Blue and Forgetting What I Should Do: An Investigation into the Attentional Mechanisms underlying Depressed Mood and Impaired Prospective Memory

Yanqi Ryan Li

B.A (Honours)

School of Psychology

The University of Western Australia

This thesis is presented for the degree of

Doctor of Philosophy at the University of Western Australia

2014
ABSTRACT

The present series of studies investigated the hypothesis that the reduced initiative to allocate attentional resources to relevant tasks underlies depression-related prospective memory (PM) deficits (i.e., cognitive initiative hypothesis). Specifically, in the first three studies, the performance of individuals with high and low depressive symptomatology (HDS and LDS respectively) was examined under a series of PM paradigms (the Memory for Intentions Screening Test [MIST], a laboratory time-based PM task, and a laboratory event-based PM task), with the strategic demands of the PM task systematically manipulated on key variables such as cue type (i.e., time-based, event-based), length of delay interval (i.e., 2 minute versus 15 minute), and task importance (PM task relative to ongoing task). To further evaluate the attentional mechanisms underlying depression related PM deficits, the time-based and event-based studies (Studies 2 & 3) compared HDS and LDS groups on the pattern of decrements to ongoing task performance as a result of PM task performance (i.e., costs in the form of longer response times). The amount of incurred costs was assumed to reflect the extent of cognitive resources voluntarily allocated to the PM task (i.e., cognitive initiative). Collectively, the findings from these three studies suggest that (1) PM performance in individuals with HDS is negatively impacted by strategically demanding PM tasks, (2) these deficits are associated with inefficiencies in the utilization of allocated attentional resources in event-based tasks, and (3) individuals with HDS are less inclined to initiate the internal control processes crucial to the successful completion of time-based PM tasks. In view of the findings of the first three studies, a fourth study investigated whether implementation intentions (i.e., an encoding strategy which purportedly reduces the strategic demands of PM tasks) and goal maintenance training (GMT; a strategy which encourages intermittent self-initiated goal reviews) assist with the attentional function and PM performance of HDS and LDS individuals. Importantly, the study showed that the attention allocation and PM performance of HDS individuals benefitted from implementation intentions and GMT compared to standard PM instructions and that these benefits occurred to the same extent as LDS individuals. Based on the overall findings from the four studies, it was concluded that reduced cognitive initiative do contribute to PM deficits in HDS. However, PM deficits appear to be more likely under certain conditions (e.g., long delay intervals, time-based PM tasks, and important event-based PM tasks) than others (e.g., short delay intervals, unimportant event-based PM tasks, and non-focal event-based PM tasks).
PREFACE

The complex relationship between mood and cognitive function has been a central feature of psychological research for many years. One particular aspect that has recently attracted attention is the impact of depression or high depressive symptomatology on prospective memory (PM). See Chapter 1 for a general introduction of the literature on depression and prospective memory. The cognitive initiative hypothesis (Hertel, 2000) states that depression is associated with a reduced initiative to allocate available resources to perform relevant tasks. Accordingly, some researchers have predicted that PM deficits in individuals with depressed mood would be more likely under conditions of higher strategic demand where the initiative to control attentional resources is required (Altgassen, Kliegel, & Martin, 2009; Rude, Hertel, Jarrold, Covich, & Hedlund, 1999). Indeed, studies have shown that depressed mood is associated with poorer performance on time based PM tasks (defined as the ability to remember to perform a task at a specific time, which is highly dependent on the initiative to internally judge time and externally check the clock as the appropriate time approaches, Rude et al., 1999) and on non-focal event based PM tasks (i.e., require significant monitoring of PM targets as target features are not relevant to ongoing task performance, Altgassen et al., 2009; Chen et al., 2013). Conversely, PM deficits in depressed individuals have not been found in tasks with either focal PM targets (i.e., target features that are relevant to ongoing task performance and require less resources to detect, Altgassen et al., 2009) or salient PM targets (i.e., red bold font, Albiński, Kliegel, Sędek, & Kleszczewska-Albińska, 2012).

To examine how depressed mood is related to PM performance with different PM cue types, Kliegel and Jäger (2006) compared time-based and event-based PM performance in a sample of participants with normal levels of depressive symptoms. Participants’ PM accuracy and ongoing task (i.e., n-back) performance were found to be significantly poorer on the time-based PM task than on the event-based PM task. This difference was found even though the two PM tasks were matched on the number of PM targets (i.e., five), appearance interval (i.e., every two minutes), and ongoing task type (i.e., n-back). They also found that depressive symptoms were uniquely and inversely related to time-based PM accuracy but not to event-based PM accuracy. Overall, their findings suggest that time-based PM tasks may be more strategically demanding than event-based PM tasks and that there may be a relationship between mild depressive symptomatology and time-based PM performance. However so far, no study has
simultaneously compared time-based and event-based PM performance in individuals with high depressive symptomatology, or compared the pattern of their performance on the two PM task types to individuals with low depressive symptomatology. As cognitive initiative is likely to be lower with more severe depressive symptoms, the difference in PM performance between time-based and event-based cues would likely be greater (in terms of effect size) if individuals with high depressive symptomatology were employed (cf. participants with normal levels of depressed mood as in Kliegel & Jäger, 2006). Hence, the first study of the thesis (Study 1, Chapter 2, N = 64) simultaneously examined time-based and event-based PM in individuals with high and low depressive symptomatology (HDS and LDS respectively) on a semi-naturalistic PM task - the Memory for Intentions Screening Test (MIST, Raskin, Buckheit, & Sherrod, 2010). In addition, the study also examined the effects of different delay intervals (i.e., 2 minute versus 15 minute) on PM performance. Delay interval length has not been investigated in previous depression-related PM studies (Altgassen et al., 2009; Chen, Zhou, Cui, & Chen, 2013; Kliegel & Jäger, 2006; Rude et al., 1999) but it is a variable likely to be affected by reduced cognitive initiative. Based on the cognitive initiative hypothesis and previous findings (Kliegel & Jäger, 2006), it was predicted that the difference in PM performance between HDS and LDS participants would be greater with time-based cues than with event-based cues. Similarly, it was predicted that the difference in PM performance between HDS and LDS participants would be greater on tasks with a 15-minute delay interval than on tasks with a 2-minute delay interval. Indeed, the analyses showed that the HDS participants demonstrated significantly poorer PM performance than the LDS participants on time-based PM tasks but not on event-based PM tasks. The HDS participants also demonstrated significantly poorer PM performance than the LDS participants on PM tasks with long delay intervals (15 minutes) but not on tasks with shorter delay intervals (2 minutes). Results therefore support the view that PM deficits in depression are more likely to emerge under conditions of higher strategic demands (i.e., time-based PM tasks and long delay intervals) where greater cognitive initiative may be required (Altgassen et al., 2009; Kliegel & Jäger, 2006; Rude et al., 1999).

The findings of Study 1 and previous studies (Altgassen et al., 2009; Kliegel & Jäger, 2006; Rude et al., 1999) indicate that PM deficits in HDS or depressed individuals are more likely under conditions which place greater demands on self-initiated processing. Whilst the information on PM accuracy under various strategic conditions is useful, it does not provide precise information about the extent of attention
allocated by HDS individuals to support PM task requirements. To evaluate the
cognitive initiative hypothesis, it would be important to actually measure attention
allocation in HDS individuals under PM conditions and compare it to LDS individuals.
Altgassen et al. (2009) attempted to examine attention allocation in depressed and non-
depressed participants by comparing their ongoing task performance (i.e., vowel
judgement task accuracy and response times) under PM conditions relative to a no-PM
baseline condition. The increase in ongoing task response times under PM conditions
relative to the baseline condition (i.e., costs) was assumed to reflect the allocation of
additional attentional resource to support PM task requirements. In the study, the
researchers found that the slower ongoing task response times (costs) demonstrated by
the depressed participants relative to non-depressed participants in the focal condition
occurred to a similar extent in the non-focal condition. This led them to suggest that
their vowel judgment task was perhaps not sensitive enough to allow them to detect the
reduced attention allocation or reduced cognitive initiative of depressed individuals.

To better examine attention allocation in depressed individuals under PM
conditions, the following series of studies employed a paradigm capable of detecting
PM task-associated costs under a variety of strategic conditions (e.g., multiple PM
targets embedded in a lexical decision task, Einstein & McDaniel, 1990; Hicks, Marsh,
& Cook, 2005; Marsh, Cook, & Hicks, 2006; Smith, 2003). This allowed for the
evaluation of the hypothesis that depressed individuals do not initiate or allocate as
much attentional resource to support PM task requirements as non-depressed
individuals. Specifically, two studies were conducted to investigate whether HDS
individuals when given a PM task would demonstrate reduced costs to ongoing task
performance compared to LDS individuals (i.e., whether HDS individuals allocate less
attentional resource to support PM task requirements than LDS individuals); how costs
are manifested on time-based and event-based PM tasks for HDS individuals compared
to LDS individuals given that different strategic demands could be involved with each
type of PM task (Kliegel & Jäger, 2006); whether emphasizing the importance of the
PM task increases ongoing task costs in HDS individuals compared to LDS individuals;
and whether ongoing task costs are associated with improved PM performance in HDS
individuals compared to LDS individuals.

Study 2 (Chapter 3) was conducted to further investigate the attentional
mechanisms underlying the impaired PM performance of HDS individuals under time-
based conditions. Specifically, the internal control processes (i.e., time-estimation,
maintenance of the intention, coordination of PM and ongoing task response) and external control processes (i.e., frequency and timing of active clock-checking during the task to aid the timely performance of the PM task) related to time-based PM performance were examined. In this study ($N = 62$), participants were required to press the F1 key on the 4th, 8th, and 12th minutes into ongoing task performance (i.e., lexical decision task). They could check the time by pressing the spacebar key to display a clock. Based on earlier findings (Rude et al., 1999), it was predicted that HDS participants would check the clock less often than LDS participants due to their lack of cognitive initiative (i.e., allocate less attentional resource to externally control PM task performance).

Previous studies in healthy individuals have shown that ongoing task performance was significantly slower under time-based PM conditions compared to no-PM conditions (Hicks, Marsh, & Cook, 2005; Huang, Loft, & Humphreys, in press; Marsh, Hicks, & Cook, 2006; Waldum & Sahakyan, 2012). Importantly, the slower response times or costs were based on trials which did not include clock checking, suggesting that resource demanding processes are continuously engaged during PM task conditions. These PM task-associated costs have been thought to reflect internal control processes (e.g., the use of internal time-estimation strategies, the maintenance of the intent to make PM task responses, the coordination between ongoing task demands and making PM task responses, Huang et al., in press). If the initiative to allocate resources to relevant tasks is reduced in depression, then it is quite likely that HDS individuals may not allocate attentional resource to internally control PM task performance as well. Thus, it was predicted in Study 2 that HDS individuals would demonstrate significantly less ongoing task costs than LDS individuals. Finally, overall PM performance was expected to be lower in HDS than LDS individuals.

Indeed, the findings showed that overall PM accuracy was significantly lower in the HDS participants than in the LDS participants. Importantly, the study also found a significant difference in ongoing task costs between the HDS and LDS participants. The LDS participants demonstrated significant costs on the ongoing task by slowing down significantly in the embedded PM condition relative to the no-PM condition. This suggested that extra attentional resource was allocated when a PM task was given. In addition, these costs for the LDS participants were positively associated with PM accuracy, suggesting that the allocated resource was functional to PM performance. In contrast, the HDS participants did not incur significant costs with additional time-based
PM task requirements and there was no relationship between their ongoing task response time and PM performance. This suggested that depression is associated with the reduced allocation of resources to internally control time-based PM tasks and supports the view that cognitive initiative is reduced in depression. Clock checking frequency was also numerically lower in HDS participants than LDS participants. This suggested that HDS participants might not have externally controlled the time-based PM task to the extent of LDS participants although this difference in clock checking frequency was only marginal.

Study 3 (Chapter 4) was conducted to examine attention allocation and event-based PM performance in HDS individuals. Event-based PM deficits under strategically demanding conditions have been observed in depressed individuals in some studies (Altgassen et al., 2009; Chen et al., 2013). However, other studies which also employed multiple non-focal cues have not consistently found PM deficits (Altgassen, Henry, Bürgler, & Kliegel, 2011). Likewise, Study 1 found no difference in PM performance between HDS and LDS participants on event-based tasks in the MIST. In view of the inconsistent findings, Study 3 was conducted to further examine the task conditions in which event-based PM deficits would emerge in HDS individuals relative to LDS individuals. Additionally, the importance emphasized on the PM task relative to the ongoing task was manipulated in order to examine for differences in the ability of HDS and LDS individuals to prioritize attention to the PM task. In this study, participants were required to make a PM response whenever one of five previously studied target words was presented during an ongoing lexical decision task. It was predicted that LDS participants would incur significant costs in the PM task conditions relative to the baseline condition and that costs in the condition where the importance of the PM task was emphasized (PM Important, or PMI) would be greater than the condition where the importance of the ongoing task (Ongoing Important, or OI) was emphasized (Loft & Yeo, 2007; Smith & Bayen, 2004). Accordingly, a corresponding improvement in PM performance was expected in the PMI condition compared to the OI condition for the LDS participants. HDS participants were expected to allocate less attentional resource to the PM task (i.e., incur less cost to the ongoing task) than LDS participants. In addition, the difference in the magnitude of costs incurred between the PMI and OI conditions for HDS participants was also expected to be significantly less than the LDS participants.
The study found that under OI conditions, ongoing task response times and PM accuracies did not differ between the HDS and LDS groups. This finding is consistent with previous research demonstrating that event-based PM task accuracy is not always impaired by depression, even when the PM task is resource demanding (Albiński, Kliegel, Sędek, & Kleszczewska-Albińska, 2012; Altgassen et al., 2011; Kliegel & Jäger, 2006). The study also found that both HDS and LDS participants incurred significantly greater costs in the PMI condition than the OI condition. However, a corresponding improvement in PM performance from the OI to the PMI condition was observed in LDS participants but not HDS participants. This suggested that HDS participants are able to allocate greater attentional resource to PM tasks when directed to do so, but the allocated resources may not always be efficiently utilized. The findings highlight the need to not only consider whether resources have been allocated to support PM task requirements, but also whether these attentional resources have been effectively utilized.

The findings of Study 2 demonstrated reduced attention allocation and the findings of Study 3 suggested inefficient resource utilization in HDS individuals under PM task conditions. Hence, Study 4 (Chapter 5) was conducted to investigate whether intervention strategies such as implementation intentions and goal maintenance training (GMT) would scaffold the attentional function of depressed participants (i.e., increase attention allocation or improve efficiency of resource utilization) and subsequently improve PM performance. In addition, in view of the fact that Studies 1 and 3 found no clear evidence of PM deficits in HDS individuals under event-based conditions, Study 4 examined whether PM deficits would emerge under more strategically demanding event-based PM conditions. In this study, a resource demanding event-based PM paradigm similar to the one used in Meeks and Marsh (2010) was employed (i.e., PM cues were syllables [e.g., ‘tor’] embedded in real words [e.g., ‘tortoise’] in an ongoing lexical decision task). There were four independent groups – HDS individuals receiving intervention with implementation intentions in the second block and GMT in the third block (HDS+I), HDS individuals with no intervention who only received standard PM instructions in the second and third blocks (HDS+Std), LDS individuals receiving intervention with implementation intentions in the second block and GMT in the third block (LDS+I), and LDS individuals with no intervention who only received standard PM instructions in the second and third blocks (LDS+Std).
Surprisingly, there was no difference in PM accuracy between the HDS and LDS participants under the strategically demanding paradigm employed in Study 4. This finding suggests that performance on highly demanding event based PM tasks may not always be impaired in HDS individuals, and extends the findings of Studies 1 and 3 which found no definite event-based PM difference between HDS and LDS participants. Nevertheless, the current study found that HDS participants’ PM performance benefitted from implementation intentions to the same extent as LDS participants (i.e., both HDS+I and LDS+I participants’ PM accuracy were significantly greater than HDS+Std and LDS+Std participants receiving standard PM instructions). Ongoing task response times for both HDS and LDS participants receiving implementation intentions were marginally greater than the ongoing task response times for both HDS and LDS participants receiving standard PM instructions. Although inconclusive, the trend of the response time findings suggests that implementation intentions have the potential to increase attention allocation to PM tasks.

Both HDS and LDS participants receiving GMT were found to have significantly better PM performance than both HDS and LDS participants receiving standard PM instructions. Ongoing task response times for HDS and LDS participants receiving GMT were significantly greater than the HDS and LDS participants receiving standard PM instructions. Importantly, the response times for both the HDS and LDS participants receiving GMT were shown to be positively associated with PM accuracy rate whereas this association was not found for HDS and LDS participants receiving standard PM instructions. Thus, GMT appears to be an effective way of increasing attention allocation to PM tasks and improving PM performance in HDS as well as LDS participants. Overall, the findings of Study 4 showed that intervention strategies such as implementation intentions and GMT are effective ways of improving PM performance and that HDS individuals are able to benefit from these interventions to a similar extent as LDS individuals.

In Chapter 6, the overarching objective of the thesis and the rationale for the four studies were restated (i.e., examine the claim that reduced cognitive initiative underlies depression related PM deficits by measuring changes in ongoing task performance under strategic PM conditions relative to no-PM conditions). The findings of all four studies were summarised and reconciled with the extant literature on depression and PM to arrive at a general impression of the PM function of depressed individuals (i.e., more vulnerable to impairments under time-based conditions than
event-based conditions; likely due to the greater attentional control required with time-based PM tasks). Future research ideas arising from the current work were discussed (e.g., directly compare time-based and event-based PM performance in depressed individuals, examine the effects of implementation intentions and GMT in depressed individuals under time-based PM conditions, compare attention allocation and PM function of depressed and non-depressed individuals using regular and irregular time-based PM cues). Limitations on the generalizability of the current findings were also raised (i.e., findings should be replicated with individuals that are demographically dissimilar to the current samples; depressed individuals who are older, have chronic recurrent depressive episodes or comorbid conditions, etc). Finally, it was concluded that cognitive initiative is reduced in depression under strategic PM conditions (time-based PM tasks) and that cognitive efficiency (effective utilization of allocated resource) could potentially be reduced as well. Importantly, more work would need to be done to compare the extent of inefficiency between depressed and non-depressed individuals.
# Table of Contents

ABSTRACT ....................................................................................................................... i  
PREFACE ....................................................................................................................... ii  
Table of Contents .............................................................................................................. x  
Publications Arising from this Thesis ............................................................................ xiv  
Statement of Contribution ............................................................................................... xv  
Acknowledgement .......................................................................................................... xv  
CHAPTER 1 ..................................................................................................................... 1  
  An Introduction to Depression and Prospective Memory ................................................. 1  
  Neurocognitive Features of Depression ................................................................. 3  
  Neurobiological Features of Depression ............................................................... 4  
  Understanding Prospective Memory ............................................................... 5  
  Types of Laboratory PM Paradigms ................................................................. 6  
  Phases of Information Processing in PM .......................................................... 7  
  Neuropsychology of Prospective Memory ........................................................... 8  
  Preparatory Attentional and Memory Theory ....................................................... 9  
  Multi-process Theory ......................................................................................... 10  
  Attentional Allocation Policy Theory ............................................................... 11  
  Investigations of Depression on PM Function ............................................... 12  
  Rationale for Studies: Strategic Manipulation and Costs Analysis to Reflect Cognitive Initiative ......................................................................................................................... 16  
  References ............................................................................................................ 19  
CHAPTER 2 ................................................................................................................... 33  
  Patterns of prospective memory impairment amongst individuals with depression: the influence of cue type and delay interval. ........................................................................ 33  
  Abstract ................................................................................................................. 34  
  Method .................................................................................................................... 36  
  Participants ............................................................................................................. 36  
  Materials and Procedure ....................................................................................... 37  
  Results .................................................................................................................... 38  
  Discussion .............................................................................................................. 40  
  References ............................................................................................................ 43  
CHAPTER 3 ................................................................................................................... 46  
  Cognitive control processes underlying time-based prospective memory impairment in individuals with high depressive symptomatology .............................................. 46
CHAPTER 5 ................................................................................................................... 90
Effects and mechanisms of implementation intentions and goal maintenance training on
prospective memory performance in individuals with high levels of depressive
symptomatology .............................................................................................................. 90
Abstract ....................................................................................................................... 91
Implementation Intentions ........................................................................................... 93
Goal-maintenance Training ......................................................................................... 94
Current Study .............................................................................................................. 95
Methods ....................................................................................................................... 97
Participants .............................................................................................................. 97
Materials and Procedure .......................................................................................... 98
PM Paradigm ......................................................................................................... 100
Stimuli.................................................................................................................... 100
Implementation Intention Intervention .................................................................. 101
GMT Intervention .................................................................................................. 102
Results ....................................................................................................................... 104
PM Accuracy Rate ................................................................................................. 104
LD Task Performance ............................................................................................ 105
Relationship Between Ongoing Task Performance and PM Accuracy ................. 107
Perceived Importance of PM Task ........................................................................ 107
Discussion ................................................................................................................. 107
Summary and Conclusions .................................................................................... 111
References ................................................................................................................. 113
Appendix A ............................................................................................................... 117
Appendix B................................................................................................................ 118
Appendix C................................................................................................................ 119
CHAPTER 6 ................................................................................................................. 120
General Discussion ....................................................................................................... 120
Restating General Rationale: Strategic Manipulation and Costs Analysis to reflect
Cognitive Initiative .................................................................................................... 121
Summary of Studies and Key Findings ..................................................................... 122
Study 1 ................................................................................................................... 122
Study 2 ................................................................................................................... 123
Study 3 .................................................................................................................. 124
Publications Arising from this Thesis

This thesis comprises a series of studies which were conducted to explore the relationship between depressive symptomatology and prospective memory. The thesis takes the combined form of published papers and empirical studies that are presented in a format suitable for publication in peer-reviewed journals. Publications arising from this thesis include

Chapter 2:


Chapter 3:


Chapter 4:

Statement of Contribution

Each of the studies contained in this thesis was designed by the candidate in collaboration with his supervisors, Associate Professor Michael Weinborn, Associate Professor Shayne Loft and Professor Murray Maybery. All experimental programming and data collection were performed by the candidate. All statistical analyses were conducted by the candidate except for the multi-level modelling in Study 3 in which Associate Professor Gillian Yeo and Associate Professor Shayne Loft contributed their expertise. This manuscript was written by the candidate with revisions made in accordance with suggestions from supervisors and from journal editors and reviewers.
Acknowledgement

The dissertation would not be possible without the kind, wonderful and patient support of the following people. Words cannot do them justice but I shall try anyway.

To my patient and tremendously supportive supervisors, Associate Professor Michael Weinborn, Associate Professor Shayne Loft and Professor Murray Maybery. You have been very helpful and encouraging throughout this journey, especially when I was dealing with my own depression. One could not ask for better academic mentors. You have provided a lot of guidance and valuable advice. I am glad to have published my work under your tutelage and I hope to have the opportunity to collaborate with you in future. To A/Prof. Weinborn who first introduced me to prospective memory research, thank you for opening this wonderful door and showing me how interesting the topic is. To A/Prof. Loft who has provided a lot of valuable feedback, thank you for investing so much of your time and effort. To Prof. Maybery who is always able to impart useful insight to improve the quality of the papers, thank you for your wise and experienced presence. Special thanks to Prof. Romola Bucks for her valuable suggestions and ideas during every annual review.

To Jasmine, my wonderful, caring, patient and supportive wife. You have been my best friend, my soul mate, my carer and my cook (and a good one at that!). Things have not been easy for you but I am really thankful for all that you have done. Some pampering is in order once the thesis is submitted. To my family and Jasmine’s family. Thank you for being so supportive throughout this journey. To my sister who is battling cancer right now, stay strong and get well soon. To my lovely colleagues/friends, Andrew, Anne, Vanessa, Doris, Helen, Ken, Amanda, Jerline, Luke, Ross, Suzanna, Stewart and Shane. Thanks for making everything so much nicer. Finally, to that imaginary pet dog I wish I had for sitting at my feet and giving me lots of imaginary warm company as I worked on my dissertation. Thanks for scaring away imaginary burglars when I am not at home.
CHAPTER 1

An Introduction to Depression and Prospective Memory
Depression: Dynamic, Prevalent and Burdensome

The influence of depression on cognitive function has long been an area of research interest. Depression refers to a state of negative affect involving feelings of sadness, low self-esteem, lethargy, loss of interest in pleasurable activities and functional impairment (American Psychiatric Association, 2013). Depressed mood can vary in both severity (e.g., minor versus major depression) and chronicity (e.g., chronic “low grade” forms such as dysthymia or persistent depressive disorder versus severe, acute forms such as major depressive disorder). Longitudinal studies have shown that individuals with a major depressive disorder (MDD) can also fluctuate between varying levels of symptom severity and diagnostic categories throughout several years of the course of their illness (Judd et al., 1998; Judd, Akiskal, & Paulus, 1997; Kennedy, Abbott, & Paykel, 2004), spending a substantial period of time in the subthreshold or subclinical range (Judd et al., 1998; Kennedy, Abbott, & Paykel, 2004). This reinforces the view of depression as a dynamic condition. To further complicate the picture, depression has often been found to be comorbid with other mental or behavioural conditions such as anxiety (Sartorius, Üstün, Leckrubier, & Wittchen, 1996), personality disorders (Hirschfeld, 1999), alcohol use disorders (Grant & Harford, 1995), substance use disorders (Davis, Uezato, Newell, & Frazier, 2008) and physical ailments such as diabetes, arthritis, asthma, and cardiovascular disease (Moussavi et al., 2007), making it difficult to study the effects of depression in isolation. Nevertheless, the recognition of the severe consequences associated with depression has led to great efforts to better understand the condition.

Depression is not an uncommon condition. According to the 2007 National Survey of Mental Health and Wellbeing (Slade, Johnston, Oakley Browne, Andrews, & Whiteford, 2009), the 12-month prevalence of dysthymia and depressive episodes (including mild, moderate and severe episodes) in Australia were found to be 4.1% and 1.3% respectively. The number of individuals affected by an affective disorder (i.e., dysthymia, depression or bipolar disorder) was estimated to be around 995,900 with the 12-month prevalence found to be higher for women than men (7.1% vs. 5.3%). The lifetime prevalence of dysthymia and depressive episodes in Australia were reported at 1.9% and 11.6% respectively. Women were again found to be higher than men on rates of dysthymia (2.4% vs. 1.5%) and depressive episodes (14.5% versus 8.8%) for lifetime prevalence. The socioeconomic burden associated with depression is substantial. It is now one of the leading causes of disability in Australia (Begg, Vos, Barker, Stanley, &
Lopez, 2008) and worldwide (Moussavi et al., 2007). As mentioned above, depression is commonly comorbid with other serious health conditions. However, research has further shown that patients suffering from depression in addition to serious health conditions such as cancers (Pinquart & Duberstein, 2010), strokes (Pan, Sun, Okereke, Rexrode, & Hu, 2011), myocardial infarction (Meijer et al., 2011), and diabetes (Sullivan et al., 2012), experience higher mortality rates than those without depression. In the workplace, depression severity has been associated with reduced productivity and increased absenteeism (Beck et al., 2011; Birnbaum et al., 2010; Lerner et al., 2004a; Wang et al., 2004). Depressed individuals are also less likely to maintain employment (Lerner et al., 2004b). The direct and indirect annual costs associated with depression in Australia per capita have been estimated to be around $2557 and $406 respectively (Luppa, Heinrich, Angermeyer, König, & Riedel-Heller, 2007). The national costs of depression in Australia have been estimated to be greater than $3 billion annually (Mathers, Vos, & Stevenson, 1999). In view of the monumental socio-economic-health challenges associated with depression, the Australian government established beyondblue (Hickie, 2004), a national initiative to reduce the burden of depression through a series of measures (e.g., prevention, early intervention, expanding evidence-based treatments, improved access to subsidies for depression treatment, promotion of research on related health services).

