Prospective memory in the fourth age: Evidence from the ALSA Daily Life Time Sampling (ADuLTS) study

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Declaration

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

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BPsych (Hons)

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Table of Contents

Title..... i

Declaration..... ii

Acknowledgements..... iii

Table of Contents..... iv

List of Tables..... xiii

List of Figures..... xv

Abstract..... xvi

Chapter 1: Thesis Overview..... 1

1.0 Overview..... 1

1.1 Ageing in Australia..... 1

1.2 Prospective Memory..... 2

1.3 The ADuLTS Study..... 6

1.4 Studies Providing the Focus for the Current Thesis..... 7

1.4.1 Study 1: Prospective memory in the fourth age..... 8

1.4.2 Study 2: Stress and prospective memory..... 8

1.4.3 Study 3: Cognitive predictors of prospective memory in the fourth age..... 10

1.5 Structure of the Thesis..... 11

1.6 Summary..... 12

Chapter 2: Review of the Prospective Memory Literature..... 14

2.0 Overview..... 14

2.1 Introduction to Prospective Memory..... 14

2.1.1 Characteristics of prospective memory..... 15

2.1.2 Four phase theory of prospective memory processes..... 17

2.1.3 Prospective memory as a unique construct..... 19

2.2 Theories of Prospective Memory..... 21

2.2.1 Spontaneous retrieval mechanisms..... 22

2.2.2 Attentional monitoring mechanisms..... 24

2.2.2.1 PAM: Preparatory attentional monitoring theory..... 25

2.3 The Multiprocess Framework of Prospective Memory..... 29

2.3.1 The Multiprocess Framework and age-related effects in event-based tasks..... 31

2.3.2 The Multiprocess Framework and age-related effects in time-based tasks..... 33
2.3.3 Target cue characteristics and the Multiprocess Framework..... 34
2.3.3.1 Cue focality..... 35
2.3.3.2 Cue regularity..... 36
2.3.3.3 Cue distinctiveness..... 37
2.3.3.4 Length of retention period..... 37
2.4 Rationale for Study 1..... 38
Chapter 3: Study1. Event- and Time-based Prospective Memory in Community Dwelling Oldest-old Adults..... 42
3.0 Overview..... 42
3.1 Introduction to Study 1..... 42
3.1.1 Naturalistic versus laboratory research..... 43
3.1.2 Characteristics of the prospective task and target cue..... 45
3.1.3 Summary..... 48
3.2 Aim of Study 1..... 49
3.3 Hypotheses for Study 1..... 49
3.4 Method..... 49
3.4.1 Participants..... 49
3.4.2 Design..... 51
3.4.3 Materials..... 51
3.4.4 Baseline measures..... 51
3.4.4.1 The Mini-Mental State Examination..... 52
3.4.4.2 The CES-D 10..... 53
3.4.4.3 Self-reported stress..... 53
3.4.5 Time-sampling measures: Questionnaires and saliva samples..... 54
3.4.5.1 Saliva samples..... 54
3.4.5.2 Morning questionnaires..... 54
3.4.5.3 Daily questionnaires..... 56
3.4.5.4 Prospective memory items..... 57
3.5 Procedure..... 58
3.6 Analytic Approach..... 61
3.6.1 Prospective memory measures..... 61

3.6.2 Software..... 61
3.7 Results..... 62
3.7.1 Demographic and descriptive results..... 62
3.7.2 Preliminary analyses of prospective memory performance..... 64
3.7.3 EBPM forgetting and recovery ratios..... 65
3.7.4 Prospective memory performance and age..... 67
3.7.4.1 Prospective memory performance and age group..... 67
3.7.4.2 Prospective memory performance and linear chronological age..... 68
3.8 Discussion..... 73
3.8.1 Limitations and future directions..... 81
3.9 Conclusion..... 83
Chapter 4: Intra-individual and inter-individual predictors of prospective memory..... 85
4.0 Overview..... 85
4.1 Intra-individual and Inter-individual Constructs Informing Current Research..... 85
4.2 Stress Processes and Prospective Memory: Study 2..... 88
4.2.1 Stress pathways..... 88
4.2.2 Stress processes: The Hypothalamic-Pituitary-Adrenal (HPA) axis..... 88
4.2.3 Stressor exposure and individual reactivity..... 90
4.2.4 Stress, cortisol, ageing, and cognition..... 95
4.2.5 Summary..... 97
4.3 The Association of Executive Function, Working Memory, and Retrospective Memory with Prospective Memory: Study 3..... 98
4.4 Executive Function..... 99
4.4.1 Models of executive function..... 100
4.4.2 Executive function and age-related decline..... 102
4.4.3 Executive function and prospective memory in older age..... 104
4.4.4 Executive function and the dual-process theory..... 108
4.4.5 Summary and rationale for executive function as a predictor of prospective memory..... 110

4.5 Working Memory..... 111
4.5.1 Models of working memory..... 112
4.5.2 Working memory and age-related decline..... 114
4.5.3 Working memory and prospective memory..... 116
4.5.4 Summary and rationale for working memory as a predictor of prospective memory..... 120
4.6 Retrospective Memory..... 121
4.6.1 Summary and rationale for retrospective memory as a predictor of prospective memory..... 124
4.7 Summary and Aim of Study 3..... 124

Chapter 5: Study 2. The effect of stress on prospective memory in the fourth age... 126

5.0 Overview..... 126
5.1 Introduction..... 126
5.2 Rationale for Study 2: Stress, Cortisol, and Prospective Memory..... 128
5.2.1 Stress and prospective memory..... 132
5.3 Hypotheses for Study 2..... 134
5.4 Method..... 136
5.4.1 Participants..... 136
5.4.2 Design..... 136
5.5 Materials..... 136
5.5.1 Baseline measures..... 136
5.5.2 Time sampling measures..... 137
5.5.2.1 Morning and daily questionnaires..... 137
5.5.2.2 Prospective memory items..... 138
5.5.2.3 Cortisol..... 138
5.6 Procedure..... 139
5.7 Overview of cortisol variables..... 139
5.7.1 Cortisol sample completion rate..... 139
5.7.2 Cortisol measures..... 140
5.7.2.1 Area under the curve..... 140
5.7.2.2 Deviation in cortisol at measurement occasion..... 141
5.7.2.3 Intra-individual standard deviation..... 141
5.7.2.4 Cortisol awakening response..... 142

5.8 Results..... 143
5.8.1 Overview..... 143
5.8.1.1 Prospective memory descriptive results..... 143
5.8.1.2 Cortisol descriptive results..... 143
5.8.1.3 Preliminary analyses of major variables..... 144
5.8.2 Statistical model and analytic approach..... 150
5.8.2.1 Overview of multi-level modelling and generalised linear mixed models..... 150
5.8.2.2 Model definition..... 152
5.8.2.3 Software..... 156
5.8.2.4 Covariance structure..... 156
5.8.2.5 Estimation of logit coefficients and probabilities..... 156
5.8.2.6 Model estimation..... 157
5.8.3 Results for focal EBPM models..... 157
5.8.4 Results for non-focal EBPM models..... 164
5.8.5 Results for TBPM analyses..... 168
5.8.6 Summary of results..... 170
5.9 Discussion..... 173
5.9.1 Limitations and future directions..... 183
5.10 Conclusion..... 185
Chapter 6: Study 3. The association of executive function, working memory, and retrospective memory with prospective memory in the fourth age..... 186
6.0 Overview..... 186
6.1 Introduction..... 186
6.2 Rationale for Study 3..... 187
6.2.1 Executive function..... 187
6.2.2 Working memory..... 193
6.2.3 Retrospective memory..... 196
6.3 Summary..... 198
6.4 Aim of Study 3..... 199
6.5 Hypotheses for Study 3..... 200
6.6 Method..... 201
6.6.1 Participants..... 201

6.6.2 Design..... 202
6.6.3 Materials..... 202
6.6.3.1 Baseline and covariate measures..... 202
6.6.3.2 Digit Symbol Substitution Test..... 203
6.6.3.3 Time sampling and prospective memory measures..... 204
6.6.3.4 Tests of executive function..... 204
6.6.3.4.1 Initial Letter Fluency Test..... 205
6.6.3.4.2 Excluded Letter Fluency Test..... 206
6.6.3.4.3 CLOX 1..... 208
6.6.3.5 Tests of working memory..... 208
6.6.3.5.1 MMSE: Spelling backwards, serial sevens, and 3-stage command..... 208
6.6.3.5.2 Working memory, the MMSE, and covariate predictors..... 210
6.6.3.6 Tests of retrospective memory..... 211
6.6.3.6.1 The MMSE and retrospective memory..... 211
6.6.3.6.2 Digit Symbol Subtest and retrospective memory..... 212
6.7 Procedure..... 213
6.8 Analytic Approach..... 214
6.8.1 Prospective memory measures..... 214
6.8.2 Software..... 214
6.9 Results..... 215
6.9.1 Overview..... 215
6.9.2 Preliminary analyses of prospective memory performance and executive function, working memory, and retrospective memory..... 215
6.9.2.1 Correlation between major variables..... 216
6.9.2.2 Hypothesis testing..... 221
6.9.3 Results of HMR analysis for focal EBPM and executive function, working memory, and retrospective memory..... 223
6.9.3.1 Focal EBPM proportion correct and executive function, working memory, and retrospective memory..... 223
6.9.3.2 Focal EBPM forgetting ratio and executive function, working memory, and retrospective memory..... 224
6.9.3.3 Focal EBPM recovery ratio and executive function, working memory, and retrospective memory..... 225

6.9.4 Results of HMRA for non-focal EBPM and executive function, working memory, and retrospective memory..... 229
6.9.4.1 Non-focal EBPM proportion correct and executive function, working memory, and retrospective memory.. 229
6.9.4.2 Non-focal EBPM forgetting ratio and executive function, working memory, and retrospective memory.. 229
6.9.4.3 Non-focal EBPM recovery ratio and executive function, working memory, and retrospective memory..... 230
6.9.5 Results of logistic regression analyses for TBPM and executive function, working memory, and retrospective memory..... 234
6.10 Discussion..... 235
6.11 Limitations..... 248
6.12 Conclusion..... 250
Chapter 7: 253
7.0 Overview..... 253
7.1 Introduction..... 253
7.2 Review of major findings from Studies 1, 2, and 3..... 254
7.2.1 Study 1..... 254
7.2.2 Study 2..... 257
7.2.3 Study 3..... 260
7.3 Review of the design and strengths of the ADuLTS study..... 263
7.3.1 Ecological validity..... 263
7.3.2 Micro-longitudinal design..... 264
7.3.3 Ambulatory assessment..... 265
7.4.4 Summary..... 266
7.4 Alternative explanations for the current findings..... 266
7.4.1 Categorisation of the focality of event-based cues..... 267
7.4.2 Perceptual and affective processing of cues..... 268
7.4.3 Contextual theories of prospective memory..... 273
7.4.3.1 Contextual factors and prospective memory..... 273
7.5 Limitations..... 276
7.6 Future directions for research in prospective memory processes in the oldest-old..... 279
7.6.1 Prospective memory in frail oldest-old adults..... 279
7.6.2 Stress reactivity in the oldest-old in laboratory studies..... 280

7.6.3 The influence of social partners in prospective memory performance..... 281
7.6.4 The role of cognitive training and interventions to support prospective memory..... 282
7.6.4.1 The use of interventions and emerging technologies to support prospective memory..... 282
7.6.4.2 Cognitive training and prospective memory..... 284
7.7 Conclusion..... 285

References..... 287

Appendices..... 341
Appendix A: Preliminary forms for participants in the ADuLTS study..... 341
A.1 ADuLTS recruitment letter for ALSA participants..... 342
A.2 ADuLTS recruitment letter for non-ALSA participants..... 343
A.3 ADuLTS information sheet for ALSA participants..... 344
A.4 ADuLTS information sheet for non-ALSA participants..... 345
A.5 Consent form and general information..... 346
Appendix B: Participant guidelines and instructions..... 349
B.1 Participant guidelines..... 351
B.2 Saliva sample collection instructions..... 353
Appendix C: Questionnaires and assessment forms..... 355
C.1 Baseline questionnaire..... 356
C.2 Morning questionnaire..... 369
C.3 Daily questionnaires..... 371
C.4 Feedback interview..... 381
Appendix D: Prospective memory items..... 383
D.1 Prospective memory items..... 384
Appendix E: Baseline tests administered in the ADuLTS study..... 385
E.1 Mini-Mental State Examination (MMSE)..... 386
E.2 Digit Symbol Substitution Test (DSST)..... 387

E.3 Digit Symbol Subtest..... 388
E.4 Initial Letter Fluency Test (FAS)..... 389
E.5 Excluded Letter Fluency Test (ELF)..... 390
E.6 CLOX 1..... 391
Appendix F: Selected SPSS output and analyses for Study 1..... 392
F.1 HMRA of focal EBPM proportion correct with covariate predictors..... 393
F.2 HMRA of non-focal EBPM proportion correct with covariate predictors..... 395
F.3 Logistic regression for TBPM with covariate predictors 397
Appendix G: Selected SPSS output and analyses for Study 2..... 398
G.1 Probability of proficiency on the focal EBPM task across measurement occasions..... 399
G.2 Probability of proficiency on the non-focal EBPM task across measurement occasions..... 400
G.3 Final model (E) of GLMM for focal EBPM, cortisol indices, and covariates..... 401
G.4 Final model (E) of GLMM for non-focal EBPM, cortisol indices, and covariates..... 405
G.5 Logistic regression analysis of TBPM, cortisol indices, and covariates... 409
Appendix H: Selected SPSS output and analyses for Study 3..... 411
H.1 HMRA of focal EBPM proportion correct and executive function, working memory, and retrospective memory..... 412
H.2 HMRA of focal EBPM forgetting ratio and executive function, working memory, and retrospective memory..... 414
H.3 HMRA of focal EBPM recovery ratio and executive function, working memory, and retrospective memory..... 416
H.4 HMRA of non-focal EBPM proportion correct and executive function, working memory, and retrospective memory..... 418
H.5 HMRA of non-focal EBPM forgetting ratio and executive function, working memory, and retrospective memory..... 420
H.6 HMRA of non-focal EBPM recovery ratio and executive function, working memory, and retrospective memory..... 422
H.7 Logistic regression of TBPM and executive function, working memory, and retrospective memory..... 424

List of Tables

Table	3.1.	Participant Descriptive Statistics.	63
Table	3.2.	Percentage of Successful Responses for Prospective Memory Tasks by Age Group.	66
Table	3.3.	Mean Scores for Event-based Prospective Memory Items and Ratios by Age Group.	71
Table	3.4.	Results of Regression Analyses of Proportion Correct of Event-based Prospective Memory Tasks with Age, Gender, Education, and Depressive Symptoms.	72
Table	3.5.	Results of Logistic Regression Analysis of Time-based Prospective Memory and Age, Gender, Education, and Depressive Symptoms.	73
Table	5.1.	Comparative Table of Mean Diurnal Cortisol Levels for All Participants in the Current Study with Levels Previously Reported.	146
Table	5.2.	Sample Mean AUC, CAR, and *i*SD Cortisol Levels Across Days.	147
Table	5.3.	Between Day Correlations of Average AUC, CAR, and *i*SD	148
Table	5.4.	Correlations of Sample Mean Cortisol and Descriptive Variables	149
Table	5.5.	Formulae for Transforming Logits and Odds to Probabilities.	156
Table	5.6.	Results of GLMM Analysis of Focal EBPM (Circle Capital Task).	159
Table	5.7.	Results of GLMM Analysis of Non-focal EBPM (Initial Box Task).	166
Table	5.8.	Results of Logistic Regression Predicting Likelihood of Proficiency on TBPM Task.	172
Table	6.1.	Mean and Standard Deviations for Cognitive and Covariate Variables.	217
Table	6.2.	Correlation Matrix of Major Variables with Focal and Non-focal EBPM.	218

Table	6.3	Mean and Standard Deviations for Cognitive and Covariate Variables for ALSA and Non-ALSA Participants.	222
Table	6.4.	Results of HMR Analysis of Focal EBPM Proportion Correct Across Days with Executive Function, Working Memory, and Retrospective Memory.	226
Table	6.5	Results of HMR Analysis of Focal EBPM Forgetting Ratio Across Days with Executive Function, Working Memory, and Retrospective Memory.	227
Table	6.6	Results of HMR Analysis of Focal EBPM Recovery Ratio Across Days with Executive Function, Working Memory, and Retrospective Memory.	228
Table	6.7	Results of HMR Analysis of Non-focal EBPM Proportion Correct Across Days with Executive Function, Working Memory, and Retrospective Memory.	231
Table	6.8	Results of HMR Analysis of Non-focal EBPM Forgetting Ratio Across Days with Executive Function, Working Memory, and Retrospective Memory.	232
Table	6.9	Results of HMR Analysis of Non-focal EBPM Recovery Ratio Across Days with Executive Function, Working Memory, and Retrospective Memory.	233
Table	6.10	Results of Logistic Regression for TBPM and Executive Function, Working Memory, and Retrospective Memory.	235

List of Figures

Figure	1.	Percentage of correct prospective memory responses.	65
Figure	2.	Event-based prospective memory forgetting and recovery ratios.	67
Figure	3.	Mean diurnal cortisol secretion levels across ADuLTS participants.	145
Figure	4.	Contrasting diurnal patterns of cortisol secretion for three ADuLTS participants.	145

Abstract

Prospective memory (PM) is defined as remembering a future delayed intention, for instance, remembering to take medication at the appropriate time or post a letter on the way home from work. As such PM supports day-to-day functioning and is critical for maintenance of independence into older age. In light of mixed findings from laboratory based studies as to the nature and direction of age-related changes in PM and a paucity of research with oldest-old adults, this thesis investigated PM performance in adults over the age of 85 years in naturalistic environments, and examined the effect of bio-physiological and cognitive predictors on performance during a 7-day micro-longitudinal diary study.

In Study 1, PM was examined in terms of task characteristics, target cue focality, and age. Seventy-four participants from the Australian Longitudinal Study of Ageing (ALSA) or a community sample (*M* age = 88.7 years, range = 84 – 102 years, 68% female) completed six self-report questionnaires daily over seven days. A time-based PM task, and focal and non-focal event-based PM tasks were presented across the week. Performance on event-based tasks was better relative to performance on time-based PM. Although overall proficiency was slightly higher for non-focal PM than for focal PM, there were no significant differences between forgetting and recovery ratios for the two event-based categories. Chronological age showed a small linear association (r = -.22) with successful focal PM performance.

The role of interindividual differences and intraindividual variation in physiological stress on PM performance was examined in Study 2. Stress was determined by salivary cortisol levels collected concurrently with each daily questionnaire. Generalised linear mixed modelling showed lower odds of proficiency on focal event-based PM to be associated with a higher cortisol awakening response. Overall,

physiological stress was not a strong predictor of performance. Basal cortisol levels and intraindividual lability in cortisol were not associated with event-based PM. Participants with increased cortisol secretion at task execution showed better time-based PM performance. Interestingly, covariate predictors revealed associations with PM. Higher education predicted performance on focal tasks and higher depressive symptoms were related to poorer time-based performance.

Study 3 found that executive function and working memory were significant predictors of prospective memory. Regression analysis showed performance on focal event-based PM was strongly related to higher executive functioning, with working memory predicting performance on non-focal tasks, after controlling for speed of perceptual processing. Better retrospective memory predicted lower forgetting ratios for event-based PM. Finally, time-based PM showed no association with the three cognitive measures.

These findings indicate that event-based PM is relatively spared in healthy oldest-old adults tested in naturalistic environments, in contrast to marked impairment in time-based PM. However, across the studies, and challenging predicted outcomes, performance on focal event-based tasks was generally poorer than on non-focal tasks and more vulnerable to intraindividual differences in bio-physiological and cognitive factors. Consistent with these findings, results are discussed in terms of dual-task processing and PM – ongoing task interference effects.

Chapter 1.

Thesis Overview

Prospective memory, or memory for future realisation of intentions (Craik, 1986), is an essential memory process for the maintenance of independence and functionality in ageing adults. Although prospective memory theory has informed much contemporary research into cognitive ageing, equivocal findings of age-related decline (Henry, MacLeod, Phillips, & Crawford, 2004), or conversely, sparing of prospective memory (Einstein & McDaniel, 1990; Rendell & Thomson, 1999) continue to challenge researchers. The overarching aim of this thesis is to clarify and identify key correlates of prospective memory in a cohort of "oldest-old" adults. Specifically it examines the effect of bio-physiological and cognitive mechanisms on performance, with the goal of ultimately contributing to a better understanding of prospective memory pathways in normal ageing.

1.1 Ageing in Australia

The end of the twentieth century witnessed a re-definition of the term old age. Although the criteria for being 'old' was traditionally linked to the eligible pension age of 65 years (WHO: World Health Organisation, 2013), rapid social change and an increased focus on optimising successful ageing has resulted in an ageing population demographic. Gains in terms of increased physical and mental fitness with each successive cohort (Schaie, 2013), have culminated in a stratification of older adults over the age of 60 years into two distinct groups, the 'young-old' and the 'old-old'. Baltes and Smith (2003) have posited a demographic definition for the *oldest-old* as those aged 85 years plus, otherwise commonly referred to as the *fourth age*. Whilst the 2010 Intergenerational Report

(Australia to 2050: Future Challenges, 2010) estimates that 23% of the population will be 65 years or older by the year 2050, individuals aged 85 years plus are the most rapidly ageing group. The oldest-old represented 1.6% of the population in 2007, with the cohort predicted to quadruple to reach approximately 1.8 million people by 2050 (ABS, 2010). This trend has been identified in most developed countries (WHO, 2013) with immense ramifications for welfare, health, and social policy. Importantly, the changing age demographic has afforded researchers the opportunity to examine the bio-psycho-social factors and constructs associated with advanced older age, and is a central theme of this thesis.

From a socio-demographic perspective, the burgeoning aged population presents new and unique challenges. A fundamental goal for policy and health care professionals is to mitigate the consequences associated with advanced older age by preventing or delaying disabilities. In so doing, the need for institutionalised care with associated costs to individuals, families, and health care systems can be attenuated. At present, the majority of older Australians (94%) live in private homes or self-care accommodation, a quarter of whom live alone (AIHW: Australian Institute of Health and Welfare, 2011-12). By the fourth age however, almost 50% live alone. Assisting older adults to maintain functionality and independent living is critical in view of the predicted increase in this cohort, the premise of which has informed recent national policy. For example, the Australian Commonwealth Government recently tabled the Living Longer, Living Better policy (AIHW, 2011-12) advocating a substantial nation-wide increase in consumer directed, in-home care packages to assist older adults to retain independence for as long as possible.

With current directives aimed at supporting community dwelling older adults, it is timely to explore the factors that may sustain or impede maintenance of independence into the fourth age and support active ageing. The WHO defines active ageing as "the process of optimizing opportunities for health, participation, and security in order to enhance quality of life as people age" (WHO, 2013, p 12) and acknowledges that "as people age, their quality of life is largely determined by their ability to maintain autonomy and independence" (WHO, 2013, p 13). Despite limitations presented by biological ageing, many older adults are able to maintain independence and a sound quality of life into the fourth age based on physiological and mental health, financial security, continued activity and social inclusion. To this end, cognition is a key resource supporting productive, independent, and socially engaged older age (Carstensen, Mikels, & Mather, 2006). Indeed, psychological resources such as intelligence and cognitive capacity are strong predictors of active ageing (Schaie, 2013). One such cognitive resource is prospective memory, or remembering to perform a task in the future. Prospective memory supports day-to-day functioning in everyday life across the course of the lifespan (Ellis, 1996) and is central to the maintenance of independence into advanced age. Clarifying the factors underpinning this vital memory process in the oldest-old is therefore the focus of the current research.

1.2 Prospective Memory

Prospective memory represents a unique and complex multi-dimensional memory construct. Prospective memory tasks range in complexity and salience from the very mundane, such as remembering to purchase bread on the way home from work, through to tasks supporting a myriad of social and functional behaviours. Successful encoding, retention in memory, and retrieval of an

intended action at the appropriate time and in context, are fundamental to successful task outcomes. Multiple factors may therefore impede or support prospective memory performance at any stage from encoding an intention in memory through to task execution. Such factors include individual differences in cognitive and functional ability, motivation to complete the task, and salience of the task. Interference from competing activities and reduced windows of opportunity in which to execute a task may further inhibit successful outcomes and lead to memory failure. Thus disentangling the complex nature of prospective memory and identifying factors supporting optimal function to attenuate prospective memory failure, are an important challenge for research.

It has been estimated that almost 50% of everyday forgetting is due to prospective memory failures (Crovitz & Daniel, 1984; McDaniel & Einstein, 2007). Everyday forgetting may stem from working memory failure, for instance forgetting the reason for entering a room, or be associated with failure to recall or retrieve information, for example forgetting a person's name or the ingredients of a favourite recipe. However, with respect to ageing, prospective memory failures potentially have adverse ramifications across multiple domains, including instrumental activities of daily living, the maintenance of one's health and safety, and the continuation of social and familial relationships. From a medical perspective, older adults are faced with many health-related prospective memory tasks such as remembering to take medication or monitor blood sugar levels. Failure on these tasks may result in adverse or even life-threatening outcomes. It has been estimated that in developed countries, adherence to long-term medical therapy averages only 50% and is associated with compromised treatment efficacy and effectiveness, and reduced quality of life outcomes (Dipollina &

Sabate, 2002). Failure in prospective memory ability may well contribute to this alarming rate of non-adherence, with adverse implications not only for independently living older adults but also for their families, carers and health care providers. Furthermore, lapses in prospective memory may culminate in detrimental safety outcomes, for instance, forgetting to turn off a stove, or secure premises. Prospective memory failure also has ramifications for social connectedness and isolation if older adults regularly forget impending functions or events, or forget important milestones of friends and relatives. With social isolation an identified risk factor for ill-health and depression, minimizing the consequences of isolation becomes a challenge (Berkman, Glass, Brisette, & Seeman, 2000), especially for those living alone. Proficient prospective memory is therefore an important resource supporting optimal day-to-day functioning in multiple domains and underpins successful ageing. It is apt therefore, for contemporary prospective memory research to focus on delineating the mechanisms supporting prospective performance into very advanced older age.

