 (3.92)
RRS (M, SD)	42.33 (13.85)*	43.27 (14.07)	34.65 (9.02)
TICS (M, SD)	-	-	36.28 (3.93)

Note. PHQ-9: 9-Item Patient Health Questionnaire; GAD-7: 7-Item Generalized Anxiety Disorder; RRS: Ruminative Responses Scale; TICS; Telephone Interview for Cognitive Status; F: Female; M = mean; SD = Standard deviation. *$p < .05$.

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