**Neurocognitive Features of Depression**

Although typically conceived of as a mood disorder, disturbances to multiple cognitive domains have been reported in depression. Broadly, the literature suggests that controlled or higher-order thought processes (i.e., executive function) may be more severely affected in depression (Snyder, 2013). Executive function is a broad term and refers to cognitive processes involving the organization, management and regulation of complex information, thoughts and behaviour (e.g., planning, inhibition of irrelevant information, mental flexibility, self-monitoring, problem solving). Studies of depressed individuals have found greater difficulty with set-shifting and using feedback to regulate behaviour (Channon, 1996; Degl'Innocenti, Ågren, & Bäckman, 1998; Martin, Oren, & Boone, 1991; Merriam, Thase, Haas, Keshavan, & Sweeney, 1999; Ravnkilde et al., 2002). Deficits in the ability to plan and strategize through multi-step problems have also been found (Beats, Sahakian, & Levy, 1996; Fossati, Ergis, & Allilaire, 2002). Another commonly reported observation in depressed individuals is the inability to inhibit irrelevant or emotionally negative information (Goeleven, De Raedt, Baert, &
Koster, 2006; Joormann & Gotlib, 2008, 2010). Deficits in working memory have also been found in depressed individuals in several studies (Harvey et al., 2004; Joormann & Gotlib, 2008; Nebes et al., 2000; Pelosi, Slade, Blumhardt, & Sharma, 2000; Rose & Ebmeier, 2006; Weiland-Fiedler et al., 2004). Attentional deficits in depressed individuals have been reported with studies showing a poorer ability to sustain and divide attention (Egeland et al., 2003; Koetsier et al., 2002; Ravnikilde et al., 2002; Thomas, Goudemand, & Rousseaux, 1998; Weiland-Fiedler et al., 2004). A significant association between depression and episodic memory impairment has also been documented (Burt, Zembar, & Niederehe, 1995). However, not all areas of memory appear to be equally affected. Studies have generally shown greater deficits on tasks involving free recall as opposed to cued recall or recognition (Burt et al., 1995; Hertel & Milan, 1994; Roy-Byrne, Weingartner, Bierer, Thompson, & Post, 1986; Watts & Sharrock, 1987). This suggests that memory deficits may be related to the impaired retrieval of stored information rather than the improper consolidation or maintenance of information. Finally, psychomotor retardation has also been featured in several studies (Den Hartog, Derix, Van Bemmel, Kremer, & Jolles, 2003; Egeland et al., 2003; Nebes et al., 2000; Tsourtos, Thompson, & Stough, 2002).

Neurobiological Features of Depression

In parallel with the extensive cognitive and behavioural impairments, researchers have also found neurophysiological abnormalities in depression at multiple levels of analyses (i.e., from neurochemical dysregulation to hormonal imbalance to neurostructural disturbances). Studies involving blood, urinary and cerebrospinal fluid analyses of individuals with depression have typically revealed abnormal levels of several key monoamines that are implicated in mood and cognitive function (e.g., serotonin, dopamine, norepinephrine) and their metabolites (e.g., 5-hydroxyindoleacetic acid, 3,4-Dihydroxyphenylacetic acid, homovanillic acid and 3-methoxy-4-hydroxyphenylglycol) (Koslow et al., 1983; Linnoila, Miller, Bartko, & Potter, 1984; Post, Ballenger, & Goodwin, 1980; Roy, Pickar, De Jong, Karoum, & Linnoila, 1988). Higher levels of glucocorticoid hormones implicated in stress reactivity such as cortisol and ACTH (McAllister-Williams, Ferrier, & Young, 1998; Pariante & Lightman, 2008; Zunszain, Anacker, Cattaneo, Carvalho, & Pariante, 2011) and enlarged pituitary and adrenal glands (Krishnan, 1993) have been found in depressed individuals, suggesting that hyperactivity in the hypothalamus-pituitary-adrenal (HPA) axis might be involved in the pathophysiology of depression. The immune system has also been implicated in
depression with research showing high levels of immunoreactive proteins associated with inflammation and illness such as interleukin-1, interleukin-2, interleukin-6, tumor necrosis factor-alpha, and C-reactive protein (Dantzer, O'Connor, Freund, Johnson, & Kelley, 2008; Howren, Lamkin, & Suls, 2009; Miller, Maletic, & Raison, 2009; Raison & Miller, 2013).

Abnormalities in various brain structures have also been found in depression. For the prefrontal cortex, there have been reports of reduced gray matter volume in the left anterior cingulate cortex (Botteron, Raichle, Drevets, Heath, & Todd, 2002; Coryell, Nopoulos, Drevets, Wilson, & Andreasen, 2005; Drevets et al., 1997), the orbito- and ventrolateral prefrontal cortex (Drevets, Price, & Furey, 2008), and the anterolateral prefrontal cortex (Drevets et al., 2008). For the striatum, reduced volume has been found in the caudate nucleus and the putamen (Baumann et al., 1999; Krishnan et al., 1992). Atrophy in the hippocampus, a structure responsible for memory consolidation, has also been reported in depressed individuals (Bremner et al., 2000; Frodl et al., 2002; Sheline, Wang, Gado, Csernansky, & Vannier, 1996). Functional neuroimaging studies have revealed abnormal brain activation for depressed individuals in several neural pathways, such as those involved in reward based decision-making (Forbes et al., 2006; Pizzagalli et al., 2009; Smoski et al., 2009; Tremblay et al., 2005), the processing of emotional information (Beauregard et al., 1998; Grimm et al., 2008; Siegle, Steinhauer, Thase, Stenger, & Carter, 2002), cognitive inhibition (Eugène, Joormann, Cooney, Atlas, & Gotlib, 2010; Langenecker et al., 2007; Wagner et al., 2006), and working memory (Matsuo et al., 2007; Schöning et al., 2009; Vasic, Walter, Sambataro, & Wolf, 2009).

**Understanding Prospective Memory**

Having summarized the various neurobiological features and the cognitive functions affected by depression, the discussion will now focus on an aspect of cognitive function that has received significantly less attention in depression research, namely, prospective memory (PM). PM refers to the ability to remember to perform an intended action in the future. PM tasks have been categorised as event-based (i.e., remembering to perform an intended action when a specific event occurs such as remembering to relay a message when a colleague shows up for work tomorrow) or time-based (i.e., remembering to perform an intended action at a specific or elapsed time such as remembering to watch a favourite program at 7 pm or stirring a pot every 5
minutes). PM is relevant to our daily functions as we frequently need to defer actions and remember on our own to perform them some point in the future (e.g., keeping appointments, submitting assignments, returning a phone call, taking medication, cooking, etc). Therefore, it is reasonable to assume that the capacity to function independently would be negatively affected if PM function is reduced. Indeed, studies have found a positive association between PM function and self-reported abilities to independently carry out instrumental activities of daily living or adhere to a medication regime (Pirogovsky, Woods, Vincent Filoteo, & Gilbert, 2012; Woods et al., 2014; Woods, Weinborn, Velnoweth, Rooney, & Bucks, 2012; Zogg, Woods, Sauceda, Wiebe, & Simoni, 2012).

**Types of Laboratory PM Paradigms**

In the real world, a deferred intended action would usually need to be retrieved and executed while an individual is occupied with concurrent ongoing task activities. Experimenter have thus attempted to emulate this in the laboratory. In a typical PM paradigm (Einstein & McDaniel, 1990), participants are usually required to remember to perform an intended action (e.g., press a designated key) whilst concurrently performing an ongoing task (e.g., making word judgments or answering questions). An example of a standard event-based PM task can be found in McDaniel and Einstein (2000) where participants were required to press the F1 key whenever the target word “rake” was encountered whilst performing a lexical decision task (i.e., deciding whether a shown letter string was a real word or not). An example of a standard time-based PM task can be found in the study by Rude and colleagues (Rude, Hertel, Jarrold, Covich, & Hedlund, 1999) where participants were required to press a designated key every five minutes while answering general-knowledge questions. Crucially, one important feature of PM tasks which distinguishes them from retrospective memory tasks is that participants are not reminded by the experimenter to remember to perform the intended action during the ongoing task. Instead, participants are required to initiate the action by themselves whenever the cue or target event appears. The number or proportion of times participants remembered to perform the action (e.g., press the F1 key) when the target event (e.g., “rake”) is presented, or the when the correct target time occurs (e.g., every five minutes), is used as a measure of PM performance.

Note that PM paradigms are not limited to computerized tasks. In fact, substantial effort has been put into the development of PM tasks that are more...
naturalistic or more closely simulate real world demands, whilst still affording reasonably high degrees of experimental control. One such example is the Memory for Intentions Screening Test (MIST, Raskin, Buckheit, & Sherrod, 2010). Specifically in the MIST, participants are presented with eight PM tasks which vary on cue type (time-based or event-based), delay interval (2 minutes or 15 minutes) and mode of performance (verbal or physical). The PM instructions for all eight tasks are gradually administered one at a time while participants perform a word search puzzle as their ongoing task. The PM tasks in the MIST are naturalistic in the sense that they approximate behaviours that occur in real life (e.g., writing one’s name when being shown a red pen, reminding the experimenter to take a break in 15 minutes, etc). Another example of a naturalistic PM task is Virtual Week (Rendell & Craik, 2000), a board game in which participants move through squares to simulate the passage of time (i.e., one round equals one virtual day) and collect event cards which instruct them of what PM tasks they are required to do (ten per virtual day for seven virtual days). Sample PM tasks include reminding the experimenter to phone the plumber when they cross the 4 p.m. square or pick up dry-cleaning when out shopping. More recently, a computerized and shortened version of Virtual Week was developed which further enhanced its applicability in clinical settings (Rendell & Henry, 2009).

**Phases of Information Processing in PM**

Several important phases are thought to be involved in PM. According to Ellis and Freeman (2008), a PM task begins with the encoding/formation of the intention. This is followed by the consolidation or retention of the intention over an interval (i.e., delay interval). When the appropriate opportunity arises, retrieval of the intention occurs. The final phase involves the execution of the intended action and the evaluation of whether the PM action has been properly performed (Ellis & Freeman, 2008). Research efforts have mainly revolved around the intention retrieval phase as “remembering to remember” at the appropriate moment appears to be the most crucial aspect of a PM task. The intention retrieval phase itself has been further subdivided into a prospective and a retrospective component (Ellis & Freeman, 2008). The prospective component involves the acknowledgement that a criterion for task execution has been fulfilled (i.e., the recognition that an event or time signals the appropriate opportunity to perform the PM task, Ellis & Freeman, 2008). In other words, it involves the awareness that something has to be done. The retrospective component involves the retrieval of the contents or information associated with the intention (i.e., the specification of what is to
Several cognitive processes have been theorised to be involved in each phase (Kliegel, Jager, Altgassen, & Shum, 2008). For example, planning appears to be required for a complex intention during intention formation whereas proper consolidation appears to be required to prevent the decay of the intention-related information during the retention phase (Kliegel et al., 2008). Successful intention initiation whilst engaged in an unrelated but demanding ongoing task appears to require executive-related processes such as target monitoring and the strategic division of attentional resources between the PM task and ongoing task. The successful retrieval of intention related information appears to be dependent on well-functioning retrospective memory processes (Kliegel et al., 2008).

**Neuropsychology of Prospective Memory**

Given the multiple processes involved in a PM task (from intention formation to task execution), it is unsurprising that neuroimaging studies have implicated a distributed network involving multiple neural regions during PM task performance. This includes areas such as the rostral prefrontal cortex (Brodmann area 10), the parietal cortex, and the hippocampal complex (Burgess, Quayle, & Frith, 2001; Burgess, Scott, & Frith, 2003; Cohen & O’Reilly, 1996; Gilbert, 2011; Okuda et al., 1998; Rubens & Zanto, 2011). Prefrontal areas of the brain appear to be more involved in executive function processes (e.g., planning, monitoring, division or allocation of attention) and the prospective component (Burgess et al., 2008) whereas medial temporal structures appear to be more involved in the retrospective component of PM tasks (Okuda et al., 1998).

Further evidence of the neuroanatomical basis of PM has been gathered from research involving clinical populations with insults to one or more of the important structures discussed above. Specifically, impaired time and/or event-based PM have been found in patient groups with traumatic brain injuries (Knight, Harnett, & Titov, 2005; Mathias & Mansfield, 2005; Shum, Valentine, & Cutmore, 1999), neurodegenerative diseases such as Alzheimer’s disease (Brodaty, 2010; Huppert, Johnson, & Nickson, 2000; McDaniel, Shelton, Breneiser, Moynan, & Balota, 2011), Parkinson’s disease (Costa, Peppe, Caltagirone, & Carlesimo, 2013; Foster, Rose, McDaniel, & Rendell, 2013; Raskin et al., 2011b), multiple sclerosis (Rendell et al., 2012; Rendell, Jensen, & Henry, 2007), human-immunodeficiency virus (Morgan et al., 2012; Zogg et al., 2011), and epilepsy (Adda, Castro, Além-Mar e Silva, de Manreza, &
To complement the evidence from neurological patient groups, PM deficits have also been found in studies employing samples with psychiatric conditions such as schizophrenia patients (Henry, Rendell, Kliegel, & Altgassen, 2007; Woods, Twamley, Dawson, Narvaez, & Jeste, 2007) and individuals with substance abuse (Rendell, Gray, Henry, & Tolan, 2007; Weinborn, Woods, Nulsen, & Park, 2011a; Weinborn, Woods, O'Toole, Kellogg, & Moyle, 2011b).

**Preparatory Attentional and Memory Theory**

Several theories have been proposed to explain how individuals remember to perform an intended action in the future. One such theory is the preparatory attentional and memory process (PAM) theory (Smith, 2003; Smith & Bayen, 2004). According to this theory, individuals actively engage or allocate attentional resources in order to prepare for the appearance of PM targets (i.e., attentional resources are allocated to monitor for PM targets). Thus, remembering to perform a delayed intention is thought to be resource-demanding and never automatic. In support of this view, Smith (2003) demonstrated that ongoing task (i.e., lexical decision) performance was significantly slower under a condition where a PM task was supposed to be performed (i.e., press the F1 key whenever a PM cue appears) compared to a condition where no PM was to be performed (i.e., ongoing task cost). Importantly, this cost was calculated based on trials where the PM target was not presented, suggesting that the increased response times were not associated with the physical execution of the PM task. The ongoing task costs were interpreted as the allocation of attentional resources to support PM task requirements. In support of this view, Smith (2003) found that participants with better PM performance had slower lexical decision response times than participants with poorer PM. Thus, there appears to be a functional relationship between the costs incurred on the ongoing task and PM performance. Since Smith (2003), many studies have successfully replicated her initial findings and have shown that PM task requirements lead to significant ongoing task costs compared to conditions where no PM task requirements are involved (Loft, Kearney, & Remington, 2008; Loft & Yeo, 2007; Marsh, Hicks, Cook, Hansen, & Pallos, 2003; Smith, Hunt, McVay, & McConnell, 2007). PM task-associated costs therefore appear to be a relatively robust phenomenon.
Multi-process Theory

In contrast to the view that PM performance is always resource demanding, the multi-process theory (McDaniel & Einstein, 2000) states that multiple processes are involved in PM. Specifically, PM may involve attentionally demanding processes, but it can also involve spontaneous processes at other times (i.e., the intention can be automatically or involuntarily retrieved with minimal resource). Importantly, whether prospective remembering occurs through effortful or spontaneous means has been thought to depend on the task conditions present. Using the intention to buy a loaf of bread as an example, McDaniel and Einstein (2000) stated that remembering would be spontaneous if the PM cue is distinctive or salient (e.g., a large advertisement signboard of a supermarket), if the PM cue is well-associated with the intended action (e.g., buying a loaf of bread is cued when one sees a supermarket), if the PM cue is relevant to the ongoing activity that one is currently engaged in (i.e., focal, for example, while one is at grocery store shopping for fruit). Accordingly, under the conditions just stated, remembering the intention would be relatively spontaneous and costs to ongoing task performance would be minimal. Conversely, the multi-process theory states that remembering would require significant attentional resource if the PM cue is non-distinctive (e.g., a small or dull advertisement signboard), if the PM cue is not well-associated with the intended action (e.g., buying a loaf of bread not being cued when one sees a hardware store), or if the PM cue is not relevant to one’s ongoing activity (i.e., non-focal). McDaniel and Einstein (2000) further stated that if an intended action is considered to be important (e.g., the bread is needed for some special occasion), then it is likely that more attentional resource would be allocated to the PM task. Accordingly, greater costs to ongoing task performance should be observed under these conditions.

In support of multi-process theory, studies have shown that an embedded PM task do not significantly affect ongoing task performance when the PM cues are focal to the ongoing task, salient, or when the importance of the PM task is not emphasized (Einstein, McDaniel, Manzi, Cochran, & Baker, 2000; Einstein et al., 2005; Kliegel, Martin, McDaniel, & Einstein, 2004). Furthermore, PM performance appears to be maintained at relatively high levels under those conditions. In contrast, ongoing task performance have been found to be significantly slower when PM cues are non-salient, not focal to ongoing task performance, or when the importance of the PM task is emphasized (Einstein et al., 2000, 2005). A recent study showed that ongoing task
response times were significantly slower on the trials where PM cues occurred unexpectedly (e.g., during a phase where participants were not expecting to perform the PM task, Knight, Meeks, Marsh, Cook, Brewer, & Hicks, 2011). This suggested that the PM cues were noticed spontaneously even though the participants were not instructed to actively search for them. This shows that spontaneous processes could be involved when a PM cue is encountered and further supports the multi-process view that prospective remembering does not only involve resource demanding processes.

**Attentional Allocation Policy Theory**

As the cognitive system has limited resources, some researchers have argued that possessing an intention would be maladaptive and detrimental to ongoing activities if there is no meta-cognitive process in place to regulate the allocation of attention to the PM task (Einstein et al., 2005). According to the attentional allocation policy (AAP) view (Marsh, Hicks, & Cook, 2006), a set of mental policies are created to determine when and how much attentional resources to appropriately allocate to the PM task. Importantly, these policies are based on the information, beliefs and predictions one has about an intention, such as the environmental context, the time at which an intention is expected to be performed, and the perceived importance attached to each of the PM and ongoing tasks (Marsh et al., 2006). For example, if one expects to encounter a colleague only in the office, then a policy to allocate attentional resource to monitor for the colleague only when one is in the office would be formed. If a PM task is perceived as important (e.g., obtaining the signature of the chief executive officer), then a policy to allocate significant resources to monitor for the opportunity to complete the task would be formed.

In support of the attention allocation policy theory, researchers have found that costs to the ongoing activity were significantly less when participants knew what the specific targets were (e.g., “when the word ‘hit’ or ‘nice’ is encountered” versus “when the word refers to an animal”) and when to specifically respond (e.g., ‘on the 4th and 8th minute’ as compared to ‘between the 3rd and 5th minute’, or ‘between the 7th to 9th minute’, Hicks, Marsh, & Cook, 2005). Furthermore, participants who were informed of when the PM cue would appear (e.g., Phase 3 of the ongoing task) showed no interference to ongoing task performance in the previous phase where the target was not expected (Marsh et al., 2006). In contrast, participants who were not informed of when the PM cue would appear showed significant costs throughout the ongoing task (Marsh
et al., 2006). Interestingly, Loft and colleagues recently showed that ongoing task costs were progressively reduced (but not eliminated) when the expected PM cues failed to appear (Loft et al., 2008). This demonstrates that attentional policies can be quite flexible and adaptive to changes in PM task demands. In summary, the findings show that when one has specific intention-related information (e.g., context and time of target appearance, what specific targets are involved), interference to the ongoing task can be minimised. In contrast, when one has little information about the intention, ongoing-task interference can be quite substantial.

**Investigations of Depression on PM Function**

In the earlier sections, a brief summary of the neurobiological and neuropsychological features of depression was provided. The cognitive and neuropsychological aspects of PM were also discussed. Together, it seems that neurocognitive processes affected by depression overlap significantly with the neurocognitive processes considered important for proper PM function (i.e., executive functions, divided attention, free recall, etc). Thus, it would be reasonable to expect PM deficits in individuals with depression. However as is discussed below, PM deficits in depression do not appear to be a universal finding.

There have been a number of studies on the effects of negative mood on PM functioning (Albiński, Kliegel, Sędek, & Kleszczewska-Albińska, 2012; Altgassen, Henry, Bürgler, & Kliegel, 2011; Altgassen, Kliegel, & Martin, 2009; Chen, Zhou, Cui, & Chen, 2013; Harris & Menzies, 1999; Kliegel & Jäger, 2006; Kliegel et al., 2005; Rude et al., 1999). However, only a limited number of studies have been based on individuals with depression or high depressive symptomatology (Harris & Menzies, 1999; Kliegel & Jäger, 2006; Kliegel et al., 2005). For example, the study by Kliegel and Jäger (2006) examined the PM performance of participants with depressive symptoms in the normal range ($M = 2.57, SD = 1.97$, range $= 0-8$ on the Hospital Anxiety and Depression Scale). In this study, they found that depressive symptoms were inversely correlated with PM accuracy scores for time-based PM tasks but not for event-based PM tasks. In another study, Kliegel and colleagues (Kliegel et al., 2005) used a mood induction procedure (exposure to sad film versus neutral film) and measured participants’ levels of pleasantness, calmness, and wakefulness. In this study, they found that participants who were successfully induced to have sad mood (i.e., mood responders) performed more poorly on a time-based PM task (i.e., press a key
every minute) than participants with neutral mood. However, the authors noted that poor PM performance was temporary and only occurred in the first half of the experiment. Harris and Menzies (1999) employed a sample of undergraduate students in their study but did not report their levels of depressive symptomatology. In the study, a multiple regression analysis was performed to examine the relationship between depressive symptoms and event-based PM performance (i.e., draw a cross on a piece of paper whenever a word that represents a piece of clothing or a part of the human body is heard). A trend-level association between depression scores and event-based PM scores was found ($\beta = .22, p = .07$) in the study.

PM deficits have been more notable for studies that employed individuals with more severe depressive symptoms. In one study (Rude et al., 1999), researchers investigated the time-based PM performance of individuals with major depression. In the study, participants were instructed to remember to press a key every five minutes while they responded to ongoing multiple-choice general knowledge questions presented on the computer. Note that participants could check for the elapsed time by pressing a different key to display a clock. Previous research (Hertel, 1994, 1997; Hertel & Milan, 1994; Hertel & Rude, 1991) has shown greater memory deficits between depressed and non-depressed participants in conditions involving strategic recall (i.e., recalling words presented as unstructured, non-meaningful information) than in conditions involving cued or structured recall (i.e., recalling words presented as structured, meaningful information). This suggested that depressive symptoms are more likely to affect performance when strategic demands are high. As such, Rude et al. predicted that PM deficits in depressed participants would emerge on the time-based PM task due to the strategic demands associated with its performance. Indeed, the researchers found that compared to non-depressed participants, depressed participants demonstrated significantly lower PM accuracy and initiated less clock checks as the target time approached. This suggested that impaired PM performance in depressed individuals could be related to a reduced initiative to allocate resources to control processes such as clock-checking or time-monitoring. As Rude et al. did not include a no-PM baseline condition and did not measure ongoing task response time, it was not possible to examine the cost to ongoing task performance incurred by the depressed participants compared to non-depressed participants.

In another study (Altgassen et al., 2009), the PM performance of individuals with major depression and non-depressed individuals were compared on a computerized
event-based task. In this study, participants were required to press a pink key whenever target words were presented during an ongoing vowel judgment task (i.e., whether the left or right word on the monitor had more vowels). Crucially, the researchers manipulated the strategic demands of the PM task by varying the focality of the PM cues (i.e., the relevance of the PM target features to ongoing task performance). In the focal condition, participants were instructed to respond whenever a word with three ‘e’s was shown. In the non-focal condition, participants were instructed to respond whenever a verb was shown. Based on the multi-process view that non-focal PM targets are more strategically demanding than focal PM targets (McDaniel & Einstein, 2000) and the view that depression is associated with a reduced initiative to direct attentional resource to relevant tasks (Hertel, 1997; Hertel, 2000; Hertel & Milan, 1994), the researchers predicted that an interaction between depression and focality would occur for PM performance. Specifically, the impaired PM demonstrated by depressed participants relative to non-depressed participants was expected be greater in the non-focal condition than in the focal condition. Indeed, they found significantly poorer PM performance for the depressed participants relative to the non-depressed participants in the non-focal condition but no group difference in PM performance was found in the focal condition. When ongoing task performance was examined, the researchers found that the depressed participants consistently demonstrated slower response times than non-depressed participants across the baseline, focal and non-focal conditions (i.e., response time differences occurred to a similar across the three conditions). Response times for both depressed and non-depressed participants were consistently slower in the non-focal condition than the focal condition. Together, these findings suggested that the difference in response times between depressed and non-depressed participants was not significantly greater with non-focal cues relative to focal cues. Thus, the study was not able to demonstrate that attention allocation was reduced to a greater extent in depressed individuals than in non-depressed individuals under conditions of greater strategic demands. This led the researchers to suggest that their vowel judgment task was perhaps not sensitive enough to detect the reduced ‘monitoring costs’ (Altgassen et al., 2009, p. 11) in depressed individuals.

In a study by Albiński et al. (2012), the PM performance of subclinically depressed and non-depressed individuals were examined on event-based and time-based PM tasks. In their event-based design, participants were required to press the ‘Q’ key whenever they saw a word with red bold font while they performed a logical reasoning
task (e.g., “Tom is taller than Mike, Mike is taller than Ben. Tom is taller than Ben, True or False?”). No difference in PM performance between subclinically depressed and non-depressed participants was found on this PM task. This is unsurprising given the salient nature of the PM cue employed. In the Albiński et al. time-based design, participants were required to stop the ongoing task (i.e., reading stories) and to start answering questions about the stories after four minutes had passed. Surprisingly, the researchers found that subclinically depressed participants showed better PM performance on this task than non-depressed participants. They also found that subclinically depressed participants checked the clock more often in the minute preceding the target time than non-depressed participants. The reason for this finding is unclear, but the researchers speculated that perhaps there was mild rumination present in their subclinically depressed sample which functionally benefitted time monitoring and PM performance (although rumination was not formally measured in the study).

Based on previous findings of biased processing of emotionally negative information in depressed individuals (Breslow, Kocsis, & Belkin, 1981; Denny & Hunt, 1992; Rinck & Becker, 2005), Altgassen et al. (2011) examined whether cue valence would also affect PM performance in depressed individuals. Cue valence was manipulated by employing words that were neutral (apple, rabbit, surfboard), positive (love, beauty, happiness), or negative (sadness, tiredness, sorrow). In the study, depressed and non-depressed participants were required to respond to any of nine target words during an ongoing category decision task (i.e., judge whether the left or right word belongs to a presented category). The researchers found that non-depressed participants performed better than the depressed participants with positive PM cues. This was likely due to the biased processing of positive information by non-depressed participants (i.e., positivity effect). However, there was no difference in PM performance between the depressed and non-depressed participants with negative or neutral PM cues. Thus, the expected negativity effect in depressed participants (i.e., better PM performance than non-depressed participants with negative cues) was not found. Crucially, the findings of the study suggest that event-based PM is not always impaired in depressed individuals even under potentially demanding conditions. Although cue valence, rather than strategic demands, was manipulated in their study design, it is reasonable to assume that their PM task was strategically demanding as well given that multiple cues were employed and that the cues were not focal to ongoing task performance. Unfortunately, ongoing task response times were not measured in the
study. Hence, it was not possible to examine whether depressed participants allocated less attentional resource to support PM task requirements than non-depressed participants (i.e., incurred less costs to ongoing task performance under PM conditions relative to no-PM conditions).

More recently, Chen et al. (2013) examined the PM performance of clinically depressed and non-depressed individuals in an eye tracking study. In this study, participants performed an ongoing visual search task where they were presented with a word in one slide and were required to indicate whether an image of the word (i.e., target) was present or absent in one of the four quadrants in the next slide (by pressing ‘1’ or ‘2’). The PM task was to press another key (‘3’) whenever the participant saw the image of a fruit (i.e., the cue). Thus, a categorical cue was employed in their design. The researchers found that the PM accuracy of depressed participants was significantly worse than non-depressed participants. However, the depressed and non-depressed participants did not differ in ongoing task accuracy or response times. Importantly, despite the poorer PM accuracy, depressed participants showed a greater number of fixations and longer fixation durations on PM cues than non-depressed participants. This suggested that although the depressed participants were attending to the relevant information, they might not be processing the information efficiently.