To this end, a burgeoning body of research over the last three decades has contributed to a gradual understanding of the processes involved in prospective memory. However, the nature of the changes in prospective memory processes and performance with age remains contentious. There is a mixed pattern of results reported in the extant literature, with some studies reporting minimal age-related differences and others showing robust decline with age. Older adults often out-perform their younger counterparts in real-world, naturalistic settings and yet exhibit age deficits on tasks undertaken in laboratory settings. Such contrasting findings in the literature have been termed the *age-prospective memory paradox* (Rendell & Craik, 2000). Further encapsulating this paradox are divergent age-

related effects consistent with the characteristics and demands of a prospective memory task. These issues pose a conundrum for researchers in the field in defining the actual nature and direction of age-related change associated with healthy, normative ageing.

A further challenge to defining age-related effects in prospective memory performance stems from the large number of laboratory-based cross-sectional studies informing the current literature. These studies have typically compared extreme age groups of younger (for example, undergraduate students aged in their early twenties) and older adults rather than examining age-related effects within old age. Zeintl, Kliegel, and Hofer (2007) reported a notable exception, investigating prospective and retrospective memory performance within a restricted age band, that is the third age (i.e., 60 to 80 years of age), posited to "provide a more accurate account of prospective memory as a function of age" (p. 826). Several commentators concur with this contention (Ellis & Kvavilashvili, 2000; Huppert, Johnson, & Nickson, 2000).

The first rationale for this thesis was founded on the paucity of research examining age-related effects in extreme older age outside of laboratory paradigms. The second rationale for examining prospective memory in the oldest-old was based on issues arising from the age-prospective memory paradox reported in the literature. The ALSA Daily Life Time Sampling (ADuLTS) study collected data from adults within the fourth age in real world settings, providing a unique opportunity to examine age-related effects in prospective memory processes in this cohort.

1.3 The ADuLTS Study

The ADuLTS study was conducted under the umbrella of a larger study, the Australian Longitudinal Study of Ageing (ALSA). The ALSA is a long-running prospective longitudinal study of older adults, conducted by the Flinders Centre for Ageing Studies at the Flinders University, South Australia. The ALSA, which commenced in 1992, has collected 12 waves of data up to 2013. The ALSA project and methodology have previously been described elsewhere (Andrews et al., 2002; Chiu, Hoppmann, Gerstorf, Walker, & Luszcz, 2014; Chui et al., 2013; Luszcz et al., 2007).

At Wave 11 (2010) 50 eligible ALSA participants were recruited to participate in the ADuLTS study, with an additional 25 community dwelling participants recruited from outside of the ALSA participant pool. The ADuLTS study, conducted in 2010 and 2011, was a micro-longitudinal study conducted over seven consecutive days in a participant's own home. Data obtained from a range of measures were collected seven times per day using ecological momentary assessment. The ADuLTS data provided a foundation to this thesis enabling the relationships between the determinants of prospective memory and performance in advanced age to be investigated through a specific focus on inter-individual differences and intra-individual variability in prospective memory performance.

1.4 Studies Providing the Focus for the Current Thesis

From a life-span perspective, older adults are far from one homogeneous group but display robust individual diversity and differences along physiological, psychological and cognitive dimensions (Ram & Gerstorf, 2009). A major aim of this thesis is to examine some of the inter- and intra-individual factors

determining prospective memory performance in advanced age, to enable clarification of the pathways associated with prospective memory processes. Three studies are presented investigating theoretically derived predictors of prospective memory performance. Study 1 examines the effect of the characteristics of a prospective memory task and target event cue on prospective memory performance. Study 2 examines the relationship between bio-physiological stress processes and prospective memory. Study 3 investigates the association between cognitive abilities, namely executive function, working memory and retrospective memory, on prospective memory outcomes. The following section will briefly outline the rationale for each of the three studies, each of which is elaborated on in subsequent chapters.

1.4.1 Rationale for Study 1: Prospective memory in the fourth age.

Current conceptualisations of prospective memory suggest age-related declines or paradoxical gains in prospective memory are coupled with numerous constructs. These include the setting of the task, the characteristics of the task, the strategic demands of the task, and the characteristics of the task cue prompting execution of an intended action. Differential age-related effects have been reported from naturalistic based studies compared to laboratory based environments, with apparent gains in ecologically valid studies and age-related losses in laboratory studies. Delineating a consistent direction of age-effects is further complicated by the nature of the prospective task. A theoretical viewpoint posited by McDaniel and Einstein (2000) argues age-related deficits are a function of the strategic demand associated with the nature of a task (i.e., event-based versus time-based tasks) and the characteristics of a target cue signalling the event (i.e., focal versus non-focal cues). However, to date few studies have

explored this contention in the oldest-old in naturalistic environments. Study 1 therefore aims to assess (1) the extent or otherwise of normative age-related losses in prospective memory in this cohort, and (2) to assess if the task and target cue characteristics differentially impact performance.

1.4.2 Rationale for Study 2: Stress and prospective memory. During the last decades, stress has become synonymous with life in modern societies (Almeida, Piazza, Stawski, & Klein, 2011). Implicated in the aetiology of a plethora of psychological and physical health complaints, stress has been associated with acceleration of the ageing process (Piazza et al., 2010). First investigated in a biological context in the 1930's (Seyle, 1956), stress has been defined as the inability of an organism to respond and adapt effectively to, stressor demands, be they physiological, psychological or emotional stressors. A primary biomarker of stress, salivary cortisol, is increasingly used in neuropsychological research to assess the relationships between individual stress response and cognitive domains (Kirschbaum & Hellhammer, 2000). Detriments in memory performance, in particular declarative (Kirschbaum et al., 1996) and working memory (Qin et al., 2009; Schoofs, Wolf, & Smeets, 2009), have been associated with elevated cortisol levels. Elevations in cortisol can arise from pharmacological administration, pathophysiological processes, response to stressor demand, and normative age-related increases in basal levels. With a rapidly ageing population, appraising stress responses and memory processes in the oldest-old, could provide important insights into the factors and conditions conducive to optimal ageing. Indeed, few studies have considered the effect of stressor demand upon such a vital memory process.

The aim of Study 2 is to elucidate the relationship between lability in stress processes and prospective memory performance in the oldest-old. Specifically it aims (1) to examine the co-occurrence of daily stress with daily fluctuations in prospective memory within naturalistic settings using data from the ADuLTS micro-longitudinal study, and (2) to examine the effects of daily stress on event-based and time-time based prospective memory.

1.4.3 Rationale for Study 3. Cognitive predictors of prospective memory in the fourth age: Executive function, working memory, and retrospective memory. Executive function and working memory are cognitive processes responsible for higher level cognition and attentional control. Executive function is a complex, multi-dimensional process, fundamental to optimal cognition, memory and functional status (Lezak et al., 2012; Luszcz, 2011). Related to, but partially dissociable from executive function, is the concept of working memory. Working memory is a limited capacity system responsible for the manipulation and maintenance of information (Baddeley, 2003), related to general fluid intelligence, episodic memory and attentional capacity (Engel & Kane, 2004). Primary ageing is associated with declines in both executive functioning (Luszcz & Bryan, 1999) and working memory. Deficits in attentional control processes predict memory decrement with advancing age (Crawford, Bryan, Luszcz, Obonsawin, & Stewart, 2000), and declines in optimal everyday functioning (Royall, Palmer, Chiodo, & Polk, 2004). There is some confirmatory evidence for executive function (Glisky, 1996; Martin, Kliegel, & McDaniel, 2003; Schnitzspahn et al., 2013) and working memory (Einstein et al., 2000; Logie et al., 2004; Reynolds, West, & Braver, 2009) support of prospective memory processes in terms of the degree of controlled attentional processing

required for successful task outcomes. However, few studies have investigated the role of these cognitive constructs in supporting prospective memory performance in advanced older age.

Retrospective memory is memory for past events, people, and experiences and is usually personal in nature with temporal reference (Tulving, 1972). Retrospective memory is an integral component of prospective memory, enabling the recall and retrieval of the content and context of an intended action. Although implicated as a component of the prospective memory process, studies to date suggest it is not a major determinant in proficiency (Henry et al., 2004; Kliegel, MacKinlay, & Jäger, 2008; McDaniel & Einstein, 2007; Zimmermann & Meier, 2006). As is the case for executive function and working memory, the relationship between retrospective memory and prospective memory in advanced older age remains to be determined.

Study 3 therefore aims to (1) test the influence of controlled attentional processes in the form of executive function and working memory, on prospective memory performance in terms of cue type and task characteristics, and (2) examine the effect of retrospective memory ability on prospective memory proficiency in terms of cue type and task characteristics.

1.5 Structure of the Thesis

A brief overview of the remaining structure of this thesis follows.

The current literature related to prospective memory will be reviewed in Chapter 2, to define the theoretical concepts underpinning empirical work in this thesis. Prospective memory is defined and contemporary models of prospective memory processes described. The factors implicated in performance and differential age-related effects are summarised. Particular emphasis is given to the

nature of the prospective memory task and characteristics of the task cue which are examined in all three studies. The literature pertinent to age-related changes in prospective memory proficiency is next evaluated and the rationale for investigating prospective memory in older adults presented.

In Chapter 3 Study 1 is presented. The methodology for the ADuLTS study, which applies across studies, is also presented.

Chapter 4 summarises the literature underpinning the two subsequent studies which seek to identify non-age-related predictors of performance. Part one will evaluate the literature and empirical evidence for Study 2, specifically neuroendocrine correlates of stress processes and prospective memory performance in an ageing context. Inter-individual differences and intra-individual variability in physiological stress levels and their proposed effect on prospective memory proficiency are explored. The second section of Chapter 4 reviews the cognitive predictors of prospective memory processes in the context of normative age-related change to inform Study 3.

Chapter 5 presents Study 2 on the co-occurrence of stress and prospective memory performance. In so doing, the relationship between biological function and psychological outcomes in advanced older age is explored.

Study 3 is presented in Chapter 6. It provides an examination of the association between executive function, working memory, and retrospective memory with prospective memory performance.

Chapter 7 comprises a general discussion and integration of the main findings from the three Studies. Theoretical implications and real-world applications of the findings are discussed. The final section addresses the

strengths and limitations of this thesis and proposes recommendations for future research.

1.6 Summary

With a rapidly ageing population, the question arises as to how to optimise function in the fourth age. Understanding the factors determining active ageing will enable clarification of the pathways associated with positive, independent functioning. This could potentially inform life-course choices enabling people to reach their full potential through the oldest-old years rather than simply adding leisure years or isolated, fragile years (Rowe, 2013). Unquestionably, prospective memory is a key cognitive resource supporting active ageing. If prospective memory performance is indeed spared into oldest age, it would represent an important buffer and protective mechanism to support maintenance of independence. It is therefore the overarching aim of this thesis to determine the nature of age-related effects in prospective memory in a cohort of healthy, community dwelling oldest-old adults.

Chapter 2.

Review of the prospective memory literature

2. Overview

The following critical review of the current literature relating to prospective memory lays the groundwork for Study 1. The first section of the review seeks to define prospective memory processes and tasks, and explore contemporary conceptual frameworks from an ageing perspective. Two prominent contemporary models of prospective memory, the Preparatory Attentional Monitoring theory (PAM: Smith, 2003; Smith & Bayen, 2004), and the Multiprocess Framework developed by McDaniel and Einstein (2000), are evaluated. To inform Study 1, the "age-prospective memory paradox" (Rendell & Craik, 2000) will be discussed in terms of the Multiprocess Framework of prospective memory highlighting factors that could determine variability in performance in this domain. Previous research contributing to our understanding of age-related effects in prospective memory is summarised and the rationale for Study 1 outlined.

2.1 Introduction to Prospective Memory

Prospective memory has been defined as remembering to remember to perform an activity in the future (Craik, 1986), that is, to realize delayed intentions (Zeintl, Kliegel, & Hofer, 2007). In an ageing context, prospective memory is an important resource in supporting successful ageing, facilitating independent everyday living, and assisting older adults with optimal functioning in multiple domains.

Early prospective memory research predicted normative age-related decline in this memory domain concomitant with that observed across studies of

retrospective memory (Craik, 1986; Craik & Kerr, 1996). Contradictory findings have emerged from recent research, suggesting sparing of prospective memory with age, dependent upon the nature of the prospective memory task, task demand, and the ecological setting of the prospective memory task. Several theoretical approaches have been posited to clarify the mechanisms underpinning divergent findings, including task contextual models, spontaneous retrieval models, and attentional monitoring frameworks. Following a general review of the nature and characteristics of prospective memory tasks, the latter two models will be discussed in terms of prospective memory performance and age-related effects.

2.1.1 Characteristics of prospective memory. Prospective memory is a complex, multi-faceted memory process, the conceptualisation of which emerged and developed during the last 30 years from research into retrospective memory. However, unlike retrospective memory of past events, knowledge and experiences, prospective memory tasks concern something an individual plans to do in the future, either at a particular time or in concert with a particular event. Although prospective memory tasks are action plans for future execution, retrospective memory is a necessary component of successful prospective memory outcomes. Remembering the specifics of a task involves bringing a previously formed intention to awareness at the correct time and in the correct context, and importantly, remembering what it is one intended to do, representing the retrospective component of prospective memory (Uttl, 2008).

Retrieval of the intended task is stimulated by recognition of a signalling action or stimulus cue, for example, noticing the bakery while driving past, thus signalling your earlier planned intention to pick up bread, or hearing an alarm

reminder to attend a scheduled meeting. Stimulus cues are otherwise referred to in the current literature as target events or target cues. Prospective memory tasks signalled by environmental cues or events are categorised as *event-based* tasks. In contrast, *time-based* prospective memory tasks are intended actions planned for a future time or following a specified time interval that are not cued by a specific event or cue, for instance, independently remembering to make a phone call at a specific time.

Prospective memory tasks are further characterised by McDaniel and Einstein (2007) as having a constrained time frame for response initiation and execution of the task. Prospective memory tasks are therefore not nebulous, time invariant future goals or intentions such as a plan to learn a new language at some point in the next few years. In contrast, remembering to attend a French class on a specific day and at a prescribed time characterises a unique prospective memory task. Prospective tasks have also been characterised as either simple or complex in nature (Kliegel, Jäger, & Phillips, 2008). Simple tasks constitute single, non-recurring or infrequently occurring tasks, whereas complex tasks involve a series of tasks. Further, prospective memory tasks have been defined as either regular in nature, with regular, routine target cues, or as irregularly occurring tasks with irregular or novel target cues (Aberle, et al., 2010; Rendell & Craik, 2000). Thus prospective memory tasks can be characterised according to an event versus time-based target event or cue, the complexity of the task, and the regularity of the task, highlighting the multi-dimensional nature of prospective memory.

Given the definitional diversity with which prospective memory processes can be characterised, and the complexity of prospective memory processes over time, specific parameters capturing the continuum of prospective memory tasks

have been defined by researchers in this field. In particular, Kliegel and colleagues (2002) conceptualise prospective memory in terms of a series of four cognitive processes. This theory helps to define the complexity and multi-dimensional nature of this memory process and is detailed below.

2.1.2 Four phase theory of prospective memory processes. The four phase theory of prospective memory processes proposed by Kliegel, Martin, McDaniel and Einstein (2002) embodies a componential approach delineating the distinct characteristics of prospective memory tasks and their associated cognitive processes. Kliegel and colleagues classify the first component of the prospective memory process as 1) intention formation, followed by 2) intention retention, 3) intention initiation, and 4) intention execution.

Intention formation involves the voluntary formation and encoding of an intended future action and the appropriate retrieval context, that is, the what, when and where of a delayed intention or plan. Successful encoding and intention formation during this initial phase influences prospective memory performance and is largely determined by an individual's planning and motivational processes (Ellis, 1996). Ellis noted that novel or complex prospective memory tasks require more elaborate associated planning and encoding of the intention during this phase when compared to that required for routine everyday tasks. Intention formation during this phase may encompass an initial plan or action for a single task however routine or complex. Conversely intention formation may involve initial encoding for a plan or action that translates to an habitual or routine task, for instance, the task of taking a regular medication at a prescribed time each day (McDaniel & Einstein, 2007). In this latter example, regular encoding of the intention to take a recurring medication becomes redundant as retrieval of the

intended action habituates to, and is associatively paired with, an action stimulus, for example taking medication with one's breakfast cup of tea.

The second phase of prospective memory proposed under this model is intention retention, the period between intention formation and potential execution of the intended action (Kliegel et al., 2002). Intention retention represents the retrospective component of a prospective memory task. To successfully realise the *what*, and *where*, of a delayed intention, the intended action must be retrieved at the appropriate time and in the appropriate context (Uttl, 2008). This phase is characterised by ongoing activity which precludes the intended action from being actively held in working memory or being regularly rehearsed in working memory. Presentation of a time based or event based environmental stimulus or target cue activates retrieval of the intended action. This differentiates prospective memory from working memory and vigilance tasks which entail either holding the intention in working memory, regularly rehearsing the intention, or engaging in sustained monitoring (Ellis & Kvavilashvili, 2000; Graf & Uttl, 2001). The retention period may vary from as little as a few seconds to several days, but as noted by McDaniel and Einstein (2007), the retention interval is not time invariant but constitutes a constrained window of opportunity during which the prospective memory task can be initiated and realised.

Intention initiation is the third cognitive process in a prospective memory task. It is the point at which an environmental stimulus, or target cue elicit retrieval of the intended action and prompt task execution. The final phase of intention execution is the resolution of the prospective task through execution or implementation of the intended action or plan. Thus, the four phase process theory of Kliegel and colleagues (2007) suggests that prospective memory is a

complex, multi-dimensional process, successful performance of which is supported by intention formation, intention retention, intention initiation and task execution.

2.1.3 Prospective memory as a unique construct. Given retrospective memory is a component in prospective memory processes, early research theorized the age-related mechanisms associated with retrospective memory could be applicable to prospective memory. Craik (1986) proposed that prospective memory requires greater self-initiated retrieval of an intended action in comparison to retrospective memory processes and retrieval. As normative age-related declines in retrieval and recall are evident in studies of retrospective memory, it was predicted that prospective memory would exhibit similar age-related deficits. However differential age-related declines suggest that prospective memory and retrospective memory cannot be entirely subsumed under the same memory processes.

Retrospective memory is defined as memory for past experiences and events and incorporates episodic, autobiographical and semantic memory (Wheeler, Stuss, & Tulving, 1997). Episodic memory, or our conscious awareness of specific past events and experiences, is common to both prospective and retrospective memory. Retrospective memory is therefore considered to be an integral component of prospective memory permitting recollection of the specific prospective memory task at the appropriate time and context, and facilitating discrimination between salient or non-salient target cues to initiate an action plan. Although sharing common components with episodic and retrospective memory, prospective memory has been shown to be a distinct memory process (Raskin et al., 2011), partly dissociable from retrospective memory, declarative memory, and

working memory (Salthouse, Berish, & Siedlecki, 2004; Zeintl, Kliegel, & Hofer, 2007).

To demonstrate the underlying components of prospective memory, Salthouse et al. (2004) undertook research utilising confirmatory factor analyses to establish construct validity of four prospective memory variables with associated cognitive and personality factors. In addition, the study examined if there were unique age-related effects on prospective memory. Using a large sample (N = 330) across a broad age range (18 - 89 years), Salthouse and colleagues found a moderate correlation between prospective memory and other cognitive abilities, namely fluid intelligence, speed of processing, and vocabulary. Prospective memory was only weakly associated with personality factors and self-reported retrospective memory variables. Importantly, age-related prospective memory effects were not associated with failure on the retrospective memory component in three out of four prospective memory tasks employed. Salthouse concluded that age-effects in prospective memory, specifically in participants over the age of 50 years, to be independent of age-related effects in the other cognitive constructs examined. These findings lend support to prospective memory being a distinct memory process in which age-related declines do not necessarily parallel declines evident in other cognitive constructs, including retrospective memory.

Subsequent findings reported by Zeintl et al., (2007) provide evidence convergent with that of Salthouse et al. (2004). Older adults (N = 361) between 65 and 80 years were tested on three tasks each in event-based prospective memory, free recall, speed of processing, and working memory. Across this 15 year age range, age-effects were apparent for both prospective memory and free

recall with older adults showing greater deficits. Age effects were greater for prospective memory, in support of Craik's (1986) proposal that this construct necessitates greater self-initiated retrieval and has less environmental support than retrospective memory. However, age-effects in free recall were mediated by working memory and speed of processing, indicating that biological ageing impacts upon particular fluid abilities that reduce free recall capacity. Further, prospective memory was significantly related to age, but analyses demonstrated that neither working memory nor speed of processing mediated the relationship between age and prospective memory. This study is consistent with that of Salthouse et al. (2004) in providing evidence of prospective memory as a unique memory construct. Zeintl et al., (2007) provide a compelling argument in identifying substantial differences in cognitive performance among older adults within a restricted age band, highlighting the heterogeneity of the oldest-old.

Thus, current research suggests that prospective memory is dissociable from many other cognitive processes in which normative age-related declines are documented. Conceptual models of prospective memory founded on contemporary research have been proposed to contextualise the cognitive mechanisms underlying it. The role of these mechanisms in supporting prospective memory will be reviewed and two contemporary models of prospective memory discussed. In particular the relationship between age and prospective memory will be examined under each model.

2.2 Theories of Prospective Memory

Contemporary views of prospective memory revolve around two key mechanisms, namely spontaneous retrieval and attentional monitoring. Consideration of them illustrates that there is some controversy among

researchers as to the fundamental constructs accompanying prospective memory processes (Hertzog, 2008). The mechanisms and related constructs will be introduced first, followed by explication of two prominent theories they've given rise to: the Preparatory Attentional Monitoring theory (PAM: Smith, 2003; Smith & Bayen, 2004a) and the Multiprocess Framework (MPF: McDaniel & Einstein, 2000).

2.2.1 Spontaneous retrieval mechanisms. Spontaneous retrieval implies that retrieval of an intended action is an automatic and involuntary cognitive process. The rationale for spontaneous retrieval of an intended action is founded upon prospective memory processes inherent in everyday life. Long retention periods between intention formation and retrieval challenge an assumption of continual vigilance to, or rehearsal of, a prospective task (McDaniel & Einstein, 2007). For example, an intended action to post a letter is not necessarily rehearsed or brought to conscious awareness during the on-going activities of the day, but detection of the mail box while driving past evokes retrieval of the intention, providing an opportunity for task execution. Several theoretical approaches have been postulated to identify the mechanisms implicated in spontaneous retrieval.

Moscovitch (1994) proposes a reflexive-associative memory process facilitates associative encoding of an intended action and intention retrieval. At encoding, stimuli are associated in memory with existing memory representations. Upon target cue detection, the association automatically enters conscious awareness. Using the prior example, upon encoding a prospective action to post a letter, the letter is associated with a previously formed memory representation of a mail box. Upon detection of the mail box the target cue-action representation is

spontaneously activated and retrieved in memory. This conceptualisation of retrieval is upheld by anecdotal evidence from everyday life, whereby an intended prospective task just "pops into mind" (McDaniel & Einstein, 2007).

A substantial body of research also supports spontaneous retrieval of prospective intention. A study in which the associative strength between a target cue word and the intended word response was manipulated, found significantly better prospective memory performance with highly associated words (e.g., spaghetti and sauce) compared to words having low association (e.g., knife and fence) (McDaniel, Guynn, Einstein, & Bresneiser, 2004). This study provides evidence for a contextual/associative approach to prospective memory such that spontaneous retrieval of intended actions is initiated upon recognition of highly associated target cues.

An alternative view suggests prospective memory retrieval is supported through a process of spontaneous noticing, conceptualising cue detection as context-free recognition (Mandler, 1980). Upon recognition, target cues are thought to prompt a sense of familiarity thereby stimulating retrieval of the intended action, or prompting further controlled cognitive processes to contextualise the prospective task (McDaniel & Einstein, 2007). Guynn and McDaniel (2008) tested this proposition in an experiment in which young adults received either pre-exposure or no pre-exposure to a prospective memory target cue. Participants in the pre-exposure condition showed significantly better prospective memory performance than those with no prior exposure, indicating that prospective memory retrieval can be supported by spontaneous context-free recognition of target cues.

Spontaneous retrieval processes in prospective memory have also been associated with the characteristics of the target cue, including the distinctiveness and salience of the cue, and characteristics of the task, in promoting involuntary orienting of attention. In several studies, perceptually distinct cues were presented to participants in capitalised letters embedded within an on-going event-based prospective task presented in lowercase letters (Brandimonte & Passolunghi, 1994; Einstein, McDaniel, Manzi, Cochran, & Baker, 2000; West, Herndon, & Crewsdon, 2001). In all trials with distinctive target cues, performance on the prospective memory task was near ceiling level. Conceptually distinct targets such as meaningless words embedded within meaningful items (McDaniel & Einstein, 1993), and target cue salience, for instance varying the size of the target cue presentation (Uttl, 2008), have also been shown to positively influence prospective memory performance. Involuntary orienting of attention to the target cue stimulates spontaneous recognition of the cue and retrieval of the intended action, improving both accuracy and response time to the prospective task. Thus spontaneous retrieval mechanisms constitute a key facet of prospective memory. An alternative conceptualisation places emphasis on attentional monitoring mechanisms.

2.2.2 Attentional monitoring mechanisms. Attentional monitoring is fundamental to successful task initiation and prospective memory performance. Limited cognitive resources are available for allocation to either a prospective memory task or to on-going tasks. Thus, monitoring is thought to exact a cost in terms of performance of either the prospective task or other on-going tasks, in essence directing attention and cognitive resources between competing tasks. An early formal model proposed by Shallice and Burgess (1991) contended that the

Supervisory Attentional System (SAS), a component of executive function processes, mediates switching from an on-going task to an intended prospective action. The SAS or executive attentional processes, serve to encode the target event and intended action, and determine and direct monitoring of the environment for the relevant target cue. Upon target cue detection, the SAS activates relevant schemas, while inhibiting unintended or irrelevant schemas, to initiate intention retrieval and task execution. Under this model, more elaborate or novel prospective memory tasks require greater cognitive resources to be allocated to the monitoring process, resulting in higher cognitive cost to other competing or on-going tasks.

The extent and nature of monitoring required to detect a target cue and maintain a cue-intention association, is contrasted in current models of prospective memory processes. The Preparatory Attentional Monitoring theory (PAM: Smith, 2003; Smith & Bayen, 2004a) proposes a case for continuous monitoring processes, whilst other models conceptualise monitoring as either periodic checking (Guynn, 2003), being dependent on contextual factors (Marsh, Hicks, & Cook, 2005), or as a function of the strategic demands of the task and target cue (McDaniel & Einstein, 2000).

2.2.2.1 ***PAM: Preparatory Attentional Monitoring theory.*** The PAM theory (PAM: Smith, 2003; Smith & Bayen, 2004a) contends that prospective memory is supported by continuous monitoring of the environment for the target cue or stimuli necessary to initiate task retrieval and execution. The PAM theory contends that prospective tasks necessitate conscious intention formation, retrieval of which is only possible with preparatory monitoring processes that facilitate conscious response decisions to the appropriate target cue and at the

appropriate time. Whilst Smith acknowledges that spontaneous retrieval may be elicited through automatic processes that link the target cue and intended action, she argues that this is a reflexive response and not representative of a volitional intention (Smith, 2008). Further, Smith and Bayen (2005) define monitoring as non-automatic and therefore demanding of cognitive resources. It is posited that monitoring need not be continuous and may involve either explicit checking for target cues or alternatively, more subconscious monitoring of the environment (Smith & Bayen, 2005). In either case, preparatory processes and a continuous degree of attentional resources devoted to monitoring are deemed to be essential for successful prospective memory performance (Smith & Bayen, 2005).

As mentioned in the previous section, attentional monitoring is thought to incur costs in terms of cognitive capacity and resource allocation (SAS: Shallice & Burgess, 1991). Evidence has largely been determined from response time studies using different on-going and prospective tasks (Burgess, Quayle, & Frith, 2001; Smith & Bayen, 2004a). Marsh, Hicks and Cook (2005) define task interference, termed the prospective memory interference effect, as the extent of cognitive resources directed to a prospective memory task and away from on-going activity, as measured in response time latencies. Smith (2003) compared reaction times in an experiment in which a prospective memory task, namely remembering to press a specific computer key at the presentation of a target word, was embedded in an on-going lexical decision task. There was an increase in lexical decision latencies of between 200 to 300 ms in the prospective memory trials compared with control trials using the lexical task alone. Subsequently, Smith and Bayen (2004a, 2005) introduced a formal multinomial model to examine response times in prospective memory tasks. Individual differences in

baseline measures, for example working memory, were controlled in statistical analyses. In experiment 1 (Smith & Bayen, 2005), preparatory attentional processes and retrospective memory processes were distinguished from working memory capacity under the proposition that monitoring is not an automatic process but requires allocation of resources. Those with higher working memory spans were found to have a higher probability of engaging in preparatory monitoring showing better prospective memory task accuracy; however retrospective memory was not significantly related to working memory span. Further Smith and Bayen (2005) found in experiment 2 that high on-going task demand was associated with reduced accuracy on prospective memory tasks, indicative of reduced allocation of resources to preparatory monitoring.

PAM theory is further supported by research whereby Smith and colleagues (Smith, Hunt, McVay, McConnell, 2007) introduced a strong association between a prospective item target cue and the requisite task action, during a simple on-going task. It was hypothesised that highly salient target cues would be detected automatically reducing the need for preparatory monitoring. Study participants were instructed to respond to a salient target cue, their own name, while engaging in a lexical decision task. Performance was poorer in prospective memory trials compared with performance in the lexical decision trials alone indicating attentional resources were allocated to the prospective task, resulting in cost in terms of performance on the on-going task. Smith et al. contend that even with high association and salience between a target cue and task initiation, cue detection is not a purely automatic process but necessitates preparatory monitoring.

Despite evidence for the PAM theory, some studies have failed to find support for on-going costs in prospective memory tasks (Einstein et al., 2005; Marsh, Hicks, Cook, Hansen, & Pallos, 2003). Marsh and colleagues conducted four experiments to investigate response time latencies in event-based prospective memory tasks and interference from cue detection. Three studies found no incurred cost of monitoring for cue detection, nor interference from cue detection under different cue conditions. Smith argues that procedural confounds in these studies could have accounted for the failure to find cost associated with preparatory monitoring (Smith, 2008). However, Smith also acknowledges that costs reported in response time measures could represent experimental confounds, examples of which include experimental noise, small sample sizes and reduced analytical power, or alternatively, reflecting baseline differences between individuals (Smith, p.45). Despite these differential findings, the PAM theory illuminates observed age-related effects in prospective memory performance under some, but not all, conditions.

Age-related deficits reported in demanding laboratory based studies concur with the PAM theory, however studies of older adults in naturalistic studies suggest prospective memory performance is spared (Kvavilashvili & Fisher, 2007; Rendell & Craik, 2000). Smith surmises that older adults devote greater resources to preparatory monitoring processes in naturalisitc conditions thus accounting for spared performance in everyday life (Smith, 2008). However, as McDaniel and Einstein (2007) point out, continued monitoring, especially in older adults, is resource demanding and incurs costs at the expense of on-going activities. This observation, and other equivocal findings, may be better understood within a more complex theoretical framework.

In summary, it appears that both automatic retrieval and strategic monitoring mechanisms support prospective memory. The Multiprocess Framework of McDaniel and Einstein (2000) encapsulates how both mechanisms contribute to prospective memory.

2.3 The Multiprocess Framework of Prospective Memory

The Multiprocess Framework (McDaniel & Einstein, 2000) conceptualises both spontaneous retrieval and strategic monitoring processes to be consistent with prospective memory performance, offering a compelling conceptual approach encompassing the componential constructs of this memory process. The Multiprocess Framework distinguishes between spontaneous and strategic monitoring processes in prospective memory as a function of the nature of the task and task demands.

Prospective memory tasks are generally categorised as either *event-based* or *time-based* tasks (Einstein & McDaniel, 1999). Event-based tasks are reliant upon environmental cues to trigger recollection of an intended action or target event to initiate retrieval processes. Time-based tasks on the other hand, are tasks to be completed at a specific time or after an interval of time, for instance, remembering to make a phone call at a specific time or to take repeat medication four hours after the initial dose. Across studies, successful prospective memory performance is associated with cognitive monitoring for target cue detection and retrieval of an intended action, be it time-based or event-based, as exemplified by the PAM theory of prospective memory.

However, in contrast to attentional monitoring models, the Multiprocess Framework suggests that although a prospective memory intention is not held in conscious awareness, retrieval of the intended action is possible upon target cue

detection without the person being in retrieval mode or consciously monitoring for the target cue. Drawing on work by Moscovitch (1994) into automatic reflexive cognitive processes, McDaniel and Einstein (2000) propose that at encoding of a prospective task, an association is formed between the target cue and intended action. At cue detection, automatic associative cognitive processes are employed, spontaneously retrieving the intended action.

In support of spontaneous retrieval, participants in a prospective memory study reported consciously thinking about the prospective task to which they were instructed to respond, less than five per cent of the time during experimental trials (Reese & Cherry, 2002). Indeed, McDaniel and Einstein (2007) reported a response rate of 87% to prospective memory items embedded within a lexical decision experiment, despite participants being told the prospective memory task was unimportant. Further support for spontaneous retrieval was garnered by McDaniel and colleagues (McDaniel, Guynn, Einstein, & Breneiser, 2004), in research in which the strength of the association between a target cue, intended action, and task demand load were manipulated. Results supported spontaneous retrieval in the intended prospective memory action. There was better performance in the strong association (85% accuracy) condition between the target cue and intended action, compared with the weak association condition (56% accuracy). McDonald and colleagues (2004) also found task load had little effect on prospective memory performance. In this study, more salient target cues were better detected despite the inherent load associated with the task, indicating intention retrieval was not influenced by target cue monitoring but initiated spontaneously upon target cue detection. This body of research provides convergent evidence for spontaneous retrieval processes in prospective memory.

Both spontaneous retrieval and attentional monitoring mechanisms have been shown to support prospective memory. The Multiprocess Framework seeks to reconcile the role of both mechanisms in prospective memory by clarifying under what circumstances and conditions the two mechanisms are engaged. Evidence supporting attentional monitoring stems from studies in which the demands of the prospective and on-going tasks are manipulated. Attentional monitoring theories (Smith, 2003; Smith & Bayen, 2004a; Smith & Hunt, 2005) would predict increased task load to negatively impact upon prospective memory performance, due to greater allocation of cognitive resources directed toward environmental monitoring and target cue detection. This is supported by research in which increased task demand was associated with age-related deficits in prospective memory (Einstein, Smith, McDaniel, & Shaw, 1997; Kidder, Park, Hertzog, & Morrell, 1997). Such studies reinforce a case for monitoring processes in prospective memory theory whereby greater cognitive resource allocation to an on-going task elicits cost in terms of prospective memory performance. In contrast, McDaniel and colleagues (2004) reported no significant impact of task demand on prospective memory performance. Task demand has therefore been shown to affect monitoring processes in prospective memory performance, but not under all conditions. The specific characteristics of the task are theorized by McDaniel and Einstein (2000), as contributing factors to the nature of the monitoring required for successful prospective task outcome. The differentiation between event-based and time-based prospective memory and age-related effects will therefore be discussed in terms of the Multiprocess Framework.

2.3.1 The Multiprocess Framework and age-related effects in event-based tasks. McDaniel and Einstein (2000) contend that event-based prospective

memory can be supported by either strategic monitoring for target cues, or by spontaneous, automatic retrieval of the prospective intention upon cue detection and recognition. The dual-process theory of cognition (Shriffin & Schneider, 1977) differentiates between controlled and automatic processing. Automatic processing is conceptualized as involuntary, reflexive cognition of unlimited capacity, supported by the sub-cortical regions involved with conditioned and associative learning (Liebermann, Jarcho, & Satpure, 2004). Controlled processing (Shriffin & Schneider, 1977) is the active and strategic control of memory and attentional processes, encompassing reasoning and decision-making, encoding, rehearsal, and retrieval of information (Jacoby, 1991). In contrast to controlled processing, automatic processing is relatively spared with biological aging (Daniels, Toth, & Jacoby, 2006; Jacoby 1991; Jennings & Jacoby, 1993).

Preservation of automatic processes would suggest age-related deficits are absent in event-based prospective memory where target cues are readily detected and spontaneously recognised. In contrast, age-related deficits would be more apparent in event-based prospective memory tasks where the target cue is not readily detected, requiring greater environmental monitoring and controlled cognitive processing. From this model, the degree of automatic or strategic monitoring required by the demands inherent in the task may therefore serve to moderate age-related effects in event-based prospective memory, reflecting the discrepant age-related effects reported in the literature.

A recent meta-analysis of prospective memory studies found wide age differences associated with event-based prospective memory (Kliegel, Jäger, & Phillips, 2008). In naturalistic studies, older adults have been shown to outperform their younger counterparts in both event-based and time-based

prospective memory tasks (Henry, MacLeod, Phillips, & Crawford, 2004 for a review; Rendell & Thomson, 1999). Naturalistic studies are distinguished from laboratory based studies in the degree of experimenter control, artificiality, ecological validity, and time period between task encoding and opportunity for task execution (Phillips, Henry & Martin, 2008) associated with each condition. It has been postulated that age-related benefits under naturalistic conditions reflect older adults' placing greater reliance on functional factors including self-initiated external cues and strategies for successful task completion (Cavanaugh, Grady, & Perlmutter, 1983). However, laboratory based studies indicate that older adults generally display significant impairment with event-based tasks compared to younger adults (Cherry et al., 2001; Henry et al., 2004). In contrast, some studies report no age-effects in event-based prospective memory, despite evident age differences in retrospective free recall, and recognition tasks (Cherry & Le Compte, 1999; Einstein, Holland, McDonald, & Guynn, 1992; Einstein & McDaniel, 1990).

The divergent findings in prospective memory performance of older adults pose a challenge for researchers in the field and remain to be fully explained. An umbrella term known as the *age-prospective memory paradox* (Rendell & Craik, 2000) has been applied to differential age effects in prospective memory depending on the setting of the task and the nature of the task. The paradox encapsulates the current research whereby older adults show a distinct age advantage on tasks undertaken in naturalistic environments and real world settings, and exhibit age deficits on tasks undertaken in laboratory settings.

2.3.2 The Multiprocess Framework and age-related effects in time-based tasks. The age-prospective memory paradox (Rendell & Craik, 2000) is

also evident when time-based prospective memory and age-effects are considered. With few external or mnemonic cues available to prompt memory, time-based prospective memory engages the dual-tasks of monitoring and self-initiated, strategic retrieval, that is, controlled processing and allocation of attentional resources. As controlled processes show normative decline with age, time-based prospective memory is theorized to display greater age-effects than event-based prospective memory (Einstein et al., 1995). In parallel with event-based prospective memory, divergent findings of age-related effects in time-based studies of prospective memory are evident across the literature. Significant age-related declines in time-based prospective memory have been reported (d'Ydewalle, Bouckaert, & Brunfaut, 2001; Henry et al., 2004). In contrast, naturalistic studies in particular, suggest sparing of time-based prospective memory in older adults. For instance, d'Ydewalle, Luwel, and Brunfaut (1999) when comparing the performance of older and younger adults, found age-related deficits in time-based prospective memory largely disappeared when performance on the on-going task was taken into account. The remaining age-differences were better explained by general cognitive slowing rather than deficits in strategic monitoring.

2.3.3 Target cue characteristics and the Multiprocess Framework. It is apparent that observations of age differences in event-based and time-based prospective memory are influenced by the environmental setting and the strategic demands of the task. In addition, length of the retention period between the intention formation and opportunity for prospective task execution (McDaniel, Einstein, Stout, & Morgan, 2003a) and the nature of the target cue have been shown to influence the magnitude of monitoring and strategic retrieval required.

Contemporary research distinguishes target cue characteristics in terms of *focality* of the cue (Cherry & Le Compte, 1999; Einstein & McDaniel, 1990), cue *regularity* (Aberle, et al., 2010; Rendell & Craik, 2000), cue *distinctiveness* (Einstein et al., 2000, Experiments 1 & 3), and *strength of association* between the target cue and intended action (Loft & Yeo, 2007). The following section will examine the factors pertinent to this thesis in terms of their impact on prospective memory performance.

2.3.3.1 ***Cue focality***. Target cues in event-based prospective memory have been depicted by McDaniel et al. (2008) as either focal or non-focal in nature. *Focal cues* coincide with the information relevant to an ongoing activity and facilitate processing of the features of the cue whilst concurrently attending to the on-going task. Upon detection, focal cues initiate spontaneous retrieval of an intended task. As automatic processing is generally spared with age, it follows use of focal cues in event-based tasks should reduce age-decrements, a proposition supported by research (Cherry & Le Compte, 1999; Einstein & McDaniel, 1990; Ihle et al., 2013; Rendell et al., 2007).

In contrast, *non-focal cues* are prompts in the environment not directly associated with on-going task relevant information, thus necessitating greater strategic monitoring and recruitment of attentional resources for cue signalling. Non-focal cues may however be perceptually embedded within an on-going task but detection of the cue is not requisite for on-going task performance. Non-focal cues employed in experimental studies have highlighted age-related deficits in event-based prospective memory (Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997). A meta-analysis of 46 studies employing focal and non-focal cues found age-related deficits of $d\cdot = 0.54$ and $d\cdot = 0.72$, respectively, indicating older adults

(*M* = 70.8 years) have greater difficulty with non-focal cued prospective tasks (Kliegel, Jäger, & Phillips, 2008). Concurring with these results, Henry and colleagues (2004) identified in their meta-analysis of prospective memory that event-based tasks necessitating controlled strategic processes showed greater age-deficits (*r* = -.40) compared with event-based tasks supported by automatic processes (*r* = -.14).

In addition, although age-related deficits have been widely reported in laboratory studies using time-based tasks, such age deficits were eliminated with manipulation of target cue focality. Aberle, Rendell, Rose, McDaniel, and Kliegel (2010) conducted an experiment in which cue focality was enhanced. Using a Virtual Week prospective memory paradigm, participants were instructed to monitor an external clock at regular intervals, constituting a time-based task. Positioning the clock in view of participants eliminated age deficits. This was in contrast to significant age-related decrements reported in an earlier study in which the clock was out of focal awareness (Rendell & Craik, 2000). A recent meta-analysis of studies involving 5,590 younger (*M* = 26.4 years) and older (*M* = 71.4 years) participants revealed a main effect for cue type, with greater age-effects in tasks using non-focal target cues compared with focal target cues (Ihle et al., 2013). Thus cue focality has been shown to be one salient factor in determining prospective memory performance.

2.3.3.2 ***Cue Regularity***. Monitoring theories of prospective memory would predict irregular presentation of cues to demand greater resources allocated to environmental monitoring for cue detection, compared to regularly occurring cues. This is theorised to produce greater age-related deficits with irregularly cued prospective tasks and events. The two previously cited Virtual Week paradigm

studies manipulated the regularity of cue presentation in daily prospective tasks (Aberle, et al., 2010; Rendell & Craik, 2000). Significant age-related effects were evident in both studies, with older adults performing better on regular tasks compared with irregular or one-off tasks.

Cue focality and cue regularity have therefore emerged as factors impacting upon the recruitment of either automatic processing or strategic controlled monitoring in prospective memory. This provides some evidence explaining discrepant age-related differences observable across studies.

2.3.3.3 ***Cue distinctiveness***. Studies have shown that in contrast to non-distinctive cues, distinctive cues are more readily detected, aiding spontaneous processing and prospective memory performance. Einstein and colleagues (2000, Experiments 1 & 3) presented target cues as either distinctive, that is written in capital letters, or as non-distinctive, written in lowercase letters, embedded in an on-going task presented in lowercase letters. Older adults were found to have lower levels of intention retrieval over a short delay period when the target cue was non-distinctive. In parallel, highly distinctive target cues presented in capital letters were found to significantly support prospective memory performance in a sample of younger adults (Brandimonte & Passolunghi, 1994, Experiment 2).

2.3.3.4 ***Length of retention period.*** In naturalistic everyday prospective tasks, the retention period between intention formation of a prospective task and the opportunity for retrieval and task execution may vary from minutes to days. In comparison, laboratory based tasks' retention periods are often reduced to seconds. Laboratory based research in which a delay is introduced between intention formation and the opportunity for execution suggests that even brief delays can negatively affect prospective memory performance, with differential

effects for younger and older adults. McDaniel and colleagues (2003a) found short delays of between 5 and 15 seconds reduced correct responses of older adults on a prospective memory task from 93% in a no-delay condition, to 46% when a delay was introduced. In comparison, younger adults fared better, with a smaller reduction in correct responses between conditions from 97% to 85%.

In contrast to these findings several studies have shown longer retention periods to have little negative impact on performance, depending upon the focality of the target cue and strategic processes required for cue detection. Einstein and colleagues (2005, Experiment 2), found accuracy on prospective memory tasks was consistent across the quartiles of an experiment in which cues were defined as focal. Accuracy with non-focal cues on the other hand displayed declining accuracy with longer retention periods across the experiment. The authors concluded that as strategic monitoring is resource demanding and unlikely to be continuously maintained during the retention period, poorer performance with longer delays is consistent with strategic monitoring processes demanded in non-focal cue detection. Focal cues in this experiment stimulated spontaneous retrieval of the intended action regardless of the retention period, consistent with the Multiprocess Framework (McDaniel & Einstein, 2000). Little research has been undertaken to date to examine the effect on prospective memory of longer retention periods and cue focality outside of laboratory studies, providing a unique opportunity for such research.

2.4 Rationale for Study 1.

Contemporary theories of prospective memory, and in particular the Multiprocess Framework (McDaniel & Einstein, 2000), provide a robust platform from which to consider prospective memory processes. The Multiprocess

Framework encapsulates a componential model and provides the theoretical rationale for this thesis. The model offers a platform from which age-related differences in prospective memory processes can be elucidated by taking account of task demand and cue characteristics. The demands of the prospective task versus demands of on-going task/s, the nature, regularity, complexity, and ecological setting of the task, all influence the degree and nature of monitoring required for successful prospective memory performance. Also coupled with performance is the nature of the target cue in terms of focality, cue distinctiveness and accessibility, strength of the target-cue association and length of the retention period. Whilst these inherent characteristics of a prospective memory task and target cue have been shown to influence performance, no single factor accounts for the findings in the literature.

The complexity of prospective memory processes and divergent findings pose several pertinent issues with respect to age-related differences. Firstly the age-prospective memory paradox points to an age-related trend whereby older adults exhibit an advantage in naturalistic settings compared to laboratory based settings (Henry et al., 2004; Rendell & Thomson, 1999). This advantage has been shown to hold in naturalistic settings for event-based prospective tasks but not necessarily for time-based tasks. It is clear from the literature that few studies have investigated this paradigm in the oldest-old adults to ascertain the effect of event versus time-based prospective tasks in a real-world environment.

Secondly, the strategic demand of the prospective task in terms of cognitive resource allocation devoted to target cue detection has been shown to affect performance in both younger and older adults. The literature suggests that age-related deficits would be more pronounced for tasks requiring greater

strategic processing due to normative age-related decline in attentional resources. Indeed, the focality of the target cue is a factor influencing the degree of strategic processing required of prospective memory tasks. Focal target cues facilitate spontaneous retrieval of an intended action in comparison to non-focal target cues that demand greater environmental monitoring for detection. Current research suggests that focal target cues confer age-related benefits in event-based prospective memory performance (Aberle et al., 2010; Henry et al., 2004; Kliegel et al., 2008; Mc Daniel & Einstein, 2011; Park et al., 1997; Rendell & Craik, 2000). However the majority of the research reviewed has been of experimental, laboratory-based studies. It remains unclear as to whether these studies would generalise to 'real-world', naturalistic settings, unconstrained by time limits and undue demands imposed by experimental procedure and setting.

The three studies presented in this thesis have been designed to examine the extent to which functional factors, namely the characteristics of the task, setting of the task, and target cue focality relate to prospective memory performance among oldest-old adults, using the Multiprocess Framework as a theoretical scaffold. The categories of prospective memory measures, and the general prospective memory theory presented in this Chapter are applicable across the studies. Study 1 aims to provide an overview of prospective memory performance in advanced age, whilst the subsequent studies examine theoretically derived predictors of intra-individual and inter-individual differences in prospective memory in relation to the Multiprocess Framework.

The following Chapter presents Study 1, the overarching aims of which are threefold. Firstly the study will investigate prospective memory proficiency in oldest-old adults and determine how well this memory process is maintained into

late life in naturalistic settings. Secondly, age-related differences between event-based and time-based prospective tasks will be examined. Thirdly, the effect of cue focality on event-based task performance will be considered. Importantly, Study 1 will facilitate the documenting of prospective memory processes in the oldest-old outside of laboratory-based research and contribute to the extant literature in determining factors influencing performance in very old age.

Chapter 3.

Study 1: Event- and time-based prospective memory in community-dwelling oldest-old adults.

3. Overview

This chapter presents Study 1, the aim of which is to investigate prospective memory performance in a cohort of oldest-old adults in the context of a home-based, time-sampling study. In light of the age-prospective memory paradox and equivocal findings of age effects associated with prospective memory processes, Study 1 will test hypotheses derived from the Multiprocess Framework (McDaniel & Einstein, 2000) reviewed in Chapter 2. Specifically, age-differences in prospective memory performance in adults over the age of 85 years will be examined by varying cognitive resource demand through manipulation of task characteristics and target cue focality.

3.1 Introduction to Study 1

Age differences and age-related changes in prospective memory have informed contemporary research in the field, but to date, there is inconclusive evidence as to the nature and direction of age-related effects in this memory process. Of particular interest has been the "age-prospective memory paradox" (Rendell & Craik, 2000) whereby older adults tend to exhibit deficits in performance in laboratory based studies when compared to younger adults, but outperform their younger counterparts when tested in naturalistic settings (Henry, MacLeod, Phillips, & Crawford, 2004). This paradox has posed a conundrum for researchers in the field with respect to delineating under what circumstances and conditions older adults maintain optimal prospective memory performance. It is apparent from the literature, as presented in Chapter 2, that the age-prospective

memory paradox encapsulates what is a complex and multi-dimensional memory process.

Current conceptualisations and models of prospective memory processes suggest age-related effects to be associated with numerous constructs. These include, but are not limited to, the setting of the task, the characteristics of the task, the strategic demands of the task, and the characteristics of the target cue prompting execution of an intended prospective action. In the following section, these constructs will be reviewed in order to establish a theoretical rationale for the current study.