Rationale for Studies: Strategic Manipulation and Costs Analysis to Reflect Cognitive Initiative

As reviewed, some of the above studies have found depression related PM deficits on tasks with high strategic demands (Altgassen et al., 2009; Chen et al., 2013; Rude et al., 1999) but not on tasks with low strategic demands (Albiński et al., 2012). Some researchers (Altgassen et al., 2009; Kliegel & Jäger, 2006; Rude et al., 1999) have postulated that this could be related to the reduced initiative to allocate readily available resources to benefit task performance (i.e., cognitive initiative framework, Hertel, 2000). The cognitive initiative framework was initially conceived to explain the more severe retrospective memory deficits between depressed and non-depressed individuals in conditions involving strategic recall (i.e., recalling words presented as unstructured, non-meaningful information) than in conditions involving cued or structured recall (i.e., recalling words presented as structured, meaningful information, Hertel, 1994, 1997; Hertel & Milan, 1994; Hertel & Rude, 1991). The general approach of the authors of the framework has been to manipulate the strategic demands of retrospective memory tasks
and to compare the performance of depressed and non-depressed participants under high and low strategic conditions. Likewise, a similar approach is adopted here. The current thesis aimed to investigate the role of cognitive initiative in PM by systematically manipulating the strategic demands of several key PM variables (e.g., cue type, delay interval, PM task importance). The PM performance of HDS individuals is compared to LDS individuals. Findings of poorer PM under higher strategic demands would replicate previous PM findings (Altgassen et al., 2009; Chen et al., 2013; Rude et al., 1999) and would be consistent with the view that cognitive initiative is reduced in depression.

However, PM accuracy per se does not provide detailed information about the extent of attention allocated to the PM task. To properly evaluate the claim that the initiative to allocate attentional resource is reduced in depression, it would be important to measure the extent of attention allocation under PM conditions in depressed individuals and compare it with non-depressed individuals. However, previous PM studies of depressed individuals have not closely examined attention allocation with paradigms sufficiently sensitive to evaluate this construct. For example, Rude et al. (1999) employed a multiple-choice general knowledge test as their ongoing task but did not measure response time performance or include a no-PM task condition to control for baseline differences. Conversely, Altgassen et al. (2009) attempted to examine attention allocation in depressed participants by comparing their ongoing task performance (e.g., vowel judgement task accuracy and response times) under PM conditions relative to a no-PM baseline condition. However, as discussed in the preceding section, the authors did not find a greater difference in ongoing task response times between the depressed and non-depressed participants when strategic demands were increased (i.e., focal vs. non-focal cues). This led the authors to suggest that their vowel judgment task was perhaps not sensitive enough to allow them to detect the reduced attention allocation or reduced cognitive initiative in depressed individuals under higher strategic demands. Thus, it remains unclear how attention allocation or the cognitive initiative of depressed individuals would present under different strategic conditions compared to non-depressed individuals.

To address this, the current thesis employed a sensitive and well-established paradigm that has been used in previous studies (multiple PM cues embedded in an ongoing lexical decision task, Einstein & McDaniel, 1990; Marsh, Hicks & Cook, 2006, Smith, 2003) to measure the resource requirements of PM tasks. The conducted studies
examined the decrements to ongoing task performance under PM conditions relative to a no-PM condition (i.e., costs). Increased costs to the ongoing task in PM task conditions relative to conditions when no PM task is present (in the form of longer response times) was assumed to reflect attention allocation to support PM requirements (Einstein & McDaniel, 1990; Marsh, Hicks & Cook, 2006, Smith, 2003). Conversely, the lack of ongoing task costs under PM task conditions relative to a no-PM condition was assumed to reflect minimal allocation of attention to support PM. Therefore, the measured costs would provide an indication of the extent of cognitive initiative present in HDS individuals and would allow for the evaluation of the cognitive initiative hypothesis. Accordingly, costs along with PM performance were measured under the different strategic manipulations (i.e., time-based PM tasks, event-based PM tasks with relative importance manipulated) and the changes in costs demonstrated by HDS participants relative to LDS participants were taken to reflect the cognitive initiative of depressed individuals under different strategic conditions. Additionally, the relationship between the demonstrated cost and the resulting PM accuracy was investigated to examine whether the allocated resource has been utilized efficiently or functionally (i.e., is the increased costs associated with better PM performance?). Finally, the thesis examined the effectiveness of intervention strategies such as implementation intentions and goal maintenance training (GMT) and their ability to influence PM performance and attention allocation in HDS and LDS individuals. This search for effective intervention strategies would hopefully lead to the development of rehabilitation strategies that would assist depressed individuals with PM deficits in their daily function.
References


Raison, C., & Miller, A. (2013). Role of Inflammation in Depression: Implications for Phenomenology, Pathophysiology and Treatment.


altered reward processing in major depressive disorder revealed by a dopaminergic probe. *Archives of general psychiatry, 62*(11), 1228-1236.


CHAPTER 2

Patterns of prospective memory impairment amongst individuals with depression: 
the influence of cue type and delay interval.

Yanqi Ryan Li, Michael Weinborn, Shayne Loft, & Murray Maybery
Abstract

The present study investigated the impact of cue type and delay interval on prospective memory performance in depressed, compared to non-depressed, individuals using a clinically relevant measure, the Memory for Intentions Screening Test. The depressed group demonstrated impaired performance on time-based, but not event-based, prospective memory tasks relative to the non-depressed group. The depressed group also demonstrated impaired prospective memory on tasks with longer delay intervals (15 minutes), but not on tasks with shorter delay intervals (2 minutes). These data support theoretical frameworks that posit that depression is associated with deficits in cognitive initiative (i.e., reduced ability to voluntarily direct attention to relevant tasks) and thus that depressed individuals are susceptible to poor performance on strategically demanding tasks. The results also raise multiple avenues for developing interventions (e.g., implementation intentions) to improve prospective memory performance amongst individuals with depression, with potential implications for medication and other treatment adherence.
Depression has been associated with disturbances in executive function, working memory, attention, and memory (see Clark, Chamberlain & Sahakian, 2009 for a review). Impairments in prospective memory (PM), the ability to remember to perform an intended action in the future, have also been documented in depressed individuals (Altgassen, Kliegel, & Martin, 2009; Rude, Hertel, Jarrold, Covich, & Hedlund, 1999). Importantly, depression itself has been identified as an independent predictor of a variety of instrumental activities of daily living, including forgetting to take medications amongst those with chronic medical problems (see Grenard et al, 2011 for a review). Therefore, understanding the mechanisms underlying depression-related PM impairments could lead to the development of interventions to improve clinical outcomes. This is the first study to use a standardized, clinically-relevant measure of PM, the Memory for Intentions Screening Test (MIST; Raskin, Buckheit, & Sherrod, 2010), to investigate the pattern of PM deficits in depression. Specifically, we examine how PM deficits vary as a function of cue type and delay interval.

For time-based PM (assessed with tasks requiring a PM response at a specific time), impairments have been found in laboratory-based studies amongst participants with depression (Rude et al., 1999) or induced sad mood (Kliegel et al., 2005), compared to controls (but see Albiński, Kliegel, Sędek, & Kleszczewska-Albińska, 2012). When participants are required to make a PM response to an event embedded in an ongoing task (event-based PM task), one study reported PM impairments as a function of depression (Altgassen et al., 2009), but two others did not (Albiński et al., 2012; Altgassen, Henry, Bürgler, & Kliegel, 2011). To our knowledge, no study has directly compared whether the magnitude of PM deficits associated with depression varies as a function of cue type in a single standardized clinically-relevant PM measure. This is important as, according to the multi-process view of PM (Einstein & McDaniel, 2005), time-based PM tasks require more self-initiated strategic monitoring than event-based PM tasks. Furthermore, according to Hertel’s (2000) cognitive initiative framework, depression is associated with reduced initiative or ability to voluntarily direct attention to relevant tasks. We subsequently predicted that depression-related PM deficits would be greater for time-based, compared with event-based, PM on the MIST.

The present study also evaluated the profile of depressed individuals for another important variable, the PM task delay interval. Delay interval refers to the period between the formation of an intention, and the appropriate time for its execution. During this interval, the individual usually performs other engaging ongoing activities, while
also monitoring for PM retrieval cues. The multi-process theory posits that greater strategic monitoring demands are imposed as delay interval lengthens (Einstein & McDaniel, 2005). This could be due to the decaying activation of PM task goals in memory with longer intervals (Anderson & Lebiere, 1998), making it more difficult to remember to allocate resources to PM tasks. Consistent with this possibility, laboratory studies with healthy individuals have shown poorer PM with longer delay intervals (Martin, Brown, & Hicks, 2011). Furthermore, clinical groups with compromised executive function (e.g., ecstasy users, individuals with Parkinson’s disease) have displayed greater vulnerability to the effects of longer PM delay intervals than healthy controls (Raskin et al., 2011; Weinborn, Woods, Nulsen, & Park, 2011). Based on the cognitive initiative framework’s assumption that depression is associated with a reduced initiative to direct attentional resources, we predicted that PM deficits for the depressed group compared to the non-depressed group would be greater for longer (15 minutes) compared with shorter (2 minutes) delay intervals. To our knowledge, no previous study has examined whether depression-related PM deficits vary as a function of delay interval.

**Method**

**Participants**

Approximately 800 undergraduate psychology students completed the Beck Depression Inventory-Second Edition (BDI-II) or the Depression Anxiety and Stress Scales-21. Students with scores in the upper and lower quartiles of the distribution on either questionnaire were invited to participate, and subsequently screened again using a common method (the BDI-II) on the day of testing to allow for allocation into depressed and non-depressed groups based on current mood. Based on a self-report medical and psychiatric history questionnaire, participants with substance/alcohol dependence, neurological or psychiatric conditions unrelated to mood, or use of substances within the past five days were excluded. For the second screening, those in the depressed group (N = 32) had moderate to severe depressive symptomatology (BDI-II scores between 13 and 53) whereas the non-depressed group (N = 32) had no, or minimal depressive symptomatology (BDI-II scores of 0-12). Nine participants in the depressed group had moderate to severe depressive symptomatology during screening reported minimal depression on the testing day, and subsequently were reassigned to the control group. None of these participants had a history of diagnosed depression. One participant with low levels of depressive symptomatology during screening reported high levels of depression on the day of testing and was thus reassigned to the depressed group.

---

1 Eight participants with elevated depressive symptomatology during screening reported minimal depression on the testing day, and subsequently were reassigned to the control group. None of these participants had a history of diagnosed depression. One participant with low levels of depressive symptomatology during screening reported high levels of depression on the day of testing and was thus reassigned to the depressed group.
reported a previous diagnosis of major depression and five were taking antidepressants. The depressed group had a mean BDI-II score in the moderate to severe range (see Table 1), similar to means reported for depressed groups in previous PM studies (e.g., Altgassen et al., 2009, 2011; Rude et al., 1999). The groups did not differ significantly in gender distribution, ethnic composition, predicted IQ, years of education, alcohol use (Alcohol Use Disorders Identification Test, AUDIT, Bohn, Babor, & Kranzler, 1995) or digit span scores (all ps > .10, see Table 1).

Materials and Procedure

The study was approved by the University of Western Australia Human Research Ethics Office. Participants completed questionnaires on basic demographics, medical history, and alcohol use (i.e., the Alcohol Use Disorder Identification Test). Predicted IQ and basic attention function were assessed with the Wechsler Test of Adult Reading and Wechsler Adult Intelligence Scale-III, Digit Span subtest. Participants then completed the research version of the MIST (Woods, Moran, Dawson, Carey & Grant, 2008), with minor task modifications for the young adult sample (see Weinborn et al, 2011 for details). The MIST is a well-validated PM measure that has been used extensively in healthy (e.g., Woods et al, 2008) and clinical groups (e.g., Raskin et al, 2011, Weinborn et al, 2011), with a duration of 30 minutes. The experimenter gave instructions for each of eight PM tasks successively while participants completed an engaging word search puzzle (i.e., distractor task) as quickly and accurately as possible. The MIST contained four time-based and four event-based tasks. Half of the time-based and event-based tasks had a delay interval of 2 minutes, and half had a delay interval of 15 minutes. Participants needed to perform the time-based action at the appropriate time (within 1 minute of the specified time for 2-minute tasks, or 2 minutes for 15-minute tasks), or needed to perform the event-based action when the cue appeared, to receive the maximum 2 points for that task. Participants received 1 point if they performed the correct action at the wrong time or the wrong action at the right time. No points were awarded for no PM response. See Woods et al. (2008) for more details on scoring criteria. Participants also completed a three-choice recognition test for each PM task.
Table 1

Demographics, Neuropsychological and MIST Variables for Depressed and Non-depressed Participants

<table>
<thead>
<tr>
<th>Variable</th>
<th>Depressed (N = 32)</th>
<th>Non-depressed (N = 32)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>BDI-II</td>
<td>26.06 (9.92)</td>
<td>6.91 (3.63)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Gender distribution (n)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22f/10m</td>
<td>24f/8m</td>
<td>.58</td>
</tr>
<tr>
<td>Ethnicity (n)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>22C/9A/1O</td>
<td>22C/7A/3O</td>
<td>.54</td>
</tr>
<tr>
<td>Age</td>
<td>17.81 (0.93)</td>
<td>18.16 (0.81)</td>
<td>.12</td>
</tr>
<tr>
<td>Years of education</td>
<td>12.09 (0.30)</td>
<td>12.06 (0.25)</td>
<td>.65</td>
</tr>
<tr>
<td>AUDIT</td>
<td>7.35 (5.35)</td>
<td>7.22 (4.89)</td>
<td>.92</td>
</tr>
<tr>
<td>WTAR Predicted IQ</td>
<td>110.97 (7.02)</td>
<td>111.91 (6.12)</td>
<td>.57</td>
</tr>
<tr>
<td>Digit span forward raw score</td>
<td>10.66 (2.18)</td>
<td>10.66 (2.13)</td>
<td>1.00</td>
</tr>
<tr>
<td>Digit span backward raw score</td>
<td>6.56 (1.93)</td>
<td>6.72 (1.49)</td>
<td>.72</td>
</tr>
<tr>
<td>MIST Summary&lt;sup&gt;c&lt;/sup&gt; (median, interquartile)</td>
<td>39.0 [36.0, 45.0]</td>
<td>45.0 [39.0, 48.0]</td>
<td>.04</td>
</tr>
<tr>
<td>Time-based</td>
<td>7.0 [6.0, 7.0]</td>
<td>7.0 [7.0, 8.0]</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Event-based</td>
<td>7.0 [6.0, 8.0]</td>
<td>7.0 [6.0, 8.0]</td>
<td>.42</td>
</tr>
<tr>
<td>15-minute</td>
<td>6.0 [5.0, 7.0]</td>
<td>7.0 [6.0, 8.0]</td>
<td>.03</td>
</tr>
<tr>
<td>2-minute</td>
<td>8.0 [7.0, 8.0]</td>
<td>8.0 [8.0, 8.0]</td>
<td>.12</td>
</tr>
<tr>
<td>Error Frequency (median, interquartile)&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omission</td>
<td>0 [0, 1]</td>
<td>0 [0, 0]</td>
<td>.05</td>
</tr>
<tr>
<td>Loss of Time</td>
<td>0 [0, 1]</td>
<td>0 [0, 0]</td>
<td>.12</td>
</tr>
<tr>
<td>Loss of Content</td>
<td>0 [0, 1]</td>
<td>0 [0, 0]</td>
<td>.40</td>
</tr>
<tr>
<td>Task substitution</td>
<td>0 [0, 1]</td>
<td>1 [0, 1]</td>
<td>.27</td>
</tr>
<tr>
<td>Recognition</td>
<td>8.0 [8.0, 8.0]</td>
<td>8.0 [8.0, 8.0]</td>
<td>.65</td>
</tr>
<tr>
<td>Distractor Task</td>
<td>20.0 [15.25, 29.0]</td>
<td>18.5 [17.0, 30.0]</td>
<td>.99</td>
</tr>
</tbody>
</table>

Values are means (standard deviations) or medians (interquartile ranges) unless otherwise specified<sup>a</sup>f = female, m = male, <sup>b</sup>C = Caucasian, A = Asian, O = Others; Group differences based on t-tests unless otherwise indicated, Mann-Whitney test. BDI-II = Beck Depression Inventory-Second Edition. AUDIT = Alcohol Use Disorder Identification Test. WTAR = Weschler Test of Adult Reading, performance based estimate. MIST = Memory for Intentions Screening Test. Omission = Failing to perform intended action at all. Loss of Time = Failing to perform intended action at the right time. Loss of Content = Failing to remember the specific action to be performed despite knowledge that an action has to be performed. Task substitution = Replacing an appropriate intended action with the action of another task.

Results

Indices typically reported from the MIST include the Summary, Time-based and Event-based subscale scores (aggregated across the two delay intervals), and 2-min and 15-min subscale scores (aggregated across the two cue types). Descriptive statistics for
these traditional indices along with Mann-Whitney tests are reported in Table 1. However, for the purpose of the current study, we categorised the eight MIST items into four 2-item scales: (1) time-based/2min, (2) time-based/15min, (3) event-based/2min, (4) event-based/15min (scores ranged from 0-4). This allowed us to perform a 2x2x2 repeated-measures mixed ANOVA with group (depressed vs. non-depressed) as the between-subjects variable, and cue type (event-based vs. time-based) and delay interval (2-min vs. 15-min) as within-subjects variables.

A main effect of group, $F(1, 62) = 4.90, p = .03, \eta^2_p = .07$ was qualified by a significant group by cue type interaction, $F(1, 62) = 4.93, p = .03, \eta^2_p = .07$. As shown in Figure 1, the difference in PM performance between depressed and non-depressed groups was greater for time-based (depressed; $M = 3.19, SD = 0.67$; non-depressed, $M = 3.63, SD = 0.52$), compared to event-based tasks (depressed; $M = 3.42, SD = 0.49$; non-depressed, $M = 3.50, SD = 0.57$). Tests of simple effects confirmed that the groups differed significantly on time-based, $t(62) = 2.91, p = .01, d = .74$, but not event-based PM, $t(62) = 0.59, p = .56, d = .15$.

![Time Based PM Performance](chart1_time.png) ![Event Based PM Performance](chart1_event.png)

*Figure 1.* Prospective memory performance (MIST) as a function of group and delay interval. The left hand panel represents the time-based tasks, and the right hand panel represents the event-based tasks. Error bars represent standard error of the mean.

$^3$MIST data did not meet assumptions for parametric approaches to analysis due to negative skew. As there is no non-parametric equivalent, and ANOVA is robust to violations of normality with adequate sample sizes (Howell, 2005), the mixed design ANOVA remained the most appropriate approach. However, non-parametric analysis with the Mann-Whitney test (see Table 1) for group differences on the subscale scores confirmed a similar pattern of findings as found for the ANOVA.
A main effect of delay interval was also found, $F(1, 62) = 55.63, p < .01, \eta^2_p = .47$. This main effect and the aforementioned main effect of group, were qualified by a significant group by delay interval interaction, $F(1, 62) = 4.90, p = .03, \eta^2_p = .07$. As shown in Figure 1, the difference in performance between depressed and non-depressed groups was greater for 15-minute (depressed; $M = 2.84$, $SD = 0.86$; non-depressed, $M = 3.31$, $SD = 0.68$) compared to 2-minute (depressed; $M = 3.77$, $SD = 0.28$; non-depressed, $M = 3.81$, $SD = 0.42$) delays. Tests of simple effects confirmed that the groups’ PM performance differed significantly on the 15-minute, $t(62) = 2.42, p = .02, d = .62$, but not 2-minute delay interval tasks, $t(62) = 0.53, p = .60, d = .11$. No other main effects or interactions were found (all $F$s < 1).

Importantly, there was no group difference on the MIST distractor or recognition tests (see Table 1). Thus, the observed PM deficits in the depressed group are unlikely to be due to a differential trade-off between groups in the attention they devoted to the PM task relative to the ongoing distracter task, or the ability of the two groups to retain the PM instructional set in retrospective memory (i.e., encoding of the cue-intention pairs).

**Discussion**

Previous studies have found PM deficits in depressed individuals for both event-based and time-based laboratory tasks (e.g., Altgassen et al., 2008; Rude et al., 1999). However, this is the first study of depression to have used a single standardized clinically-relevant measure that manipulated multiple important PM task characteristics (cue type, delay interval). As predicted, we found interactions between group and cue type, as well as between group and delay interval. The depressed group demonstrated impaired time-based, but not event-based PM. Further, the depressed group demonstrated impaired PM for tasks with 15-minute, but not 2-minute, delay intervals. Of note, the medium-to-large effect sizes found between the groups as a function of cue type and delay interval, as well as the level of performance for the depressed group, were similar to those seen in other clinical groups on the modified MIST (e.g., ecstasy users, Weinborn et al 2011). Importantly, these findings are unlikely to be artefacts of differences in demographics, general attentional function, ongoing task/PM task trade-offs, or inadequate encoding of cue-intention pairs as the groups did not differ on measures of these variables.
Multi-process theory (Einstein & McDaniel, 2005) postulates that time-based PM tasks require more self-initiated strategic monitoring than event-based PM tasks. Further, the cognitive initiative framework (Hertel, 2000) posits that depression is associated with reduced ability to voluntarily direct attentional resources. Consistent with Rude et al. (1999) and Kliegel et al. (2005), we found time-based PM deficits in the depressed group (but see Albinski et al., 2012). Further, consistent with the predictions of both relevant theoretical accounts, we found greater depression effects for time-based compared to event-based PM. The null group effect for event-based tasks is consistent with two previous studies that found no depression-related event-based PM deficits (Albiński et al., 2012; Altgassen et al., 2011). However depression-related deficits have been demonstrated when event-based PM targets were non-focal to ongoing tasks, and thus required more attentional resources to detect (Altgassen et al. 2009). The strong semantic associations between the event-based cue-intention pairs on the MIST, which might have enhanced the likelihood intentions were spontaneously retrieved (Einstein & McDaniel, 2005), could explain the current null findings. This is unlikely, however, because we found an effect of delay interval on event–based PM, suggesting that the MIST event-based tasks required participants to allocate attentional resources, albeit less so than for time-based tasks.

It is likely that we found depression effects on tasks with 15-minute compared with 2-minute delays because longer delay intervals reduced the likelihood that the depressed group effectively allocated attentional resources to the PM tasks. This group by delay interval interaction parallels outcomes for previous studies that examined the effects of PM delay interval amongst ecstasy users (Weinborn et al., 2011), HIV-positive (Morgan et al., 2012) and Parkinson’s disease patients (Raskin et al., 2011). Although a 15-minute delay interval remains modest compared to more “real world” PM tasks (which could have delay intervals of days/weeks), it is important to note that research with other clinical samples has shown PM deficits on the MIST (with 15-min delays) to be associated with “real world” outcomes such as medication adherence (Poquette et al., 2012) and self-reported PM lapses in everyday living (Weinborn et al., 2011b) and self-reported levels of ability to perform instrumental activities of daily living (Woods, Weinborn, Velnoweth, Rooney, & Bucks, 2012). However, the use of longer delay intervals in future research is warranted. Additionally, research regarding the relationship between PM and medication adherence, or psychotherapy outcomes, amongst depressed individuals would be an important avenue for future investigations.
Some caution should be exercised in interpreting the nonsignificant interaction between group, cue type and delay interval in our analysis since the MIST provided only two PM trials for each cue type by delay interval combination. Future research incorporating more PM trials per combination would be desirable. However, note that, relative to using MIST indices, our analysis did not substantially change the way the main effects of delay and cue type, and their interactions with group, were assessed (since scores for each delay or cue-type condition were based on four items).

The current findings are consistent with research indicating disturbances to attention and/or executive function in depression (Clark et al., 2009). Note, however, that the null group effects observed for MIST recognition task performance do not entirely rule out the contribution of impaired episodic memory to the observed PM deficits. Specifically, the MIST does not assess free recall of the cue-intention pairs, but instead only assesses their recognition. If strategic attention allocation deficits indeed underlie PM impairments in depression, interventions could be directed towards teaching planning and encoding strategies that capitalise on spontaneous retrieval processes and minimise dependence on strategic monitoring processes, such as the formation of implementation intentions (McDaniel, Howard, & Butler, 2008). Alternatively, goal maintenance training (Levine et al. 2000) may improve the quality of attentional resource allocation for depressed individuals.
References


CHAPTER 3

Cognitive control processes underlying time-based prospective memory impairment in individuals with high depressive symptomatology

Yanqi Ryan Li, Michael Weinborn, Shayne Loft, & Murray Maybery
Abstract

The current study compared time-based prospective memory (PM) for individuals with high depressive symptomatology (HDS) and low depressive symptomatology (LDS). We examined PM accuracy rate, clock-checking frequency, and decrements in ongoing task performance (i.e., costs to ongoing tasks) associated with an embedded time-based PM task. HDS participants demonstrated numerically lower but statistically comparable clock-checking frequency to LDS participants. However, their PM performance was significantly poorer than that of LDS participants. The pattern of observed costs to ongoing tasks and correlational analyses between ongoing task performance and PM accuracy showed that, relative to LDS participants, HDS participants were restricted in their allocation of attentional resources to support PM. We concluded that although HDS and LDS participants externally controlled their time-based PM task performance (i.e., clock-checking) similarly, the HDS participants lacked the cognitive initiative to allocate attentional resources to internally control PM task performance. Such internal control might reflect time-estimation processes, the resources required to maintain the PM task response intention, and/or the ability to coordinate the PM task response with ongoing task demands. To our knowledge, this is the first paper to have examined time-based PM strategies used by HDS individuals beyond clock-checking. The data suggest that interventions that encourage intermittent strategic reviews of PM goals may be beneficial for individuals with high depressive symptomatology.
Evidence of impaired prospective memory (PM), the ability to remember to perform an intended task at a particular moment in the future, has recently emerged in studies of depressed individuals (Altgassen, Henry, Bürgler, & Kliegel, 2011; Altgassen, Kliegel, & Martin, 2009; Li, Weinborn, Loft, & Maybery, 2013; Rude, Hertel, Jarrold, Covich, & Hedlund, 1999). Attempts at characterizing the nature of this impairment have generally revealed PM performance deficits under conditions where PM retrieval involves a greater degree of self-initiation or strategic control. Conversely, significant depression-related PM deficits under conditions where PM retrieval is strongly prompted from the environment, and therefore is less attentionally demanding, have not been found. Importantly, while the extant literature has supported this general pattern of depression-related PM impairment, identification of more specific cognitive mechanisms underlying depression-related PM deficits remains inadequately studied.

In particular, the cognitive processes underlying time-based PM (remembering to perform a task at a specific time) have received little attention. Studies to date have found time-based PM impairment amongst depressed individuals (i.e., individuals formally diagnosed with clinical depression; Rude et al., 1999) or individuals with high depressive symptomatology (i.e., HDS - elevated self-reported depressive symptoms; Li et al., 2013), and that the underlying mechanisms of the time-based PM deficit may be related to reductions in the frequency with which individuals check the external clock (Rude et al., 1999). However, the role of internal cognitive control processes has not been examined. It is crucial to do so, because research with non-depressed samples has shown that participants tasked with time-based PM requirements can be slower to perform intervening ongoing tasks than participants without PM task requirements, suggesting that the demands of a time-based intention extend beyond the immediate need to check an external clock (Hicks, Marsh, & Cook, 2005; Marsh, Hicks, & Cook, 2006; Waldum & Sahakyan, 2012). These ‘costs’ to ongoing tasks may reflect the use of internal time-estimation strategies, or the attentional resources required to maintain the intent to make PM task responses, and/or to co-ordinate PM responses with ongoing task demands (Huang, Loft, & Humphreys, in press). If depressed individuals have particular difficulties with these internal control processes, and if this is linked to their time-based PM deficits, then this knowledge could assist in the development of appropriate interventions to improve PM functioning. The objective of the current study was to evaluate differences in external (clock-checking) and internal control processes used by individuals with HDS and low depressive symptomatology (LDS, that is, those
individuals who report minimal depressive symptoms) to remember to perform time-based PM tasks.

**Neuropsychology of Prospective Memory**

PM is not a unitary construct but involves a complex, coordinated interaction of multiple neurocognitive processes. Specifically, PM involves (a) intention formation (during which the intention is formed and encoded), (b) intention retention when the intention is maintained in memory while performing other ongoing activities, (c) intention initiation which involves recognizing the appropriate opportunity to execute an intention (the prospective component); and finally (d) the retrieval of the content of the intention (the retrospective component) and its execution (Kliegel, Martin, McDaniel, & Einstein, 2002). Several cognitive processes come into play in each of these phases (Ellis & Freeman, 2008). For example, the ability to effectively learn and consolidate intentions, and to retrieve intention-related contents, is dependent on retrospective memory. Successful intention initiation whilst engaged in a demanding ongoing task requires multiple inter-related executive processes, including the ability to strategically divide attentional resources between the competing ongoing task and PM task demands. Additionally, effective self-monitoring and response co-ordination is required to ensure that the intended PM action is executed in the correct manner when the time to do so has been correctly recognized.