3.1.1 Naturalistic versus laboratory research. The setting of the prospective memory task has been shown to influence the nature and direction of age-related effects reported in the literature. In laboratory based experiments using event-based paradigms, older adults generally show age-related deficits in prospective memory performance (d'Ydewalle, Luwel, & Brunfaut, 1999; Henry et al., 2004; Maylor, 1996; Vogels, Dekker, Brouwer, & de Jong, 2002), but there are also cases where some event-based laboratory studies have found no significant effect of older age (Cherry & Le Compte, 1999; Einstein & McDaniel, 1990; Reese & Cherry, 2002). Time-based prospective tasks on the other hand display consistent age-related deficits in both laboratory and real-world studies (Einstein & McDaniel, 1996; Einstein et al., 1995; Henry et al., 2004; Park et al., 1997).

A clear picture of age-related effects and prospective memory is further complicated when considering results of studies conducted in naturalistic settings. Naturalistic studies introduce experimenter designated tasks within a person's own home or naturally occurring environment, with varying degrees of ecological

validity depending on the nature and artificiality of the task. Across studies, older adults perform as well as, or better than younger adults under these conditions (Hertzog, Park, & Morell, 2000; Maylor, 1990; Rendell & Thomson, 1999) in particular with event-based tasks. A notable exception to these findings was reported by Huppert, Johnson, and Nickson (2000). An event-based prospective memory task was given to a large sample of older adults (N = 11,956) during cognitive screening in their own homes for future inclusion in a population-based study. Participants were informed that during the testing session an envelope would be given to them, upon which they would be asked to write a name and address recited to them by the researcher. The prospective memory task was to remember to seal the envelope and initial the back following this task. The delay between intention formation and task execution was approximately 10 minutes, with participants undertaking further screening during the retention phase of the prospective task. Despite being in their familiar home, only 54% of participants remembered the prospective task direction. Logistic regression analysis found impairment in prospective memory was linearly related to older age, with male gender, lower education and lower socio-economic status also being risk factors for lower proficiency. This research supports the caveat proposed by some theorists that apparent sparing of prospective memory in naturalistic studies may actually reflect confounding factors. The motivation of the person toward task completion (Rendell & Craik, 2000), the salience of the task, and use of external reminders and cues (Hertzog et al., 2000; Maylor, 1990) may all support performance in real world settings. Huppert and colleagues demonstrated that when older adults are tested within their own environment, removing the opportunity for rehearsal and use of external cues may negatively impact upon

prospective memory performance under an experimenter controlled event-based paradigm.

Consideration has also been given to lifestyle and social role factors when comparing performance in naturalistic studies, the notion being that younger adults have busier lifestyles and are less motivated toward task performance than their older counterparts (Rendell & Thomson, 1999). This could account for older adults outperforming younger adults under these conditions when in fact prospective memory processes may be compromised in older age.

The consensus from the literature supports the notion that prospective memory generally declines with age, particularly in laboratory based studies. With a few exceptions, a substantial body of research also demonstrates that older adults appear to maintain performance in real-world settings. This may reflect the life experience of older adults, better time management, reduced social role demands with less interference from competing tasks, or greater reliance on external cues and reminders. It is contentious under what circumstances and conditions the contradictory results from naturalistic and laboratory based studies generalise to everyday prospective memory performance in the oldest-old. It is timely therefore to assess prospective memory performance in older adults within their own homes to clarify if this ubiquitous and important memory process is maintained into very old age.

3.1.2 Characteristics of the prospective task and target cue. The Multiprocess Framework (McDaniel & Einstein, 2000) distinguishes between the demands of prospective task conditions, that is, event-based tasks versus time-based tasks, and characteristics of target cues in determining performance. Generally, as event-based prospective memory is associated with or signalled by

an event or environmental cue, it is theorised to be less demanding than time-based prospective memory, which is more reliant on self-initiated monitoring and retrieval. However, as reviewed, age-related deficits are often found in event-based laboratory studies but not under all conditions. A recent meta-analysis found age-deficits in event-based tasks to be more prevalent in tasks with higher strategic demand (Henry et al., 2004). This is in comparison to time-based prospective memory tasks which exhibit consistent age-related deficits across studies (Einstein & McDaniel, 1996; Park et al., 1997). As argued in Chapter 2, event-based prospective memory is supported by environmental cues to trigger recollection of an intended action. The nature of the cue, be it focal to the on-going task or non-focal, predicts the degree of cognitive resource allocation required for strategic monitoring (McDaniel & Einstein, 2000). Detection of focal cues initiates automatic cognitive processing through involuntary orienting of attention to the cue, thereby prompting spontaneous retrieval of the associated intended action (McDaniel & Einstein, 1993). Non-focal cues on the other hand, demand greater cognitive resource allocation directed toward strategic environmental monitoring for target cue detection and intended action retrieval. As increasing age is associated with normative decline in attentional resources (Hasher & Zacks, 1988), it follows that prospective memory performance would be differentially affected by the degree of cognitive monitoring required of the particular task.

The Multiprocess Framework therefore argues age-related deficits in prospective memory performance to be a function of strategic demand associated with the nature of the task and the characteristics of the target cue signalling the event. Certainly, studies have upheld this theoretical viewpoint. Experiments

employing non-focal cues have found robust age differences (Maylor, 1993, 1996; Park et al., 1997; Maylor, 2002) in contrast to experiments using focally cued prospective memory paradigms (Cherry & Le Compte, 1999; Einstein & McDaniel, 1990). Rendell and colleagues (2007, Experiment 1) found a significant age by target cue type interaction that typifies differential effects in prospective memory. Younger and older adults were randomly assigned to a prospective memory focal or non-focal cue condition, or a control group. Younger adults recorded similar performance across cue types (focal M = .90, non-focal M = .87) whereas deficits were pronounced for older adults in the non-focal cue condition (focal M = .78, non-focal M = .55), reflecting the cognitive resource demand imposed by strategic monitoring for target cue detection.

In addition to focality of the target cue, the distinctiveness of the cue and the association between the target cue and intended action also impact on prospective memory performance. Studies have shown highly distinctive cues to be more easily detected, supporting spontaneous processing and intended action retrieval (Brandimonte & Passolunghi, 1994, Experiment 2; Einstein et al., 2000, Experiments 1 & 3). Further, highly associated target cues and intended actions reduce the degree of environmental monitoring required for action retrieval, again supporting spontaneous processing of a prospective memory task (Loft & Yeo, 2007). Subsequent research has also demonstrated that focal prospective memory cues that are appropriate to the on-going task negate the need to shift the level of processing between the on-going task and cue detection, supporting spontaneous processing. Thus, current evidence demonstrates that event based prospective memory tasks display differential age-related effects according to the nature of the target cue. Focally cued targets should elicit spontaneous retrieval processes

due to high detectability and association between the target cue and intended action. Conversely, non-focally cued targets requiring greater strategic environmental monitoring for the target cue are more demanding of limited attentional resources. That being the case, age-related deficits on non-focally cued event-based prospective memory tasks should be more pronounced than on focally cued tasks. Moreover, the consensus from the literature suggests that time-based prospective memory tasks require greater self-initiated monitoring for retrieval of an intended action at the appropriate time or after a specified interval in comparison to event-based tasks. As such, time-based prospective memory tasks are more demanding of age-related limited attentional resources and should display robust age-related deficits, as evidenced in research to date (Henry et al., 2004). The majority of the findings highlighted thus far have stemmed from cross-sectional research comparing extreme age groups of younger and older adults. The current study proposes to investigate the association between linear age and the prospective memory constructs outlined across the restricted age band of oldest-old adults as recommended by Zeintl, Kliegel, and Hofer (2007) and others (Ellis & Kvavilashvili, 2000; Huppert, Johnson, & Nickson, 2000).

3.1.3 Summary. In summary, the Multiprocess Framework and the age-prospective memory paradox posit that age-related differences in prospective memory performance are associated with the environmental setting of the task, nature of the task, and target cue characteristics. Naturalistic studies point to sparing of prospective memory processes when older adults are tested in their own environment, more so with event-based tasks. This study has therefore been designed to address several substantive questions concerning prospective memory processes operating in a naturalistic context among very old adults. Using a

micro-longitudinal measurement study set in participants' own homes, the nature and direction of age-related effects in prospective memory will be examined. The current study offers a unique opportunity to delineate prospective memory processes and effect of chronological age across a restricted age band in community-dwelling oldest-old adults.

3.2 Aim of Study 1

Study 1 will assess prospective memory using time-based and event-based prospective memory measures, incorporating both focal and non-focal cue signalling to elucidate age-effects on prospective memory under contrasting strategic demand and task characteristics.

3.3 Hypotheses for Study 1

It is predicted that:

1. There will be an effect of task characteristic on prospective memory performance such that overall performance on event-based tasks will be better than performance on time-based tasks.
2. There will be an effect of cue type on event-based prospective memory such that there will be better performance on focally cued event-based tasks compared to non-focally cued event-based tasks.
3. There will be an effect of chronological age on prospective memory such that poorer performance on all prospective memory tasks will be associated with older age.

3.4 Method

3.4.1 Participants. Data for the current study come from a larger parent project, the ALSA Daily Life Time Sampling study (ADuLTS), undertaken by the Flinders Centre for Ageing Studies (FCAS) at the Flinders University, South

Australia. A total of 75 community dwelling volunteers were recruited from the greater Adelaide metropolitan area, 50 of whom were long-term participants in the Australian Longitudinal Study of Ageing (ALSA: Luszcz et al., 2007). The other 25 participants were recruited through local retirement complexes and from a database of potential volunteers held by FCAS.

Current cognitive functioning was screened through administration of the Mini Mental Status Examination (MMSE: Folstein, Folstein, & McHugh, 1975; for a full description refer to the Materials section, Section 3.4.4.1 of this Chapter). Participants scoring below 24 on this measure were excluded from the study as scores below this cut-off could indicate possible cognitive impairment. Participants were required to be fluent in English, both verbal and written, and to have adequate assisted or unassisted visual acuity and hearing. An information sheet and letter of introduction informed participants of the study approval by the Flinders University Social and Behavioural Research Ethics Committee and informed consent was sought from each participant (see Appendices A.1 to A.5).

The study was conducted by appointment in participants' own homes over a period of seven consecutive days. The study commenced with participants undertaking an introductory training session during which baseline descriptive and demographic data were collected. ALSA participants had recently completed a battery of cognitive tasks during the 11th Wave of that study. Participants not involved in the ALSA were asked to complete the same battery of cognitive tasks at the introductory session. The study was then commenced and completed over seven consecutive days (nominated Day 1 to Day 7). On the day following study conclusion, participants completed an exit session with their research assistant.

3.4.2 Design. The microgenetic study was a mixed, within and between-person design, using a seven-day measurement burst protocol. Prospective memory items were embedded within the daily questionnaires completed five times per day for seven days. The predictor variables were two event-based prospective memory tasks, comprising focal (11 items) and non-focal (9 items) event-based cues, and a single time-based prospective memory task. Where they occurred during the seven-day study is detailed in Appendix D.2. The dependent variables were prospective memory proficiency, measured as proportion correct, forgetting ratio, and recovery ratio for each level of the event-based prospective memory predictor variables, and proportion correct for the time-based prospective memory item (for a full description of the scoring and computation of prospective memory measures, see Section 4.6.1).

3.4.3 Materials. This and the procedure section present a detailed description of the seven-day time-sampling protocol. It is important to note that not all variables reviewed were used in this thesis.

3.4.4 Baseline measures.

Demographic, health and control measures were collected for each participant, including age, gender, marital status, height and weight, household demographics, education level, and previous occupation. Self-rated health, physiological conditions known to impact basal cortisol levels, and self-reported feelings of anxiety or depression were measured. Control variables known to affect salivary cortisol assays, namely alcohol and caffeine consumption, and current smoking status (see Appendix C.1), were also recorded.

Current health status was considered via an eleven item self-report measure of physical symptoms, for example, having experienced back pain,

headaches, or shortness of breath during the preceding two weeks. Responses were answered on a 3 point scale from "not bothered at all" (1), to "bothered a lot" (3). For frequency of health symptoms, questions 1, 2, and 3 are recoded and scored as either "not bothered" (0), or "bothered" (1). The eleven items were summed to give a total score ranging from 0-11. Higher scores on this measure reflect more frequent experience of physical symptoms. Intensity of health symptoms were assessed with items summed to provide a total score ranging from 11-33.

Participants were asked if they had ever received a confirmed medical diagnosis of chronic conditions namely, arthritis, cancer, chronic bronchitis or emphysema, diabetes, fractured hip, heart attack, heart conditions, hypertension, myocardial infarction, osteoporosis, or other chronic condition(s). These data not only inform health status, but also indicate presence of possible conditions affecting basal cortisol levels (i.e., hypo- or hyper-thyroidism).

Medication use was assessed with participants reporting all prescription and non-prescription medicines taken during the preceding two weeks, including vitamins, minerals, and dietary supplements (see Appendix C.1). Medicines identified as possible confounders for cortisol assays include steroid inhalers, cortisone, hormonal medications (e.g., hormone replacement medications), and antidepressant or anti-anxiety medications (Almeida, Piazza & Stawski, 2009; Granger, Hibel, Fortunato, & Kapelewski, 2009).

3.4.4.1 ***The Mini-Mental Status Examination.*** The 30-item MMSE (Folstein, et al., 1975) was employed to assess current cognitive ability and screen for possible cognitive dysfunction (see Appendix E.1). The MMSE tests orientation, attention, calculation, language and recall. Items are summed to give

a total score ranging from 0-30, higher scores indicative of better cognitive functioning. The MMSE has good test-retest reliability (Pearson co-efficient of .89), and acceptable concurrent validity with performance and verbal IQ demonstrated through correlations of .66 and .77 respectively (Folstein et al., 1975).

3.4.4.2 ***The CES-D 10.*** Depressive symptoms were screened using a short version of the Centre for Epidemiological Studies Depression Scale (CES-D 10; Andresen et al., 1994; Radloff, 1977), as detailed in Appendix C.1 (Question number 13, a-j). Depression has been associated with increased cortisol levels (Gomez et al., 2009) and is a possible confounding variable that has been shown to contribute to poor memory. The CES-D 10 comprises ten items asking how respondents behaved or felt during the preceding week. Items are answered on a four-point rating scale anchored from "rarely" (0) to "most of the time" (3). Questions5 (e) and 8 (h) are reverse scored, with items summed to give a total score ranging from 0-30. A total score of ten or more is indicative of possible depression. The CES-D 10 has good internal consistency with a Cronbach's alpha co-efficient of .84 (Corcoran & Fisher, 1987). Depressive symptoms will be used as a covariate control variable in the current study due to the established association between depression and memory (Lockwood, Alexopoulas, Kakuma, & Van Gorp, 2000).

3.4.4.3 ***Self-reported stress.*** Participants were asked to report on seven perceived stressors experienced during the preceding two weeks, such as having had financial or health problems or worries. Items were anchored from "not bothered at all" (1) to "bothered a lot"(3) (see Appendix C.1, Question number 17, a-g). Stress frequency was calculated as the sum of scores following recoding of

items 1, 2, and 3. Scores for stress frequency ranged from 0-7. Stress intensity was assessed according to the anchored responses. Items were summed to provide a score range from 7-21. Higher scores for both measures reflect greater self-reported stress frequency and intensity.

3.4.5 Time sampling measures: Questionnaires and saliva samples.

3.4.5.1 ***Saliva samples.*** Salivary cortisol samples were obtained concurrently with each morning and daily questionnaire using Salivettes (Sarstedt, Rommelsdorf, Germany). Salivettes comprise a plastic lidded vial containing a synthetic swab. It is rolled in the mouth for approximately two minutes until impregnated with saliva. Extensive instructions for saliva sample collection were provided to all participants (presented in Appendix B.2). Once collected, saliva samples were stored in participant's refrigerators and returned to the FCAS at study completion. Salivettes were then frozen at -20ºC awaiting shipment to Germany for bio-analysis. Salivary free cortisol was analysed using luminescence immunoassay (LIA: IBL Hamburg, Germany).

3.4.5.2 ***Morning questionnaires.*** Two morning questionnaires accompanied by a saliva sample, were completed on each day of the study (see Appendix C.2); the first was completed immediately upon waking. Participants stamped a required field with an electronic date and time stamp, pre-programmed by the research assistant, and put a salivette in their mouth. In contrast to studies relying on participant self-report, the automated stamps facilitated accurate recording of questionnaire commencement and completion, and of salivette timing, providing a measure of control with non-compliant data and recordings. Participants then set a kitchen timer, provided for the course of the study, to 30

minutes, at which time the second set of morning questions were answered and the second saliva sample provided.

First morning questionnaire. The first morning questionnaire included items on the presence of others, and their relationship, and self-reported sleep control variables including time spent in bed, sleep onset latency, wake-up time and estimated total sleep time. Participants reported on their number of night awakenings answered on a four point rating scale from “never” (0), to “greater than three times” (3), and also reported their reasons for disturbed sleep (e.g., felt too hot, had pain). Subjective sleep quality was self-rated on a five point Likert scale anchored from "very good" (1) to "very bad" (5) and use of sleep medication was reported.

Mood was assessed with the first morning questionnaire and subsequently with each within-day assessment. Participants rated their positive and negative affect at that moment using 6- items from the Positive and Negative Affect Scale (PANAS: Watson, Clark & Tellegen, 1988b). In addition, 3 items measuring low positive arousal, i.e., how calm, sleepy or quiet do you feel, were included. Questions were answered on a five-point rating scale anchored from "not at all" (1), to "very much" (5). Similar items from the PANAS have been used successfully with older adults in time-sampling affect research (Chui et al., 2013; Hoppmann & Klumb, 2006). The PANAS has demonstrated high internal consistency of .89 for negative affect and .85 for positive affect (Crawford & Henry, 2000) and good convergent and discriminant validity (Watson et al., 1988b). Although not included as a variable in the current study, the affect items were used to present the focally cued event-based prospective memory items during the daily questionnaires (see section ‘Prospective memory items’ for a

detailed description of prospective memory measures, Section 3.4.5.4, this Chapter).

Items tapping cortisol control variables were self-reported on, for instance having had or done any of the following since awakening,: nicotine, caffeine, alcohol, medicine /drugs, food, exercise, cold shower, brushed teeth, or nothing. Upon completion of the questionnaire, the salivette was removed and replaced in its vial for storage in a refrigerator or freezer. Participants recorded the day and number of the first salivette used on the questionnaire.

Second morning questionnaire. After the 30 minute interval participants completed the second morning questionnaire. The date and time were stamped at commencement and the second salivette of the day rolled in the mouth for two minutes. Participants were asked to report again on cortisol control variable use since the last questionnaire, to record the day and number of the second saliva sample and to date and time stamp the questionnaire at completion. Participants were instructed to return the completed questionnaire to its labeled envelope, sealing the envelope and stamping across the seal with the date and time. The Salivette was dealt with as described above.

3.4.5.3 ***Daily questionnaires.*** Five daily questionnaires (numbered from 3 to 7) were completed by participants at regular intervals of approximately three hours, during each day of the seven day study (see Appendix C.3). Participants determined convenient scheduling of questionnaire times with their research assistant prior to study commencement. Acoustic electronic alarm devices engineered at Flinders University were provided to sound at scheduled intervals, at which time the appropriate questionnaire and salivette were obtained. Each questionnaire was date and time stamped at commencement and completion.

Whilst providing the saliva sample, participants completed the 9-item PANAS questions (as in the first morning questionnaire) to assess positive and negative affect and serenity at each trial during the day. Presence of others (including relationship), current location (i.e., outside, home, travelling), and cortisol control variable use since the last questionnaire (as in the morning questionnaires) were also reported. In addition, activities since the last questionnaire were reported. Participants were instructed to indicate their main activities, presence of others, and personal salience of each activity from the time of the last questionnaire to the present time in half hour blocks. At completion of each daily questionnaire, participants sealed it in its corresponding, labeled envelope and date- and time-stamped across the seal. Salivettes were dealt with as previously described.

3.4.5.4 ***Prospective memory items.*** Two distinct event-based prospective memory (EBPM) items were interspersed throughout the daily questionnaires (see Appendix D.1 for specific examples and scheduling of items). Procedural instructions for both event-based tasks were provided at the initial training session. A written procedural reminder was included on each morning questionnaire but no further prompts were included on subsequent daily questionnaires.

The first group of EBPM tasks representing *focal* memory items, were randomly embedded within the nine affect questions and presented in capital letters, for instance, HOW ANGRY ARE YOU? (Day 1, Questionnaire number 4), or HOW STILL ARE YOU? (Day 1, Questionnaire number 7). Participants had been instructed to make two circles (instead of one) around their response on the associated rating scale upon detecting capitalised items. Items were scored

correct for two circles around the response. An incorrect score was given for responses circled only once, or not at all.

The second group of EBPM items, were classified as *non-focal* to the on-going task and presented as a printed square box on the right-hand bottom of the questionnaire, to be initialed when detected. Nine trials were included amongst the daily questionnaires, scored as correct if initialed, or incorrect if blank.

A single time-based prospective memory (TBPM) item was presented at the end of Day 3 (questionnaire number 7), with participants instructed to call their research assistant (RA) the following morning to report on progress, at which time the reason for the call was ascertained by the RA, and the date and time recorded. Participants were instructed at baseline that this task was not optional and would be presented at some stage during the study protocol. A correct response was scored if participants called the researcher at any time during the subsequent morning as a direct result of the written prompt, giving participants a window for execution of the task of several hours. An incorrect response was scored for participants failing to call the researcher, calling at the incorrect time, or alternatively calling on the designated morning but for an alternative reason (i.e., to report equipment failure or to present a general query with protocol).

3.5 Procedure

Upon acceptance into the ADulTS study, an appointment was made for an introductory session on the day preceding commencement of the measurement burst protocol, during which an information sheet and study outline were provided to participants prior to obtaining informed consent (see Appendices A.1 to A.5). At this session, a trained research assistant gave instruction to participants

about saliva sample collection and storage, and familiarized them in questionnaire completion. A daily schedule individualised for each participant around meal times and scheduled activities was developed in consultation with the research assistant. An electronic acoustic timer was pre-programmed to signal the daily questionnaire times, default times being 9am, noon, 3pm, 6pm, and 9pm with these times amended and individualized for each participant if requested. Participants were given instruction in use of a kitchen timer and familiarized in use of an electronic date and time stamp. Sample morning and daily questionnaires were completed with assistance of the researcher and envelope sealing and stamping instructions provided.

Baseline measures were administered for each participant at the introductory session. For non-ALSA participants this included the MMSE, Digit Symbol Substitution Test (Wais-III, 1981), the CLOX 1 (Royall et al., 1999), and Verbal Fluency Tasks including the Initial Letter Fluency test (FAS: Benson, 1968; Benson & Spreen, 1969) and the Excluded Letter Fluency test (Bryan, Luszcz, & Crawford, 1997). Cognitive tests are detailed in Appendices E.1 to E.6. Cognitive measures for ALSA participants had been collected at administration of Wave 11 of the ALSA which occurred in 2010. Research assistant mobile phone contact details were provided, with participants instructed to call at any time should they have queries or experience difficulties with the protocol or equipment. A follow-up appointment was made for day two, so that the research assistant could ascertain that each participant fully understood and engaged with all procedures.

Study materials were provided in an expanding file with seven sections labeled Day 1 to Day 7. Each section contained six envelopes individually labeled

with the day and questionnaire number, colour coded with stick-on dots (i.e., Day 1 Questionnaires 1 & 2, Day 1 Questionnaire 3… to Day 1 Questionnaire 7; all Day 1 envelopes having blue dots, Day 2 orange dots etc.). Each unsealed envelope held a corresponding questionnaire. In addition, a plastic zip-lock bag in each section contained seven Salivette tubes, each labeled with participant identification number, day and Salivette number, and a colour-coded dot with hand-written number for easier recognition (i.e., Salivette 1 = Day 1 Number 1 with number 1printed on a blue dot, Salivette 2 = Day 1 Number 2 with number 2 printed on a blue dot etc.). Upon awakening and at each alarm, participants were required to remove the appropriate swab from the Salivette tube and roll in their mouth during completion of the corresponding questionnaire. Questionnaires were to be returned to their envelope, sealed and stamped, and the swab returned to its Salivette vial and zip-lock bag for storage in a freezer, an established field study protocol for storage of saliva samples (Kertes & Gunnar, 2004; Kirschbaum & Hellhammer, 2000).

During the follow-up visit on Day 2 of the study, the protocol was discussed with participants, and Day 1 questionnaires examined by the research assistant for procedural difficulties, with additional instruction provided as required. Questionnaires from Day 1 were then sealed in a larger envelope by the research assistant who stamped across the seal. An exit session appointment time was agreed for the day following study completion during which materials, questionnaires and Salivettes were collected and a feedback interview conducted (see Appendix C.4). Participants were thanked for volunteering and given a small gift voucher in appreciation of their time and participation.

Once all data had been collected, each envelope and questionnaire was checked for corresponding times and dates, including the stamp across the envelope seal, with each item scored and recorded. Salivette day and numbers were checked against each questionnaire. Individual Salivettes were re-labeled with cold-resistant labels and allocated consecutive numbers which were recorded in a database in preparation for shipment to Germany for assay.

3.6 Analytic Approach

Study 1 has been designed to examine broad patterns of prospective memory performance within the restricted age band of the oldest-old from a between-person perspective. Correlates of within-person variability in performance will be considered in a subsequent study. The following section will detail the operationalisation of prospective memory measures used in analyses for the current and subsequent studies in this thesis.

3.6.1 Prospective memory measures. Event-based prospective memory measures were calculated as the total number of correct responses for each individual in each category of task. The proportion correct was then calculated for each participant as a proportion of correct responses from the total number of available items attempted across the study in each category. To further examine event-based prospective memory performance, responses for both focal and non-focal items were coded as being either a successful response, that is, a *hit*, or a failed response, or *miss*. Performance was then represented in terms of forgetting and recovery probabilities for each event-based task rather than averaging performance on the task across trials (Maylor, 1996; Vogels et. al., 2002). Evidence presented by Maylor, and Vogels and colleagues, suggests that in averaging prospective memory successes or totaling the number of successes,

effects such as temporal fluctuations in performance across trials are obscured. Forgetting and recovery ratios are therefore more sensitive to momentary lapses in intention retrieval rather than complete forgetting of the prospective task. Forgetting and recovery ratios employed in research have highlighted robust age-variance between younger and older adults in prospective memory processes, the age-related variance being less distinguishable when averaged performance data are analyzed (Maylor, 1996; Vogels et. al., 2002).

Forgetting ratios were calculated as the number of prospective memory hits for that task followed by a miss, divided by the number of opportunities for forgetting (Vogels et.al). Recovery ratios were calculated as the number of prospective memory misses followed by a hit, divided by the number of opportunities for recovery. That is,

$$\text{Forgetting ratio} = \frac{\text{PM}_{\text{HIT}} : \text{PM}_{\text{MISS}}}{\text{Number of opportunities for forgetting}}$$

$$\text{Recovery ratio} = \frac{\text{PM}_{\text{MISS}} : \text{PM}_{\text{HIT}}}{\text{Number of opportunities for recovery}}$$

3.6.2 Software. All data were analysed using the Statistical Package for the Social Sciences (IBM SPSS: Version 21).

3.7 Results

3.7.1 Demographic and descriptive results. Of the initial 75 participants (66.6% female), 49 females and 25 males (N = 74) completed the ADuLTS study protocol. One participant withdrew from the study after completing day one. Participants ranged in age from 83 to 102 years (M = 88.13, SD = 3.15). Twenty-one were married or in defacto relationships (28.4%) with 53 (71.6%) widowed, never married, or divorced and 77% were Australian born. Participants had

received an average of 10.6 years of education with 58% leaving school at 15 years of age or more. Self-rated health was generally very good (*M* = 2.38, *SD* = .77) with a low incidence of chronic health conditions reported (*M* = 2.39, *SD* = 1.45). Analyses indicated that the majority of participants had few depressive symptoms. The descriptive statistics of participants on primary demographic and study variables are presented in Table 3.1.

Table 3.1

Participant Descriptive Statistics

Characteristic	
Age (*M* ± *SD*: Range 83-102)	88.13 ± 3.15
Gender	
Male	33.3%
Female	66.7%
Marital status	
Married or de Facto	28.4%
Widowed, divorced or never married	71.6%
Education	
≤ 14 years schooling	42%
≥15 years schooling	58%
Country of birth	
Australia	77%
Other (UK = 13, Germany = 1, East Europe = 3)	23%
Self-rated health[a] (*M* ± *SD*: min = 0, max = 4)	2.38 ± 0.77
Depressive symptoms[b] (*M* ± *SD*: min = 0, max =16)	4.93 ± 3.67
Chronic conditions[c] (*M* ± *SD*: min = 0, max = 6)	2.39 ± 1.45

Note: [a] is Self-rated health (scale range 1 = excellent, 5 = very poor); [b] is CES-D 10 (scale range = 0-30; [c] is Chronic health conditions (scale range = 1-10)

3.7.2 Preliminary analyses of prospective memory performance.

Prospective memory performance for the focal and non-focal event-based tasks and the time-based task are summarised in Table 3.2. Successful performance across trials on the focal (double circle response) task was high, with 72.9 % of total responses correct (see Figure 1). Similarly, 82.8 % of responses on the non-focal (initial box) task were answered correctly. There was evidence of some ceiling effects for the two event-based tasks, with 27.4 % (n = 20) and 50 % (n = 37) of participants recording perfect scores across trials for the focal and non-focal tasks, respectively.

Given the similarity in percentage of correct responses for both the focal and non-focal event-based prospective tasks, a paired samples t-test was used to examine if there was any significant difference in proficiency between task cue types. Analysis revealed that on average there was a difference between proficiency on focal EBPM (M = 72.94, SE = 3.91) compared with non-focal EBPM (M = 82.54, SE = 3.30) which reached significance, t (71) = 2.14, $\rho < .05$, giving a small effect size with the eta squared statistic of .06 (Cohen, 1988, 1992). This is contrary to the effects of the target cue predicted in the literature and does not support the hypothesis that non-focally cued tasks would show poorer performance compared to focally cued tasks.

In contrast to the event-based tasks, overall performance on the time-based prospective memory task was poor, with 78.4 % (n = 58) of participants failing to successfully complete the task.

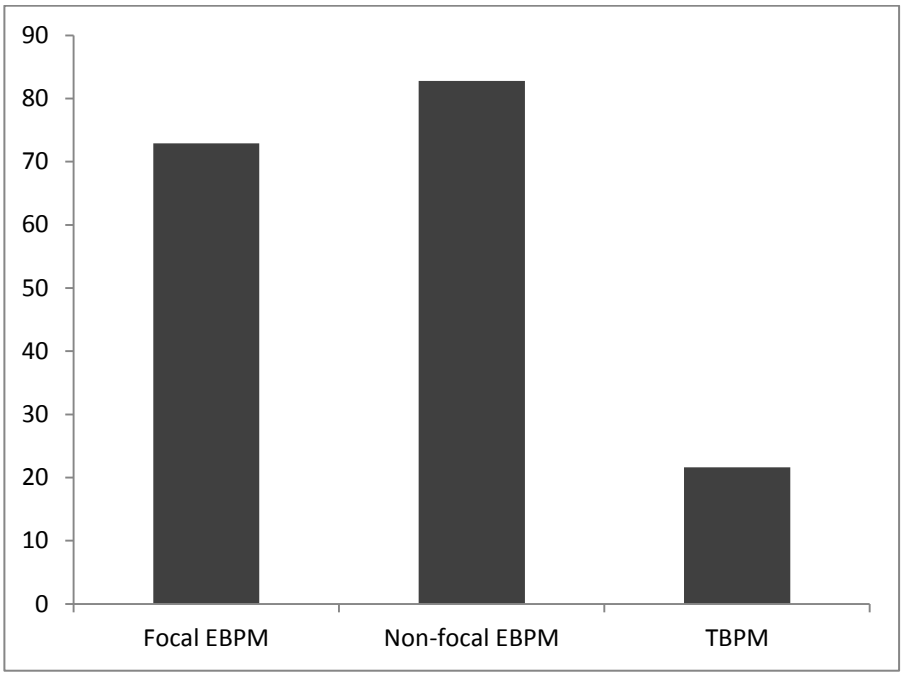

Figure 1. *Percentage of correct prospective memory responses.*

3.7.3 EBPM forgetting and recovery ratios. Forgetting and recovery ratios for the event-based prospective memory items are presented in Table 3.3. Forgetting ratios in the current study were .17 (*SD* = .30) for the focal task and .11 (*SD* = .23) for the non-focal prospective memory task. A paired samples t-test indicated there was no significant difference between the forgetting ratios for the focal and non-focal tasks t (71) = 1.43, $\rho > .05$. The mean difference in ratios was .06, 95% CI [-.02 to .14]. The eta squared statistic ($\eta^2 = .03$) indicated a small effect size between the EBPM task ratios (Cohen, 1988, 1992).

Table 3.2

Percentage of Successful Responses for Prospective Memory Tasks by Age Group

	83 – 89 years (n = 53)	90 + years (n = 21)	Overall (n = 74)
Measure	% (n)	% (n)	% (n)
Event-based prospective memory			
Focal task	75.3	66.8	72.9
Non-focal task	81.8	85.3	82.8
Time-based prospective memory			
Successful response	18.9 (10)	28.6 (6)	21.6 (16)
Failed response	81.1 (43)	71.4 (15)	78.4 (58)

Similarly, as presented in Figure 2, the recovery ratios obtained in the current study are comparable between the focal (*M* = .08, *SD* = .09) and non-focal (*M* = .07, *SD* = .09) prospective memory tasks. A paired samples t-test found no significant difference between the recovery ratios (t (71) = 1.43, $\rho > .05$, 95% CI [-.02, .04]. As with the forgetting ratios, the high probability of recovery illustrates the high overall proficiency exhibited across trials. Participants were just as likely to remember and recover performance for both the focal EBPM tasks across trials as they were on the non-focal EBPM tasks.

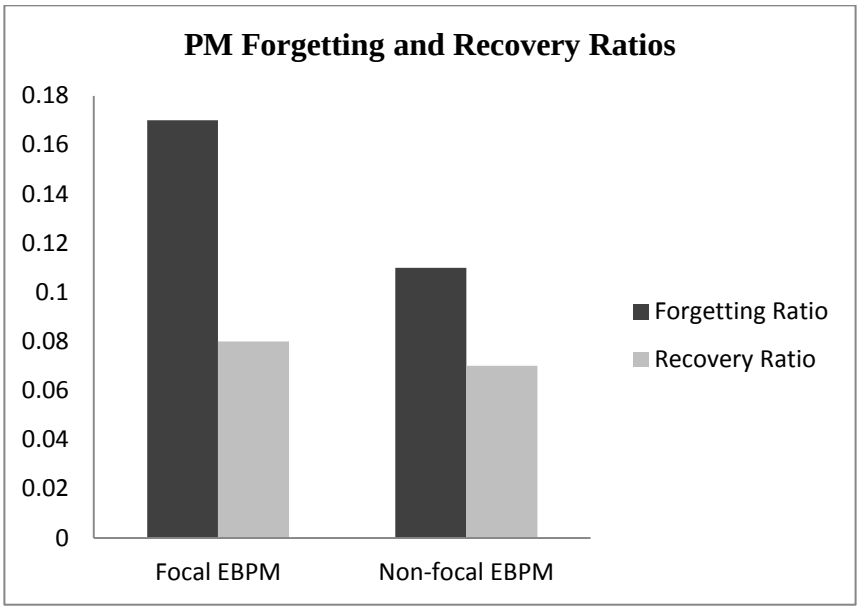

Figure 2. *Event-based prospective memory forgetting and recovery ratios.*

3.7.4 Prospective memory performance and age. To investigate the effect of age on prospective memory performance, two sets of analyses were undertaken, firstly, with age stratified into groups, and secondly, with age as a linear chronological predictor.

3.7.4.1 ***Prospective memory performance and age group*****.** Probability ratios of prospective memory performance were analysed with age stratified into two groups as the between subjects factor. Group 1 was defined as those aged between 83 and 89 years (n = 53), and group 2 were aged 90 years plus (n = 21). The probability of forgetting on the focal task was lower for the younger participants (group 1 M = .16, SD = .29) when compared to group 2 (M = .19, SD = .35). ANOVA between age group and forgetting ratios indicated no effect between groups (eta squared = .00). This relationship failed to reach statistical significance, F (1, 70) = 0.17, ρ >.05, with very small differences in mean ratios

apparent between groups. Similarly, there was no significant difference between age group and recovery ratios for the focal prospective memory tasks, F (1, 70) = 0.08, ρ >.05, (η^2 =.00), with very similar recovery ratio means between groups (see Table 3.3).

The non-focal prospective memory task displayed similar results. Forgetting and recovery ratios as displayed in Table 3.3, were similar between age groups. ANOVA of age group and forgetting ratios, F (1, 71) = 1.16, ρ >.05 was not significant, with a small effect size (η^2 = .02) (Cohen, 1988, 1992). Similarly, ANOVA of age group and recovery ratios for the non-focal task, F (1, 70) = .05 ρ >.05, η^2 = .00) also failed to find a significant result and indicated a very small effect size.

Overall performance on the time-based prospective memory task was poor with only 16 participants (21.6%) remembering to phone their research assistant at the allotted time. Successful response on this task decreased with increasing age, with 10 participants (13.5%) from group 1 and 6 participants (8.1%) from group 2 completing the task. A Chi-square test for independence found the relationship between age and time-based prospective memory to be non-significant, χ^2 (1, n = 74) .55, ρ >.05. The phi coefficient (.11) indicated a small effect size for this relationship (Cohen, 1988).

3.7.4.2 ***Prospective memory performance and linear chronological age.*** To test hypothesis 3, hierarchical multiple regression was used to assess the effect of linear chronological age in predicting levels of event-based prospective memory in terms of forgetting and recovery probabilities, after controlling for the effect of gender, education level, and depressive symptoms. Participants with recovery ratios at ceiling level and forgetting ratios at floor level could not be

included in the analysis. Preliminary analyses found no violation of the assumptions for normality, linearity, multicollinearity and homoscedasticity. For the HMR, age was entered at Step 1, and gender, education level, and depressive symptoms were entered at Step 2. Age and the covariate predictors were not statistically significant predictors of the forgetting or recovery ratios for either focal or non-focal event-based prospective memory tasks (results of these analyses are presented in Appendices F.1 to F.3).

Hierarchical multiple regression analysis was then undertaken to ascertain if there was a linear association between chronological age and overall prospective memory performance. Prospective memory was operationalised as the proportion correct across the week with gender, education level and depressive symptoms as control variables. Variables were entered into the regression with age at Step1 and covariate predictors at Step 2. Results of analyses for the two event-based prospective memory tasks are presented in Table 3.4.

For the focal EBPM tasks, at Step 1there was a small negative association between age and the focal EBPM proportion correct, β = -.22, ρ < .05, n = 72, with age explaining 5% of the variance in overall performance (R^2 = .05). This indicated that an increase in age of one standard deviation (3.11 years) predicted a decrease in the proportion correct on this task by approximately 7 %. Although not statistically significant at ρ < .05, the association is of sufficient magnitude (ρ = .08) to interpret as reliable given the small sample size and associated low power (Cumming, 2012). After entry of gender, education level, and depressive symptoms at Step 2 the total variance explained by the model remained at 5% (R^2 = .05). The covariate predictors were unrelated to prospective memory performance and age was no longer a significant predictor.

Results for the HMR analysis examining if age predicted overall performance on the non-focal EBPM are presented in Table 3.4. At Step 1, age was a non-significant predictor of performance. At Step, the model explained only 3% (R^2 = .03) of the variance in performance, and neither age nor the covariate variables were significant predictors of non-focal EBPM performance.

To examine linear age effects with the time-based prospective memory task, logistic regression analysis was used, the results of which are presented in Table 3.5. It was predicted that chronological age would predict poorer performance on this task after controlling for gender, education level, and depressive symptoms. The dependent variable was time-based prospective memory (i.e., did they call their RA). Age was entered at Step 1 and covariate predictors at Step 2.The full model correctly classified 79.4% of participants but failed to reach statistical significance, $\chi^2(8, N = 68) = 7.90$, $\rho > .05$, explaining between 5% (Cox and Snell R^2 = .05) and 7% (Nagelkerke R^2 = .08) of the variance in TBPM scores. Age, gender, education, and depressive symptoms were not statistically significant predictors of success on this task.

Table 3.3

Mean Scores for Event-based Prospective Memory Items and Ratios by Age Group

Measure	85 - 89 (n = 53) M (SD)	90 + (n = 21) M (SD)	Overall (n = 74) M (SD)
Background measures			
Age	86.7 (1.6)	92.0 (2.8)	88.2 (3.1)
Event- based prospective memory hits			
Focal task (range 0 – 11)	8.0 (3.4)	7.2 (4.0)	7.79 (3.6)
Non-focal task (range 0 – 9)	6.9 (2.8)	7.7 (1.9)	7.11 (2.6)
Event-based prospective memory probabilities			
Focal task Forgetting Ratio	0.16 (0.29)	0.19 (0.35)	0.17 (0.31)
Focal task Recovery Ratio	0.08 (0.10)	0.07 (0.07)	0.08 (0.09)
Non-focal task Forgetting Ratio	0.13 (0.26)	0.06 (0.08)	0.12 (0.23)
Non-focal task Recovery Ratio	0.07 (0.09)	0.08 (0.09)	0.07 (0.09)

Table 3.4

Results of Regression Analyses of Proportion Correct of Event-based Prospective Memory Tasks with Age, Gender, Education, and Depressive Symptoms

Predictor	B	β	$R^2\Delta$
Focal EBPM			
Step 1			
Age	-2.30	-.22	.05
	R^2 = .05, F (1,65) = 3.16, ρ = .08		
Step 2			
Age	-2.09	-.20	.01
Gender	-0.74	-.01	.01
Education	1.23	.02	.01
Depression[1]	-.83	-.09	.01
	R^2 = .05, F (4,62) = .88, ρ = .49		
Non-Focal EBPM			
Step 1			
Age	.17	.02	.00
	R^2 = .00, F (1,66) = 0.02, ρ = .88		
Step 2			
Age	.47	.05	.03
Gender	.58	.01	.03
Education	5.26	.09	.03
Depression[1]	1.26	-.16	.03
	R^2 = .03, F (4,63) = .46, ρ = .77		

Note: [1]Depression is depressive symptoms scored on the CES-D 10

Table 3.5

Results of Logistic Regression Analysis of Time-Based Prospective Memory and Age, Gender, Education, and Depressive Symptoms

Predictor	β	SE	z	Exp (β)	95% CI Exp (B)	
					Lower	Upper
Time-based PM						
Step 1						
Age	.04	.00	.21	1.04	.88	1.26
Step 2						
Age	.11	.12	.84	1.12	.88	1.42
Gender	.21	.68	.09	1.23	.32	4.69
Education	.30	.71	.18	1.35	.34	5.43
Depression[1]	-.18	.12	2.29	.83	.66	1.06
Constant	-10.65	10.60	1.01	.00		

Note: Standard errors are in parentheses. -2LL = 72.59 [1]Depression is depressive symptoms scored on the CES-D 10.
$^{*}\rho < .05$, $^{**}\rho < .01$, $^{***}\rho < .001$

3.8 Discussion

This study examined performance on event-based and time-based prospective memory undertaken by a sample of oldest-old adults in their own homes. The event-based tasks were classified according to the nature of the target cue signal as either focal to the on-going task or non-focal. It was argued that focally cued targets would elicit spontaneous retrieval processes due to high association and detectability of the target cue. Non-focal target cues would demand greater strategic monitoring and be associated with poorer performance. Participants were required to respond to 11 focally cued items and 9 non-focally

cued items across the course of a week-long micro-longitudinal study. The time interval between the morning prompt for the event-based prospective memory items and item presentation ranged from 3 - 15 hours. The time-based task required participants to make a telephone call on a particular morning of the study. The time interval between instruction presentation, to the window of opportunity for execution of the time-based prospective task was approximately 12 hours (i.e., overnight). Prospective memory performance was defined as successful if the participant remembered to correctly double circle a capitalised question (i.e., a focal target cue), initial a box (i.e., a non-focal target cue), or call their research assistant during the nominated morning.

The initial focus of this study was to explore the influence of prospective memory task characteristics in determining the nature and direction of age-related effects in 'real-world' environments. A major finding was the high proficiency of older adults on event-based prospective memory tasks, in stark contrast to very poor performance on a time-based prospective memory task. Overall, participants successfully completed focally cued event-based prospective memory items on 73% of trials across the course of seven days. Similarly, successful performance was recorded on 83% of trials for non-focally cued items. For both event-based tasks, ceiling effects were evident, with a substantial number of participants recording perfect, or near perfect, scores. The low incidence of event-based prospective memory errors is also reflected in the low average forgetting ratio and high recovery ratio. The forgetting ratios are comparable to those reported in a study by Vogel and colleagues (2002) in which older adults were tested on three prospective memory tasks. Forgetting ratios in the Vogel study ranged from .16 for a simple three-in-a-row task, to .25 for a picture task, and .31 for a more

demanding word comparison task. Forgetting ratios for older adults aged 70 to 80 years as high as .54 have also been reported in the literature from demanding event-based tasks (Maylor, 1996). The relatively low forgetting ratios in the current study are consistent with those reported for the least demanding of the tasks employed by Vogel, namely the three-in-a-row task. The low sample-average forgetting ratio reflects the high proportion of successful event-based prospective memory responses across trials and the high percentage of participants performing at or near ceiling level. In this respect, it is reasonable to conclude that event-based prospective memory is preserved in older adults in naturalistic environments as reported in a substantial body of the literature (Einstein & McDaniel, 1990; Henry et al., 2004; Maylor, 1998; Park et al., 1997).

The current data support the hypothesis derived from the Multiprocess Framework of prospective memory (McDaniel & Einstein, 2000), of differential effects in performance dependent upon task characteristics. As predicted, task characteristics exerted an effect on proficiency, with time-based prospective memory severely compromised when compared to performance on event-based tasks. As proposed by McDaniel and Einstein (2000), event-based tasks are generally considered the 'easier' of prospective memory tasks as they are supported by environmental target and associative cues to trigger retrieval of an intended action. The results suggest that this was the case, with detection of both the focal and non-focal cues during questionnaire completion instigating action retrieval and appropriate execution in the greater majority of trials.

Conversely, participants in this study exhibited distinct difficulty with the time-based prospective task. This is consistent with the research previously reviewed showing well-defined age-related deficits with time-based prospective

memory both in naturalistic and laboratory studies. The current findings lend credence to the views that propose high levels of self-initiated retrieval processes are required for successful time-based prospective memory performance (Craik, 1996). As decline in attentional and cognitive resources are assumed to accompany normative ageing, it follows that task encoding and action retention over an extended period (i.e., overnight) was especially difficult. Participants were required to not only retain the intended action, but to engage in sustained monitoring for the opportunity for task execution the following morning. In the absence of a written morning prompt and experimentally supplied external cues, self-generated internal cues and monitoring were requisite to successful task completion. It is pertinent to note that the use of self-initiated external reminders or prompts was at the discretion of the participants with no experimenter-imposed restrictions. Older adults have been observed to place greater reliance on the use of external reminders and cues when compared to their younger counterparts. This observation has been cited as the reason for preserved prospective memory function in older adults in naturalistic studies (Maylor, 1990, 1996). In the current study, when asked at the final feedback interview what strategy was used to complete the prospective memory items, only one participant indicated that 'they wrote themselves a note'. The overwhelming majority of participants therefore relied on internal cues and self-initiated monitoring to remember this task. It could be speculated that failure to see or read the written task instruction contributed to an unsuccessful response for some participants and this could well be the case. However in light of widely reported age-related deficits associated with time-based prospective memory, the overall poor performance on this task suggests there was reduced attentional resource available for environmental monitoring

amongst this cohort older adults. As such the findings provide evidence in support of the Multiprocess Framework and also for attentional monitoring theories such as the PAM. The results support the view that prospective memory task characteristics and accompanying strategic demand are important factors in determining the nature and direction of age-related differences in this memory process.

A further issue of interest in the current study was the examination of age differences in prospective memory performance within a narrow age band of oldest-old adults. Whilst naturalistic studies have shown event-based prospective memory to be preserved in older adults, few studies to date have tested adults in advanced old age, namely over the age of 85 years. When considering event-based prospective memory, the current data suggest that the very old display proficiency in this memory task, at least when tested on relatively simple tasks presented in an environmentally valid setting. Moreover, the results display a robust pattern in this sample of older adults in maintaining associative encoding of an event-based prospective target cue and intended action in a highly active state, even over long retention periods. As discussed, the converse was true of time-based prospective memory performance.

Given a nineteen year difference between the youngest (83 years) and oldest (102 years) participant in the current study, and the paucity of prospective memory research in very old age, it was of interest to ascertain if there was a relationship between chronological age and proficiency. Analyses revealed no significant association between either linear age, or stratified age group, and overall performance on prospective memory tasks. There was some evidence for linear age to be related to performance on the focal EBPM task. Covariate factors

of gender, education, and depressive symptoms previously identified as confounding factors in prospective memory research (Cherry & Le Compte, 1999; Duncan et al., 1996) were not associated with performance in this instance. The absence of significant age differences within the restricted age band of the fourth age is a critical finding of this research and suggests similarity in performance in those over the age of 85 years. This is inconsistent with studies reporting linear chronological age effects associated with prospective memory deficits in a large cohort of very old adults (Huppert, Johnson, & Nickson, 2000). Huppert and colleagues tested 984 adults over the age of 85 years, 206 of whom were 90 years or older, representing 21% of their sample. In this age group, almost 75% failed on an event-based prospective memory task and performance across the sample was negatively associated with increasing age. Although the sample in the current study was smaller compared to the Huppert study, there was a higher proportion of participants over the age of 90 years (n = 21, 28% of participants). However, interpreting the apparent absence of age differences within the restricted age band in the current study is not straightforward. Results may reflect the small sample size and associated reduction in statistical power, or be an artefact of selection bias in sampling. The issue of participant selection will be addressed in greater detail when considering limitations in the present study.

It was hypothesised that the nature of the target cue would exert an effect on event-based prospective memory performance and was a major consideration in this research. There was a significant difference between focally and non-focally cued event-based prospective memory tasks when looking at overall performance. However, the differential effects were not in the direction predicted. The Multiprocess Framework (McDaniel & Einstein, 2000) argues that focal target

cues initiate spontaneous retrieval processes, are less demanding of cognitive resources, and display less age-related decrements when compared to non-focally cued target cues. A substantial body of research to date supports this contention (Cherry & Le Compte, 1999; Einstein & McDaniel, 1990; Einstein et al., 1995, Experiments 2 & 3; Park et al., 1997; Maylor, 1993, 1996; Maylor et al., 2002). In direct contrast with these studies, participants in the current study responded more successfully to non-focal event-based tasks than to focal tasks. The Multiprocess Framework provides a solid rationale for describing the effect of task characteristics (i.e., event-based versus time-based) on prospective memory performance in this study. However it is problematic in explaining the results obtained for focally and non-focally cued target cue items using this conceptual platform.