Given the multiple processes involved in the successful completion of a PM task, it is unsurprising that neuroimaging studies have implicated a distributed network involving multiple neural regions. This includes the rostral prefrontal cortex (Brodmann area 10), thought to be involved in executive processes (e.g., planning, monitoring, strategic attention allocation) and the prospective component (Burgess et al., 2008), and the hippocampal complex which appear to be involved in the retrospective component of PM tasks (Burgess et al., 2008; Okuda et al., 1998; West, 2008).

**Neurocognitive and Prospective Memory Deficits in Depression**

Depression is associated with neurostructural abnormalities such as reduced gray matter volume in the hippocampus, prefrontal cortex, cingulate cortex, and striatum; and neurochemical dysregulation in the dopaminergic, serotonergic and cholinergic systems (Drevets, Price, & Furey, 2008). Further, while some individual variability exists, group-level neurocognitive deficits in depression such as disturbances in executive
function, attention, memory, and speed of processing have been documented (Clark, Chamberlain, & Sahakian, 2009). As can be seen, some of the neuroanatomical and neurocognitive processes affected in depression are also implicated in normal PM functioning, suggesting that PM impairments are more likely in depressed individuals or those with HDS. To better predict the nature of PM impairment in depression, a particular theoretical framework, the cognitive initiative hypothesis (Hertel, 2000) has been drawn upon (e.g., Altgassen et al., 2009; Li et al., 2013). Specifically, the cognitive initiative hypothesis proposes that depression is associated with a reduced initiative to direct attentional resources to relevant tasks. Subsequently, researchers investigating PM function in depression or HDS have predicted deficits to emerge primarily under conditions that depend on strategic resource allocation.

For example, in the event-based PM literature, it has been reported that depressed participants performed more poorly than matched control participants when PM targets were non-focal to the processing required for the ongoing task (Altgassen et al., 2009; Chen, Zhou, Cui, & Chen, 2013), but not when they were focal to ongoing tasks (Altgassen et al, 2009) or salient (i.e., presented in red bold font, Albiński, Kliegel, Sędek, & Kleszczewska-Albińska, 2012). For time-based PM, early work by Rude et al (1999) found that when depressed participants were required to perform a habitual time-based PM task (i.e., press a key every five minutes), they checked the clock less often and had poorer time-based PM performance than non-depressed participants. Li et al. (2013), using a clinical semi-naturalistic measure of PM (the Memory for Intentions Screening Test), found poorer PM performance for HDS participants compared to LDS participants on time-based PM tasks and PM tasks with longer delay intervals (15 minutes), but not on event-based PM tasks, or PM tasks with shorter delay intervals (2 minutes). Note however that Li et al. did not measure clock-checking behaviour in the time-based PM tasks. In contrast, Albiński et al. (2012) reported better time-based PM performance (i.e., the PM task was to stop a story-reading task after four minutes) and significantly more clock-checking in the final minute preceding the target time, for HDS participants compared to non-depressed participants. Albiński et al. speculated that perhaps the mild rumination in their HDS sample might have functionally kept their time-based intention heightened compared to the non-depressed participants, and that this facilitated PM performance. We return to this rather surprising finding of the Albiński et al. (2012) study in the Discussion.
Current Study

The current study was concerned with the relationship between depressive symptomatology and time-based PM. Notably, none of the three aforementioned studies that investigated this relationship (Albiński et al., 2012; Li et al., 2013; Rude et al., 1999) incorporated a baseline condition in which participants performed the ongoing task without PM demands. That is, PM tasks demands were always embedded in the ongoing task. Rude found significantly poorer ongoing task performance (general knowledge test) in the depressed participants compared to the non-depressed participants, whereas Li et al. and Albiński et al. found no difference between HDS and LDS groups on an ongoing word-search puzzle task and story-reading task, respectively. However without a non-PM baseline condition in these studies, it is not possible to compare the extent to which depressed or HDS participants and matched control participants allocated attentional resources to internally control their time-based PM task demands. Therefore, we incorporated a non-PM baseline to compare changes in ongoing task performance (i.e., costs) for HDS and LDS participants that resulted from time-based PM demands.

The current study presented participants with an ongoing lexical decision task that required them to remember to press a specific key after 4, 8 and 12 minutes had elapsed. We chose a lexical decision task because this task has been shown to be a sensitive measure of costs in PM paradigms (Hicks et al., 2005; Huang et al, in press; Loft & Yeo, 2007; Waldum & Sahakyan, 2012). Based on our preceding analysis of neurocognitive deficits in depression (e.g., Hertel, 2000; Clark et al., 2009) and past empirical research, our predictions were as follows. Firstly, given that two out of the three time-based PM studies conducted to date have found PM deficits with depression or HDS (Rude et al., 1999; Li et al., 2013), we expected HDS participants to have poorer time-based PM performance than LDS participants. We also expected that HDS participants would check the clock (external control; Huang et al, in press) less often than LDS participants (Rude et al., 1999). In addition, we expected greater costs to ongoing tasks for LDS participants compared to HDS participants, reflecting the fact that LDS participant would be more likely to use internal control strategies. To the extent that internal control strategies adopted by participants increase the likelihood of successfully making time-based PM responses, response times to the lexical decision task and PM accuracy should be positively correlated.
Method

Participants

Potential participants were identified from a pool of 800 undergraduate psychology students. Those who scored in the upper and lower quartiles of the distribution on the depression subscale of the Depression, Anxiety and Stress Scales-21 (DASS-21) were invited to participate. We administered the Beck Depression Inventory-2nd Edition (BDI-II) on the day of the testing to allocate participants into experimental groups (HDS vs. LDS) based on current mood. We selected participants who scored in the moderate to severe range of the BDI-II (BDI-II > 19) for inclusion in the HDS group (N = 31, BDI-II M = 30.06, SD = 6.60), and participants who endorsed minimal depressive symptoms (i.e., BDI-II ≤ 5) were allocated to the LDS group (N = 31, BDI-II M = 1.94, SD = 1.84). The HDS group’s mean BDI-II score was similar to or higher than those reported for depressed or HDS groups in previous PM studies (Altgassen et al., 2011; Altgassen et al., 2009; Chen et al., 2013; Li et al., 2013; Rude et al., 1999). Three participants (all in the HDS group) were on anti-depressant medication. Based on a self-report medical history questionnaire, participants with a previous substance/alcohol dependence, severe neurological or psychiatric conditions (i.e., schizophrenia), or use of psychoactive substances (i.e., benzodiazepines, cannabis, ecstasy) within the past five days were excluded. All participants were native English speakers. The groups did not differ significantly in gender distribution, age, predicted IQ, years of education or alcohol use patterns (all ps > .10, see Table 1). Additionally, groups did not differ in basic attentional ability as measured by the Digit Span subtest (all ps > .10).

Materials and Procedure

The study was approved by the University of Western Australia Human Research Ethics Office. All participants initially completed the DASS-21 early in the semester as part of the screening process to identify potential participants. On the day of the experiment, participants first completed questionnaires on current mood (BDI-II), basic demographics, medical history, and alcohol use (i.e., the Alcohol Use Disorder Identification Test, Bohn, Babor, & Kranzler, 1995). Predicted IQ was then assessed with the Wechsler Test of Adult Reading (WTAR) and basic attention was assessed
with the Wechsler Adult Intelligence Scale-III, Digit Span subtest (forward and backward). Finally, the computerized PM paradigm was administered.

PM Paradigm

We employed a standard laboratory paradigm where a time-based PM task was embedded in an ongoing lexical decision task. For the PM task, participants were required to press the “F1” key on the 4th, 8th and 12th minute into the lexical decision task. Participants could press the spacebar at any moment during the lexical decision task to display a clock representing the elapsed time at the lower right-hand corner of the screen. In the lexical decision task, participants had to decide as quickly and accurately as possible whether presented letter strings were English words or non-words (by pressing “Yes” or “No” keys designated on the keyboard). For the word stimuli, 270 medium frequency words (20-50 occurrences per million) of 4-6 letters in length were selected from the Sydney Morning Herald word database (Dennis, 1995). For the non-word stimuli, 270 pronounceable non-words (also 4-6 letters in length) were obtained from the Macquarie University ARC non-word database (Rastle, Harrington, & Coltheart, 2002). There were two blocks of lexical decision trials, with 270 trials in each block (135 words and 135 nonwords). On each trial, a fixation cross ‘+’ was first displayed in black on a white background for 500 ms, followed by a letter string (word or non-word) that remained on the screen until a response was detected. The inter-trial interval was calculated by subtracting lexical decision response time and fixation time from 3 s (duration of each trial, see Hicks et al., 2005). The fact that each trial had 3 s duration meant that each block’s duration was 13 min, 30 s. In the baseline block, participants performed only the lexical decision task. In the PM block, participants performed the lexical decision task with the time-based PM task requirement embedded. Block order was counterbalanced within groups; half of the participants performed the baseline block first followed by the PM block, whereas the other half performed the PM block first followed by the control block.

All participants were first instructed that “a series of letter strings will appear in the centre of the computer monitor. Your task is to decide whether each letter string shown is a real word or not” and to respond “as ACCURATELY and as QUICKLY as you can”. All participants then completed ten lexical decision practice trials. Participants who performed the baseline block first were then presented the lexical decision instructions again and performed 270 baseline lexical decision trials. After a
one-minute break, they were instructed that “in addition to your word-nonword task performance, the experimenter is also interested in your ability to remember to perform an action in the future. Therefore, in the subsequent block of word-nonword trials, besides performing the word-nonword task, you will be required to press the F1 key on the 4th, 8th and 12th minute into the task”. Participants were also instructed that they could check the clock by pressing the spacebar key which would yield a momentary display of the elapsed time for two seconds at the bottom right hand corner of the monitor. Participants then completed a 3-minute distractor task (Sudoku puzzle), and were then presented 270 lexical decision trials with the embedded PM task (no reminder of the PM task was provided).

In contrast, participants who performed the PM block first proceeded to the PM block after the practice trials. They were first shown the aforementioned lexical decision and PM instructions, completed the Sudoku puzzle, and were then presented the lexical decision trials with the embedded PM task. After a one-minute break, they were informed that “For the subsequent block of word-nonword trials, please note that you are only required to perform the word-nonword task. Unlike the previous block of trials, you do NOT need to remember to press the F1 key”. Participants were then presented the 270 baseline lexical decision trials.

At the end of the experiment, all participants used 5-point Likert scales (1 being the least and 5 being the most) to indicate their self-perceived level of effort (“For the tasks that you have completed, how much effort did you put into performing it?”), and the level of distractibility that they experienced whilst completing the tasks (“During the experiment, did you frequently experience any distracting thoughts which might have affected your ability to perform the tasks?”).

Results

PM Accuracy

PM performance was scored correct when a response was recorded within +/- 20 s (e.g. Hicks et al., 2005; Huang et al., in press) of the target time (e.g., 03:50 – 04:10 for the 4th minute). PM accuracy rate was derived by dividing the number of correct responses by the total number of PM target times (i.e., 3). The PM accuracy rate of HDS participants ($M = .74$, $SD = .27$) was significantly lower than for LDS participants.

Using a shorter (10 second) or longer window (30, 40 or 50 seconds) did not affect the significant pattern of our findings.
(M = .88, SD = .20), t(60) = 2.32, p = .02, Cohen’s d = .59 (medium-to-large effect size).

Clock-checking

To examine clock-checking frequency, we divided the period before each of the three target times (4th, 8th, and 12th minute) into four one-minute quarters – 1st quarter (e.g., 0 to 1st minute, 4th to 5th minute, 8th to 9th minute), 2nd quarter (1st to 2nd minute, 5th to 6th minute, 9th to 10th minute), 3rd quarter (2nd to 3rd minute, 6th to 7th minute, 10th to 11th minute) and 4th quarter (3rd to 4th minute, 7th to 8th minute, 11th to 12th minute). Therefore, each 1st quarter was temporally furthest from a PM target time, and each 4th quarter was temporally closest to a PM target time.

We performed a 2 (Group: HDS vs. LDS) x 4 (Quarter: first, second, third and fourth) mixed ANOVA on the clock checking frequency scores. Although there was an overall trend for HDS participants (M = 25.84, SD = 14.28) to check the clock less frequently in each quarter than LDS participants (M = 32.23, SD = 15.96), there was no main effect of group, F(1,60) = 2.76, p = .10, ηp² = .04, indicating that the frequency of clock checks did not significantly differ between the two groups (see Figure 1a). There was a significant effect of quarter, F(3,180) = 138.83, p < .001, ηp² = .70. A post-hoc analysis using least significant difference (LSD) revealed a significantly greater frequency of time checks in the 4th (M = 4.74, SD = 2.45) than in the 3rd quarter (M = 1.87, SD = 1.19), p < .001, Cohen’s d = 1.49, and in the 3rd than in the 2nd quarter (M = 1.57, SD = 1.08), p = .004, Cohen’s d = .26 (see Figure 1a). There was no significant interaction between group and quarter, F(3,180) = .90, p = .44, ηp² = .02.

For the ANOVAs conducted, while there was some mild departure from normality, it was not pronounced enough to unduly influence the outcomes as ANOVAs are robust to mild violations of normality with adequate and equal sample size (Howell, 2005).
Figure 1. The left panel Figure 1(a) represents the frequency of clock-checking (mean) as a function of Group (HDS and LDS) and Quarter (1st, 2nd, 3rd and 4th) with each quarter representing the respective minute into the task for each target time. The right panel Figure 1(b) represents the reaction time (in ms) as a function of Group (HDS and LDS) and Block (Baseline and PM). Error bars represent standard error of the mean.

Lexical Decision Performance: Costs

For lexical decision accuracy and response time analyses, we excluded lexical decision trials where participants checked the clock (Huang et al., in press). For lexical decision response time, we also excluded incorrect lexical decisions, non-word trials, and response times greater than 3 SDs from the participant’s mean for each block (Hicks et al., 2005; Huang et al., in press; Marsh et al., 2006).

We conducted a 2 (Group: HDS vs. LDS) x 2 (Block: Baseline vs. PM) mixed ANOVA on lexical decision task accuracy (see Table 1 for means). A main effect of block was found, with lexical decision accuracy significantly lower in the PM block ($M = .95 [.947], SD = .04 [.036]$) than in the baseline block ($M = .95 [.953], SD = .04 [.042]$), $F(1,60) = 5.55, p = .02, \eta_p^2 = .09$, indicating a cost to ongoing task accuracy from the embedded time-based PM task. There was no interaction between group and block, $F(1, 60) = .36, p = .55, \eta_p^2 = .006$, and no main effect of group, $F(1, 60) = .23, p = .64, \eta_p^2 = .004$.

A 2 (Group) x 2 (Block) mixed ANOVA conducted on lexical decision response time (see Table 1 for means) revealed no main effect of group, $F(1, 60) = .04, p = .85, \eta_p^2 = .001$, but a main effect of block, $F(1,60) = 18.64, p < .001, \eta_p^2 = .24$, and a group x block interaction, $F(1, 60) = 8.13, p = .006, \eta_p^2 = .12$ (see Figure 1b). Follow-up simple effect tests showed that the LDS participants were significantly slower in the PM block.
(\(M = 678.19, \ SD = 111.12\)) than the baseline block (\(M = 622.39, \ SD = 97.46\)), \(t(30) = 4.51, p < .001, \text{Cohen’s }d = .53\); incurring a cost of 56 ms. In contrast, the HDS participants were not significantly slower in the PM block (\(M = 651.11, \ SD = 109.12\)) than in the baseline block (\(M = 639.71, \ SD = 110.55\)), \(t(30) = 1.21, p = .24, \text{Cohen’s }d = .10\); a difference score of only 11 ms.

Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>HDS (N = 31)</th>
<th>LDS (N = 31)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender distribution (n)(^a)</td>
<td>10m/21f</td>
<td>16m/15f</td>
<td>.12(^b)</td>
</tr>
<tr>
<td>Age</td>
<td>18.10 (.94)</td>
<td>17.90 (.79)</td>
<td>.39</td>
</tr>
<tr>
<td>Years of education</td>
<td>12.10 (.30)</td>
<td>12.16 (.45)</td>
<td>.51</td>
</tr>
<tr>
<td>Alcohol use (AUDIT total score)</td>
<td>5.68 (5.35)</td>
<td>5.94 (4.51)</td>
<td>.84</td>
</tr>
<tr>
<td>WTAR Predicted Full Scale IQ</td>
<td>106.50 (4.52)</td>
<td>106.32 (3.87)</td>
<td>.87</td>
</tr>
<tr>
<td>Digit span forward raw score</td>
<td>10.94 (2.05)</td>
<td>12.06 (6.38)</td>
<td>.35</td>
</tr>
<tr>
<td>Digit span backward raw score</td>
<td>6.81 (2.02)</td>
<td>7.06 (1.63)</td>
<td>.58</td>
</tr>
<tr>
<td>Lexical decision accuracy rate</td>
<td>.95 (.05)</td>
<td>.96 (.03)</td>
<td>.57</td>
</tr>
<tr>
<td>Baseline</td>
<td>.95 (.05)</td>
<td>.95 (.02)</td>
<td>.74</td>
</tr>
<tr>
<td>PM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lexical decision reaction time (ms)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>639.71 (110.55)</td>
<td>622.39 (97.46)</td>
<td>.52</td>
</tr>
<tr>
<td>PM</td>
<td>651.11 (109.12)</td>
<td>678.19 (111.12)</td>
<td>.34</td>
</tr>
</tbody>
</table>

Values are means (standard deviations) and all p-values are based on independent samples t-test unless otherwise specified. \(^a\)f = female, m = male. \(^b\)Value based on Pearson chi square analysis. BDI-II = Beck Depression Inventory-Second Edition. AUDIT = Alcohol Use Disorder Identification Test. WTAR = Wechsler Test of Adult Reading, performance based estimate.

Correlations Between PM accuracy, Clock-checking Frequency and Lexical Decision Performance

We conducted Spearman’s correlations for which there is no assumption of normality. Clock-checking frequency was positively correlated with PM accuracy for both the HDS participants, \(r (29) = .42, p = .02\), and LDS participants, \(r (29) = .36, p = .049\). These two correlations did not differ significantly, Fisher’s \(z = .26, p = .79\). A significant positive correlation was found between PM block lexical decision response time and PM accuracy for the LDS participants, \(r (29) = .47, p = .008\), but not for the
HDS participants, \( r(29) = -0.10, p = 0.59 \). These correlations for the two groups did differ significantly, Fisher’s \( z = 2.28, p = 0.02 \). Lexical decision response times were not correlated with clock-checking frequency for the LDS participants, \( r(29) = 0.27, p = 0.14 \), or the HDS participants, \( r(29) = -0.24, p = 0.19 \), but there was a marginal difference in these two correlations, Fisher’s \( z = 1.95, p = 0.05 \).

**Effort and Distractibility**

There was no difference in self-reported effort between the LDS (\( M = 3.45, SD = 1.29 \)) and HDS (\( M = 2.87, SD = 1.38 \)) groups, \( t(60) = 1.71, p = 0.09 \), Cohen’s \( d = 0.43 \). The HDS participants reported a greater frequency of distracting thoughts (\( M = 3.26, SD = 1.12 \)) than the LDS participants (\( M = 2.26, SD = 0.89 \)), \( t(60) = 3.88, p < 0.001 \), Cohen’s \( d = 0.99 \). However, self-reported distractibility was not correlated with PM accuracy, clock-checking frequency, or lexical decision response time for either the HDS (all \( ps > 0.17 \)), or the LDS participants (all \( ps > 0.24 \)). Note that all participants correctly reported the task instructions to the experimenter at the end of the experiment, demonstrating that they had retained the PM task requirement.

**Discussion**

While some studies have supported depression-related deficits in time-based PM (e.g., Rude et al, 1999, Li et al, 2013) the cognitive control processes underlying this potential deficit have not been extensively studied. The objective of the current study was to examine the internal and external cognitive control processes underlying depression-related time-based PM deficits.

Consistent with previous studies (Li et al., 2013; Rude et al., 1999), we found significantly poorer time-based PM performance for HDS participants compared to LDS participants. This difference in time-based PM performance between groups was of medium-to-large effect size. Our PM findings (Mean BDI-II = 30.06), together with findings from previous studies which employed depressed (Rude et al., 1999; Mean BDI-II = 24.8) or HDS participants (Li et al., 2013, Mean BDI-II = 26.06), are contrary to the findings reported by Albiński et al. (2012; Mean BDI-II = 16.3, Mean Geriatric Depression Scale = 14.22) who found better time-based PM performance in their HDS group compared to a control group. Perhaps the differences in findings between Albinski et al. (2012) and both the current study and other prior work (Li et al., 2013, Rude et al., 1999) could be related to the extent of depression or depressive
symptomatology, that is, time-based PM deficits might be more likely in individuals with clinical depression (Rude et al., 1999), or at least with relatively high depressive symptomatology (current study & Li et al. 2013), and less likely when depressive symptomatology is milder (Albinski et al. 2012). However, this does not explain why Albiński et al. (2012) found that mild depression symptomology was a benefit to time-based PM. Related to this and the point below, it is also not clear why mild depression symptomatology increased clock checking behaviour. Further research (replication) is required for examining time-based PM in individuals with mild depression symptomology.

Consistent with previous time-based PM experiments with healthy controls (e.g., Hicks et al., 2005; Huang et al., in press; Kliegel, Martin, McDaniel, & Einstein, 2001), a J-shaped pattern of clock-checking emerged with clock-checking peaking close to the target time for both HDS and LDS participants. However, unlike Rude et al. (1999), who found that PM deficits were accompanied by less frequent clock-checking in depressed participants, as well as a lack of the expected steep increase in clock-checking frequency with approaching target time by depressed participants, we did not find a significant difference in clock-checking frequency (external control) between our HDS and LDS participants. Our lack of finding in this regard could have been due to the nature of our sample (tertiary students versus Rude et al.'s clinical sample). However, our clock-checking data trended (with a small effect size) in the same direction as Rude et al., with our HDS participants numerically checking the clock less often than LDS participants, including in the 4th quarter when approaching the time-based PM target times. That is, in the 4th quarter the LDS participants checked the clock 5.19 times on average, compared to 4.39 times on average for the HDS participants. The reduced external control of the time-based PM task in the HDS group as the target time approached could quite likely have contributed to the 14% difference in PM response likelihood between the groups. In line with this, the significant correlations between clock-checking frequency and PM performance for both groups indicate that clock-checking was indeed functionally related to PM performance. However, while externally controlling the time-based PM task by clock-checking is clearly crucial to PM performance, it is not the only form of cognitive control strategy that might functionally support time-based PM retrieval (Huang et al., in press). As outlined in the introduction, previous findings of costs to ongoing tasks with healthy controls suggests that participants also must allocate internal control processes to time-based PM tasks.
The current study is the first to evaluate ongoing task performance under non-PM baseline conditions relative to time-based PM conditions (i.e., costs to ongoing tasks) in HDS individuals. We found that ongoing task accuracy was not significantly different between the groups; both groups demonstrated a reduction in lexical decision accuracy in the PM block relative to the baseline block. Importantly, for response times, we found significant costs to the ongoing task for the LDS participants, but not for the HDS participants. This suggested that LDS participants allocated more attentional resources away from the ongoing task and toward the PM task than HDS participants. This is consistent with both Hertel’s (2000) cognitive initiative hypothesis, which states that depressed individuals are less inclined to direct attentional resources to relevant tasks, and the broader literature showing prefrontal cortex hypoactivity (Drevets et al., 2008) and executive function deficits (Clark et al., 2009) in depression. Furthermore, lexical decision response time in the PM block was positively correlated with PM accuracy for the LDS participants (e.g., the increased costs to the ongoing task were associated with better PM performance). This indicates that the LDS participants were able to engage internal control processes to support PM performance, at significant cost to response times for the ongoing task.

Although the finding of costs to the ongoing task indicates that some form of attentional resource or internal control process was allocated to the PM task by LDS participants, the current methodology provides little specification of the exact nature of these resources. There are several theories regarding the cognitive mechanisms that give rise to costs in event-based PM (see Loft & Humphreys, 2012; Smith, Hunt, McVay & McConnell, 2007), but less specific theorizing about the nature of costs in time-based PM. It is plausible that costs represent a few potential types of internal control processes (see Huang et al., in press). Firstly, participants may be estimating the passage of time internally as well as checking the clock, and this time temporal judgment process may compete for resources with non-temporal information processing such as ongoing task performance (Brown & Merchant, 2007; Zakay & Block, 1996). Secondly, internal control processes may be required to maintain the intent to make the PM task response. That is, even if timing estimation is accurate, a PM failure can occur if the PM intention is not retrieved. Thirdly, internal control may be needed to interrupt the ongoing task activity at the appropriate time and to coordinate the timely execution of the PM response. Given the resource demands and high self-initiation requirement associated
with such time-based PM internal control processes, HDS participants may be less likely to use internal control, consistent with the cognitive initiative hypothesis (Hertel, 2000).

**Summary and Conclusion**

Previous studies with depressed individuals have generally shown PM impairment under more cognitively challenging conditions. However, the underlying mechanisms have not been well-specified, particularly with time-based PM. The current study, by incorporating a baseline condition, examined both the external and internal control processes used by HDS and LDS participants on a time-based PM task. Although the HDS participants demonstrated statistically comparable clock-checking frequency when compared to LDS participants, analyses of costs to ongoing task suggest that HDS participants did not internally control the time-based PM task to the extent that LDS participants did. We theorized that perhaps to some extent the HDS participants, due to a lack of cognitive initiative, were less inclined to direct attentional resources to service the time-based PM task. If that were indeed the case, then one implication for intervention strategies would be to compensate for reduced cognitive initiative by teaching depressed individuals strategies that encourage intermittent reviews of goals (e.g., content free cueing or goal maintenance training).

One potential issue in this study is the possible use of antidepressant medication by our HDS sample. However, all the patterns of significant and non-significant findings remained the same even when the small number of medicated participants in the HDS group ($n = 3$) were excluded from the analyses. We note that this is the first paper to have examined time-based PM in HDS participants with such a detailed look at changes in ongoing task performance. We encourage researchers to continue to not only measure overt clock checking behaviour but also investigate the internal cognitive events that intervene between clock observations. Although our HDS participants had significantly elevated BDI-II scores (comparable to samples in previous studies) and demonstrated PM deficits, we acknowledge that we did not use a formal depression diagnosis in our inclusion criteria. It is important to consider the implications of PM studies that use clinical samples of depressed individuals vs. those that focus on samples with HDS. Specifically, elevations on depressive symptoms scales may occur for reasons other than depression (e.g., grief, Walker & Pomeroy, 1996). Therefore results from the present study may be more generalizable to individuals with HDS in the real
world due to a broader range of factors as well as a diagnosable mood disorder. Of note, however, it is likely that our sample included individuals with a diagnosable, but not yet identified and treated depressive disorder. Supporting this, mean BDI-II scores in the range seen in the current study are typical of individuals of those seen in previous research with samples with a clear clinical diagnosis of depression (e.g. mean BDI-II scores ranging from 20.9-30.4 in studies of depression reviewed McEvoy & Nathan, 2007). However, findings of PM deficits may be even stronger if future investigations were to focus on individuals who carry a formal depression diagnosis with clinically significant symptomatology.
References


CHAPTER 4

Event-based prospective memory deficits in individuals with high depressive symptomatology: Problems controlling attentional resources?