An alternative theoretical explanation for the direction of the current results is provided by the Preparatory Attentional and Monitoring model advocated by Smith (PAM: 2003). As reviewed in Chapter 2, the PAM model posits successful interpretation of a prospective memory target cue to require not only preparatory encoding of the cue-action association, but environmental monitoring for cue detection. The model does not differentiate between cue focality but theorises monitoring for target cues to be demanding of attentional resources. Essentially, the prospective task and on-going task compete for limited cognitive capacity in a dual-task paradigm. As age-related decline in attentional resources is considered a normative aspect of cognitive ageing (Hasher & Zacks, 1988), age deficits in prospective memory would ensue if attention is divided between environmental monitoring for target cue detection and on-going task performance (Smith & Bayen, 2005). The focal prospective target cues embedded in the daily

questionnaires completed by participants were capitalised and defined as highly distinctive, with appropriate presentation of the cue and on-going task characteristics. This was predicted to attenuate the need to shift perceptual monitoring between the on-going task and the target cue, instigating spontaneous retrieval of the prospective task. Inherent in this perspective is the ability to maintain the relevant target-cue-action in an accessible and activated state. The PAM model would suggest that performance on the focal items showed greater deficit than the non-focal items as attentional resources were directed toward maintaining on-going task performance at the expense of environmental monitoring and prospective performance. The non-focal items on the other hand, were not embedded within an on-going task but presented at the bottom of the page and required detection and execution following completion of questionnaire items on that page. It is plausible under the PAM model that attentional resources could therefore be directed toward target cue monitoring without diversion to an immediate on-going task, accounting for better proficiency on these prospective memory items. Age-related deficits in prospective memory performance under the PAM model have generally been evaluated in terms of cost associated with on-going task performance (Burgess, Quayle, & Frith, 2001; Smith, 2003; Smith & Bayen, 2004a). Unfortunately, results in the current study cannot be evaluated in terms of response time latencies, or on-going task accuracy. The PAM model however, offers a credible explanation for the differential results obtained between focal and non-focal prospective tasks and supports the attention depletion hypothesis of normative ageing (Hasher & Zacks, 1988).

A major focus of the current study was to determine the influence of task characteristics and target cue focality on retrieval processes in prospective memory

in the oldest-old. Small differential effects were found between performance on event-based tasks and time-based tasks. The nature of the target cue and strategic monitoring demand also influenced performance. Overall, the findings are consistent with the age-prospective memory paradox and suggest that event-based prospective memory performance is preserved in the very old in naturalistic settings, whilst time-based prospective memory is compromised.

3.8.1 Limitations and future directions. There are several potentially relevant methodological issues to consider when evaluating the current results including practice effects associated with the prospective tasks and issues with participant selection. This study administered repeated event-based prospective memory items across the course of a week with preservation of the same or similar target cues (i.e., box for the non-focal task, capitalised question for the focal task). Repeated presentation may have afforded participants the opportunity to practice and master the event-based tasks, permitting a degree of automatisation in task execution with reduced demands on the retrospective component of the task. As such, incorporation of the prospective task requirements into an overall strategy for completion of the on-going task may have enhanced performance on the event-based items. This was the case in previous research in which habituation and practice with repeated tasks were found to enhance prospective memory performance in older adults (Duncan et al., 1996). Practice effects may therefore have accounted for the high success rate on the event-based prospective tasks in this study. This would be in contrast to age-deficits reported for single event-based trials found in several naturalistic studies.

In addition to the issue of practice effects, although prospective memory tasks were experimenter controlled, there were no experimenter imposed time

constraints, nor limitations enforced on use of self-initiated prompts or cues. Participants were free to complete each questionnaire in their own time and revisit questionnaire items. Proficiency could therefore be artificially exaggerated in this age-group and generalising to one-off event-based items with constrained windows of opportunity for task execution problematic.

There are several pertinent issues with respect to participant sampling in the current study that warrant discussion. Participants represented a group of independent living, reasonably high functioning older adults, willing and able to negotiate a relatively demanding seven-day study protocol. As such, participants were not necessarily representative of adults in the fourth age. As noted by Hofer, Sliwinski, and Flaherty (2002, p. 27), selection into longitudinal studies is often non-random, with those exhibiting the least change over time being the most likely to continue participation. They further assert that self-selection into studies, as was the case with the 25 non-ALSA participants, is biased toward those experiencing the least amount of age-related change and variation.

Such selection features in sampling are largely unavoidable with this type of study and the age group under consideration. This being the case, selection bias could have impacted on the results with mean trends in the sample confounding the data. In addition, a larger more representative sample of community dwelling oldest-old adults may well reveal linear age differences across the fourth age as reported by Huppert and colleagues (2000) and certainly calls for future investigation. Despite these potential confounds, the current results posit a case of similarity in prospective memory performance for resilient and high functioning oldest-old adults.

The opportunity exists for future research to examine prospective memory processes in naturalistic studies with the oldest-old, using shorter, less demanding study protocols and more representative sample selection. Methodological issues could also be enhanced through incorporation of several time-based trials, to ascertain if the very poor performance on this task in the current findings is in fact indicative of reduced capacity for self-initiated monitoring during older age or an artefact of a single trial or task. Ideally, longitudinal studies of prospective memory in individuals during the fourth age would help delineate age related variance and individual differences in rates of change, thereby clarifying prospective memory processes and perhaps unravelling the age-prospective memory paradox.

3.9 Conclusion

The oldest-old represent the fastest growing cohort in most societies with implications for policy, lifespan development perspectives, personal growth, participation, and societal recognition of the needs of older adults. Participants in the current study were community dwelling adults from this cohort, maintaining relatively independent functioning in society. Although age-related declines in cognitive functioning tend to be widely assumed, the current findings point to preserved event-based prospective memory in the oldest-old.

The key message from this research is that a sub-set of healthy, high functioning oldest-old adults are capable of carrying out intended event-based actions in their everyday lives. Remembering intended future actions, the nature of which are likely to contribute to safety in the home and maintenance of health, well-being, and social activity and inclusion, may contribute to resilience against cognitive and physical losses in this age group. In particular the importance of task

regularity and high association between an intended action and target cue in the everyday lives of older adults cannot be under-estimated. Carers and health care professionals should be cognizant of the role of regularity and habituation in attenuating memory related age deficits in the very old, in particular when routine is interrupted by unforseen events, illness, or change of environment. In contrast to event-based prospective memory, findings point toward compromised proficiency on time-based tasks in this cohort. Given the large number of community dwelling older adults, many of whom live alone, the current study identifies areas of concern with respect to prospective memory. Establishing training to support older adults with prospective memory, in particular with time-based tasks, will help equip older adults with the skills, techniques, and emerging technology to maintain independent functioning.

Study 1 highlights prospective memory performance in the very old from a broad between-person perspective. It is evident that although event-based prospective memory performance was generally spared, a small sub-set of ADuLTS' participants experienced difficulty with these tasks. Moreover, time-based performance was compromised for the greater majority of participants. The subsequent studies in this thesis aim to identify some of the theoretically relevant factors that may attenuate or exacerbate age-related declines. Hence, the following chapter will present a review of the literature pertinent to Studies 2 and 3.

Chapter 4.

Intra-individual and inter-individual predictors of prospective memory.

4. Overview

Intra-individual or within-person variability and inter-individual or between-person differences have been proposed to influence prospective memory processes. Given the paradoxical findings surrounding prospective memory performance in older adults discussed in Chapter 2, identifying factors affecting fluctuations within individuals and differences between individuals may help unravel contradictory research results. This chapter will introduce some of the factors and constructs embodied in research to date as contributing to prospective memory proficiency. The literature directly informing Studies 2 and 3 will then be overviewed. For Study 2, an argument for stress as a predictor of prospective memory performance deficits is presented. For Study 3, the role of cognitive processes involving executive function, working memory, and retrospective memory performance will be reviewed to provide a theoretical basis for that study.

4.1 Intra-individual and Inter-individual Constructs Informing Current Research

Intra-individual variation is defined as relatively short-term variability or fluctuation experienced by an individual in an adaptive response to exogenous and endogenous influences (Ram & Gerstorf, 2009). Several within-person constructs have been hypothesised to influence successful prospective memory performance. These include, but are not limited to, an individual's optimal time of day for cognitive and physiological functioning, and fluctuations in an individual's level of anxiety, affect, and stress.

West and Craik (1999) found participants tested at their optimal time of day (Hasher & Zacks, 1988) showed better prospective memory performance than those tested at non-optimal times. This was thought to reflect improved attentional processes and speed of processing when an individual is functioning at their optimal level. Additional constructs informing recent literature include individual anxiety levels and daily fluctuations in positive and negative affect (Adam et al., 2006; Chida & Steptoe, 2009; Nater, Hoppmann, & Klumb, 2010; Wrosch et al., 2008) as factors influencing prospective memory performance. McDaniel and Einstein (2007) posit a case for the influence of daily stressors and on-going concerns negatively impacting prospective memory performance, in particular, diverting attentional resources away from strategic monitoring processes. However to date, there is little empirical evidence available for the association between prospective memory and stress processes particularly when considering oldest-old adults. As such, Study 2 was designed to test the influence of intra- individual fluctuation and inter-individual differences in base-line and concurrent stress levels on prospective memory performance.

The association between prospective memory and cognitive constructs, including executive function, working memory, and retrospective memory have also informed research. Again, as with the research examining personality factors, results to date remain inconclusive. Working memory for example, has been postulated to play a crucial role in prospective memory, with higher working memory hypothesised to support prospective memory by allowing greater storage and processing capacity for current information, and better integration between the intended action and target cue (McDaniel & Einstein, 2007). Findings have not been unambiguous, with strong correlations reported between working memory

and prospective memory across several studies (Einstein et al., 2000, Experiments 1 & 2; Cherry & Le Compte, 1999; Smith, 2003; West & Craik, 2001) and no correlation reported in other research (Einstein et al., 2000, Experiment 3; West & Craik, 2001, Experiment 2). Working memory and executive function are related but partially dissociable attentional control mechanisms, both of which have been shown to exhibit normative age-related decline. The first aim of Study 3 is to examine the role of inter-individual differences in working memory and executive function upon prospective memory performance in the fourth age.

The second aim of Study 3 is to assess the influence of a third cognitive construct, retrospective memory, on prospective memory performance. Retrospective memory, although dissociable from prospective memory, is never-the-less, an important component of prospective memory processes, as retrospective memory is central to remembering the content of an intended action. Paralleling inconsistent findings in the literature examining the role of working memory and executive function in prospective memory, the influence of retrospective memory remains contentious. Kliegel et al., (2005) reported retrospective memory was predictive of prospective memory (Kliegel et al., 2005) whereas others have found deficits in retrospective memory to be associated with diminished prospective memory performance (Foster et al., 2013; McFarland & Glisky, 2009; Raskin et al., 2011).

The following section will review the constructs identified, namely, 1) inter-individual differences and intra-individual variation in stress pathways and processes, and 2) executive functioning, working memory, and retrospective memory, and in particular age-related changes in these cognitive processes.

4.2 Stress Processes and Prospective Memory: Study 2

4.2.1 Stress pathways. Stressors are the internal or external psychological, emotional or physical stimuli triggering a stress response, (i.e., acute arousal), and are broadly distinguished as either significant life events or daily stressors (Almeida, Piazza, Stawski, & Klein, 2011). Significant life events are significant incidents necessitating major life adjustment such as marriage, job loss, or the death of a spouse. Daily stressors and hassles, otherwise known as quotidian stressors, are small, accumulative everyday events affecting a person's life and may be chronic or acute in nature (Almeida, 2005; Bolger, Davis, & Rafaeli, 2003; Piazza, Almeida, Dmitrieva, & Klein, 2010). Chronic quotidian stressors, for instance long-term care-giving, are persistent and recurring stressors which can result in chronic arousal of the individual from accumulated stress. Acute daily stressors include major, non-recurring events and minor everyday hassles, directing spikes in arousal from adaptive short-term physiological responses to external or internal challenges (Almeida, 2005; Piazza et al., 2010). Both chronic and acute quotidian stressors impact upon an individual's daily well-being. The accumulation and interaction of different sources of stress can also potentially exacerbate individual reactivity to stress. Before discussing inter- and intra-individual variations in stress reactivity, a brief overview of the normative stress response is warranted.

4.2.2 Stress processes: The Hypothalamic-Pituitary-Adrenal (HPA) axis. The physiological response to stress has been well documented. Stress activates two response pathways, initially the Sympathetic-Adrenal-Medullary (SAM) axis responsible for the "fight-or-flight" response, followed by recruitment of the Hypothalamic-Pituitary-Adrenal (HPA) axis, a longer term hormonal

response to stress. The latter is the primary focus in this thesis. The HPA axis supports control and regulation between the central nervous system and the endocrine system (Kudielka & Wüst, 2008), co-ordinating glucocorticoid hormone release in response to stressor demand (Wrosch, Miller & Schulz, 2009), and supporting homeostatic biological functioning. Cortisol, a steroidal adrenal hormone, is the primary glucocorticoid responsible for the stress response (Kirschbaum & Hellhammer, 2000), accounting for approximately 95 % of glucocorticoid activity (Kudielka & Wüst, 2008; Tortora & Derrickson, 2009). Cortisol supports physiological functioning and, at basal levels, that is, an individual's normal baseline secretion levels, exhibits a distinct circadian rhythm. Lowest levels are evident during the second half of the night and increase upon awakening, with peak levels occurring approximately 30-45 minutes post awakening (Wilhelm et al., 2007). This phenomenon has been labelled the cortisol awakening response (CAR). Cortisol levels then continue to decrease over the course of the day. However, cortisol surges occur as a result of exposure to stress and challenge (Born et al., 1999). During such episodes, the cerebral cortex activates the paraventricular nucleus of the hypothalamus from which corticotrophin releasing hormone is released. Upon reaching the pituitary gland, corticotrophin releasing hormone stimulates the release of arginine vasopressin, a hormone that supports the fight-or-flight response. In addition, adrenocorticotrophin hormone is released, activating the cortex of the adrenal glands to synthesize and release glucocorticoids.

The physiological effects of cortisol arm the body for resistance to stress. Cortisol stimulates 1) energy stores to be mobilised via gluconeogenesis, lipolysis, and protein breakdown, 2) blood pressure to be increased, 3) anti-inflammatory

effects, and 4) depression of immune responses (Piazza et al., 2010). The majority of circulating cortisol is rapidly bound to carriers in the bloodstream; the remaining 2 to 15% of unbound or "free" cortisol exerts effects in peripheral tissues and the brain due to its ability to cross the blood-brain barrier (Kirschbaum & Hellhammer, 2000). As such, cortisol is measured in the blood in both free and bound form, and in saliva as free cortisol. Cortisol rapidly enters saliva by passive diffusion following stressor demand, peaking in 10 to 30 minutes post release. Kirschbaum and Hellhammer (2000) report high correlations between salivary cortisol and blood cortisol levels ($r \geq .9$). However salivary cortisol has the advantage of being an easily accessed bio-marker, or biological indicator (Piazza et al., 2010) of individual reactivity to stress; it can be obtained largely non-invasively and is suitable for ambulatory, momentary assessment. In addition, cortisol levels remain stable in saliva for up to four weeks at room temperature and indefinitely at -20°C storage, and are effectively analysed by immunoassay. Salivary cortisol is therefore an established biomarker of stress increasingly utilised in neuropsychological and endocrine research, and was employed in the current study to assess ambulatory, momentary cortisol levels, and hence stress fluctuations in a sample of community dwelling, oldest-old adults.

4.2.3 Stressor exposure and individual reactivity. Stressor reactivity has been defined as the "dynamic within person relationship between stressors and well-being" (Almeida et al, p.193). Although physiological response to stress is adaptive in the short-term, exposure to chronic and daily stressors has been shown to negatively affect emotional and physical health, and adjustment (Zautra, 2003). Importantly, robust inter-individual differences and intra-individual fluctuations are evident in both reactivity to stress and in the frequency of exposure to

stressors. Research suggests an individual's vulnerability and resilience to stress are largely determined by socio-demographic factors including age, gender, socio-economic status, social support, income, and education (Almeida et al., 2011). Stable psychosocial factors such as personality traits are additional determinants in reactivity to stress (Almeida et al.). The interplay of situational and individual factors can attenuate a person's opportunity for exposure to stressors and modify their reaction to, or appraisal of, the stressor once exposed. How an individual reacts to stress can determine both proximal and distal outcomes (Chui et al., 2013). Heightened reactivity to stress is linked with individual differences in life-time exposure to cortisol (Lupien et al, 1994, 1996, 2007), genetic factors, and tissue sensitivity to glucocorticoids (Wüst et al., 2004). Research shows that chronic exposure to heightened levels of cortisol is associated with cardiovascular disease, depression, and immunosuppression (Cacioppo et al., 1998; Tsigos & Chrousos, 2002; Wüst et al., 2004). Moreover, studies indicate that heightened cortisol levels are associated with individual differences in affect, in particular increased negative affect and decreased positive affect (Wrosch, et al., 2007). Conversely, higher levels of mastery (Cairney & Krause, 2008), social support, the use of secondary control strategies such as the setting of goals and causal attributions (Heckhausen & Schulz, 1993; Wrosch, Miller, & Schulz, 2009; Wrosch, et al., 2007) and higher positive affect (Simpson et al., 2007) have been shown to reduce reactivity to stress. In addition, lifestyle factors such as robust sleep-wake cycles (Wrosch et al., 2008), diet, and exercise have also been identified as moderators of stress reactivity. In contrast to these findings, some studies suggest that lower levels of cortisol and blunted diurnal cortisol profiles are

linked with greater reactivity to stress resulting in detrimental physical and mental health outcomes (Chui et al., 2013; Miller, Cohen, & Ritchey, 2002).

The association between cortisol secretion levels and adverse outcomes is therefore inconclusive. In addition to this, and with respect to aging research, few studies have examined the association between stress reactivity and cortisol responses in advanced older age. Three models have been postulated to account for individual differences in stress reactivity that may occur with normative ageing. Firstly, Socio-emotional Selectivity Theory (Carstensen, 1999) emphasises a coupling of psychological mechanisms with stress reactivity, and proposes a dampening of reactivity to stress with age. The second model, conceptualised by authors including Kendler et al. (Kendler, Thornton, & Gardner, 2001) and Sliwinski and colleagues (2009), proposes an alternative view. This allostatic load model (Seeman, McEwen, Rowe, & Singer, 2001) suggests biological pathways drive heightened reactivity to stress with age. The theory of strength and vulnerability integration (SAVI: Charles, 2010) is the third model, and serves to amalgamate biological and emotional pathways in stress reactivity in older age.

Socio-emotional Selectivity Theory (SST: Carstensen, Isaacowitz, & Charles, 1999) posits that older adults reduce their exposure and reactivity to stressors through selective goal choice and improved impulse control (Diehl, Coyle, & Labouvie-Vief, 1996). Further, older adults demonstrate better emotion regulation compared to younger adults (Lang, Staudinger, & Carstensen, 1998) and engage in knowledge-based reinterpretation and appraisal of stressors (Whitbourne, 1986). Socio-emotional Selectivity Theory predicts older adults would show increased resilience and dampened reactivity to stress, despite physiological changes in stress processes. Several studies attest to reduced

reactivity to stress with age. For example, age was found to be a significant moderator of the within-person effect of daily stress on cognitive interference associated with rumination resulting from stress induced negative affect (Stawski, Mogle, & Sliwinski, 2011). Uchino and colleagues also posit a case for decreased reactivity, showing older adults to have lower levels of negative affect co-occurring with stress in comparison to younger adults (Uchino, Berg, Smith, Pearce, & Skinner, 2006). Further evidence is provided by Stawski, Sliwinski et al. (2008). They examined the concurrent association between emotional reactivity and frequency and severity of perceived daily stress and daily hassles in adults. Younger (M = 20 years, n = 67) and older participants (M = 80, n = 116 years) completed daily diaries six times over a 14 day period. Results showed that within-person intra-individual variability in emotional response to daily stress fluctuated with concurrent changes in perceived global stress in both younger and older adults. Although younger adults experienced more frequent daily stress events consistent with SST (Carstensen et al., 1999), the intensity of emotional reactivity to stress did not differ between groups. This study partially supports the tenets of the SST but also posits a case for biological models of stress reactivity in advanced age.

The allostatic load model (Seeman & Gruenewald, 2006; Seeman et al., 2001) suggests reactivity to stress increases with age. In this model, repeated exposure and response to stress over time is posited to sensitize neural networks, increasing reactivity to stress and stressor demand (Kendler, 2001; Sliwinski et al., 2009). Review of the literature suggests age-related, increased sensitivity of the HPA axis to be normative (Seeman et al., 2001; Simpson et al., 2007). This line of research suggests older adults display greater sensitivity to negative affect due to

age-related changes in the amygdala and limbic systems, both regions involved in emotion and memory processing. From this model, it follows that age-related physiological change would render older adults more vulnerable to stress effects (Lupien et al., 2002b; Weist et al., 2004). Evidence in support of this is provided by Sliwinski, Smyth, Hofer, and Stawski (2006) who assessed performance on cognitively demanding tasks in younger and older adults. High stressor days were associated with poorer performance for both groups, but deficits were larger for older compared to younger adults. Mroczek and Almeida (2004) also found older adults to have a higher increase in negative affect associated with stress compared to younger adults. However to date, little research has directly assessed bio-physiological markers of stress and reactivity in the oldest-old in the context of daily life.

The theory of strength and vulnerability integration (SAVI: Charles, 2010) provides a robust platform from which to reconcile the two opposing models of biologically or emotionally driven age-related changes in stress reactivity. The SAVI is a theoretical model describing emotional pathways in aging through which older adults develop an enhanced ability to employ strategies to avoid or limit exposure to adverse or negative stimuli. However, the model contends that when subjected to unavoidable heightened arousal older adults take longer to return to equilibrium and tend to experience greater negative distress when compared to younger adults in similar circumstances (Charles, 2010). Almeida and colleagues (2011) invoked the theory of SAVI to conceptualize explanatory mechanisms of intra-individual variability and change, and inter-individual differences in stress reactivity. They argue that psychosocial, situational and

physiological resources available to an individual throughout adult development modify an individual's reactivity to stress.

Reactivity to stress may therefore be a process underpinning individual differences apparent in physiological and cognitive ageing. However, the empirical evidence assessing stress and cortisol secretion levels in older adults is sparse. Of the research available, most have induced acute stress under experimental, laboratory-based conditions with reduced ecological validity (Dickerson & Kemeny, 2004; Saxbe, 2008). In Study 2, repeated ambulatory cortisol assessments will be incorporated with daily diary measures to map onto the daily life of oldest-old adults. The study will attempt to elucidate inter-individual differences and intra-individual variability in cortisol secretion levels and the consequent impact on prospective memory performance. The following section will review the empirical evidence for the association between cortisol and cognitive performance from an ageing perspective.

4.2.4 Stress, cortisol, ageing and cognition. Although physiological and emotional mechanisms may influence individual reactivity to stressors and daily hassles, empirical research shows fundamental age-related structural and functional changes in HPA activity. Basal and diurnal cortisol levels and patterns change across adult development, with implications for physiological and cognitive health and well-being. Mean basal cortisol levels have been shown to increase with age due to a weakening of the regulatory negative feedback loop of the HPA axis, with a concomitant flattening of the diurnal cortisol pattern and an attenuated CAR response (Cacioppo et al., 1998; Piazza et al., 2010; Tsigos & Chrousos, 2002; Wüst et al., 2004). Compared with younger adults, older adults exhibit a higher cortisol nadir with less steep decline of cortisol in the evening

hours. Age-related dysregulation of the HPA axis is theorised to reflect allostatic load (wear and tear), accounting for day-to-day fluctuations in the stress response of older adults, stemming from compromised regulation of cortisol synthesis and negative feedback regulation (Almeida, Piazza, & Stawski, 2009). From a functional viewpoint, HPA dysregulation manifests in adverse physiological and mental health outcomes due to increased circulating cortisol (Piazza et al., 2010). Additionally, higher basal levels of cortisol have been associated with functional disability over a two year period (Wrosch et al., 2009) and global cognitive decline over a seven year period (Seeman et al., 2001). Structurally, longitudinal evidence reveals a significant negative association between high basal cortisol levels and hippocampal volume (Lupien et al., 1998). Research has found cortisol binds to glucocorticoid receptors in the frontal lobes and hippocampus, interfering with cognitive processes and neuronal transmission, ultimately affecting function and behaviour (Lupien et al., 1998; Wolf, 2003). Both brain areas are implicated in memory function, the hippocampus in particular with emotional processing and memory and the frontal lobes with working memory and executive control (Gazzaniga, Ivry & Mangun, 2002). Studies also suggest repeated exposure to cortisol, as in extended or high-dose cortisone-based anti-inflammatory medication, results in neuronal death (Sapolsky, 1999). Normative physiological changes in the HPA axis and stress reactivity are therefore expressed in terms of structural and functional decrements with age.

Cortisol-induced structural and functional neuroantatomical changes point to a link between cognition and stress, a proposition supported by current research with both younger and older adults. The effects of stress on a number of cognitive domains have been replicated in laboratory, naturalistic and clinical studies. Both

younger and older adults show reduced working and episodic memory, and reduced speed of processing when stress is induced by eliciting recall of negative life-events (Klein & Boals, 2001; Stawski, Sliwinski, & Smyth, 2006). With older people, chronic stress has been associated with reduced global cognitive function (Lee, Kawachi, & Grodstein, 2004) and reduced processing speed (Caswell et al., 2003; Stawski, 2006). Further, the working memory of older adults shows marked declines in the presence of daily stressors (Sliwinski et al., 2006). Raised basal levels of cortisol in older adults aged from 60 to 90 years have been associated with decrements in episodic memory (Lupien et al., 1994, 1996), and in declarative, spatial and verbal memory (Kirschbaum et al., 1996). In younger adults, elevated basal levels have also been associated with poor retrieval of items encoded prior to stress induction (Het, Ramlow, & Wolf, 2005; Kuhlmann, Piel, & Wolf, 2005b).