Yanqi Ryan Li, Shayne Loft, Michael Weinborn, & Murray T. Maybery
Abstract

Depression has been found to be related to neurocognitive deficits in areas important to successful prospective memory (PM) performance, including executive function, attention, and retrospective memory. However, research specific to depression and PM has produced a mixed pattern of results. The current study further examined the task conditions in which event-based PM deficits may emerge in individuals with high depressive symptomatology (HDS) relative to individuals with low depressive symptomatology (LDS) and the capacity of HDS individuals to allocate attentional resources to event-based PM tasks. Sixty-four participants (32 HDS, 32 LDS) were required to make a PM response when target words were presented during an ongoing lexical decision task. When the importance of the ongoing task was emphasized, response time costs to the ongoing task, and PM accuracy, did not differ between the HDS and LDS groups. This finding is consistent with previous research demonstrating that event-based PM task accuracy is not always impaired by depression, even when the PM task is resource demanding. When the importance of the PM task was emphasized, costs to the ongoing task further increased for both groups, indicating an increased allocation of attentional resources to the PM task. Crucially, while a corresponding improvement in PM accuracy was observed in the LDS group when the importance of the PM task was emphasized, this was not true for the HDS group. The lack of improved PM accuracy in the HDS group compared with the LDS group despite evidence of increased cognitive resources allocated to PM tasks may have been due to inefficiency in the application of the allocated attention, a dimension likely related to executive function difficulties in depression. Qualitatively different resource allocation patterns may underlie PM monitoring in HDS versus LDS individuals.
Depression is characterized by persistent feelings of sadness, negative self-worth, anhedonia, and lethargy (American Psychiatric Association, 2000). Depression-related memory impairments, particularly for tasks requiring self-initiated cognitive control, have been well documented (Gotlib & Joorman, 2010). However, knowledge regarding the relationship between depression or depressive symptomatology and prospective memory (PM) is less comprehensive. PM refers to the ability to remember to execute a delayed intention at a specific time (time-based), or in response to an environmental event (event-based). Depression has been found to predict aspects of daily function such as medication adherence (see Grenard et al., 2011 for a review). Further, Withall, Harris and Cumming (2009) reported that PM was a unique predictor of socio-occupational outcomes in individuals with depression. Therefore, studying the underlying cognitive mechanisms of PM performance related to depressive symptomatology has implications for understanding how PM failures occur, and this in turn may facilitate the development of intervention strategies to improve clinical outcomes (e.g., improving medication and psychotherapy treatment adherence).

The handful of studies examining PM performance in individuals with depression or high depressive symptomatology (Albiński, Kliegel, Sędek, & Kleszczewska-Albińska, 2012; Altgassen, Henry, Bürgler, & Kliegel, 2011; Altgassen, Kliegel, & Martin, 2009; Li, Weinborn, Loft, & Maybery, 2013; Rude, Hertel, Jarrold, Covich, & Hedlund, 1999) have produced varied findings, and provide limited information about the mechanisms by which depression may impact PM. The current study examines the cognitive mechanisms underlying depression-related PM deficits by systematically evaluating the capacity of individuals with high depressive symptomatology (HDS) to prioritise attentional resources to event-based PM tasks, relative to individuals with low depressive symptomatology (LDS).

Neuropsychology of Prospective Memory and Depression

Ellis and Freeman (2008) described the phases in a PM task as involving intention formation, intention retention (over a delay interval), intention initiation during which the specific intention and its associated information are retrieved, and intention execution during which the PM task is performed. Several cognitive processes are important to each of the phases. For example, the ability to retain intention-related information over a delay or retrieve it upon PM target appearance is dependent on retrospective memory. Successful intention initiation whilst engaged in a demanding
ongoing task is dependent on executive processes, such as the strategic division of
attentional resources between competing task demands and the coordination of multiple
responses. Additionally, self-monitoring is required to ensure correct execution of the
intended action. Given the multiple processes involved, neuroimaging studies of PM
have implicated a network of distributed neural regions. Specifically, prefrontal cortical
regions (i.e., rostral prefrontal, dorsolateral, ventrolateral, anterior cingulate cortex)
have been found to be involved in executive processes (e.g., planning, monitoring,
strategic attention allocation) during PM task performance (Burgess et al., 2008;
Burgess, Gonen-Yaacovi, & Volle, 2011; Okuda et al., 1998), whereas the hippocampal
complex has been found to be involved in retrospective memory processes during PM
task performance (Burgess et al., 2008, 2011; Okuda et al., 1998; West, 2008).

Depression and depressive symptomatology have been associated with
neurostructural abnormalities (e.g., reduced gray matter volume in the hippocampus,
prefrontal cortex, cingulate cortex, and striatum (Drevets, Price, & Furey, 2008; Felder
et al., 2012), neurofunctional disturbances to higher order networks (e.g., limbic-
cortical-striatal-pallidal-thalamic circuits; Drevets et al., 2008; Felder et al., 2012;
Ottowitz, Tondo, Dougherty, & Savage, 2002; Sumich, Kumari, Heasman, Gordon, &
Brammer, 2006; Veiel, 1997), and behavioural deficits in multiple cognitive domains
(e.g., executive function, attention, retrospective memory, and processing speed (Clark,
Chamberlain, & Sahakian, 2009), particularly in areas related to strategic control (Henry
& Crawford, 2005; Holmes & Pizzagalli, 2007; Langenecker et al., 2005; Quinn, Harris,
& Kemp, 2012; Veiel, 1997). As many of the neuroanatomical and neurocognitive
processes affected in depression and depressive symptomology are also implicated in
normal PM functioning, depression-related PM impairments would be expected.

**Depression-related Prospective Memory Deficits**

The cognitive initiative hypothesis (Hertel, 2000), which proposes that
depression is associated with a reduced initiative to direct attentional resources to
relevant tasks, has been drawn upon to account for depression-related PM deficits (e.g.,
Altgassen et al., 2009). Specifically, this theory predicts that strategically demanding
PM task conditions should be particularly challenging to depressed individuals. The
multi-process view of PM (MPV; Einstein & McDaniel, 2005) provides a framework
with which to evaluate the strategic demands of a PM task. The MPV claims that
specific task conditions determine the attentional resources required for PM, including
target focality (the extent to which the ongoing task directs attention to the relevant features of a PM target), retrieval cue salience, retrieval cue type (time- or event-based), and the extent to which the PM task is given importance over the ongoing task.

Altgassen et al. (2009; also see Chen, Zhou, Cui & Chen, 2013) manipulated target focality, and found that depressed participants had poorer PM than non-depressed participants under non-focal (more resource demanding), but not focal (less resource demanding), conditions, providing support for the cognitive initiative hypothesis. Also consistent with a specific depression-related deficit in attentional allocation to PM tasks, Albiński et al. (2012) found that HDS did not result in PM deficits when targets were highly salient (i.e., presented in a different colour than non-targets). Furthermore, another study evaluating time based PM (Rude et al. 1999) found that individuals with either depression or HDS checked the experimental clock less frequently, and failed to remember to perform the time-based PM task as often as non-depressed individuals. Similarly, a prior investigation based on the participants in the present study also found PM deficits for time-based PM tasks on the Memory for Intentions Screening Test (MIST, Li et al., 2013), a clinically relevant measure of PM.

Three studies examining resource-demanding PM tasks in depression have produced results inconsistent with those reviewed above. Albiński et al. (2012) reported better time-based PM in mildly depressed compared to non-depressed participants. Li et al. (2013)’s findings which were based on participants in the present study demonstrated no event-based PM deficit for HDS participants compare to LDS participants on the MIST (the Memory for Intentions Screening Test). In a laboratory event-based task arguably more sensitive in detecting PM deficits than the MIST, Altgassen et al. (2011) reported no depression-related deficits (for neutrally or negatively valenced words) when participants were required to make a PM response to any of nine previously studied words presented during an ongoing task. Detection of multiple PM targets has been shown to produce response time costs to the ongoing task on non-target trials relative to a control condition with no PM task requirements (Cohen, Jaudas, & Gollwitzer, 2008; Loft, Kearney, & Remington, 2008), suggesting that the multiple PM targets used by Altgassen et al. was likely a resource demanding PM paradigm (i.e., that it increased working memory and monitoring demands). The fact that PM performance was not impaired by depression for all conditions in the Altgassen et al. study suggests that attention allocation to event-based PM tasks may not always be disrupted in depression. However, note that Altgassen et al. (2011) did report PM deficits for depressed participants for positively valanced target words, which the researchers
attributed to a preferential processing of positive stimuli in healthy participants compared to depressed participants (i.e., mood congruence effect).

The current study further examined the task conditions in which PM deficits can emerge in individuals with HDS relative to those with LDS, and explicitly examined the capacity of HDS individuals to prioritise attentional resources to event-based PM tasks. We used a lexical decision task as the ongoing task as it has demonstrated sensitivity in measuring costs in event-based PM (Smith, Hunt, McVay, & McConnell, 2007). The PM task required participants to respond to any of five previously-studied words presented during the ongoing task, which has been shown to be a resource demanding PM task (e.g., Loft et al., 2008). Instead of varying the difficulty (e.g., focality or salience) of the PM task, we kept the PM task unchanged, and manipulated within-subjects the importance of the PM task relative to the ongoing task. Instructions either emphasized the importance of the PM task (PMI condition), or the importance of the ongoing task (OI condition).

Previous research with non-depressed participants has consistently reported both increased costs to ongoing task performance and improved PM accuracy under PMI, compared to OI, conditions (Loft et al., 2008; Loft & Yeo, 2007; Smith & Bayen, 2004), reflecting increased allocation of attentional resources to the PM task. We expected to replicate these PM importance effects with our LDS participants. However, the crucial research question concerned whether the increased ongoing-task cost and improved PM accuracy under PMI conditions compared to OI conditions would be of similar magnitude for HDS participants. The extent to which HDS participants could also demonstrate increased costs and simultaneously improved PM accuracy under PMI conditions will provide a direct indication of their capacity to allocate additional useful attentional resources to PM tasks when prompted by the instructions. Given the neurostructural abnormalities and neurocognitive deficits associated with depression that implicate networks and processes involved in executive processes and attentional control (Clark et al., 2009; Drevets et al., 2008; Gotlib & Joorman, 2010), and previous PM studies demonstrating poorer PM performance on strategic tasks (Altgassen et al., 2009; Li et al., 2013; Rude et al., 1999), we would expect our HDS participants to be less adept at modulating attention allocation to PM tasks when compared to LDS participants. Further, our experimental design can assist interpretation of the previous inconsistent results in the literature. Specifically, the report by Altgassen et al. (2011) of no depression-related PM deficits with a multiple-target PM task is inconsistent with Hertel’s (2000) cognitive initiative framework, and with Altgassen et al.’s (2009)
previous conclusion that depressed participants have difficulty allocating attentional resources to PM tasks. Presumably, Altgassen et al. (2011) placed equal importance on both the ongoing and PM tasks. Crucially, the present study will manipulate task importance, and we might therefore be more likely to detect PM deficits in the HDS group in the OI condition as the secondary nature of the PM task could further augment the effect of reduced cognitive capacity on PM performance.

Finally, we examined whether response costs on non-target trials were functionally related to PM performance at the within-subjects level by calculating the difference between response times on trials preceding PM hits compared to those preceding PM misses (Loft & Yeo, 2007; West, Krompinger, & Bowry, 2005). Based on the commonly held assumption that slowed decision-making on the ongoing task reflects increased attention allocation to the PM task (for reviews see Loft & Humphreys, 2012; Smith et al., 2007), pre-PM hit response times should be slower than pre-PM miss response times if the costs to ongoing tasks reflect diversion of beneficial attentional resources. In contrast, if PM misses largely reflect attentional resource withdrawal, or diminished resource availability, for both the ongoing task and PM task sets, we might expect null results or the opposite result (longer response times preceding PM misses than PM hits). The demonstration of longer response times on trials preceding PM hits compared to those preceding PM misses is crucial because, compared to previous studies examining event-based PM in depression, it allows us to more firmly conclude that the PM task was truly resource demanding (i.e., that PM retrieval relied on the attentional resources allocated).

Method

Participants

A total of 800 undergraduate psychology students across two semesters were screened for self-reported depressed mood using either the Depression, Anxiety and Stress Scale-42 (DASS-42; first semester) or the Beck Depression Inventory–Second Edition (BDI-II, Beck, Steer & Brown, 1996; second semester), two well-validated and reliable measures of depressive symptoms (Crawford & Henry, 2003; Osman, Kopper, 5

Although it was not ideal that our prescreening in each semester was based on different instruments, the prescreening purpose was to simply identify individuals with extreme levels of depression. Since DASS and BDI scores are highly correlated (Osman et al., 1997), there is not likely to have been any substantial impact of using the different instruments across two semesters.
Barrios, Gutierrez, & Bagge, 2004; Storch, Roberti, & Roth, 2004). This screening was conducted to identify individuals with elevated (upper quartile) or minimal (lower quartile) depressive symptoms, who were then invited to participate in our study (one of several studies available to them) for course credit. The 92 students who volunteered then underwent testing within the same semester. A common measure (i.e., the BDI-II) was administered on the day of testing to allow for allocation into HDS and LDS groups based on current mood. Participants with BDI-II scores above 13 (mild to severe depression) were assigned to the HDS group, whereas participants with scores between 0 and 12 (i.e., minimal) were assigned to the LDS group. Exclusion criteria included a history of or current episode of any significant neurological condition (e.g., Traumatic Brain Injury, seizures), severe psychiatric condition other than depression (e.g., schizophrenia, bipolar disorder), developmental disorder (e.g., attention deficit hyperactivity disorder, dyslexia), diagnosed alcohol/substance use/abuse, high-risk drinking patterns as indicated by the Alcohol Use Disorders Identification Test (AUDIT, Bohn, Babor, & Kranzler, 1995), or use of psychoactive substances (i.e., benzodiazepines, cannabis, ecstasy) within the past five days (to minimise acute or residual effects of drug withdrawal). Consequently, 28 individuals were excluded for the above reasons. Sixty-four participants remained after our exclusion criteria; 32 each in the HDS and LDS groups. Nine participants in the HDS group had been diagnosed with major depression and five were currently using medication. None of the other HDS participants reported any diagnosed psychiatric disorder. There was minimal crossover from HDS to LDS groups between the screening and testing sessions, with 84% remaining in their original grouping. Of the remaining 16%, eight participants with elevated depression screening scores had subsequent scores in the minimal range (HDS to LDS), and two participants with originally minimal symptoms reported elevated symptoms on the second testing (LDS to HDS). BDI-II scores in our HDS cohort ($M_{HDS} = 25.75, SD = 9.98; M_{LDS} = 7.72, SD = 3.32$) were substantially elevated and similar or greater than the mean BDI-II scores reported in previous studies (Altgassen et al., 2009, 2011; Albiński et al., 2012; Chen et al., 2013; Rude et al., 1999). As this was part of a larger study undertaken to investigate the effects of depressive symptomatology, note that the participants in this study were also employed in another study using the MIST PM measure (Li et al., 2013).

Groups did not differ in gender distribution (HDS: 11 males; LDS: 8 males), ethnic composition, alcohol use patterns on the AUDIT ($M_{HDS} = 7.64, SD = 5.24; M_{LDS}$}
Materials and Procedure

Procedures were approved by the University of Western Australia Human Research Ethics Committee. Participation credit in psychology units was provided. After providing informed consent, participants completed the BDI-II, AUDIT, and a basic demographics and medical history questionnaire. Participants then completed digit span forward (DSF) and backward (DSB) subtests of the Wechsler Adult Intelligence Scale-Third Edition (WAIS-III) to assess attention and working memory, and the Wechsler Test of Adult Reading (WTAR) to estimate premorbid IQ. Finally, participants completed the PM procedures.

Prospective memory paradigm. We employed a standard laboratory paradigm with a PM task embedded in an ongoing lexical decision task. Participants decided as quickly and accurately as possible whether letter strings presented were English words or non-words (by pressing “Yes” or “No” keys). On each trial, a fixation cross was presented on the computer screen followed by a presentation of the letter string. The letter string was removed from the display and replaced by a fixation cross for the next trial after the participant responds, or after the maximum duration of 3000 ms, whichever occurred first. The PM task required participants to press the “F1” key whenever one of any five previously studied target words was presented.

A list of 150 medium frequency words (20-50 occurrences per million) of 4-6 letters in length was selected from the Sydney Morning Herald word database (Dennis, 1995). As depressed mood has been associated with attentional biases to negative stimuli (Leppänen, 2006), words with negative emotional connotation as judged by the experimenters (e.g., “bloody”, “suffer”, “worry”) were excluded. A list of 150 pronounceable non-words (also 4-6 letters in length) was obtained from the Macquarie University ARC non-word database (Rastle, Harrington, & Coltheart, 2002). There were three experimental blocks of 100 trials each; a baseline block with no PM task, the OI block, and the PMI block. In the Baseline block participants performed only the lexical decision task. In the PM blocks participants performed the lexical decision task as well as the PM task. Thirty-two sets of stimuli were created by randomly assigning the words and non-words to the three blocks (baseline, OI & PMI). For the two PM blocks, 10 words from the pool were randomly selected to be PM targets, and five
assigned to each PM block. The five targets in each block were presented every 18-21 ongoing task trials. Each of these stimulus sets (including the embedded PM targets words) was then used for one HDS and one LDS participant. Overall then, the two groups received identical stimuli (i.e., the first LDS participant received the exact same stimuli as the first HDS participant; the second LDS participant received the exact same stimuli as the second HDS participant, and so on).

Participants first completed ten practice lexical decision trials. In order to include a pure measure of baseline lexical decision performance, we followed the procedure of Altgassen et al. (2009) and presented the baseline block before the PM blocks (Smith et al., 2007). After the baseline block, participants were informed that the researcher was also interested in their ability to remember to perform actions in the future. Participants studied five PM target words for 2 minutes, and needed to correctly recall all of them before being able to proceed. This ensured that participants had encoded all PM targets before performing the PM task. Participants then completed either the OI or PMI block, the order of which was counterbalanced across participants. Consistent with previous research (e.g., Loft & Yeo, 2007; Loft et al., 2008; Smith & Bayen, 2004), the OI instructions emphasized the importance of the lexical decision task (“Please note that in this case, your performance on the word-nonword task is more important than remembering to press the F1 key. In other words, we would like you to put more effort into performing the word-nonword task”). In contrast, the PMI instructions emphasized the importance of the PM task (“Please note that in this case, remembering to press the F1 key is more important than your performance on the word-nonword task. In other words, we would like you to put more effort into remembering to press the F1 key”). Participants completed a two-minute distractor puzzle before commencing each PM block. After each PM block participants completed a recognition memory test for the five PM targets. Ten words (i.e., five targets from the PM block and five new words) were randomly presented one at a time. Participants pressed a “Yes” or “No” key to indicate whether the word presented was a target. Finally, participants filled in two Likert-scales probing the level of effort they put forth and extent of distracting thoughts they experienced during the task.
Table 1

Neuropsychological Characteristics, Prospective Memory and Ongoing Task Performance as a Function of Group and Block

<table>
<thead>
<tr>
<th>Performance Variables</th>
<th>HDS (n=32)</th>
<th>LDS (n=32)</th>
<th>Group F(df)</th>
<th>Importance F(df)</th>
<th>Interaction F(df)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Neuropsychological Assessment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DSF</td>
<td>10.75 (2.13)</td>
<td>10.59 (2.12)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DSB</td>
<td>6.50 (1.95)</td>
<td>6.75 (1.50)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predicted-IQ on the WTAR</td>
<td>110.69 (7.03)</td>
<td>111.72 (5.77)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Target Recognition Corrected Hit Rate</strong></td>
<td></td>
<td></td>
<td>1.67 (1, 62)</td>
<td>.27 (1, 62)</td>
<td>.27 (1, 62)</td>
</tr>
<tr>
<td>OI</td>
<td>.93 (.20)</td>
<td>.98 (.11)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMI</td>
<td>.96 (.12)</td>
<td>.98 (.08)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PM Accuracy</strong></td>
<td></td>
<td></td>
<td>5.25** (1, 62)</td>
<td>4.91** (1, 62)</td>
<td>4.91** (1, 62)</td>
</tr>
<tr>
<td>OI</td>
<td>.69 (.26)</td>
<td>.74 (.24)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMI</td>
<td>.69 (.28)</td>
<td>.88 (.17)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ongoing Task Accuracy</strong></td>
<td></td>
<td></td>
<td>.16 (1, 62)</td>
<td>.04 (2, 124)</td>
<td>&lt;.01 (2, 124)</td>
</tr>
<tr>
<td>Baseline</td>
<td>.95 (.03)</td>
<td>.95 (.05)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OI</td>
<td>.95 (.04)</td>
<td>.95 (.03)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMI</td>
<td>.95 (.03)</td>
<td>.96 (.04)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ongoing Task Reaction Time (ms)</strong></td>
<td></td>
<td></td>
<td>.24 (1, 62)</td>
<td>97.81* (2, 124)</td>
<td>.72 (2, 124)</td>
</tr>
<tr>
<td>Baseline</td>
<td>595.50 (73.02)</td>
<td>588.23 (71.20)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OI</td>
<td>721.86 (156.15)</td>
<td>747.51 (118.58)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMI</td>
<td>784.88 (170.11)</td>
<td>806.46 (149.12)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. Values are means and standard deviations in parenthesis; HDS = high depressive symptomatology; LDS = low depressive symptomatology; DSF = Digit Span Forward subtest; DSB = Digit Span Backward subtest; OI = ongoing task important; PMI = PM task important; WTAR = Weschler Test of Adult Reading.
*p < .001, **p < .05
Results

Intelligence and Working Memory

Independent groups t-tests revealed no significant differences between the HDS and LDS groups on the DSF, DSB, or predicted IQ (all $t_s <1$).

Response Costs to the Ongoing Task

A 2 (Group; HDS, LDS) x 3 (Block; baseline, OI, PMI) mixed ANOVA was performed on the ongoing lexical-decision task accuracy. Consistent with previous research (e.g., Loft & Yeo, 2007; Smith et al., 2007) accuracy was near ceiling (see Table 1), and all effects were non-significant.

Lexical decision response times were based on word trials only (e.g., Loft et al., 2008; Smith et al., 2007) and descriptive statistics are presented in Table 1. We excluded incorrect lexical decisions, and response times greater than 3 SDs from the participant’s mean for each block. A 2 (Group; HDS, LDS) x 3 (Block; baseline, OI and PMI) mixed ANOVA on response times revealed no main effect of group, and no interaction between block and group. However, there was a significant main effect of block, $F(2, 124) = 97.81, p < .001, \eta^2_p = .61$. As illustrated in Figure 1a, follow-up simple effects tests revealed that lexical decision response times were slower in the OI condition ($M = 734.68, SD = 138.15$) than in the baseline condition ($M = 597.86, SD = 71.63$), $t(63) = 9.38, p < .001, d = 1.24$, and slower in the PMI condition ($M = 795.67, SD = 159.06$) than in the OI condition, $t(63) = 4.91, p < .001, d = .41$. Overall, the lexical decision response time data indicate that both LDS and HDS groups increased allocation of attentional resources to the PM task to a similar extent when the importance of the PM task was emphasised.

PM Accuracy

To examine PM accuracy (i.e., the proportion of targets correctly responded to with the “F1” key), a 2 (group) x 2 (block) ANOVA was performed (see Table 1 for descriptive statistics). Significant main effects of group, $F(1,62) = 5.25, p = .03, \eta^2_p = .08$, and block, $F(1,62) = 4.91, p = .03, \eta^2_p = .07$, were qualified by a significant interaction, $F(1,62) = 4.91, p = .03, \eta^2_p = .07$. We conducted simple effects analyses (using pooled mean square error) with Bonferroni corrections for multiple comparisons (alpha = .0125). As illustrated in Figure 1b, PM accuracy did not differ in the OI block.
between the HDS \((M = .69, SD = .26)\) and LDS \((M = .74, SD = .24)\) groups, \(F(1,62) = .54, p = .47\). However, the HDS group demonstrated poorer PM \((M = .69, SD = .28)\) than the LDS group \((M = .88, SD = .17)\) in the PMI block, \(F(1,62) = 9.78, p = .002, \eta^2_p = .144\). For the LDS group, PM accuracy improved significantly from the OI block to the PMI block, \(F(1,31) = 9.74, p = .003, \eta^2_p = .27\). In contrast, the HDS group’s PM accuracy did not increase from the OI block to the PMI block, \(F < 1\). Thus, the PM accuracy of the HDS group failed to improve to the same extent as the LDS group when the relative importance of the PM task over the ongoing task was increased.

**Figure 1.** Ongoing task response time (Figure 1A, left panel) and prospective memory accuracy (Figure 1B, right panel) as a function of group and block. Error bars represent standard error of the mean.

**Response Times Preceding PM Hits and PM Misses**

To assess whether PM retrieval relied on attentional resources, we compared response times on the four word trials preceding PM hits to response times on the four word trials preceding PM misses (Loft & Yeo, 2007; West et al., 2005). We had a mixed 2 (Group) x 2 (Block) x 2 (Trial type; PM pre-hit vs. PM pre-miss) design, and used multilevel modelling (hierarchical linear modelling; Raudenbush & Bryk, 2002) to analyse the data because this methodology allowed the inclusion of participants with data missing from one of the four within subjects cells (e.g., a participant who did not miss any PM targets in the OI or PMI block). Block and trial type were within subject factors (level 1 predictors) and group was the between subjects factor (level 2 predictor). There was a main effect of block, \(t(208) = 3.11, p = .003, d = .36\), indicating slower response times on the PMI block \((M = 779.78, SD = 154.73)\) than the OI block \((M = 724.67, SD = 155.29)\). There was also a main effect of trial type, \(t(208) = 4.14, p <\)
.001, $d = .39$, with response times slower to trials preceding PM hits ($M = 782.10, SD = 155.26$) than to trials preceding PM misses ($M = 715.25, SD = 182.65$). There were no other main effects or interactions (smallest $p = .26$). These data suggest that the attentional resources allocated to the PM task by LDS and HDS participants were useful to target detection, under both OI and PMI conditions.

**Retrospective Memory for Prospective Memory Targets**

We examined potential group differences in retrospective memory for the PM targets by conducting a 2 (group) x 2 (block) ANOVA on the post-block target recognition corrected hit rates (hit rate - false alarm rate). There were no significant effects (see Table 1). Thus, the HDS and LDS groups did not differ significantly in their ability to recognise targets after completion of the PM task. We re-ran our PM accuracy analysis including only the participants who had perfect memory (i.e., corrected hit rate $= 1$) for the target words (HDS: $n = 24$; LDS: $n = 27$), and found the same pattern of significant PM accuracy findings as those reported above.

**Self-reported Effort and Distractibility**

There was no difference in self-reported effort between the groups on the post-experiment questionnaire, $t(62) = 1.34, p = .19, d = .33$. However, the HDS group reported a greater frequency of distracting thoughts ($M = 1.16, SD = .92$) than the LDS group ($M = .66, SD = .70$), $t(62) = 2.45, p = .02, d = .61$. Reported distracting thoughts for the LDS group were not significantly correlated with BDI scores ($r = .40, p = .02$); however, they were not associated with PM accuracy in either the OI ($r = -.15, p = .42$) or the PMI block ($r = -.25, p = .02$). Reported distracting thoughts for the HDS group were positively associated with BDI scores ($r = .40, p = .02$); however, they were not associated with PM accuracy in either the OI ($r = -.15, p = .42$) or the PMI block ($r = .17, p = .36$).

**Discussion**

Our objective was to examine task conditions in which PM deficits might emerge in depression, and to more precisely examine the capacity of HDS individuals to prioritise attentional resources to event-based PM tasks. Previous research in depression or depressive symptomatology has indicated neurocognitive symptoms, including executive and attentional deficits (Clark et al., 2009; Drevets et al., 2008; Gotlib &
Joorman, 2010). Furthermore, studies of PM in depressed individuals have suggested deficits under strategically demanding conditions (Altgassen et al., 2009; Rude et al., 1999). Accordingly, we expected that compared to the LDS participants, the HDS participants would be less adept at modulating attention allocation to the PM task. We also predicted that emphasizing the importance of the ongoing task may augment any effect of the reduced cognitive control of the HDS participants on PM performance.

Under OI conditions, which we found to be resource demanding for both groups of participants (as indicated by the significant costs), there was no difference in PM between HDS participants and LDS participants. The costs observed in the OI block also appeared functionally related to PM performance. Furthermore, when the importance of the PM task was emphasized, the increase in costs compared to the OI block was of similar magnitude for both groups. Taken together, these findings suggest that under OI conditions, HDS participants could allocate attentional resources to PM tasks as effectively as LDS participants. These findings are consistent with some previous studies reporting no effect of depression on resource-demanding PM tasks (Albiński et al. 2012; Altgassen et al., 2011), and our earlier finding based on the same participants in the present study (Li et al., 2013) that there was no depression-related event-based PM deficits when using the MIST.

However, PM accuracy within the HDS participants did not improve when the importance of the PM task was emphasized. This was in contrast to the LDS group, whose PM performance improved with the increased allocation of attentional resources to the PM task under PMI conditions, consistent with prior research with healthy individuals (e.g., Loft et al., 2008; Loft & Yeo, 2007; Smith & Bayen, 2004). As PM tasks involve a retrospective memory component (Smith et al. 2007) and previous research in naturalistic settings has shown depressive symptomatology to be related to poorer performance on the retrospective component of PM (in an older adult sample; Livner, Berger, Karlsson, & Bäckman, 2008), one possibility is that despite adequate attentional resource allocation, HDS participants had more difficulty than LDS participants in discriminating targets from non-targets in the PMI block. However, this is unlikely. First, Livner et al’s findings have not been replicated in young adult depressed samples, and we failed to find a group difference in post PMI block retrospective memory for the targets. Perhaps more importantly, in Smith and Bayen’s (2004) mathematical model of PM, emphasizing PM importance increases the contribution of the preparatory attentional processes to PM, without increasing the contribution of retrospective memory processes. This makes sense, given that targets in
the Smith and Bayen study, and in our study, were encoded to criterion before the importance instructions were administered. Although the role of retrospective memory cannot be completely ruled out, it is more likely that the observed depression deficits under PMI conditions are linked to some form of attentional resource allocation impairment.

Overall, the current findings are important because they reveal a more subtle picture of the nature of attention allocation to PM tasks by participants with depression. The expectation in most research to date (Albiński et al., 2012; Altgassen et al., 2009; Rude et al., 1999), including our own research (Li et al., 2013), has been that any effects of depression on PM should be most evident under task conditions that increase PM resource requirements. For example, it is common to draw upon the MPV to dichotomize event-PM tasks into resource demanding (e.g., using non-focal, or multiple targets) versus automatic (e.g., using focal, or salient targets), and to predict a clinical deficit only under the resource demanding conditions. This has undoubtedly been a useful approach. However, in the current study we found that HDS participants could perform a resource demanding PM task as well as LDS participants (OI conditions), but at the same time found that the HDS participants could not further improve their PM performance as well as LDS participants when instructed of PM importance. The fact that the HDS participants could not further improve their PM performance despite evidence of having allocated similar amounts of resource as the LDS participants suggests that the PM intention is held but there are inefficiencies in resource allocation (i.e., quality versus quantity).

Smith and Bayen’s (2004) mathematical model of PM using healthy participants has shown that the contribution of attentional resource allocation to the probability of PM retrieval is significantly increased under PMI conditions compared to OI conditions. That is, the increased PM accuracy with greater PM task importance is largely driven by the increased allocation of attention to the PM task. It is possible that HDS participants used inefficient monitoring strategies, thereby not allowing these additional resources to benefit PM performance when the importance of the PM task was emphasized. That is, while HDS participants demonstrated equivalent costs under PMI conditions (an indicator of overall attention allocation to the PM task), it does not imply that they used qualitatively similar attentional processes as LDS participants. Similarly, although the fact that response times preceding PM-hits were slower than response times preceding PM-misses under PMI conditions indicates some level of dependence of PM retrieval on resource allocation, this methodology provides little indication of the extent to which
attentional resources were allocated optimally. Processes employed during PM attention allocation are unlikely unitary; instead, multiple distinct resource allocation patterns, reflecting different PM monitoring processes, are likely. For example, Guynn (2003) proposed that costs reflect two qualitatively different processes. First, individuals maintain their memory system in a retrieval mode, described as a mental set for treating ongoing task items as PM retrieval cues. Second, individuals more intermittently “check” for targets. Both processes are required for successful target detection. Despite adequate maintenance of a retrieval mode, HDS participants may have actively checked for targets less frequently, possibly due to an increase in distracting thoughts (as self-reported). A major challenge for further research will be to move away from describing one single aspect of controlled PM processes (such as ‘attentional resources’) in characterizing the qualitatively different resource allocation patterns that depressed individuals may exhibit while engaging in strategic PM monitoring.

Previous research in depression has revealed neurostructural and neurocognitive disturbances in depression that have implications for the PM functioning of depressed individuals. Thus, our findings which are suggestive of inefficient resource allocation could be partly related to the hypoactive prefrontal networks mediating executive function and attentional control in depression. This inefficiency in depression could be a further dimension of higher order executive function in relation to not only whether resources have been allocated, but also the extent to which the allocated resources have been utilized effectively or strategically applied. This phenomenon of executive function-mediated PM deficits in HDS individuals parallels the findings of previous PM research on other clinical samples with compromised executive function such as individuals with HIV infection (Carey et al., 2006), Alzheimer’s disease (Farina, Young, Tabet, & Rusted, 2013), traumatic brain injury (Henry et al., 2007) or a history of ecstasy use (Weinborn, Woods, Nulsen, & Park, 2011).

It is important to note that our sample comprised young, high functioning students, and not all carried a formal depression diagnosis (although symptom severity was similar or greater than that reported in previous studies). Thus, further research is warranted. Nevertheless, the fact that depression-related PM deficits were found in individuals with high intellectual function and relatively short symptom duration is important, and raises the possibility that individuals with more chronic courses of depression, and lower educational attainment or IQ, may display more severe PM deficits. In addition, the presence of PM deficits in a sample of individuals with HDS (which, in addition to those with Major Depressive and Persistent Depressive Disorders,
also may include individuals with anxiety, adjustment disorders and grief reactions) raises the possibility that PM deficits are possible in a broader range of mood-related disturbances. Further research evaluating PM in those with anxiety and other related disorders is needed.

It is also important to note that by including individuals in the LDS group who demonstrated elevated depressive symptomatology during initial screening (i.e., HDS at screening but LDS at testing), our LDS group were more likely representative of the general population, as transient and/or subthreshold depressive symptoms are not uncommon (Lewinsohn, Solomon, Seeley, & Zeiss, 2000; Rosenthal & Schreiner, 2000). This approach is therefore arguably more conservative than selecting a “pure” comparison sample with consistent and very low levels of depressive symptoms, and our finding of a HDS-related PM deficit is more likely to be generalizable.

The finding of PM deficits in a high functioning HDS sample, and likelihood of more severe deficits in clinically diagnosed depression suggests important implications for treatment, where psychotherapeutic and psychopharmacological interventions both require substantial PM capability for treatment adherence and favorable outcomes. Future studies using participants with chronic depression are clearly needed. Given suggestions of inefficiencies in attention allocation in the HDS participants, future studies should investigate the efficacy of interventions that either seek to direct attention to relevant tasks in a structured manner such as goal maintenance training (Levine et al., 2000), and/or directly enhance PM recall via enhanced intention encoding such as implementation intentions (Gollwitzer, 1999). Given the debilitating nature of depression, future studies illuminating the effectiveness of such interventions would assist in the development of rehabilitation strategies relevant to those suffering from depression-related cognitive impairments.
References


CHAPTER 5

Effects and mechanisms of implementation intentions and goal maintenance training on prospective memory performance in individuals with high levels of depressive symptomatology
Abstract

Prospective memory (PM) deficits under strategically demanding event-based conditions have not been consistently found in individuals with depression or high depressive symptomatology. The present study investigated the possibility that previous null findings were due to insufficient strategic PM task demands by employing a particularly well-established resource demanding PM paradigm. In addition, based on previous findings of reduced attention allocation and inefficient resource utilization in individuals with high depressive symptomatology (HDS), the study investigated the effects of implementation intentions and goal maintenance training (GMT) on the attentional function and PM performance of HDS participants. Attention allocation was investigated by comparing the changes to ongoing task costs (i.e., lexical decision response time) between groups of individuals with high and low depressive symptomatology (LDS), and between the intervention groups (i.e., implementation intentions and GMT versus standard PM instructions). Findings showed that the PM performance of HDS and LDS participants were not different under strategically demanding PM conditions. Implementation intentions led to better PM performance for both HDS and LDS participants compared to standard PM instructions. Although inconclusive, there was some suggestion that resource demanding processes were involved in this implementation intention PM advantage. The PM performance of HDS and LDS participants receiving GMT was also better than the performance of HDS and LDS participants receiving standard PM instructions. Relative to standard PM instructions, GMT significantly increased attention allocation (reflected by greater ongoing task costs) and enhanced resource utilization (i.e., costs were positively related to PM performance) in HDS and LDS participants. Overall, the findings showed that in spite of previously documented attentional problems during PM performance, HDS individuals have the potential to benefit from intervention strategies.
As reviewed in previous chapters, depression related prospective memory (PM) deficits have been found under strategically demanding conditions (Altgassen, Kliegel, & Martin, 2009; Chen, Zhou, Cui, & Chen, 2013; Rude, Hertel, Jarrold, Covich, & Hedlund, 1999). For example, PM deficits in depressed individuals have been consistently demonstrated under time-based PM conditions where there is a need to self-initiate clock checking with increasing frequency as the appropriate time approaches for the PM response (Rude et al., 1999). This has been further corroborated by two studies conducted in this thesis (Studies 1 and 2). Also, studies using event-based PM tasks have found poorer PM performance for HDS compared to LDS participants with non-focal PM targets, that is, targets which possess features that are not relevant to ongoing task performance, and therefore require extra resources to detect (Altgassen et al., 2009; Chen et al., 2013). However, this finding has not been consistently found, with two studies from the current thesis (Studies 1 and 3) and previous investigations (Altgassen, Henry, Bürgler, & Kliegel, 2011) showing no effect of depression on PM performance with non-focal cues.

The study findings reported in Chapter 3 (Study 2) of this thesis indicated reduced allocation of resources to support time-based PM performance. Similarly, the findings reported in Chapter 4 (Study 3) on event-based PM suggest that participants with HDS may be inefficient in the utilization of allocated resources. Further, this notion of a processing inefficiency underlying depression-related PM deficits was reinforced by an eye-tracking study conducted by Chen et al. (2013) which found that depressed participants demonstrated more fixations and longer fixation durations on PM targets despite corresponding lower PM accuracy. Given the suggestion of reduced attention allocation and inefficiencies in resource processing in previous chapters and Chen et al. (2013), the present study investigated whether intervention strategies designed to enhance PM would assist with the attentional function of depressed participants (i.e., increase attention allocation or improve efficiency of that resource utilization). Specifically, the study examined the effectiveness of implementation intentions, an encoding strategy that has been shown to benefit PM performance under conditions of high strategic load (Brandstätter, Lengfelder, & Gollwitzer, 2001; Brewer, Ball, Knight, Dewitt, & Marsh, 2011; Chasteen, Park, & Seward, 2001; McDaniel, Howard, & Butler, 2008; McFarland & Glisky, 2012; but also see McDaniel & Scullin, 2010 for different findings). As a secondary interest, the study also examined whether an adapted version of goal management or maintenance training (GMT, Levine et al., 2000) with elements of content-free cueing (Fish et al., 2007; Manly, Hawkins, Evans,
Implementation Intentions

Implementation intentions refer to a method of encoding an intention such that the criterion for its execution is stated specifically and deliberately linked with the intended action (Gollwitzer, 1999). Implementation intentions are usually instantiated in the form of “if-then” or “when-then” statements. Although standard PM instructions in typical laboratory studies (e.g., “when you see the word ‘rake’, remember to press the F1 key”) strongly resemble implementation intentions, the distinguishing feature of implementation intentions is that the associative link between the criterion and the intended action is deliberately strengthened or emphasized during encoding whereas the associative link is not emphasized during encoding in standard PM instructions (Cohen & Gollwitzer, 2008). Associative links are commonly strengthened in implementation intentions through techniques such as verbal repetitions of if-then or when-then statements (e.g., “when I see the word spaghetti, I will press the Q key”) and/or visual imagery (McDaniel et al., 2008; McDaniel & Scullin, 2010; McFarland & Glisky, 2012; Meeks & Marsh, 2010). Some implementation intentions studies have examined the component involving the strengthening of target-response (‘if-then’) associations separately from the visual imagery component (McFarland & Glisky, 2012; Meeks & Marsh, 2010) whereas other studies have combined the if-then and the visual imagery components together and considered it as implementation intentions (Chasteen et al., 2001; McDaniel et al., 2008; McDaniel & Scullin, 2010). The current study adopted the latter approach and considered both the verbal strengthening of the if-then association and visual imagery as implementation intentions.

Evidence gathered from laboratory based studies with healthy individuals show that implementation intentions, relative to standard PM instructions, are effective at maintaining PM performance under attentionally or strategically demanding conditions (Brandstätter et al., 2001; Brewer et al., 2011; Chasteen et al., 2001; McDaniel et al., 2008; McFarland & Glisky, 2012; but also see McDaniel & Scullin, 2010 for different findings). Implementation intentions have also been found to benefit the PM of healthy older adults (Zimmermann & Meier, 2010), older adults categorised as having low frontal lobe function (McFarland & Glisky, 2011), individuals undergoing opiate withdrawal (Brandstätter et al., 2001) and individuals with schizotypal personality
features (Chen et al., 2013). The exact mechanism of implementation intentions is not entirely clear but posited mechanisms include automatizing intention retrieval via heightened cue accessibility (Gollwitzer, 1999; Rummel, Einstein, & Rampey, 2012), enhancing associative retrieval with successful PM execution contingent upon the availability of further resource to coordinate between PM task execution and current ongoing task demands (McDaniel & Scullin, 2010; McFarland & Glisky, 2011), and increasing the amount of attention allocated to the PM task by enhancing the PM task’s perceived importance (Meeks & Marsh, 2010). Studies that employ well-specified PM cues (McDaniel & Scullin, 2010; McFarland & Glisky, 2011; Rummel et al., 2012) tended to postulate less resource demanding mechanisms underlying the benefits of implementation intentions whereas studies that used poorly specified PM cues (e.g., searching for the ‘tor’ syllable in words) tended to postulate more resource demanding mechanisms (Meeks & Marsh, 2010).

Goal-maintenance Training

Another cognitive compensatory intervention which appears promising but has not been investigated in PM research is goal management or maintenance training (GMT, Levine et al., 2000). GMT is a structured intervention strategy that uses a series of self-review steps (i.e., stop, define, list, learn, check) to hierarchically organize and decompose complex daily activities or behaviours in a goal-oriented manner (Levine et al., 2000, see appendix B for a detailed description of the five GMT steps adapted for use in the current study). By doing so, GMT seeks to actively structure, direct and maintain one’s attention onto task relevant goals. GMT was initially developed to assist with problems such as distractibility, neglect of relevant task goals and disorganized behaviour in traumatic brain injury patients (Levine et al., 2000; Levine et al., 2011). GMT has since been shown to be useful for other populations such as polysubstance abusers (Alfonso, Caracuel, Delgado-Pastor, & Verdejo-García, 2011), older adults (Levine et al., 2007) and spina bifida patients (Stubberud, Langenbahn, Levine, Stanghelle, & Schanke, 2013). Although GMT has been shown to benefit the performance of neurologically impaired patients on particular neuropsychological tasks such as proof-reading, grouping of multidimensional information, Go/no-go and Tower tests (Levine et al., 2000; Levine et al., 2011; Stubberud et al., 2013), the effectiveness of GMT on PM performance in depressed individuals has not been investigated. If GMT can be shown to improve PM performance in individuals with high depressive
symptomatology, then there could be implications for its specific use for PM deficits in clinical or cognitive rehabilitation settings. This would be a useful addition to the limited number of neurocognitive rehabilitation strategies targeted at depression related cognitive deficits (e.g., cognitive control training developed by Siegle, Ghinassi, & Thasi, 2007).

In the current study, content-free cueing was incorporated into the GMT procedure to enhance its effectiveness (Fish et al., 2007). Basically, content-free cueing is a strategy that seeks to prompt the recall or review of task-relevant goals through the intermittent provision of cues (Fish et al., 2007). It has been implemented in the form of intermittent alerts involving auditory stimuli (Manly et al., 2002) or texts such as ‘STOP!’ (Fish et al., 2007), and has been shown to be successful at assisting brain injury patients with the performance of simulated administrative tasks such as running a hotel (i.e., the ‘Hotel’ test, Manly et al., 2002) or remembering to make telephone calls to the experimenter (Fish et al., 2007).

**Current Study**

As noted earlier, not all studies that employed non-focal PM tasks have consistently found an effect of depression on PM performance (Altgassen et al., 2011; Studies 1 and 3 of current thesis). The findings of Study 3 which employed multiple non-focal but specific cues embedded in an ongoing lexical decision task showed that event-based PM was unimpaired under conditions where the ongoing task’s importance was emphasized. Likewise, Altgassen et al. (2011) found no difference in PM performance with emotionally neutral (“apple, rabbit, surfboard”) or negative cues (“sadness, tiredness, sorrow”) which were non-focal (i.e. irrelevant) to ongoing task performance (i.e., whether the left or right word matches a category). The current study investigated whether event-based PM deficits in depression would be found with a more strategically challenging PM task such as the one used in Meeks and Marsh (2010). In this paradigm, PM cues were syllables (e.g., ‘tor’, ‘ver’, ‘fer’) embedded in English words (e.g., ‘tortoise’, ‘version’, ‘circumference’, etc) where were presented during an ongoing lexical decision task. Healthy participants have been shown to incur significant ongoing task costs with this paradigm which demonstrates the strategically demanding nature of the task (Einstein et al., 2005; Loft & Remington, 2013; Meeks & Marsh, 2010). Furthermore, Meeks and Marsh (2010) found that their non-specific cue conditions (i.e., respond to words with the ‘tor’ syllable or animal words) led to greater
response times on the ongoing task than their multiple specific cue condition (i.e., respond to ‘deer’ or ‘cow’). This shows that resource demands are greater with non-specific cues than multiple specific cues. Thus, if the null findings in Studies 1 and 3 were strictly due to insufficient strategic task demands (from the use of multiple specific cues), then PM deficits between high depressive symptomatology (HDS) and low depressive symptomatology (LDS) participants may be more likely to emerge under this paradigm using non-specific cues.

Based on the reviewed effectiveness of implementation intentions in enhancing PM performance in various healthy and non-healthy populations, the current study investigated the capacity of implementation intentions to assist with the attentional function and PM performance of individuals with HDS. The findings reported by Meeks and Marsh (2010) of increased ongoing task costs and greater PM accuracy with implementation intentions relative to standard PM instructions indicate that implementation intentions could potentially increase the attention allocated to PM tasks. Accordingly, it was predicted that HDS and LDS participants receiving implementation intentions would demonstrate greater costs to ongoing task performance and greater PM accuracy than HDS and LDS participants receiving standard instructions. It would also be interesting to see whether HDS participants who are prone to attentional deficits and PM problems would benefit more or less from implementation intentions than LDS participants. As investigating implementation intentions was the primary research aim of the current study, its order in the experiment was prioritized over that of GMT. Thus, implementation intention was employed after the collection of baseline ongoing task performance in the second block, whereas GMT was always implemented in the third block after participants received implementation intentions. Therefore, the order of implementation intentions and GMT was not counterbalanced as the study’s primary objective was to obtain a ‘pure’ assessment of the effectiveness of implementation intentions. The reader should note that with this non-counterbalanced design, GMT should only be viewed as additive or adjunctive. For GMT, based on the theoretical claim that it redirects or restructures attention towards task relevant goals (i.e., PM task), it was predicted that the LDS and HDS participants receiving GMT would experience greater costs to ongoing task performance and greater PM accuracy than LDS and HDS participants receiving standard instructions.

The present study employed a multifactorial 2x2x2 mixed design. Depressive symptomatology group (HDS vs. LDS) and Intervention group (no intervention vs intervention) were between subject-factors, and block, the within-subject factor
(baseline, Block 2, Block 3). More specifically, there were four independent groups of participants - LDS with intervention that received implementation intentions at Block 2 and GMT at Block 3 (LDS+I), HDS with intervention that received implementation intentions at Block 2 and GMT at Block 3 (HDS+I), LDS without intervention that received standard PM instructions at Block 2 and Block 3 (LDS+Std) and HDS without any intervention and receiving standard PM instructions at Block 2 and Block 3 (HDS+Std). Note that all four groups of participants performed a baseline lexical decision block (without PM requirements) at Block 1.

Methods

Participants

Potential participants were identified from a pool of 800 undergraduate psychology students. Those who scored in the upper and lower quartiles of the distribution on the Depression subscale of the Depression, Anxiety and Stress Scales-21 (DASS-21) were invited to participate. The Beck Depression Inventory-2nd Edition (BDI-II) was administered on the day of the testing to allocate participants into experimental groups (HDS vs. LDS) based on current mood. Note that individuals with a self-reported history of substance/alcohol dependence, severe neurological or psychiatric conditions (i.e., schizophrenia), or use of psychoactive substances (i.e., benzodiazepines, cannabis, ecstasy) within the past five days were excluded. Participants who scored in the mild to severe range of the BDI-II (BDI-II > 13) were allocated to the HDS group, and participants who endorsed minimal depressive symptoms (i.e., BDI-II ≤13) were allocated to the LDS group. Then, participants within each group were randomly assigned to the intervention or non-intervention group. Thus, there were four separate groups: HDS+I (N = 26), HDS+Std (N = 21), LDS+I (N = 30), and LDS+Std (N = 34). The HDS groups (M = 27.64, SD = 8.94) endorsed significantly greater depressive symptomatology than the LDS groups (M = 5.25, SD = 3.72), but there was no significant difference in depressive symptomatology between the HDS+I (M = 25.96, SD = 8.35) and HDS+Std (M = 29.71, SD = 9.40) groups, t(45) = 1.45, p = .16, d = .42, or between the LDS+I (M = 5.83, SD = 3.82) and LDS+Std (M = 4.74, SD = 3.60) groups, t(62) = 1.18, p = .24, d = .29. Note that the HDS groups’ mean BDI-II scores were similar to those reported in previous chapters (Studies 1, 2 and 3) and in previous PM studies (Altgassen et al., 2009, 2011; Chen et al., 2013; Rude et al., 1999). See Table 1 for the demographic characteristics of each group. Gender distribution was
not significantly different between the groups ($p = .94$). No effect of depressive symptomatology, intervention group or any interaction between depressive symptomatology and intervention group were found for age, predicted IQ, years of education, alcohol use patterns or forward digit span (all $p$s > .10, see Table 1). However, there was an effect of depressive symptomatology on backward digit span, $F(1,107) = 8.24, p = .005, \eta^2 = .07$, with the LDS groups demonstrating higher backward digit span ($M = 7.35, SD = 1.61$) than the HDS groups ($M = 6.51, SD = 1.40$). There was no effect of intervention or any interaction between depressive symptomatology and intervention group on backward digit span score ($p$s > .10).

Materials and Procedure

Procedures were approved by the University of Western Australia Human Research Ethics Committee. After providing informed consent, all participants completed questionnaires on basic demographics, medical history and alcohol use (the Alcohol Use Disorder Identification Test [AUDIT]). Participants then completed the digit span forward (DSF) and backward (DSB) subtests of the Wechsler Adult Intelligence Scale-Third Edition (WAIS-III) to assess basic attention and working memory, and the Wechsler Test of Adult Reading (WTAR) to estimate premorbid IQ. Finally, participants completed the PM procedures.
Table 1
Demographics, Neuropsychological and Performance Variables for Intervention and Non-intervention Groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Intervention (N = 56)</th>
<th>Non-intervention (N = 55)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LDS+I (n = 30)</td>
<td>HDS+I (n = 26)</td>
</tr>
<tr>
<td>Gender distribution (m = male, f = female)</td>
<td>13m/17f</td>
<td>8m/18f</td>
</tr>
<tr>
<td>Age in years</td>
<td>18.20 (1.38)</td>
<td>18.00 (1.13)</td>
</tr>
<tr>
<td>Years of education</td>
<td>12.37 (.96)</td>
<td>12.19 (.57)</td>
</tr>
<tr>
<td>Alcohol use (AUDIT total score)</td>
<td>6.00 (4.25)</td>
<td>5.15 (4.20)</td>
</tr>
<tr>
<td>WTAR Predicted Full Scale IQ</td>
<td>106.17 (3.79)</td>
<td>106.88 (3.89)</td>
</tr>
<tr>
<td>Digit span forward raw score</td>
<td>12.03 (6.41)</td>
<td>11.31 (2.00)</td>
</tr>
<tr>
<td>Digit span backward raw score</td>
<td>7.27 (1.70)</td>
<td>6.73 (1.31)</td>
</tr>
<tr>
<td>Lexical decision accuracy rate</td>
<td>Baseline: .95 (.04)</td>
<td>.96 (.04)</td>
</tr>
<tr>
<td>Block 2 (implementation)</td>
<td>.96 (.03)</td>
<td>.96 (.03)</td>
</tr>
<tr>
<td>Block 3 (GMT)</td>
<td>.97 (.02)</td>
<td>.97 (.02)</td>
</tr>
<tr>
<td>Lexical decision word response time (ms)</td>
<td>Baseline: 571.67 (57.74)</td>
<td>576.29 (52.76)</td>
</tr>
<tr>
<td>Block 2 (implementation)</td>
<td>748.12 (105.22)</td>
<td>740.82 (128.70)</td>
</tr>
<tr>
<td>Block 3 (GMT)</td>
<td>766.35 (151.03)</td>
<td>780.80 (176.09)</td>
</tr>
<tr>
<td>PM accuracy rate</td>
<td>Block 2 (implementation)</td>
<td>.70 (.20)</td>
</tr>
<tr>
<td>Block 3 (GMT)</td>
<td>.80 (.26)</td>
<td>.78 (.16)</td>
</tr>
<tr>
<td>PM task perceived importance</td>
<td>Block 2 (implementation)</td>
<td>4.73 (1.36)</td>
</tr>
<tr>
<td>Block 2 (GMT)</td>
<td>4.90 (1.37)</td>
<td>5.07 (1.23)</td>
</tr>
</tbody>
</table>
PM Paradigm

The study employed a standard laboratory paradigm with a PM task embedded in an ongoing lexical decision (LD) task. Participants had to respond as quickly and as accurately as possible to whether letter strings presented were English words or non-words (by pressing “Yes” or “No” keys). On each trial, a fixation cross was presented on the computer screen for 1000 ms followed by a presentation of the letter string. The letter string was removed from the display and replaced by a fixation cross for the next trial after the participant responded, or after the maximum duration of 3000 ms. There were 600 experimental LD trials in total (300 word and 300 nonword trials) which were divided into three blocks of 200 trials (Baseline, Block 2 and Block 3). There were 100 word and 100 nonword trials in each block with the trial type ordered in a random manner. Participants performed only the LD task in the Baseline block whereas they performed the LD task as well as the PM task in Block 2 and Block 3. The PM task required participants to press the “F1” key whenever any word containing a target syllable was shown (either ‘tor’, ‘ver’, or ‘fer’ depending on which particular syllable was assigned to the block). There were five different PM targets in each block, that is, five words that contained the target syllable for that block. To minimise the predictability of target appearances, the targets were presented at irregular intervals, appearing on trials 36, 89, 125, 171 and 198 (27-53 trials apart).

Stimuli

For the current study, 285 medium frequency words (20-50 occurrences per million) from the Sydney Morning Herald word database (Dennis, 1995) were selected to create a list of word stimuli for the LD task. To create a list of non-word stimuli, another 300 medium frequency words were selected from the same database and the vowels in each word were replaced to generate a list of pronounceable non-words (e.g., chemist to chamust). For the PM targets, as indicated above, three target syllables (‘fer’, ‘tor’, and ‘ver’) were used to create three sets of target words for each experimental block: for Set A, the target syllable was ‘fer’ (offering, transfer, referee, feral and suffer); for Set B, the target syllable was ‘tor’ (factory, victory, editor, monitor and investor); and for Set C, the target syllable was ‘ver’ (coverage, deliver, recover, poverty and version). For each of the four experimental groups, the first participant was presented with Set A in the Baseline block, Set B in Block 2, and Set C in Block 3 (ABC); the second participant was presented with targets in the order ACB and so forth.
Thus the set orders used for successive participants in each experimental group were ABC, ACB, BAC, BCA, CAB and CBA, followed by repetition through this cycle. Thus, the order of the experimental sets used was counterbalanced between participants in each of the four experimental groups. Note that whenever a set of target stimuli (e.g., ‘fer’) was assigned to the Baseline block, the words (e.g., offering, transfer, referee, feral and suffer) were presented but no PM response was required as participants were not introduced to the PM instructions yet.