4.2.5 Summary. A robust effect of memory-impairing consequences of cortisol and stress has been revealed by recent research. However few studies have considered the effect of stress and cortisol on prospective memory, or among the oldest-old members of our society. Whilst this memory process has been widely researched during the last three decades (McDaniel & Einstein, 2008), much remains to be reconciled about prospective memory performance and age-related changes. Study 2 will therefore directly address three pertinent issues arising from the review of the literature. Firstly, the study provides a unique opportunity to redress the paucity of research into stress processes in very old adults who are functioning independently in their own homes. Multiple daily measurements will allow for the diurnal pattern of cortisol secretion and momentary fluctuations in secretion, and thereby the occurrence of physiologically experienced stress, to be

assessed. Secondly, the study adds to pioneering research into the association of stress with prospective memory performance in extreme old age. Thirdly, by decomposing salivary cortisol profiles, separate evaluation can be made of the various components of daily cortisol concentrations and their association with prospective memory performance. For example, the cortisol awakening response (CAR), the area under curve (AUC) representing total daily secretion levels, and individual standard deviations (*i*SD) in momentary secretion levels may be varying components of the cortisol profile associated with varying levels of prospective memory performance. In so doing, Study 2 will provide a fine-grained analysis of possible links between cortisol and prospective memory and will contribute to the current literature through the exploration of inter-individual differences and intra-individual variations in bio-physiological stress and prospective memory performance in a cohort of oldest-old adults within a naturalistic, but experimenter-influenced, environment.

4.3 The Association of Executive Function, Working Memory, and Retrospective Memory with Prospective Memory: Study 3

A critical issue in prospective memory research arises from the divergent findings of age-related effects in performance reported in the literature. Although no single factor appears to account for the observable discrepancies, the *age-prospective memory paradox* suggests the direction of age-effects on prospective memory tasks to be a function of the task setting, cue characteristics, task demand, task implementation strategy, habituation, and motivation. In addition neurobiological and neurocognitive factors have been theorised to influence prospective memory performance. A review of the literature confirms neurocognitive constructs such as attentional control processes including executive

function and working memory, and retrospective memory, play an influential role in prospective memory proficiency. Executive function and working memory embody controlled attentional processes and, to date, the extent to which controlled attentional processes explain age-related variance in prospective memory performance remains inconclusive. A review of the literature confirms that most studies have focused on either working memory or global measures of executive function. The major focus of the current review is to explore the processes and neural correlates of each construct and explore their age-related association with prospective memory. The rationale for examining both constructs as related, interdependent facets of controlled attention underlying prospective memory will be presented. An additional focus of the current review and of Study 3 is to examine retrospective memory processes in prospective memory, the role of which remains contentious. The interplay of each cognitive construct with prospective memory will therefore be examined and a theoretical rationale for Study 3 proposed.

4.4 Executive Function.

Executive function is broadly defined as a set of complex, adaptive behaviours attributed with the integration, regulation, and co-ordination of higher order cognitive processes (Daniels, Toth, & Jacoby, 2006; Luszcz & Bryan, 1999). Decline in executive functioning is associated with normative, primary ageing (Luszcz, 2011; Luszcz & Bryan, 1999; Luszcz & Lane, 2008) and has been found to predict age-related memory deficits (Bryan & Luszcz, 2000; Crawford, Bryan, Luszcz, Obonsawin, & Stewart, 2000), functional status, and task performance of older adults (Royall et al., 2004). Although deterioration in executive control processes accompanies primary ageing, the effect of such decline is far from

immutable. Research suggests functional status is augmented if older adults are supported with tasks in familiar environments through practice, compensatory neural recruitment (Park & Reuter-Lorenz, 2009; Phillips & Andrés, 2010), or strategic focus on selected tasks salient to the individual (Phillips & Henry, 2005). As executive function deficits are associated with memory decline in older age, it follows that executive function might also predict prospective memory proficiency in advancing years, with age-related effects determined by the degree of strategic demand placed on executive processes. To explore this contention, the following section will review the processes and neural correlates of executive function, and present the current literature capturing the role of executive function in prospective memory.

4.4.1 Models of executive function processes. Executive function has been conceptualized as either a unitary control process (Miyake et al., 2000), or conversely as an interaction of diversified sub-processes sharing a common executive component (Blair, 2006; Rabbitt, 2005). More recently, theorists have argued that executive function can be viewed both as an all encompassing unitary function, and also as a process with diverse componential functions (Banich, 2009; Friedman et al, 2008). Although multiple models of executive function have been developed, the distinct functions that elucidate this complex cognitive construct will be discussed.

Executive functions can be subsumed under four broad cognitive sub-processes, namely, volition, planning and decision-making, purposive action, and self-regulation (Friedman et al., 2008; Lezak, Howieson, Bigler, & Tranel, 2012; Salthouse, Atkinson, & Berish, 2003). These componential sub-processes underpin successful psycho-social functioning through control and regulation of goal-

oriented or stimulus-driven behaviour (Gazzaniga et al., 2002), and support emotional processes through regulating the interplay between emotion and cognition (Friedman et al., 2008). Importantly, the components of executive function embody specific higher order behaviours and cognitive processes central to optimal performance in complex cognition and memory processes (Lezak et al., 2012), and to performance on non-routine tasks and in novel situations (Banich, 2009; Lezak et al., 2012; Shallice, 1982).

In a simplified model with high construct validity, Miyake and colleagues (2000; Friedman & Miyake, 2004) identified three basic executive sub-processes using latent-variable analysis, namely inhibition, shifting, and updating. They defined inhibition as the "deliberate inhibition of dominant, automatic, or prepotent responses", requiring attentional control to limit interference from task-irrelevant information and responses (Miyake et al., 2000, pp. 55-57). Shifting was defined as the ability to shift attentional control between "multiple tasks, operations, or mental sets" depending on the demands of the situation. Updating was defined as the "updating and monitoring of working memory representations" involving the short-term storage of information. Although representative of the multidimensionality of executive control processes, the sub-processes outlined are theorised to be partially interdependent functions of the central executive, with demand on one sub-process reducing attentional and cognitive resources available to the other sub-processes (Friedman & Miyake, 2004). This interdependent conceptualization of executive processes is typically regarded as a valid theoretical model. The current study will adopt a theoretical approach focusing on the unity of executive processes sharing common executive control functions (Blair, 2006;

Shallice & Burgess, 1993), due in part to the limited range of executive function measures available in the ADuLTS data.

4.4.2 Executive function and age-related decline. Whether construed as a unitary or multi-faceted construct, executive function decrements are associated with advancing adult age. Reduced neurological integrity of brain regions, in particular the prefrontal cortex, accompanies normative primary ageing (Crawford, Bryan, Luszcz, Obonsawin, & Stewart, 2000; Luszcz & Bryan, 1999). The frontal-executive hypothesis of cognitive ageing (West, 1996) assumes the frontal cortex region supports executive function processes. Indeed, current opinion suggests all fluid executive functions recruit frontal regions, in particular the dorsolateral prefrontal cortex (Alvarez & Emory, 2006; Phillips & Della Sala, 1998). Structural and functional deterioration of the prefrontal cortex is therefore thought to underpin memory loss and cognitive decline with advancing age. Evidence in support of the frontal-executive hypothesis of cognitive ageing is demonstrated in an extensive body of work, including neurophysiologic, morphologic, and behavioural studies.

Early neuroanatomical imaging research provided support for frontal involvement in executive functions. For instance, Okuda et al. (2000) found activation of the frontal regions a study using a semantic task designed to recruit executive control processes. Participants learnt 10 target words, to be identified during an experimental condition in which the ongoing task required verbal repetition of a series of 10 sets of 5 nouns. Using neuroimaging, marked increase in cerebral blood flow to the medial frontal lobe, right inferior and middle frontal gyri, left anterior cingulate gyrus, left superior frontal gyrus, and the parahippocampal gyrus was revealed during the experimental condition in

comparison to the control condition. Neuroanatomical imaging studies also provide reliable evidence for activation of prefrontal regions during executive tasks and cognitively demanding tasks in older adults (Leshikar et al., 2010; West, Schwarb, & Johnson, 2010).

Neurophysiological studies replicate the findings from neuroanatomical imaging. Across studies, the frontal lobes reveal early age-related loss in structural integrity not observed in other brain regions, exemplified by volumetric atrophy and reduced white matter density (Charlton et al., 2010; Head, Rodrigue, Kennedy, & Raz, 2008; Raz 2005). In addition, neurotransmitter integrity is compromised with age, evident in reduced dopamine levels in the frontal cortex (Salat, Kaye, & Janowsky, 2002). Deficits of executive function observed in clinical populations also mirror normative executive function declines in older adults. These include executive deficits associated with traumatic brain injury to the frontal lobes (Damasio, Anderson, & Tranel, 2011; Henry & Crawford, 2004b), left frontal lesions (Davidson et al., 2008), Alzheimer's disease (Henry & Crawford, 2004; Rainville et al., 2002), Parkinson's disease, and Multiple Sclerosis (Henry & Crawford, 2004c, 2006).

Additional evidence for the frontal-executive hypothesis stems from neuropsychological studies whereby older adults typically perform more poorly than younger adults on tests sensitive to executive function including deficits in free recall, sequencing, and spatio-temporal memory (Luszcz & Lane, 2008). Further, executive function has been found to mediate the relationship between age and episodic memory, incidental memory, and strategic retrieval (Bryan & Luszcz, 2000; Crawford et al., 2000). Executive function decrements associated with ageing have also been theorized to affect individual variability in performance.

West et al., (2002) argued that greater performance variability and fluctuations in executive function over time are associated with older age, thus tasks more demanding of executive function would exhibit more lapses of intention and variability in performance in older compared with younger adults. Their study demonstrated greater performance variability in older adults compared to younger adults using an *n*-Back task requiring active recruitment of executive processes. This is in comparison to their finding no significant age-related differences in a non-executive immediate response task.

There is consensus in the literature that executive function is intimately associated with memory, and partially mediates age-related deficits in performance as espoused by the frontal-executive hypothesis of cognitive ageing. If this is the case, it follows that executive control processes might mediate prospective memory performance, with differential effects depending on the degree of frontal recruitment required of the task. The following section will therefore appraise the literature pertinent to executive function and prospective memory processes.

4.4.3 Executive function and prospective memory in older age. Early research into executive function and prospective memory provided little definitive empirical evidence for an association between the two processes. For instance, Bisiacchi (1996) failed to demonstrate any apparent involvement of executive control function in prospective memory processes in older adults aged between 50 and 92 years. In contrast, Glisky (1996) hypothesised that the magnitude of age-related effects in prospective memory would be correlated with the degree to which the task was dependent on executive processes. This theoretical viewpoint was substantiated by subsequent neuropsychological, neuroanatomical imaging, and neurophysiological research.

Neuropsychological studies such as that reported by McDaniel et al. (1999) provide empirical evidence for an association between executive function and prospective memory. They found older adults assessed on a battery of neuropsychological tests as high frontal functioning, exhibited better event-based prospective memory performance when compared to their low functioning counterparts. Convergent evidence was reported by Salthouse, Berish, and Siedlecki (2004). Participants included 330 adults aged between 18 and 89 years. Executive function was found to mediate the relationship between age and prospective memory performance after controlling for the effects of perceptual speed of processing, fluid intelligence, and general memory.

Martin, Kliegel and McDaniel (2003) examined the role of executive function in prospective memory in older age and were the first to incorporate a time-based prospective paradigm with older adults. They hypothesised that prospective memory and age would be mediated by frontal processes, in particular for tasks more demanding of executive processes requisite during the intention formation and action execution phases of prospective tasks. Age-related differences were assessed testing 40 younger (mean age = 24.8 years) and 40 older (mean age = 69.3 years, range 60 – 80 years) adults by varying the complexity and strategic demands on four prospective memory tasks. Executive function measures tapping an inclusive construct of executive components including task switching and mental flexibility, inhibition, and planning were employed. There were no significant correlations with either event or time-based prospective memory and executive function for the younger adults, however the reverse was true of older adults for all but a simple event-based task (remembering a belonging). Individual differences in executive function explained a significant amount of the variance in

prospective memory performance, with age, non-executive measures, and executive function combining to predict complex prospective memory tasks in this study ($R^2 = .77$, $\rho < .001$). Overall, the authors concluded inter-individual differences in executive function predicted prospective memory performance in older adults but not younger adults.

The case for the involvement of executive processes in prospective memory is further substantiated with evidence from neuroanatomical imaging studies. From a functional perspective, imaging using PET scans has shown activation of the frontal cortex during prospective memory tasks (Burgess, Qualye, & Frith, 2001; Okuda et al., 1998). Burgess and colleagues (2001) tested eight males between the ages of 20 and 46 years, using three conditions, a prospective memory target expectation condition, a prospective memory action execution condition, and baseline condition. Results indicated increased blood flow to the frontal region, specifically, the right parietal, right lateral pre-frontal cortex and right pole, when a prospective memory target was anticipated, with activation of the thalamus upon task execution.

More recent investigations implicate the rostral prefrontal cortex as crucial to memory performance (Burgess et al., 2008; Uretzky & Gilboa, 2010) and in particular an area of the anterior pre-frontal cortex known as the lateral Brodmann's Area (BA 10: Burgess, Quayle, & Frith, 2001; Simons et al., 2006). This area is thought to co-ordinate the control processes and attentional resources devoted to retaining delayed intentions while processing external perceptual stimuli related to an on-going task. Another recent study using MEG (magnetoencephalography) lends support to frontal lobe activation in prospective memory. Martin et al. (2007) tested five participants using a series of prospective

memory, retrospective memory, and oddball trials. Activation of the posterior parietal cortex was detected earlier during the prospective memory trials compared with the retrospective memory trials and oddball trials, concomitant with initial detection of the target cue/event. However hippocampal activation was detected earlier during both the prospective memory and retrospective memory trials in comparison to the oddball trials, indicative of a memory search for the intended action. The authors concluded that early activation of the parietal cortex, followed by activation of the hippocampus during prospective memory trials showed a distinct pattern of a noticing plus search model, consistent with the Multiprocess Framework (Einstein & McDaniel, 1996).

Neurophysiological evidence for frontal lobe involvement in prospective memory stems from clinical presentation of patients in whom prospective memory ability is severely impaired. From a functional viewpoint, patients with clinical frontal lobe impairment may present with severe prospective memory impairment, but display normal IQ, and no apparent deficits in retrospective memory or language (Burgess, 2000).This is true of disorders such as Parkinson's Disease (Kliegel, Altgassen, Hering, & Rose, 2011), schizophrenia (Wang et al., 2009), and following frontal brain injury (Uretzky & Gilboa, 2010).

There is a substantial body of evidence implicating executive control processes as central to prospective memory performance in older age. This is particularly evident with more complex prospective tasks (Martin, Kliegel, & McDaniel, 2003) and tasks requiring higher levels of environmental monitoring (Einstein & McDaniel, 1996). It could be argued that executive control processes would have a varying degree of influence on prospective memory performance depending on the demands and complexity of the task. That being the case, a

theoretical model identifying the mechanisms through which executive control processes may support or impede optimal prospective memory performance will be reviewed.

4.4.4 Executive function and the dual-process theory. As discussed in Chapter 2, the dual-process theory of Shriffrin and Schneider (1977) conceptualizes a dissociation between controlled and automatic or implicit cognitive processing. Neuroimaging shows the prefrontal cortex is activated during tasks requiring controlled processing and in this respect it is analogous to executive function (Liebermann et al., 2004). Automatic processing on the other hand is supported by sub-cortical regions (Liebermann, Jarcho, & Sapute, 2004).

The differentiation between controlled and automatic processing is pertinent to the examination of executive function and prospective memory performance under differing demand conditions. Research has typically found age-related differences in memory tasks, particularly in explicit recollection (Daniels, Toth, Jacoby, 2006; Jacoby 1991; Jennings & Jacoby, 1993). Commentators suggest this reflects a propensity for older adults to under utilise controlled processing that is requisite for bonding and elaboration of information. In contrast, biological ageing has less of an impact on implicit memory and automatic processing. Braver and Barch (2002) contend that older adults have an increased tendency to engage in automatic processing due to inhibitory and controlled processing deficits associated with executive function decline. This is particularly evident when heavy cognitive demand or performance constraints are placed upon working memory (Hess, Emery, & Queen, 2009). It is therefore feasible that older adults with executive function decrements could be challenged by cognitive

processes demanding controlled and strategic processing and greater allocation of cognitive resources.

The Multiprocess Framework differentiates prospective memory load in terms of task and cue characteristics. As outlined in Chapter 2, time-based tasks are argued to be more demanding of cognitive resources than event-based tasks. In parallel, the nature of the target cue or stimulus imposes disparate demand on event-based tasks, with non-focal cues requiring greater resource allocation and control processes compared to focal cues. If this is the case, older adults with poor executive functioning would show poorer performance on demanding prospective memory tasks compared to those with better preserved executive function. Findings from recent research uphold this contention. Schnitzspahn, Stahl, Zeintl, Kaller, and Kliegel (2013) examined the effect of executive function on non-focal event-based prospective memory using three executive function measures. There was clear evidence for mediation of prospective memory across adulthood by two of the executive function factors, namely switching and inhibition. A meta-analysis undertaken by Ihle, Hering, Mahy, Bisiacchi, and Kliegel (2013) concurs with these results. Across studies included in the meta-analysis, there was a main effect for cue type, with age-deficits more prominent in tasks with non-focal target cues compared with focal target cues. Functional evidence for the neural correlates of cue focality has also been provided by recent studies using neuroimaging. The anterior pre-frontal cortex, involved in sustained attentional control, showed activation with non-focally cued prospective memory tasks, whereas parietal and ventral regions associated with attentional capture, target detection and episodic retrieval, were activated with focal cues (Cona, Bisiacchi, & Moscovitch, 2013; Gordon, et al., 2011; McDaniel et al., 2013). This evidence points to two distinct

neural pathways to be involved in prospective memory and lends support to the Multiprocess Framework.

4.4.5 Summary and rationale for executive function as a predictor of prospective memory. Compelling evidence is emerging for an association between executive function and prospective memory performance. The literature posits a robust case for executive control involvement in prospective memory, with differential effects depending on the demands of the task and cue characteristics. As discussed, the Multiprocess Framework predicts prospective tasks requiring controlled attentional cognitive processes to be particularly susceptible to executive function decline. It could be argued that normal age-related decline in executive function consistent with the frontal-executive hypothesis of cognitive ageing (West, 1996), could have a substantial negative impact upon prospective memory outcomes, in particular with challenging tasks. Time-based and non-focally cued event-based prospective tasks may demand higher levels of attentional control and inhibition of non-relevant stimuli for successful task identification and execution. This would be in comparison to less complex prospective memory, such as focally cued event-based tasks, which may be less reliant on executive control support for successful completion. To date, this argument is generally supported in the literature. However, there is little direct evidence regarding the association between executive function and prospective memory in the oldest-old in everyday life. Study 3 will therefore examine the role of executive function as a predictor of prospective memory performance in the oldest-old within their everyday environments.

In addition to executive function, a review of the literature also highlights a central role of working memory in prospective memory processes. The following

section will review this related but distinct construct and explore the relationship between working memory and prospective memory.

4.5 Working Memory

Working memory is generally defined as a "limited capacity system, which temporarily maintains and stores information, [supporting] human thought processes by providing an interface between perception, long-term memory and action" (Baddeley, 2003, p 829). The construct of working memory developed from early concepts of short term memory and attentional processes. Short term memory function was conceptualised as comprised of processes manipulating new information for transfer into long term memory storage, with an individual's immediate span of attention dictating their information processing capacity at any given time (Howieson & Lezak, 2002b). Recent research however, has redefined working memory as a system involved in the active maintenance, manipulation, and integration of information over short periods of time (Miyake & Shah, 1999). Studies of individual differences in working memory capacity have clarified the support working memory provides to higher order cognitive processes, including general and fluid intelligence (Colom et al., 2004), episodic memory (Kane & Engel, 2000), and controlled attention (Engel & Kane, 2004). Working memory is fundamental to memory and controlled attentional processes, and to the monitoring of ongoing activities. It follows that working memory could have a key role in prospective memory by activating the relevant target cue or facilitating retrieval of the intended action at the appropriate time for execution. Given this premise, a substantial body of research has examined the role of working memory and controlled attention in prospective memory but with somewhat equivocal findings. The following section will therefore review models of working memory and age-

related effects, and examine the role of working memory in prospective memory performance.

4.5.1 Models of working memory. Early models (Atkinson & Shiffrin, 1968) of working memory identified a unitary short term memory system which was dissociable from long term memory. This was largely based on clinical evidence from amnesia patients presenting with no impairment in short term memory, but an inability to develop new long term memories. Short term memory was theorised to be a limited capacity store with a confined capacity for retrieval, the function of which was to consolidate new information and stimuli into and out of long term storage and memory. In this model short term memory was seen as responsive to ongoing events with information decaying rapidly within 30 seconds to several minutes. Working memory capacity was typically assessed using tests such as the reading-span task (Daneman & Carpenter, 1980) and operation-span task (Turner & Engle, 1989), with immediate memory capacity seen to be limited to 7 (+ or - 3) chunks of information. Working memory was therefore conceptualised in early models as a component of short term memory. Subsequent models further delineated the role of working memory in complex cognition by specifying working memory involvement in the control of attention and inhibition.

Baddeley and Hitch (1974) developed an influential, three component model of working memory elucidating the multi-faceted nature of this memory process. The three components included combined processing, storage, and functional components supporting cognitive activity. Their model identified two modality-specific rehearsal sub-systems, the phonological loop and the visuospatial sketchpad, both under the control of a limited attentional capacity system called the central executive. The phonological loop is based on language

and auditory stimuli and maintains linguistic representations via sub-vocal rehearsal. The visuospatial sketchpad maintains representations of visual objects and spatial position. Both sub-systems compete for access to the central executive and link to lateralised brain regions, the phonological loop to the left hemisphere, and the visuospatial sketchpad to the right. The central executive component of working memory co-ordinates and controls attentional processing, controlled processing of information, goal maintenance, and long-term memory retrieval. As such, the central executive of working memory is analogous to executive function with the two processes sharing some common modalities (McCabe et al., 2010). In order to capture theorised interactions between the visuospatial sketchpad and the phonological loop, Baddeley (2003) added a fourth component, the episodic buffer, to the model. This sub-system was conceptualised as allowing temporary storage of information from long term memory in order to facilitate manipulation and integration of old information with new in the working memory process (Baddeley, 2003). This model characterises working memory as a unitary, dynamic construct related to both higher level cognition and executive and attentional processes, and will be used as the conceptual definition of working memory processes in the current study. As inter- and intra-individual differences in controlled attentional capacity have been linked to ageing (Collette & Van der Linden, 2002), the effects of normative primary ageing on working memory capacity will be discussed.

4.5.2 Working memory and age-related decline. Working memory is sensitive to age-related changes, and decline with age has been well documented. The relationship between working memory and age-related effects has been demonstrated under three broad concepts, namely individual differences in speed

of perceptual processing (Salthouse, 1996), differences in attentional control (Hasher & Zacks, 1988), and reduced structural and functional neurological integrity associated with age (Braver et al., 2007). Working memory is responsible for the short term processing and manipulation of information, and normative age-related reduction in perceptual processing speed is thought to negatively impact performance. Reduced processing speed is theorised to allow greater time for the contents of working memory to decay as information is processed over a longer period of time, resulting in reduced working memory capacity (Salthouse). An alternative explanation stems from the inhibition hypothesis of Hasher and Zacks, whereby older adults exhibit reduced ability to inhibit irrelevant information, thus reducing working memory efficiency and storage capacity for task relevant information.

Working memory decline in older age is also illustrated in neurophysiological and behavioural studies. As with executive function, anatomical studies implicate age-related changes in the structure and function of the brain in memory deterioration. Baddeley, Eysenck, and Anderson (2009) report reductions of approximately 5% to 19 % in the neurotransmitter dopamine with each decade of life. Dopamine reduction is associated with memory deficits that present in clinical populations with Parkinson's disease and Alzheimer's disease. Further, by age 80, neuronal density in the hippocampus has decreased by 20% to 30% and there is a concomitant overall increase in the size of the ventricles and reduced brain volume (Raz, 2005).

Further compelling evidence is offered in neurophysiological studies whereby normative age-related change in the pre-frontal cortex is posited to impact on working memory performance (West, 1996). Parallel to the neural

correlates of executive function, working memory recruits a network of pre-frontal cortex and parietal regions of the brain. As such the frontal-executive hypothesis of cognitive ageing (West) presented in respect to executive function is also applicable to working memory decline. The prefrontal cortex is active in working memory tasks accessing the central executive, for instance, control of attention and reduction of interference, strategy selection, inhibition of irrelevant stimuli, and manipulation of information (Conway et al., 2003). In contrast, the posterior parietal cortex is activated for the maintenance of information. Research investigating neural recruitment during working memory tasks has demonstrated activation of the pre-frontal cortex region during task processing. Braver and Bongiolatti (2002) assessed 21 young (mean age = 23 years) adults using two delayed-response working memory tasks and a semantic classification task. Functional MRI found areas of the prefrontal cortex to have a triple dissociation in activation dependent on the task, with the fronto-parietal pre-frontal cortex engaged in working memory tasks requiring monitoring and integration of information.

Convergent evidence is presented in studies examining age-related declines in verbal and spatial working memory tasks (Bopp & Verhaeghen, 2005; Zeintl & Kliegel, 2007). Neuroanatomical imaging and clinical studies have differentiated brain regions supporting the three working memory sub-systems and the loci for verbal and visuospatial processing. Neuroimaging has shown the left temporoparietal area to be activated with phonological tasks, specifically, Broca's area in rehearsal of information and BA 40 in storage of auditory stimuli (Paulesu, Frith, & Frackowiak, 1993). In contrast, visuospatial working memory tasks are associated with activation of right-sided brain regions, including the right inferior

parietal cortex, right premotor cortex, and right inferior frontal cortex (Cabeza & Nyberg, 2000; Dolan et al., 1997; Henon 2001).