**Implementation Intention Intervention**

All participants first completed ten practice LD trials. Next, in order to include a pure measure of baseline LD performance, the Baseline block was presented (in which the first set of target stimuli would have been assigned, e.g., words for the ‘fer’ syllable) before the two PM blocks (Smith et al., 2007). After the Baseline block and a one-minute break, all participants proceeded to Block 2 (in which the next set of target stimuli would have been assigned, e.g., words for the ‘tor’ syllable) where they were presented with standard PM instructions that informed them that “in addition to your word-nonword task performance, the researcher is interested in your ability to remember to perform an action in the future. If you see a word containing the syllable ‘tor’ (e.g., “tortoise”, “actor”, etc) during the word-nonword task, please press the F1 key and NOT the Yes key”. Note that this instruction was varied depending on the syllable assigned to the condition. Participants in the intervention groups (LDS+I and HDS+I) were further informed that strategies would be provided to assist them. They were then presented with the instructions for implementation intentions. As with previous studies (McDaniel et al., 2008; McDaniel & Scullin, 2010; Meeks & Marsh, 2010), the implementation intention instructions for the current study incorporated a visual imagery component and a verbal if-then component. For the visual imagery component, participants were presented with the following set of instructions “Now, please take a few moments to imagine yourself responding to a word containing the syllable ‘tor’. Please visualise yourself making a word-nonword judgment when encountering a ‘tor’ word. Then imagine yourself pressing the "F1" key in response to seeing this word. Take a few moments, close your eyes and imagine seeing a ‘tor’ word after which you will press the "F1" key. You will now be given some time to perform the visualization exercise (30 seconds was given)”. Following this visual imagery, participants proceeded to the verbal if-then component where they were required to “tell
the experimenter three times when I see a ‘tor’ word, I will press the F1 key". This was followed by a four minute distractor task (Sudoku). After this, the HDS+I and LDS+I participants performed the LD task with the embedded PM targets. Note that no reminder of the PM task was provided at this point.

After the baseline block, the non-intervention groups (LDS+Std and HDS+Std) also received the same set of standard PM instructions as the intervention groups (LDS+I and HDS+I), “in addition to your word-nonword task performance, the researcher is interested in your ability to remember to perform an action in the future. If you see a word containing the syllable ‘tor’ (e.g., “tortoise”, “actor”, etc) during the word-nonword task, please press the F1 key and NOT the Yes key”. However, instead of receiving implementation intentions after this, the non-intervention groups proceeded directly from the standard PM instructions to the distractor task. To ensure that the non-intervention groups did not start performing the ongoing task earlier in Block 2, the duration of their distractor task was lengthened (5 min 45 s). Thus, the interval from when the PM instructions were delivered to when the LD task was performed was standardized for both intervention and non-intervention groups. After the distractor task, the non-intervention groups performed the LD task with the embedded PM task. Note that no reminder of the PM task was provided at this point. At the end of the LD task in Block 2, all participants recalled the task instructions to the experimenter and used a 7-point Likert scales (1 = Extremely Unimportant, 7 = Extremely Important) to rate the importance of the LD task and the PM task.

**GMT Intervention**

Following another one-minute break, all participants then proceeded to Block 3 where they were provided with standard PM task instructions for another stimulus set (target syllable not used in the previous two blocks, e.g., words with ‘ver’. Participants in the intervention groups (LDS+I and HDS+I) were additionally informed that they would be given another set of strategies and were presented with a modified set of GMT instructions (see Appendix B). Specifically, they were shown a flowchart detailing the five steps involved (Stop, Define, List, Learn and Check) similar to Levine et al. (2000), see Appendix A. The experimenter then went through five separate slides in detail with the participants, reviewing each step via a set of standardized script. Refer to Appendix B for the entire script. To mimic the content-free cueing procedure used in Fish et al. (2007), participants were informed that a STOP sign with the words ‘Stop, Define, List,
Learn, Check’ below it (see Appendix C) would appear every now and then during the LD task for 15 seconds at a time. Participants were instructed to mentally review all the five steps for the duration of the STOP sign during its appearance. The STOP sign was presented three times on trials 50, 100 and 150 of the LD task, which were more than 20 trials away from a PM target presentation. To ensure understanding of the five steps involved in GMT, participants were then quizzed with five multiple-choice questions. Participants could only proceed if they provided the correct response for all questions; questions were repeated for any incorrect responses. Participants then performed 20 trials of the LD task as practice with the STOP sign appearing on the 5th trial and the target syllable on the 18th trial. Then participants performed another four-minute distractor task (Sudoku) before commencing the final block of LD task with the embedded PM task. No reminder of the PM task was provided at this point.

In Block 3, participants in the non-intervention groups (LDS+Std and HDS+Std) were given the same standard PM instructions as the intervention groups. Note that participants in the non-intervention groups were also informed that a STOP sign would appear occasionally during the LD task and were also exposed to the same STOP sign as the intervention groups on trials 50, 100 and 150 during the LD task. However, they were not informed of the significance of the STOP sign. Instead, they were instructed to simply wait for 15 seconds for the trials to resume. After the PM instructions, the non-intervention were not given GMT but proceeded to perform the distractor task (Sudoku) instead. However, to ensure that the non-intervention groups did not start performing the LD task earlier in Block 3, the duration of their distractor task was lengthened to 12 minutes. Thus, the interval from when the PM instructions were delivered to when the LD task was performed was standardized for both intervention and non-intervention groups. After the distractor task, the non-intervention groups performed the LD task with the embedded PM task.

At the end of the LD task in Block 3, all participants recalled the task instructions to the experimenter and used 7-point Likert scales to rate the importance of the LD task and the PM task. Note that all participants correctly recalled the PM task instructions to the experimenter at the end of each block.
Results

PM Accuracy Rate

A 2 (depressive symptomatology: HDS versus LDS) x 2 (intervention group: intervention versus no intervention) x 2 (PM block: PM Block 2, PM Block 3) mixed ANOVA was performed on the PM accuracy rate (see Table 1 for group means). There was no main effect of depressive symptomatology, $F(1, 107) = 1.15, p = .29, \eta^2_p = .01$, or any interaction between depressive symptomatology and intervention group, $F(1, 107) = .32, p = .57, \eta^2_p = .003$, or between depressive symptomatology and block, $F(1, 107) = .11, p = .75, \eta^2_p = .001$. There was a significant main effect of intervention group, $F(1, 107) = 12.29, p = .001, \eta^2_p = .10$, with participants receiving interventions of implementation intentions and GMT demonstrating greater PM accuracy ($M = .74, SD = .22$) than the participants receiving standard PM instructions ($M = .62, SD = .26$). There was also a significant main effect of block, $F(1, 107) = 6.09, p = .02, \eta^2_p = .05$, with a greater PM accuracy in Block 3 ($M = .71, SD = .26$) than Block 2 ($M = .64, SD = .24$). No interaction was observed between intervention group and block ($p = .19$). There was no three-way interaction ($p = .64$). See Figure 1.

![Figure 1. PM accuracy rate for intervention and non-intervention groups across two PM blocks.](image)

To specifically evaluate the effects of implementation intentions (separately from the additional effects of GMT), a comparison of the intervention and no intervention conditions was conducted for each block, collapsed across depressive symptomatology as the factor of depressive symptomatology did not enter into any
significant effects in the ANOVA. At Block 2, implementation intentions ($M = .69, SD = .22$) led to significantly better PM performance than standard PM instructions ($M = .60, SD = .26$), $t(109) = 2.04, p = .04, d = .37$. Likewise at Block 3, GMT ($M = .79, SD = .22$) led to significantly better PM performance than standard PM instructions ($M = .63, SD = .27$), $t(109) = 3.47, p = .001, d = .65$. To examine whether GMT had an additive effect on PM accuracy rate over implementation intentions, performance for Block 3 was compared to performance for Block 2, separately for the intervention and non-intervention groups. The analysis showed that the intervention groups had greater PM accuracy with GMT instructions at Block 3 ($M = .79, SD = .22$) than with implementation intentions at Block 2 ($M = .69, SD = .22$), $t(55) = 2.87, p = .006, d = .45$. The non-intervention groups did not differ in PM performance between Block 2 ($M = .60, SD = .26$) and Block 3 ($M = .63, SD = .27$), $t(54) = .92, p = .36, d = .11$.

LD Task Performance

A 2 (depressive symptomatology: HDS, LDS) x 2 (intervention group: intervention, non-intervention) x 3 (block: Baseline, Block 2, Block 3) mixed ANOVA was performed on LD accuracy. There was no main effect of depressive symptomatology, $F(1,107) = 1.34, p = .25, \eta_p^2 = .01$, and no interaction between depressive symptomatology and intervention group, $F(1, 107) = .05, p = .82, \eta_p^2 = .00$, or between depressive symptomatology and block, $F(2, 214) = .97, p = .38, \eta_p^2 = .01$. There was no main effect of intervention group, $F(1, 107) = .64, p = .43, \eta_p^2 = .01$. There was a significant effect of block, $F(2, 214) = 14.52, p < .001, \eta_p^2 = .12$, with significantly greater accuracy in Block 3 ($M = .97, SD = .02$) than Block 2 ($M = .96, SD = .03$) or Block 1($M = .95, SD = .03$), and marginally greater accuracy in Block 2 than Block 1 ($p = .06$). There was a marginal interaction between intervention group and block, $F(2, 214) = 2.58, p = .08, \eta_p^2 = .02$. There was no 3-way interaction ($p = .81$).

Lexical decision response time analyses were based on word trials only (Loft, Kearney, & Remington, 2008; Smith et al., 2007) and the descriptive statistics are presented in Table 1. The analysis excluded PM target trials, incorrect lexical decisions, and response times greater than 3 SDs from the participant’s mean for each block. A 2 (depressive symptomatology: HDS versus LDS) x 2 (intervention: intervention versus non-intervention) x 3 (block: Baseline, Block 2, Block 3) mixed ANOVA was performed. There was no main effect of depressive symptomatology, $F(1,107) = .05, p = .83, \eta_p^2 = .00$, and no interaction between depressive symptomatology and
intervention, $F(1, 107) = .00, p = .99, \eta^2_p = .00$, or between depressive symptomatology and block, $F(2, 214) = .55, p = .58, \eta^2_p = .01$. There was a significant interaction between intervention and block, $F(2, 214) = 5.77, p = .004, \eta^2_p = .05$. To evaluate this effect further, the data were collapsed across the depressive symptomatology groups and the response times between intervention and non-intervention groups were compared at each block. See Figure 2. These analyses revealed no significant difference in baseline response time between the intervention groups, $t(109) = .12, p = .91, d = .02$. At Block 2, the intervention groups ($N = 56$) which received implementation intentions had marginally greater response times ($M = 744.73, SD = 115.67$) than the non-intervention groups ($N = 55$) receiving standard PM instructions ($M = 710.80, SD = 95.11$), $t(109) = 1.69, p = .10, d = .32$. At Block 3, the intervention groups which received GMT demonstrated significantly longer response times ($M = 773.06, SD = 161.79$) than the groups receiving standard PM instructions ($M = 708.32, SD = 103.24$), $t(109) = 2.51, p = .01, d = .48$.

![Figure 2](image.png)

*Figure 2.* Mean lexical decision response times for word trials for intervention and non-intervention groups across three blocks.

The intervention groups had significantly greater response times at Block 2 when they were receiving implementation intentions ($M = 744.73, SD = 115.67$) than at Baseline ($M = 573.81, SD = 55.03$), $t(55) = 12.31, p < .001, d = 1.89$. In line with the view that GMT leads to the reallocation of attentional resource towards PM task goals, the intervention groups had significantly greater response times when they received GMT instructions at Block 3 than when they received implementation intentions instructions at Block 2, $t(55) = 2.12, p = .04, d = .20$. The non-intervention groups also demonstrated significantly slower response times at Block 2 than at Baseline, $t(54) =$
14.45, \( p < .001, d = 1.60 \). However, the non-intervention groups did not differ in response times between Block 2 (\( M = 710.80, SD = 95.11 \)) and Block 3 (\( M = 708.32, SD = 103.24 \)), \( t(54) = .27, p = .79, d = .02 \). This was expected as they performed the PM task twice with similar standard PM instructions.

**Relationship Between Ongoing Task Performance and PM Accuracy**

To examine the relationship between ongoing task performance and PM accuracy for implementation intentions and GMT, LD word response times were correlated with PM accuracy rate. For the non-intervention groups which received standard PM instructions at Block 2 and Block 3, LD response times were not significantly related to PM accuracy at Block 2 (\( r = .20, n = 55, p = .14 \)) or Block 3 (\( r = .06, n = 55, p = .69 \)). For the intervention groups, LD response times were not significantly related to PM accuracy when they received implementation intentions in Block 2 (\( r = .14, n = 56, p = .31 \)). However, their LD response times were significantly positively related to PM accuracy when they received GMT in Block 3 (\( r = .37, n = 56, p = .005 \)).

**Perceived Importance of PM Task**

Meeks and Marsh (2010) suggested that implementation intentions enhance the perceived importance of the PM task. Thus, a 2 (depressive symptomatology: HDS, LDS) x 2 (intervention group: intervention, non-intervention) x 2 (block: Block 2, Block 3) mixed ANOVA was performed on the perceived importance of the PM task. There was no effect of depressive symptomatology, intervention group, or block. There was no 2-way interaction between any of the factors (depressive symptomatology, intervention group, and block). No 3-way interaction was found (all \( F \)s < 1, all \( ps > .51 \)).

**Discussion**

Event-based PM deficits on strategically demanding PM tasks have been found in individuals with depression in previous studies (Altgassen et al., 2009; Chen et al., 2013; Rude et al., 1999). However, two studies conducted in this thesis (Studies 1 and 3) and other investigations (Altgassen et al., 2011) did not find PM deficits in depressed individuals on strategically demanding PM tasks. One possibility is that the event-based
PM tasks in Studies 1 and 3 which used specific cues were not strategically demanding enough to detect depression-related PM deficits. Thus, one objective of the current study was to investigate this possibility by employing a more challenging event-based PM task that has been shown in previous studies to be particularly resource demanding (Einstein et al., 2005; Loft & Remington, 2013; Meeks & Marsh, 2010). Meeks and Marsh (2010) showed that multiple specific cues (i.e., responding to ‘deer’ or ‘cow’) were less costly to ongoing task performance than non-specific cues (i.e., responding to words with ‘tor’ or animal words). If the null findings in Studies 1 and 3 were due to insufficient strategic task demands, then PM deficits between HDS and LDS participants may be expected to emerge under this paradigm which is similar to the one employed in the Meeks and Marsh (2010) study.

Another objective of the study was to determine if intervention strategies (implementations and GMT) would be as beneficial for HDS participants as they are for LDS participants. Study 2 showed that HDS participants had difficulty with the allocation of resource to support internal control processes that are likely beneficial to time-based PM (i.e., time-estimation, maintaining the intent to make the PM response). Study 3 showed that HDS participants allocated attentional resources to PM tasks but failed to benefit from these additional resources, suggesting that they were inefficiently utilized. The current study investigated the effects of implementation intentions relative to standard PM instructions on attention allocation and PM performance in HDS and LDS individuals. Based on the Meeks and Marsh (2010) study, which showed significantly increased ongoing task costs (i.e., increased attention allocation) and increased PM accuracy with implementation intentions compared to standard instruction, it was predicted that HDS as well as LDS participants receiving implementation intentions would demonstrate greater ongoing task costs and better PM performance than HDS and LDS participants receiving standard PM instructions. Similarly, the study investigated the effects of GMT with elements of content-free cueing on attention allocation and PM performance compared to standard PM instructions in HDS and LDS individuals. Based on the theory that GMT helps maintain attentional focus on task relevant goals, it was predicted that HDS as well as LDS participants receiving GMT would demonstrate greater ongoing task costs and better PM performance than participants receiving standard PM instructions.

With respect to the first prediction, the study did not find a difference in PM accuracy between HDS and LDS participants. Specifically, the HDS participants performed just as well as the LDS participants in the second block, regardless of
whether they received implementation intentions or standard PM instructions. Similarly, the HDS participants’ PM performance was not significantly different from the LDS participants at Block 3, regardless of whether they received GMT or standard PM instructions. Importantly, the lack of PM difference between HDS and LDS participants is unlikely to be due to the lack of strategic demands in the employed paradigm given that significant ongoing task costs were observed between the PM blocks and the Baseline block regardless of whether participants received standard PM instructions or implementation intentions. Note that the mean response time difference between Block 2 and the Baseline block for the non-intervention groups was 138.46 ms ($d = 1.60$).

Consistent with the findings of Studies 1 and 3 as well as the work of other researchers (Altgassen et al., 2011), the current findings further reinforce the notion that event-based deficits are not a consistently notable feature in individuals with high depressive symptomatology. Event-based deficits appear to be more readily observed in studies with patient populations (Altgassen et al., 2009; Chen et al., 2013). In contrast, time-based deficits appear to be more consistently observed in both depressed patients (Rude et al., 1999) and individuals with high depressive symptomatology (Studies 1 and 2).

Perhaps event-based PM tasks are less sensitive to depression-related PM deficits than time-based PM tasks because they usually impose less demands on self-initiated processes (but also see meta-analysis conducted by Henry, MacLeod, Phillips, & Crawford, 2004, where event-based PM tasks with substantial strategic demands were just as sensitive to age-effects as time-based PM tasks). This view appears to be supported by a study conducted by Kliegel and Jäger (2006) using a sample of participants with depression scores in the low-normal to high-normal range on the Hospital Anxiety and Depression Scale (mean score of 2.57, range = 0-8, subscale maximum score = 21). They found that depression scores were uniquely and inversely related to time-based PM performance ($r = -.23, p < .05$) but not event-based PM performance ($r < .01, p = .99$). Note that similar to the present study, Kliegel and Jäger also employed non-focal cues in their event-based paradigm (i.e., press a key whenever the picture of an animal is presented during an n-back task), suggesting that their paradigm was not low on strategic demands. Future studies designed to simultaneously compare time-based and event-based PM performance in individuals with more severe depressive symptomatology should be conducted to resolve the issue of whether time-based and event-based PM performance are differentially affected in depression.

However to reiterate, based on the collective findings of the four studies conducted in
the thesis, event-based PM deficits appear to be a less prominent feature than time-based PM deficits for HDS individuals.

Despite the lack of effect of depressive symptomatology on PM performance, the findings nevertheless showed that implementation intentions led to significantly better PM performance than standard PM instructions for both HDS and LDS participants. The ability of HDS participants to benefit from implementation intentions to the same extent as LDS participants under such strategically demanding conditions shows that implementation intentions can be an effective intervention strategy. This finding is consistent with the PM benefits demonstrated in previous research on healthy individuals (Brandstätter et al., 2001; Brewer et al., 2011; Chasteen et al., 2001; McDaniel et al., 2008; McFarland & Glisky, 2012) as well as individuals with suspected cognitive difficulties (Brandstätter et al., 2001; Chen et al., 2013; McFarland & Glisky, 2011; Zimmermann & Meier, 2010). The ongoing task costs incurred for the HDS and LDS participants receiving implementation intentions were marginally greater than the costs for the HDS and LDS participants receiving standard PM instructions (mean difference of 33.93 ms). This trend suggests that the attention allocated to the PM task might have been slightly greater for the HDS and LDS participants receiving implementation intentions than the HDS and LDS participants receiving standard PM instructions. This would be consistent with the view that resource demanding processes are involved in providing the benefits of implementation intentions (Meeks & Marsh, 2010). However, it should be noted that contrary to the suggestion that implementation intentions bias attention allocation by enhancing the perceived importance of the PM task (Meeks & Marsh, 2010), the current study found that the rated importance of the PM task was not significantly different between the implementation intentions and standard instructions groups. Perhaps implementation intentions influence attention allocation but not at a level that influences the perception of task importance. While the marginal cost findings do not allow a firm conclusion that implementation intentions significantly increase attention allocation for HDS participants, this should not detract from the important finding that PM performance is improved with implementation intentions and that it is an effective way of enhancing PM for HDS participants.

The current study found that HDS and LDS participants receiving GMT (with elements of content-free cueing) also experienced better PM performance than HDS and LDS participants receiving standard PM instructions. As with implementation intentions, the findings showed that HDS participants’ PM performance benefitted to the same extent as LDS participants with GMT over standard PM instructions. The
ongoing task costs incurred for GMT were significantly greater than those for standard PM instructions, and the extent of the costs incurred for the HDS participants was similar to that for the LDS participants. Crucially, ongoing task costs for both the HDS and LDS participants receiving GMT were positively associated with PM accuracy. However, there was no association between ongoing task costs and PM performance for the HDS and LDS participants receiving standard PM instructions. The overall pattern of findings shows that GMT increased the allocation of attention to the PM task for both the HDS and LDS participants and that the allocated resource were utilized efficiently (cf. Study 3 where HDS participants allocated more attentional resource to the PM task when PM task importance was emphasized but did not experience a corresponding improvement in PM, unlike the LDS participants). While the benefits of GMT on various neuropsychological tasks and behavioural measures have been demonstrated in several studies with various clinical populations (Alfonso, Caracuel, Delgado-Pastor, & Verdejo-García, 2011; Levine et al., 2000; Levine et al., 2011; Levine et al., 2007; Stubberud, Langenbahn, Levine, Stanghelle, & Schanke, 2013), this is the first study to have investigated the effects of GMT on the attentional function and PM performance of HDS individuals. The demonstrated ability of GMT to effectively improve PM performance, influence attention allocation and enhance resource utilization for HDS participants under such strategically demanding conditions should be investigated further. Perhaps future investigations could examine the effectiveness of GMT on time-based PM performance and explore its effects on clock-checking (e.g., whether overall frequency is increased, whether greater checking occurs as the appropriate time approaches) and ongoing task costs (e.g., whether costs reflecting internal control strategies are increased).

**Summary and Conclusions**

Depression related deficits on event-based PM tasks have not been consistently found in strategically demanding conditions. The present study examined the possibility that null findings of PM deficits in the two studies reported earlier in the thesis (Studies 1 and 3) were due to insufficient strategic demands by incorporating a more challenging PM paradigm. In addition, the study investigated the effects of implementation intentions and secondarily, GMT on the attentional function and PM performance of individuals with HDS and LDS.
The study found no difference in PM performance between HDS and LDS individuals under current strategically demanding PM task conditions. This is consistent with the findings of Study 1 and 3. It is possible that event-based PM tasks may be less sensitive than time-based PM tasks in detecting depression-related PM deficits was discussed. Nevertheless, the study found that HDS participants’ PM performance benefited from implementation intentions and GMT to the same extent as did the performance of LDS participants. There was some indication that implementation intentions increased attention allocation in HDS and LDS participants although this could not be firmly concluded. Compared to standard PM instructions, GMT significantly increased attention allocation (i.e., ongoing task costs) for HDS and LDS participants and this appeared to be functionally related to PM performance. The demonstrated effectiveness of GMT under other strategically demanding conditions (e.g., time-based PM tasks) deserves further investigation. Overall, both implementation intentions and GMT appear to be effective strategies that HDS individuals could benefit from.
References


strategic behavior in relation to goal management. *Journal of the International Neuropsychological Society, 13*(01), 143-152.


Appendix A

Stage 1
STOP!
What am I doing?

Stage 2
DEFINE
The MAIN TASK

Stage 3
LIST
The STEPS
A
B
C

Stage 4
LEARN
The STEPS
(Do I know the steps?)

NO

DO IT!!

Stage 5
CHECK
(Am I doing what I planned to do?)

YES

NO

Adapted from Levine et al. (2000)
Appendix B

1. STOP. In this step, you say “STOP” to yourself to make sure you are on track, think of what you are supposed to be doing and not get too distracted or off task. For example, watching the morning news on the television while you are meant to be preparing breakfast. Now, you don’t need to actually physically stop whatever you are doing but in your mind, it is important that you do pause for a moment when you say “STOP” to ask yourself the question, “what am I doing?” The whole purpose of this step is to pause for a moment and prevent yourself from getting too carried away with other distracting thoughts or activities. For example, when you are doing the word-nonword task, you would say STOP and quickly ask yourself “what am I doing?” and whether you are on task.

2. DEFINE. In this step, after briefly pausing and asking “what am I doing?” we define the main task or goal. So, we simply ask “what am I supposed to be doing here?” or “what am I trying to achieve?”. So for the current experiment, you would define the main task as “do the word-nonword task as well as remember to press the F1 key when needed.

3. LIST. In this step, after defining the main goal, we list the subgoals to achieve the main goal. So for the current experiment, you would review in your mind the subgoals or sub-steps as Sub-step 1. Does the letter string contain the syllable [Block3Syllable], if yes, press the F1 key. If no, go to the next substep. Sub-step 2. Is the letter string a real word? If yes, press the Yes key and not, press the No key.

4. LEARN. In this step, let’s try to review, recapture and learn what we have taught in the first 3 steps. Allow the participant to verbally recount the steps.

5. CHECK. In this step, we want you to check to see if you are doing what you planned to do. If you are on task (for example, doing the word non-word task and remembering to press the F1 key), then great, keep going. However, if you have become distracted (for example, thinking of plans for dinner), use this time to get yourself back on task. To assist you with this process, you will be provided with a STOP sign that will appear on the screen for 15 seconds during the word-nonword task. Please make sure you review the steps when you see the STOP sign.
1. Stop
2. Define
3. List
4. Learn
5. Check
CHAPTER 6

General Discussion
Restating General Rationale: Strategic Manipulation and Costs Analysis to reflect Cognitive Initiative

Previous studies have found depression related PM deficits on strategically demanding PM tasks (Altgassen, Kliegel, & Martin, 2009; Chen, Zhou, Cui, & Chen, 2013; Kliegel & Jäger, 2006; Rude, Hertel, Jarrold, Covich, & Hedlund, 1999). Many researchers (Altgassen et al., 2009; Kliegel & Jäger, 2006; Rude et al., 1999) have postulated that these PM deficits could be related to reduced cognitive initiative (i.e., lack of initiative to allocate available resource to relevant tasks). Thus, the overarching objective of this thesis was to examine the claim that reduced cognitive initiative underlies depression related PM deficits. Based on the rationale that reduced cognitive initiative in depressed individuals would be more apparent under cognitively demanding PM tasks, the thesis systematically altered the strategic demands by manipulating several key PM task variables (e.g., cue type, PM delay interval, task importance) in four studies and compared the PM performance of individuals with high and low depressive symptomatology (HDS and LDS respectively) in each of the studies.

Importantly, PM accuracy per se does not provide precise information about the extent of attention allocated to the PM task. To properly evaluate the claim that the initiative to allocate attentional resource is reduced in depression, it would be important to measure the extent of attention allocation under PM conditions in depressed individuals and compare it with non-depressed individuals. However, previous PM studies of depressed individuals might not have examined attention allocation with paradigms sufficiently sensitive to evaluate this construct. For example, Rude et al. (1999) employed a multiple-choice general knowledge test as their ongoing task but did not measure response time performance or include a no-PM task condition to control for baseline differences. Conversely, Altgassen et al. (2009) attempted to examine attention allocation in depressed participants by comparing their ongoing task performance (e.g., vowel judgement task accuracy and response times) under PM conditions relative to a no-PM baseline condition. However, the authors did not find a greater difference in ongoing task response times between the depressed and non-depressed participants when strategic demands were increased (i.e., focal vs. non-focal cues). This led the authors to suggest that their vowel judgment task was perhaps not sensitive enough to allow them to detect the reduced attention allocation or reduced cognitive initiative in depressed individuals under higher strategic demands. Thus, it remained unclear how attention allocation or the cognitive initiative of depressed individuals would present
under different strategic conditions compared to non-depressed individuals. Therefore, another aim of the thesis was to measure the extent of attention allocated by HDS individuals to support PM tasks requirements as compared to LDS individuals using a more sensitive paradigm. To do so, a well-established PM paradigm (Einstein & McDaniel, 1990; Marsh, Hicks & Cook, 2006, Smith, 2003) was employed. In this paradigm, decrements to ongoing task performance as a result of PM task requirements (i.e., costs to ongoing tasks in the form of longer response times) were measured. Increased costs to the ongoing task in PM task conditions relative to conditions when no PM task is present was used as evidence that attention had been allocated to support prospective remembering (Einstein & McDaniel, 1990; Marsh et al., 2006, Smith, 2003). Conversely, the lack of ongoing task costs in strategically demanding PM task conditions relative to conditions with no PM requirement would suggest that minimal attention had been allocated to support PM. Therefore, the costs obtained under different PM strategic manipulations (i.e., time-based PM tasks versus event-based PM tasks with relative importance of the PM task manipulated) allowed us to evaluate the cognitive initiative hypothesis of PM deficits in HDS individuals. Finally, the thesis examined the effectiveness of intervention strategies such as implementation intentions and goal maintenance training (GMT), and their ability to influence attention allocation and PM accuracy in HDS individuals as compared to LDS individuals.

Summary of Studies and Key Findings

Study 1. In the first study, the impact of cue type (time-based, event-based) and delay interval (2-minute, 15 minute) on PM performance were examined for HDS and LDS participants on the Memory for Intentions Screening Test (MIST, Raskin, Buckheit, & Sherrod, 2010), a well-validated and clinically relevant measure of PM that contains eight semi-naturalistic PM tasks. As the strategic demands of time-based PM tasks tend to be greater than event-based PM tasks (Kliegel, Martin, McDaniel, & Einstein, 2001; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997; Raskin et al., 2011; Troyer & Murphy, 2007; but also see meta-analysis conducted by Henry, MacLeod, Phillips, & Crawford, 2004, where event-based PM tasks with substantial strategic demands were just as sensitive to age-effects as time-based PM tasks), it was predicted that depressive symptomatology would interact with cue type such that the magnitude of difference in PM performance between HDS and LDS participants would be greater with time-based PM tasks than with event-based PM tasks. Likewise, longer PM delay intervals (i.e., the length of time between intention formation and intention execution)
have been found to be more strategically demanding than shorter delay intervals (Martin, Brown, & Hicks, 2011; Raskin et al., 2011; Weinborn, Woods, Nulsen, & Park, 2011). Thus, an interaction between depressive symptomatology and delay interval was predicted with a greater difference in PM performance expected between the HDS participants and LDS participants on tasks with a 15-minute delay interval than on tasks with a 2-minute delay interval. As predicted, the findings showed that relative to LDS participants, HDS participants were impaired on time-based PM tasks but not on event-based PM tasks. Also, HDS participants demonstrated significantly poorer performance than LDS participants on items with the 15-minute delay interval but not on items with the 2-minute delay interval. Together the findings demonstrate that the extent to which PM deficits would emerge in depression depends on the strategic demands of the tasks involved. While these findings are not inconsistent with the view that cognitive initiative is reduced in depression, the use of the MIST in its usual format does not allow for the specific identification of the underlying cognitive mechanism responsible for the PM deficit. That is, the present study with the MIST did not permit the measurement of the extent of cognitive initiative allocated by the HDS participants. In order to attribute the poorer PM performance to reduced cognitive initiative, it is important to further examine whether HDS participants initiate or allocate less attentional resource to support PM than LDS participants. Fortunately, existing paradigms such as the one developed by Einstein and McDaniel (1990) allowed for the examination of costs associated with PM performance. According, Study 2 was conducted to investigate the influence of depressive symptomatology on attention allocation under time-based PM conditions.

**Study 2.** The second study was conducted to further investigate the attentional mechanisms underlying the impaired PM performance of HDS individuals under time-based conditions. Specifically, the internal control processes (i.e., time-estimation, maintenance of the intention, coordination of PM and ongoing task response) and external control processes (i.e., frequency and timing of active clock-checking during the task to aid the timely performance of the PM task) related to time-based PM performance were examined (Huang, Loft & Humphreys, in press). In this study, participants were required to press the F1 key on the 4th, 8th and 12th minute into the ongoing task (i.e., lexical decision task). Participants could check the clock at any time by pressing the spacebar key to trigger a display of the elapsed time (e.g., “00:30”). The study compared PM accuracy (i.e., the proportion of F1 responses made within the 20
second window surrounding the target times; e.g., 03:50 – 04:10 for the 4th minute), pattern of clock-checking (i.e., the number of times participants triggered the clock display and whether it increased as the target times approached), and the pattern of costs incurred to lexical decision response time, between HDS and LDS participants. Based on earlier findings (Rude et al., 1999), it was predicted that HDS participants would demonstrate significantly lower clock checking frequency (i.e., less external control) and poorer PM performance than LDS participants. Importantly, it was also predicted that HDS participants would demonstrate significantly less cost to the ongoing task than LDS individuals if they lacked the cognitive initiative to strategically allocate attentional resources to internally control PM task performance (e.g., time-estimation, maintaining the intent to make PM task responses in between clock-checks, coordinating between PM and ongoing task response).

Indeed, the findings showed that overall PM accuracy was significantly lower for HDS participants than for LDS participants. Importantly, the study also found a significant difference in ongoing task costs between the HDS and LDS participants. The LDS participants incurred significant costs by slowing down on the ongoing task in the PM condition relative to the no-PM condition. In addition, these costs for the LDS participants were positively associated with PM performance, suggesting that resources were allocated to internal control processes and they were functional to PM performance. In contrast, the HDS participants did not incur significant costs with additional time-based PM task requirements and there was no relationship between their ongoing task response times and PM performance. This suggested that depression may be associated with the reduced allocation of resources to internally control time-based PM requirements and supports the view that cognitive initiative is reduced in depression. Clock checking frequency was numerically lower in the HDS participants than the LDS participants. This suggested that HDS participants might not have externally controlled the time-based PM task to the extent of LDS participants although this difference in clock checking frequency was only marginal.

**Study 3.** The third study was conducted to examine attention allocation and event-based PM performance in HDS individuals. Event-based PM deficits under strategically demanding conditions have been observed in depressed individuals in some studies (Altgassen et al., 2009; Chen et al., 2013). However, other investigations which also employed multiple non-focal cues (i.e., more resource demanding) have not consistently found PM deficits (Altgassen, Henry, Bürgler, & Kliegel, 2011). Likewise,
Study 1 found no difference in PM performance on the MIST between HDS and LDS participants on event-based tasks even though multiple non-focal cues were used. In view of the inconsistent findings, Study 3 was conducted to further examine the task conditions in which event-based PM deficits might emerge in HDS individuals relative to LDS individuals. In addition, the importance emphasized on the PM task relative to the ongoing task was manipulated in order to examine for differences in the ability of HDS and LDS individuals to prioritize attention to the PM task. In Study 3, participants were required to make a PM response whenever one of the five previously studied target words was presented during an ongoing lexical decision task. It was predicted that LDS participants would incur significant costs in the PM task conditions relative to the baseline condition and that costs in the condition where the importance of the PM task was emphasized (PM Important, or PMI) would be greater than the condition where the importance of the ongoing task (Ongoing Important, or OI) was emphasized (Loft & Yeo, 2007; Smith & Bayen, 2004). Accordingly, a corresponding improvement in PM performance was expected in the PMI condition compared to the OI condition for the LDS participants. HDS participants were expected to allocate less attentional resource to PM task conditions than LDS participants (i.e., incur less cost to the ongoing task). The magnitude of costs incurred between the PMI and OI conditions for the HDS participants were also expected to be significantly less than the LDS participants. The study found that both HDS and LDS participants incurred significantly greater costs in the PMI condition than the OI condition. However, a corresponding improvement in PM performance from the OI to the PMI condition was observed in LDS participants but not HDS participants. This suggested that HDS participants are able to increase allocation of attention to PM tasks when directed to do so, but that the resources allocated may not always be efficiently utilized.

**Study 4.** The findings of Study 2 demonstrated reduced attention allocation and the findings of Study 3 suggested inefficient resource utilization in HDS individuals under PM task conditions. Accordingly, Study 4 was conducted to investigate whether intervention strategies such as implementation intentions and goal maintenance training (GMT) would scaffold the attentional function of depressed participants (i.e., increase attention allocation or improve efficiency of that resource utilization) and subsequently improve PM performance. In addition, in view of the findings of Studies 1 and 3 demonstrating no definite evidence of PM deficits in HDS individuals under event-based conditions, Study 4 examined whether PM deficits would emerge under more...
strategically demanding event-based PM conditions. In this study, a resource
demanding event-based PM paradigm similar to the one used in Meeks and Marsh
(2010) was employed (i.e., PM cues were syllables [e.g., ‘tor’] embedded in real words
[e.g., ‘tortoise’] in an ongoing lexical decision task). There were four independent
groups – HDS individuals receiving intervention with implementation intentions in the
second block and GMT in the third block (HDS+I), HDS individuals with no
intervention who only received standard PM instructions in the second and third blocks
(HDS+Std), LDS individuals receiving intervention with implementation intentions in the
second block and GMT in the third block (LDS+I), and LDS individuals with no
intervention who only received standard PM instructions in the second and third blocks
(LDS+Std).

Surprisingly, there was no difference in PM accuracy between the HDS and
LDS participants under the strategically demanding PM paradigm employed in the
study. This finding suggests that even highly resource demanding event based PM tasks
appear to be unimpaired in HDS, and extends the findings of Studies 1 and 3 which
found no difference in PM with event-based cues on tasks with less cognitive resource
demands. Importantly, the current study showed that HDS participants’ PM
performance benefitted from implementation intentions to the same extent as LDS
participants (i.e., both HDS+I and LDS+I participants’ PM accuracy were significantly
greater than HDS+Std and LDS+Std participants receiving standard PM instructions to
the same extent). Ongoing task response times for HDS+I and LDS+I participants
receiving implementation intentions were marginally greater than the ongoing task
response times for HDS+Std and LDS+Std participants receiving standard PM
instructions. Although inconclusive, the ongoing task response time findings suggested
that implementation intentions might increase attention allocation to PM tasks for both
HDS and LDS. Further, GMT also led to significantly better PM performance in HDS+I
and LDS+I participants than HDS+Std and LDS+Std participants receiving standard
PM instructions. Ongoing task response times for HDS+I and LDS+I participants
receiving GMT were significantly greater than the ongoing task response times for
HDS+Std and LDS+Std participants. Furthermore, response times for the HDS+I and
LDS+I participants receiving GMT were significantly associated with their PM
accuracy rate whereas this association was not found for HDS+Std and LDS+Std
participants. The findings suggest that GMT is an effective way of increasing attention
allocation to PM tasks and improving PM performance in HDS as well as LDS
participants. Overall, the findings of Study 4 show that intervention strategies such as implementation intentions and GMT are effective ways of improving PM function and that HDS individuals are able to benefit from them to a similar extent as LDS individuals.

**Integrating Current Findings with the Literature**

Overall, the findings generated from the current body of work are consistent with the view that PM deficits in depression or HDS are mediated by reduced cognitive initiative (Altgassen et al., 2009; Rude et al., 1999). Specifically, the observed differences in PM performance between HDS and LDS individuals show that strategic demands interact with depressive symptomatology such that PM deficits between HDS and LDS emerge under strategically demanding conditions (time-based cues and long delay intervals in Study 1, time-based PM task performance in Study 2) but not under less demanding conditions (event-based cues and short delay intervals in Studies 1, 3 and 4). As is discussed below, some PM task conditions (i.e., time-based) appear to be more sensitive than others (i.e., event-based) in detecting PM deficits in HDS individuals.

As mentioned earlier, PM accuracy itself does not provide enough information about the extent of attention allocated to the PM tasks. Previous PM studies of depressed individuals might not have closely examined attention allocation with sufficiently sensitive paradigms (Altgassen et al., 2009; Rude et al., 1999). To address this issue, the studies in Chapters 3-5 in this thesis employed a PM task paradigm that has been shown to be sensitive enough to detect changes in costs to ongoing tasks under a variety of strategic demands (e.g., multiple PM cues, categorical cues, or syllable PM cues embedded in a lexical decision task, Einstein & McDaniel, 1990; Hicks, Marsh, & Cook, 2005; Loft & Kearney, & Remington, 2008; Marsh, Cook, & Hicks, 2006; Smith, 2003). With this paradigm, the costs incurred under time-based and event-based PM conditions relative to baseline conditions allowed researchers to measure the attentional resources allocated to support PM task requirements. This provided an important indicator of cognitive initiative for the current studies.

With time-based PM tasks (Study 2), it was found that the difference in ongoing task response times under PM conditions relative to no-PM conditions was significantly smaller in HDS participants than in LDS participants. The reduced costs demonstrated by HDS participants suggested that they might not have allocated resources of sufficient
quantity or quality to support particular internal processes such as time-estimation and/or intention-maintenance in between clock checks. Notably, with event-based PM tasks (Study 3), there was evidence of increased levels of attention allocation in HDS participants similar to LDS participants when PM task importance was emphasized compared to the condition where ongoing task importance was emphasized. However, unlike LDS participants, the allocated resource did not amount to a corresponding improvement in PM performance for HDS participants. This suggested that the HDS participants may not be efficiently utilizing the resources that have been allocated. This notion of depression-related processing inefficiency is supported by a recent eye-tracking study conducted by Chen et al. (2013). In the study, depressed participants demonstrated a greater number of fixations and longer fixation durations on PM cues than non-depressed participants. Moreover, the depressed participants demonstrated significantly poorer PM performance than non-depressed participants. This suggested that although the depressed participants allocated resources to attend to information, they were not efficiently processing the incoming information. Crucially, our current investigation and Chen et al.’s findings together suggest that future researchers should not only consider whether sufficient attentional resource has been allocated by individuals with depression or HDS (or other populations with suspected attentional deficits) but also whether the resource has been used efficiently. Efficiency in resource utilization could be investigated by measuring the association between the costs incurred on the ongoing task under strategic PM conditions relative to no-PM conditions and PM accuracy rate. A stronger relationship between incurred costs and PM accuracy would indicate greater efficiency in resource utilization. The strength of this relationship could be compared between depressed and non-depressed individuals. Participants could also be categorised into ‘efficient’ or ‘inefficient’ resource users and have their performance examined under several other strategic PM conditions to examine if it is a reliable trait (i.e., whether ‘efficient’ users consistently show such a positive relationship between response time costs and PM accuracy under different PM conditions).

Importantly, the notion that greater effort could be allocated to a task without a proportional improvement in task performance is not a novel concept in psychological research. For example, Eysenck and Calvo (1992)’s processing efficiency theory, a precursor to the attentional control theory (Eysenck, Derakshan, Santos, & Calvo, 2007), states that performance on a task could be indicated either by the final outcome
measure (e.g., accuracy of performance) which the authors referred to as performance effectiveness, or the amount of effort or resource allocated to achieve that level of performance, which the authors referred to as processing efficiency. Although the theory was initially proposed to explain the cognitive performance of individuals with anxiety, it could also be usefully applied or adapted to explain depression related PM deficits as well. However, the suggestion that cognitive inefficiency contributes to depression related PM deficits is preliminary and should be investigated further.

In comparing the overall pattern of our time-based and event-based PM findings, it is interesting to note that PM deficits on event-based PM tasks do not appear to be as consistent or notable as deficits on time-based PM tasks in HDS individuals even when high levels of strategic demands are involved in the event-based tasks (i.e., as shown by the significant ongoing task costs incurred under PM conditions relative to no-PM conditions). For example, HDS participants showed no difference in PM performance when the ongoing task’s importance was emphasized in Study 3 or when non-focal categorical cues were employed in Study 4. The only notable difference in event-based PM performance between HDS and LDS participants was in Study 3 in the condition where the importance of the PM task was emphasized. In contrast, time-based PM deficits were observed more consistently (in Studies 1 and 2).

This pattern of findings could be due to the generally greater strategic demands imposed by time-based with various studies suggesting greater resource allocation or self-initiation required in time-based than event-based tasks (Kliegel et al., 2001; Park et al., 1997; Raskin et al., 2011; Shum, Ungvari, Tang, & Leung, 2004; Troyer & Murphy, 2007). This view is consistent with the Kliegel and Jäger (2006) study which found that participants with normal levels of depressive symptoms demonstrated less accurate performance on the ongoing task and PM task when subjected to time-based conditions than event-based conditions. More importantly, the researchers found that depression scores were uniquely and inversely associated with time-based PM accuracy but not with event-based PM accuracy. Note that similar to Study 4, Kliegel and Jäger (2006) also employed non-specific PM cues in their event-based paradigm (i.e., press a key whenever the picture of an animal is presented during an n-back task), suggesting that their event-based paradigm was also not low on strategic demands.
Relating PM Findings to Neurocognitive Deficits in Depression

Earlier in Chapter 1, a brief overview of the neurocognitive features and neurobiological features of depression was provided. Importantly, the literature suggests that amongst the many cognitive deficits documented in depression, deficits in controlled processes (e.g., executive function, attentional control and free recall) appear to be the more prominent feature (Snyder, 2013). Accordingly, abnormalities in brain structure and neurocircuitry related to controlled processing have been found (Drevets, Price, & Furey, 2008). Unfortunately, the neuropsychological processes instrumental to PM performance (e.g., planning, monitoring, dividing attention) also appear to be the processes negatively affected by depression (Fossati, Ergis, & Allilaire, 2002), suggesting that PM deficits would reasonably be expected in depression. Indeed, our pattern of PM findings with deficits observed under strategic conditions (long delay intervals, time-based cues vs. short delay intervals, event-based cues) is consistent with the broader literature on the neurocognitive deficits in depression.

Episodic memory impairment, a less typical cognitive deficit reported in depression (Burt, Zembar, & Niederehe, 1995), did not seem to feature prominently in our investigations as well. That is, HDS participants were able to successfully recognise individual PM targets (Study 1 and 3) or recall the PM task requirements to the experimenter after the experiment (Study 2 and 4). However, it is important to note that our studies were not designed to specifically investigate the role of episodic memory impairments in depression related PM deficits. Hence, it is possible that the methods used in the present series of studies (e.g., recognition of individual PM cues) might not have been sensitive enough to detect retrospective memory deficits in depression. Perhaps a more sensitive design involving the free recall of multiple individual PM targets post-experiment would be more appropriate for investigating the role of episodic memory impairment in PM deficits in depression. Retrospective memory load for the PM targets could be manipulated by varying the number of individual PM targets that depressed participants are required to respond to but keeping the number of target appearances the same such as in the Einstein, Holland, McDaniel and Guynn (1992) study.

Future Research Ideas Directly Arising from the Thesis

With the findings of the studies in the thesis demonstrating time-based PM deficits in HDS individuals more consistently than event-based PM deficits, it appears
that time-based PM tasks may be more sensitive than event-based PM tasks to detect PM deficits in depression. Future studies could be conducted to directly compare time-based and event-based PM performance in severely depressed individuals. Although time-based and event-based PM was already compared in Study 1 with the MIST, note that the ongoing task in the MIST (i.e., word search puzzle) may not be sensitive enough to provide precise information about the extra attentional demands required under PM conditions compared to no-PM conditions (i.e., not sensitive enough to detect increases in ongoing task response times under PM conditions).

Therefore, it is recommended that future researchers attempting to compare time-based and event-based PM in depressed individuals employ a computerized paradigm such as the paradigm used in the current set of studies in the thesis (Studies 2, 3, and 4) or other studies (Einstein & McDaniel, 1990; Kliegel & Jäger, 2006; Marsh et al., 2006). Crucially, the time-based and event-based PM tasks should be equated on key characteristics such as number of PM targets and interval between target appearances as was done in previous studies (Hicks et al., 2005; Kliegel & Jäger, 2006). In this way, retrospective memory load for PM target information (i.e., number of PM targets that participants will have to store in memory) would be matched and any differences in PM performance between time-based and event-based PM tasks for depressed individuals can be attributed to the differences in prospective component demands between the PM tasks. With the mentioned key variables matched, depressed individuals would be expected to show significantly poorer PM performance on time-based PM tasks than event-based PM tasks. To verify if the attentional demands are greater for time-based PM tasks than event-based PM tasks for depressed individuals, the costs to ongoing task performance under PM conditions relative to no-PM conditions could be examined.

Following suggestions of greater strategic demands inherent in time-based PM tasks than event-based PM tasks (Kliegel & Jäger, 2006; Kliegel et al., 2001; Park et al., 1997; Raskin et al., 2011; Shum et al., 2004; Troyer & Murphy, 2007), and findings showing more reliable evidence of depression related deficits on time-based PM tasks (Rude et al., 1999; Studies 1 and 2), future experiments attempting to evaluate the efficacy of particular intervention strategies in depression or HDS could perhaps employ time-based PM paradigms instead of event-based PM paradigms. This increases the likelihood of finding a pre-intervention baseline difference in PM performance and would allow researchers to better examine the ability of strategies such as
implementation intentions and GMT to ‘normalise’ depression related PM deficits (i.e., do intervention strategies bring the low PM performance of severely depressed participants up to the level of non-depressed participants?). Furthermore, studies of implementation intentions have been based mainly on event-based PM tasks. There has not been any investigation into the use of implementation intentions under time-based PM conditions although the work of Cook, Marsh and Hicks (2005) suggests that it might be effective.

Whilst Cook et al. (2005) did not examine implementation intentions per se, their investigation showed that associating a time-based PM cue with its expected context led to better PM performance than when a time-based PM cue was not associated with its expected context. Specifically, it was found that when the appropriate time to perform a PM task (i.e., between the 6th and 7th minute) occurred in the context where participants were told it would occur (i.e., while they were performing an ongoing syllable rating task), their time-based PM performance was better than when the appropriate time to perform the PM task occurred in a context that was different from what they were told (i.e., during a pleasantness rating task). Therefore, instead of associating an intended response to an expected external PM cue as was done in previous studies of implementation intentions with event-based cues (McDaniel, Howard, & Butler, 2008; McDaniel & Scullin, 2010; McFarland & Glisky, 2011, 2012; Meeks & Marsh, 2010), implementation intentions adapted for time-based PM tasks could involve the association of an intended response (e.g., press the F1 key on the 5th minute) with the expected environment that a task would be performed in (e.g., while performing a lexical decision task). The associative links between the intended response and expected context for time-based PM tasks could be strengthened through measures already existing in event-based studies of implementation intentions such as verbal repetitions and visual imagery (McDaniel et al., 2008; McDaniel & Scullin, 2010; McFarland & Glisky, 2011, 2012; Meeks & Marsh, 2010). It would be interesting to see if depressed individuals benefit from time-based versions of implementation intentions and whether it influences their attention allocation to internal control (i.e., as demonstrated by increased ongoing task costs) and external control processes (i.e., clock checking frequency over time as target time approaches).

Another possible avenue to pursue is to examine the time-based PM performance of depressed individuals with irregular time-based cues. Thus far, investigations of time-based PM performance (Rude et al., 1999; Study 2) have used
regular time intervals (i.e., every five minutes in Rude et al. or every four minutes in Study 2). With irregular time intervals (e.g., press the F1 key on the 2^{nd}, 3^{rd}, 7^{th} and 12^{th} minute), the strategic demands would likely be greater than with regular intervals (e.g., press the F1 key every three minutes). This is probably because (1) more individual PM times would have to be committed to memory and resources would likely be used to maintain that information; and (2) it would be harder to establish a clock checking habit (cf. regular intervals where clock checking can be temporarily neglected after a PM response is made before being re-initiated again as the next target time approaches). Thus, the less predictable and less habit-forming nature of irregular PM intervals compared to regular intervals would likely require greater self-initiative and interfere significantly with ongoing task performance. Hence, it is quite likely that depressed individuals compared to non-depressed individuals would demonstrate greater PM deficits with irregular PM intervals than with regular PM intervals. The ongoing task costs associated with irregular intervals should also be greater than the costs associated with regular intervals for healthy individuals, suggesting that greater attentional resource has been allocated to support the greater strategic demands. However, it would also be interesting to see if depressed individuals allocate greater attentional resource to irregular intervals than regular intervals to the same extent as healthy individuals.

**Limitation of Studies**

A few points need to be considered when attempting to generalise the current set of findings to the broader population. Firstly, the samples employed in the studies are predominantly university students of relatively high socio-economic status. This means that their intellectual functioning (IQ), educational attainment and cognitive reserve are likely to be higher than the general population. As these factors have been shown to be inversely associated with declines in cognitive function (Kemppainen et al., 2008; Kesler, Adams, Blasey, & Bigler, 2003; Koenen et al., 2009; Le Carret et al., 2003), it is possible that the samples employed in the studies are more well buffered against severe cognitive deficits than individuals without such protective factors. Secondly, the samples are composed of young, highly functioning individuals. A recent meta-analysis (Uttl, 2011) showed that age contributes significantly to PM performance and that broadly, older adults perform more poorly than younger adults on both focal and non-focal PM tasks. Thus, the PM performance of older participants with depression or high depressive symptomatology would need to be examined further. Thirdly, it is also unclear how individuals with greater and more chronic depressive symptoms (i.e.,
patient populations) would perform on the current series of experiments. Individuals with recurrent depression have been shown to demonstrate more severe retrospective memory deficits than individuals with acute or first-episode depression (Basso & Bornstein, 1999; Fossati et al., 2004; Rapp et al., 2005). Thus, it is likely that individuals with recurrent depression would also show greater PM deficits, especially on PM tasks with greater retrospective memory load (i.e., more individual PM targets), than individuals with acute depressive episodes. Fourthly, comorbidity is common in depression, with co-occurrences found with other conditions such as alcohol use disorders (Grant & Harford, 1995), substance use disorders (Davis, Uezato, Newell, & Frazier, 2008) and physical ailments such as diabetes, arthritis, asthma, and cardiovascular disease (Moussavi et al., 2007). The current series of experiments attempted to examine the effects of depressive symptomatology on PM in isolation. Thus, comorbid conditions were viewed as confounds and individuals with other neurological or behavioural problems were excluded. However, given the comorbidity between depression and other conditions, it would be interesting to see if certain conditions (e.g., alcohol use) interact with depressive symptomatology and lead to more severe PM deficits. Finally, antidepressants have been shown to improve cognitive function in depressed patients (Greer, Sunderajan, Grannemann, Kurian, & Trivedi, 2014; Herrera-Guzmán et al., 2010). However, the number of participants on antidepressant medication in the current samples was too small to properly evaluate its effects on PM performance. Hence, future investigations could investigate whether the cognitive enhancing effects of anti-depressants in depressed individuals generalizes to PM performance as well.

To reiterate, the current series of findings have demonstrated in individuals with high depressive symptomatology greater deficits with time-based cues than with event-based cues on the MIST, greater deficits with long delay intervals than with shorter delay intervals on the MIST, reduced allocation of attention to internal control processes under time-based conditions, inefficient resource utilization under event-based PM conditions, more consistent time-based PM deficits than event-based PM deficits under strategically demanding conditions (but also see Henry et al., 2004), and the capacity to benefit from intervention strategies in terms of attention allocation and PM function to a similar extent as individuals with low depressive symptomatology. However, the current findings are based on samples of young, high functioning university students. Therefore, it would be important to replicate the findings further with individuals with
different socioeconomic status or backgrounds (e.g., older adults, individuals with lower educational attainment, more chronic depressive symptoms, suffer from other health, behavioural or neuropsychiatric conditions, and are on/off antidepressant medication).

**Conclusion**

Prior to the series of experiments in the current thesis, the literature on the effects of depression on PM function showed that PM deficits in depressed individuals are more likely to emerge under conditions that impose greater demands on strategic processing. The reduced initiative to allocate available resources to support PM was thought to be responsible for this pattern of findings. However, attention allocation in depressed individuals had not been examined with sufficiently sensitive paradigms at that time. As a result, the cognitive initiative account of depression related PM deficits could not be properly evaluated. Thus, a series of three studies (i.e., Studies 2, 3, and 4) was conducted in which a sensitive paradigm (i.e., multiple PM cues embedded in a lexical decision task) was employed to measure the decrements in ongoing task performance under PM conditions relative to no-PM conditions (i.e., increase in lexical decision response times or ‘costs’). Ongoing task cost was used as an indicator of the level of cognitive initiative present in participants and it was compared between depressed and non-depressed participants under a variety of strategic conditions.

In conclusion, the series of experiments conducted in the current thesis has managed to provide evidence for the view that cognitive initiative is reduced in depression under strategic PM conditions (time-based PM tasks). The current findings suggest that cognitive efficiency (i.e., effective utilization of allocated resource) could potentially be reduced as well in depression. Importantly, in the course of examining the influence of depression on PM function, the current body of work has managed to provide additional information about the effects of PM cue type and delay interval on PM performance, the internal control processes related to time-based PM task performance, the efficiency to which allocated resource is applied in event-based PM tasks, and the beneficial effects of intervention strategies (i.e., implementation intentions and GMT) on PM performance. Some of this information about individuals with high depressive symptomatology was not available before the current work. However, with some of answers provided by the current work, new questions have also emerged through the course of the investigation. Thus, more studies will need to be conducted in order to address some of the aforementioned research questions. Prior to
the current studies, there was “nearly a complete lack of studies investigating prospective memory in affective disorders such as major depression or bipolar disorder” (Kliegel, Jager, Altgassen, & Shum, 2008, p. 297). Since then, valuable findings from other researchers in this area have emerged Albiński, Kliegel, Sędek, & Kleszczewska-Albińska, 2012; Altgassen et al., 2009, 2011; Chen et al., 2013). It is also hoped that the current body of work has contributed some useful knowledge about the attentional mechanisms underlying PM performance in depressed individuals.
References