The conclusions from neuroanatomical imaging studies indicate that prefrontal cortex regions of the brain underpin working memory performance. Decline in structural and functional neurological integrity of this region, coupled with age-related reductions in attentional control and speed of perceptual processing arguably contribute to the decline in working memory accompanying ageing as documented throughout the literature. Given that working memory is associated with memory and controlled attentional processes, it is feasible that working memory ability may predict prospective memory performance. The literature examining the role of working memory in prospective memory will therefore be presented in the following section.

4.5.3 Working memory and prospective memory. A range of cognitive abilities have been proposed to support successful prospective memory performance including retrospective, semantic, controlled attention, and working memory (Logie, Maylor, Della Sala, & Smith, 2004). Working memory for instance is thought to play a key role in updating and monitoring moment-to-moment activity and to underlie controlled attentional processes. Successful prospective memory hinges on the relevant intended action being active in working memory during the window for task execution, positing a case for a close association between the two processes. However, a review of the literature examining the role of working memory in prospective memory identified divergent conclusions. Several early studies showed that higher working memory capacity supported better prospective memory performance, with age-related variance in performance reduced after controlling for working memory

performance (Cherry & Le Compte, 1999; Einstein et al., 2000). A robust association was similarly reported in a more recent study examining the relationship between working memory, prospective memory and vigilance in both younger and older adults (Rose, Rendell, McDaniel, Aberle, and Kliegel, 2010).

Other studies have not concurred with these results (Einstein et al., 2000, Experiment 3; Einstein et al., 1997; Marsh & Hicks, 1998; West & Craik, 2001). For instance, Kliegel and Jäger (2006) found no evidence of mediation by working memory of age-related differences in prospective memory performance. Consistent with these findings, Schnitzspahn and colleagues (2013) recently examined the effect of executive function, working memory (measured on two span tasks), and speed of perceptual processing on non-focal event-based prospective memory. Participants were 285 younger (mean age = 23.16, range = 18-39 years) and older adults (mean age = 66, range = 57-77 years). Age-related effects in prospective memory performance were found to be mediated by components of executive function, namely shifting and inhibition. Importantly, working memory did not predict prospective memory performance for either younger or older adults in this study. However as noted in Rose et al (2010), mixed results in the literature with lack of reported association between working memory and prospective memory in some studies, may reflect poor measurement reliability associated with prospective tasks. For instance, the nature and features of prospective tasks vary widely between studies, with some having very few target event observations.

In contrast, numerous studies provide convincing evidence of working memory involvement in prospective memory processes. For instance, using multinomial modelling, Smith and Bayen (2005) found working memory span significantly affected estimates of prospective memory proficiency in a group of

20 younger undergraduate adults. They concluded that working memory capacity was fundamental in supporting preparatory attentional processes required for successful prospective memory performance. More recent research with older adults, examined the effect of working memory, perceptual processing speed and retrospective memory on event-based prospective memory performance (Zeintl, Kliegel, & Hofer, 2007). Participants were 364 adults aged between 65 and 80 years (mean age = 72.99, *SD* = 4.43), tested on three different measures for each construct of interest. Structural equation modelling showed age effects in prospective memory with older adults performing less well even within this restricted age band, with the age differences partially explained by working memory and speed of processing. Working memory was found to be associated with prospective memory, with prospective memory partially independent from processing speed. Age effects were less evident for the free recall task assessing retrospective memory and were fully explained by individual differences in working memory and speed of processing.

The role of working memory in prospective memory is further substantiated through neuroimaging studies. Reynolds, West and Braver (2009) investigated the prospective interference effect by examining sustained and transient engagement of cortical areas during contrasting prospective memory and working memory trials. Participants were 18 young adults between the ages of 19 and 29 years who undertook a series of tasks wherein working memory load and target detection parameters were manipulated. Results indicated that prospective memory was associated with sustained response in the bilateral anterior prefrontal cortex. This was dissociable from sustained response localised in the dorso-lateral prefrontal cortex in trials associated with the working memory tasks and

maintenance of information. The authors concluded that prospective memory is supported by both sustained and transient neural processing. This being the case, the active maintenance of an on-going task, and monitoring and attention given to an embedded prospective memory task would be supported by both executive function processes and working memory (monitoring and intention retrieval).

There is mounting evidence that the demands of an on-going task on working memory influence prospective memory performance. This is demonstrated in studies, in which response times are slowed when a prospective memory task is combined with an on-going activity (Marsh et al., 2003; Smith & Bayen, 2004a; West, Bowry, & Krompinger, 2006), a phenomenon termed the prospective memory interference effect (Marsh et al.). The cost in prospective memory performance is argued by Smith to reflect allocation of preparatory attentional resources from working memory capacity toward environmental monitoring, at the expense of the ongoing activity. Indeed, Smith (2003) found slower response times on a lexical decision task coupled with a prospective memory task were not only associated with poorer prospective task accuracy but also positively correlated with a participant's working memory ability. Further, studies have shown prospective memory performance deficits are larger when multiple target cues are presented compared to single target cue paradigms (Marsh et al.). Multiple target cues require more vigilant attentional monitoring and are thought to place greater demand on working memory capacity.

In a seminal study, West, Bowry, and Krompinger (2006) examined the effect of the working memory demand of an on-going task on target cue detection and post-retrieval processes in prospective memory. Working memory demand was manipulated using progressive *n*-back tasks (1 to 3 back) in control and

prospective memory conditions. Imaging using event-related brain potentials was recorded. Results indicated that increased load on the *n*-back task had a detrimental effect on detection of prospective memory target cues, concluding that attentional resource allocation at cue noticing is sensitive to working memory demands of the ongoing task.

4.4.4 Summary and rationale for working memory as a predictor of prospective memory. The literature confirms that working memory declines are consistent with the frontal-executive hypothesis of cognitive ageing (West, 1996) and generally supports a case for working memory to be predictive of prospective memory performance. Drawing from the evidence presented, it is feasible that demand placed on working memory by the characteristics of a prospective memory task and target cue may differentially impact proficiency. The Multiprocess Framework of prospective memory contends that prospective memory performance is supported by both automatic and controlled attentional cognitive processes. Monitoring the environment for prospective memory events and distinguishing between event and non-event target cues is relatively more demanding of cognitive resources, with the extent of resource allocation depending upon the task context, cue characteristics and individual differences. This being the case, time-based and event-based prospective memory could command different levels of working memory allocation. Being more demanding of environmental monitoring and strategic search, non-focal target cues could similarly occupy higher levels of working memory and controlled attention allocation in comparison to focal target cues. Thus the role of working memory as a predictor of prospective memory performance in the oldest-old will be examined in Study 3.

4.6 Retrospective memory

Retrospective memory is an important component of the prospective memory process and is fundamental to remembering the content and context of an intended future action. Retrospective memory is a form of long-term memory for past events and experiences and may be episodic or semantic in nature (Wheeler, Stuss, & Tulving, 1997). Episodic memory is conscious awareness of past events and episodes, and is usually personal and autobiographical memory encoded with specific spatial and temporal reference (Tulving, 1972). Episodic memory is distinguished from semantic memory, which is defined as memory for knowledge, facts and information with no time reference. As discussed in Chapter 2, episodic memory facilitates prospective and retrospective memory and although sharing common components, retrospective and prospective memory remain partly dissociable constructs (Raskin et al., 2011; Salthouse, 2004; Zeintl, Kliegel, & Hofer, 2007).

Although not subsumed under the same memory processes, retrospective memory is never-the-less, an integral component of the prospective memory process. Retrospective memory permits the retention of information about an intended prospective action and facilitates retrieval at the appropriate time and in context, essentially allowing one to remember the content of a prospective task. Such remembering or retrieval of information from long-term memory may be effortful as in recall, or more automatic, as in recognition memory (Lezak et al., 2012). Recall from memory involves the active and/or strategic search for information and is an effortful process requiring allocation of cognitive resources. Recognition memory on the other hand, occurs when a stimulus triggers awareness with more automatic retrieval of information. Recognition retrieval has been

shown to be easier than recall for both normal and brain impaired adults (Johnson, 1990) and ageing is associated with differences in performance between recall and recognition memory processes.

Normative age-related declines in retrieval and recall have been shown in studies of retrospective memory, with recognition memory largely spared. Commentators suggest that prospective memory demands effortful self-initiated retrieval of an intended action in comparison to retrospective memory retrieval not associated with a prospective task (Craik, 1986). A study by Lin and Craik (2009) examined age effects in retrospective memory and information retrieval. They conducted three experiments to investigate retrieval and recollection of information between younger (mean age = 21.5 years, range = 19 to 25) and older adults (mean age = 74.1 years, range 64 to 82 years). Test lists were constructed with items presented either with or without photographic or drawn images. Older adults had reduced retrieval for highly specified information, that is, items encoded with an image. In comparison, older adults showed better retrieval of items with low specificity, that is, recollection of all items encoded either with or without an image. This effect of ageing was replicated in the younger participants when subjected to a divided attention condition. The authors concluded that memory retrieval is both effortful and demanding of cognitive resources.

The PAM theory (Smith & Bayen, 2005) concurs with this view. In addition to preparatory monitoring, the PAM theory proposes that recruitment of retrospective memory processes is required to adequately retrieve the ‘what’ component of the intended action. Strategic retrieval therefore demands allocation of cognitive resources directed toward memory search. This is also consistent with the early Notice Plus Search model of Einstein & McDaniel (1996) and the

Multiprocess Framework of prospective memory (McDaniel & Einstein, 2000). Under this model, the retrospective component of prospective memory is theorised to require strategic and conscious search to give meaning and context to the intended action and to differentiate between actual target events and non-target events. This being the case, successful prospective memory outcomes would be associated with better retrospective memory ability. Moreover, as the retrieval and recall facets of retrospective memory display age-related declines, it could be surmised that oldest-old adults would show robust age-related deficits in recalling the content of prospective tasks. However, although some studies have supported this argument, a review of the current literature identifies divergent outcomes.

In their seminal meta-analysis, Henry and colleagues (2004) found studies generally reported greater age-related impairment in retrospective memory tasks in comparison to age-related deficits in prospective memory. Numerous studies have shown contrasting findings (Cohen et al., 2003; Mäntylä, 1994; West & Craik, 2001). For instance, to unravel the distinction between prospective memory and retrospective memory, Cohen and colleagues conducted a series of experiments using a dual-response paradigm. Age related effects were greater for the prospective component compared with the retrospective component. Studies directly investigating age-related effects and the role of retrospective memory in prospective memory suggest that retrospective memory is not a significant predictor of prospective memory performance in adulthood (Kliegel, Mackinlay, & Jäger, 2008; McDaniel & Einstein, 2007; Zimmermann & Meier, 2006). However, few of the studies cited investigated the association between the two mechanisms in very advanced older age.

4.6.1 Summary and rationale for retrospective memory as a predictor of prospective memory. Age-related declines in retrospective memory with advanced older age may differentially affect prospective performance, depending on the demand of the on-going task and the degree of strategic monitoring required to successfully complete the task. Early research by Mäntylä (1994) concluded that although greater age-related decline was evident in prospective memory tasks compared to retrospective memory tasks, varying the demands of the task impacted on the efficiency of both the prospective and retrospective components. Using the findings of this study as an indicator, it follows that retrospective memory and retrieval should be affected more by high demand prospective memory tasks compared with low demand tasks. Study 3 will therefore examine the role of retrospective memory ability in predicting high demand (non-focally cued event-based and time-based) prospective memory and low demand (focally cued event-based) prospective memory. In so doing, Study 3 represents a unique opportunity to further delineate the neurocognitive mechanisms supporting prospective memory processes in the oldest-old.

4.7 Summary and Aim of Study 3

To date few studies have directly examined aspects of executive function and working memory in real world settings, in particular in reference to moment to moment monitoring, updating of information, and controlled attention with respect to prospective memory performance. Although there is a general trend in the research indicating controlled attentional processes support prospective memory processes, not all studies have produced consistent findings. Moreover, the majority of the work examining working memory and executive function

mechanisms, and age-related effects has centred on young-old adults, with few studies including participants in advanced old age.

The most recent study examining the effect of controlled attention using componential facets of both working memory and executive function did so using only non-focal event-based prospective tasks (Schnitzspahn et al., 2013). Study 3 will therefore address these shortcomings and directly examine the effect of executive function and working memory ability on time- and event-based prospective memory performance in oldest-old adults in real world settings. Observable discrepancies have also been reported with respect to the role of retrospective memory in prospective memory processes. Numerous studies have demonstrated retrospective memory to be only a minor correlate of prospective memory proficiency but as with studies investigating executive function and working memory, few pertain to oldest-old adults. As a consequence of this shortcoming, retrospective memory will be incorporated into Study 3 as a potential predictor of prospective memory performance. Overall Study 3 provides an opportunity to further elucidate the neurocognitive mechanisms supporting various components of prospective memory in advanced older age under naturalistic conditions.

Chapter 5.

Study 2: The effect of stress on prospective memory in the fourth age.

5. Overview

Chapter 5 presents Study 2, which tests hypotheses derived from the Multiprocess Framework model of prospective memory (McDaniel & Einstein, 2000) and contemporary research in the field of psycho-neuroendocrinology. Specifically, the aim of Study 2 is to examine whether proficiency in prospective memory tasks presented within the ADuLTS study is affected by stress levels, at both within- and between-person levels.

5.1 Introduction

As discussed in Chapter 3, consistent memory-impairing consequences of stress, as reflected in elevated cortisol levels, have been well documented in both younger and older adults. Parallel to this line of investigation, but with less conclusive outcomes, has been research considering prospective memory and its relationship with stress. Indeed few studies to date have considered this topic in relation to oldest-old adults. An early study investigating the relationship between stress and prospective memory in 34 young male adults was conducted by Nakayama and colleagues (2005). They reported a correlation between baseline cortisol levels and retrospective short-term memory, but no relationship between cortisol levels and event-based prospective memory. A subsequent study of 20 young male participants demonstrated that acute manipulated psychosocial stress was associated with significant decrements in time-based but not event-based prospective memory (Nater et al., 2006). In contrast, Landsinger (2002) reported significant decrements in event-based prospective memory with increased stress load, again testing 55 young adults.

Subsequent to the aforementioned studies, Walser et al. (2013) recently examined the relationship between psychosocial stress and event-based prospective memory. Psychosocial stress was induced in a laboratory-based experiment using the Trier Social Stress Test (TSST: Kirschbaum, Pirke, & Hellhammer, 1993) in a group of 83 young adults (mean age = 21.96 years, SD = 2.68). Participants were allocated to either a control (no stress) or stress condition and given computerized prospective memory tasks using focal and non-salient target cues. Tasks were practised over three trial blocks prior to the stress or no-stress induction, following which the experimental prospective tasks were performed. Results showed that salivary cortisol was elevated in the experimental group, indicative of successful stress induction. However there were no significant differences in prospective memory performance in terms of accuracy or response times between the two groups. Walser and colleagues therefore concluded that stress did not deplete cognitive resources requisite to successful event-based prospective memory. However of the studies reviewed, all were laboratory based manipulations and examined stress effects on healthy young adults. As such generalising these results to a cohort of older adults, particularly the very old, in naturalistic environments is problematic.

Relevant to the present study is research undertaken by Neupert, Almeida, Mroczek, & Spiro (2006). The relationship between naturally occurring daily stressors and everyday memory failures was examined in a cohort of 333 older adults (*M* = 73.27 years, *SD* not reported) recruited from the VA Normative Ageing Study (NAS). Daily diaries were completed over eight days with participants self-reporting on their experience of daily stressors and memory failures. Results from multi-level analyses showed a significant association between the co-occurrence of daily stress and increased memory failure, after controlling for neuroticism, stressful life events,

and self-rated health. Interestingly, the authors also found the relationship between stress and changes in memory failures to be robust from one day to the next, in particular for interpersonal stressors. Those with greater life event stressors also reported higher levels of memory failures. Although employing self-report measures of daily stress and not directly examining prospective memory, Neupert and colleagues served to provide evidence for a relationship between daily stress and memory performance in elderly subjects under naturalistic conditions.

Equivocal findings of age-effects in prospective memory, as discussed in Chapter 2, have been well documented. In addition there is evidence that manipulating stress can produce adverse consequences on memory and cognition, in particular with younger adults. It is therefore timely to investigate the effect of stress on prospective memory in a cohort of very old adults, within a naturalistic, and more ecologically valid environment. The current study therefore contributes to the extant literature in investigating stress and prospective memory processes in the fourth age and furthers the work of Neupert and colleagues (2006). Moreover, incorporating valid bio-markers of stress levels (i.e., salivary cortisol levels) in the study procedure, rather than self-report measures of stress which can often be confounded by memory lapse and retrospective report, lends strength to the study protocol.

5.2 Rationale for Study 2: Stress, Cortisol and Prospective Memory

The rationale for Study 2 proposes that age-related elevations in basal cortisol levels and individual reactivity to stressor demands may interact with age-driven compromised cognition to adversely affect memory processes. As discussed in Chapter 4, cortisol is a glucocorticoid hormone regulated by the Hypothalamic-Pituitary-Adrenal axis, displaying a distinct diurnal pattern of secretion. Lowest levels are evident during the second half of the night, with a gradual increase to

awakening, and peak levels occurring 30 to 45 minutes post-awakening, a robust phenomenon known as the cortisol awakening response (CAR). Basal cortisol levels then gradually decrease over the course of the day (Wilhelm et al., 2007). Evidence suggests basal cortisol levels increase with age, due to rising allostatic load over the lifespan and age-driven increased sensitivity of the HPA axis (Kendler, Thornton, & Gardner, 2001; Piazza et al., 2010; Sliwinski, Smyth, Hofer, & Stawski, 2006). Diurnal cortisol levels are typically represented using a calculation known as the Area Under the Curve (AUC). This estimates cortisol secretion using a trapezoid method, based on the cortisol level relative to the hours from awakening and is considered to be a reliable measure of a person's cumulative concentration of cortisol (Wrosch et al., 2009).

In addition to normative diurnal secretion, cortisol is released as a biological response to stress, physiologically preparing the individual to react to stressor demand. This phenomenon is commonly known as the 'fight or flight' mechanism. Such momentary fluctuations in cortisol secretion can be estimated as an individual's deviation in cortisol secretion level on a particular measurement occasion compared to their person-mean cortisol secretion level for that time of day.

Elevated cortisol levels from increased basal levels (AUC) can have cognitive and physiological detrimental consequences in both the short and long term. Further, although momentary stress driven secretion of cortisol is an adaptive short term response to stress, such momentary elevations in cortisol can also negatively impact cognitive processes. Research has found cortisol binds to glucocorticoid receptors in the frontal lobes and hippocampus, interfering with normal function and neuronal transmission, ultimately affecting cognitive function, capacity, and behaviour (Lupien et al., 1998; Wolf, 2003). Daily hassles and momentary stressors

experienced in the presence of accumulated stress may therefore have a compounding effect on reactivity to stress. Thus, given the documented influence of cortisol on memory processes and the dynamic processes involved in stress regulation, it is feasible that stress and elevated cortisol may adversely affect prospective memory. Inter-individual differences in basal cortisol secretion may be apparent in older adults, such that those with higher circulating basal cortisol levels may exhibit a greater reactivity to stress, with consequent larger deficit on cognitive processes. It also follows that intra-individual daily fluctuations in cortisol levels co-occurring with prospective memory tasks could impact upon performance. As such, basal levels of cortisol secretion (AUC) and momentary fluctuation in cortisol secretion (deviation in cortisol) will be employed in the current study as measures of stress and neuroendocrine system function.

An additional measure known as the intraindividual standard deviation (*i*SD) has also been used in stress research with older adults (Ram & Gerstorf, 2009). The *i*SD assesses intra-individual fluctuation around a variable and represents a dynamic measure of capacity for change and the maintenance of stability and function. Lower *i*SDs are indicative of lower variation around the mean of a variable and characterise robustness, or the ability to maintain function across conditions. Higher *i*SDs are associated with greater individual reactivity across changing conditions. The *i*SD has been used as measure of variability or inconsistency in cognition, with higher levels of variability shown to predict lower neurobiological integrity (Hulsch & McDonald, 2004). Indeed research has shown older adults with higher *i*SDs around cognitive measures to be less robust, with greater cognitive decline apparent across time, in comparison to those with lower *i*SDs (Lövdén et al., 2007). Stawski and colleagues (2008) also examined intra-individual variation in emotional responses to daily

stressors in younger and older adults. They found variability in emotional responses fluctuated concurrently with changes in perceived stress and daily hassles. However, to date few studies have used the *i*SD as a measure of variability in cortisol secretion. Ram and Gerstorf (2009) contend that the *i*SD reflects the dispersion of samples obtained by repeated measures and can be used as a valid index of cortisol secretion and reactivity of HPA function. Thus, the *i*SD in cortisol secretion at each sample assessment will be used in the current study as a measure of intra-individual variability in response to stress.

A robust measure of HPA function and reactivity, the cortisol awakening response, has also been shown to be associated with stress and stressor demand (Hellhammer et al., 2007; Pruessner, Hellhammer, & Kirschbaum, 1999; Wust et al., 2007). Research suggests the CAR reflects a daily response to social and emotional experiences (Adam, Hawkley, Kudielka, & Cacioppo, 2006), and is indicative of state arousal in anticipation of daily demands (Stalder et al., 2009). It is therefore possible that a larger CAR could be associated with higher stress levels and reactivity to stressor demand, with associated deficits on prospective memory. The CAR, in addition to the AUC, deviation in cortisol, and *i*SD, will be employed as an additional indicator of stress in the present study, the four measures providing a comprehensive picture of biological stress response, representing the dynamic processes involved in stress regulation.

Cortisol is indicative of HPA function and stress levels, and reflects general physical, emotional and cognitive health. Cortisol secretion levels are therefore influenced by multiple factors, several of which will be incorporated into the current study as covariate predictors. Across studies gender differences in cortisol secretion have been reported. Women have been shown to have lower overall output, flatter

diurnal cortisol slopes, and a lower morning rise after awakening (Kirschbaum, Kudielka, Gaab, Schommer, & Hellhammer, 1999; Lundberg, 2005). Gender-specific effects associated with ageing have also been reported (Van Couter, Leproult, & Kupfer, 1996). A review of plasma cortisol profiles in 90 men and 87 women between the ages of 18 and 83 years found basal levels increase between 20% - 50% between the ages of 20 and 50 years for both genders, with an increase in the evening nadir evident in older age. However, women exhibited an elevation in the morning peak with advancing age. Depression is an additional factor shown to affect cognition and prospective memory performance. Livner et al. (2008) found differential effects of depression, with a negative association between depressive symptoms and the retrospective component of a task, but with no effect on the prospective component. Higher accumulated and distal levels of depressive symptoms have also been linked with cortisol (Chui et al., 2013). Gender, age, and depressive symptoms will therefore be covariate predictors incorporated into analyses.

5.2.1 Stress and prospective memory. Given stress and cortisol levels negatively impact cognitive processes and given the complex nature of prospective memory, it is feasible that stress may exhibit differential effects dependent on the nature and characteristics of the prospective memory task. As proposed by the Multiprocess Framework (McDaniel & Einstein, 2000) prospective memory is a multi-faceted cognitive construct mediated by automatic and strategic processes. As reviewed in Chapter 2, proficiency is influenced by the characteristics of the task (i.e., event-based or time-based tasks), task demand, cue accessibility, and of particular pertinence to older adults, the environmental setting of the task. Prospective memory tasks are also differentiated by the degree of cognitive

processing required to bring an intended future action to fruition. It is argued that time-based prospective memory necessitates self-initiated retrieval to monitor for the window of opportunity for task enactment and is therefore demanding of cognitive resource allocation. In contrast, event-based tasks are generally supported by environmental target cues, the detection of which triggers recollection and retrieval of the encoded intention. Further, the Multiprocess Framework contends both spontaneous and controlled cognitive processes are evident in event-based prospective memory and are largely determined by focality and associative strength of the target cue. Upon cue detection, automatic associative cognitive processing facilitates spontaneous retrieval of an intended action without constant monitoring for the target cue (Hasher & Zacks, 1988; Moscovitch, 1994). Thus cues focal to an on-going task support spontaneous retrieval and are less demanding of attentional resources. In comparison, more controlled cognitive monitoring is required for event-based tasks with cue signalling less focal to the on-going task.

It is consistent with McDaniel and Einstein's (2000) conceptualization of prospective memory processes, that stressor demand may exert a detrimental effect on cognitive processes, the extent of which is determined by the degree of attentional resources required of the task. Indeed an early attention-depletion hypothesis proposed a mechanism whereby stress competes for attentional resources (Kanhemann, 1973). Under this model, intrusive thoughts, effort directed toward thought suppression, and cognitive interference demand allocation of limited cognitive resources at the cost of competing demands or tasks. Research supports this contention, with stress being found to have a greater detrimental impact on attentionally demanding tasks requiring controlled processing compared to tasks

conducive to automatic or spontaneous processing (Hasher & Zacks, 1988; Klein & Boals, 2001b; Sliwinski et al., 2006).

The current study has therefore been designed to investigate the role of stress, as measured by salivary cortisol assay, upon prospective memory processes in those over the age of 85 years, after controlling for factors potentially influencing cortisol secretion. These include physiological conditions affecting cortisol output including depressive symptoms, medication use, smoking status, and use of caffeine and alcohol. Of particular interest is the nature of the prospective memory task, namely event-based and time-based tasks, and the degree of cognitive processing required of the task. As such it is proposed that focally cued event-based prospective memory tasks will induce spontaneous retrieval and be less sensitive to the impact of stress. In contrast, non-focally cued event-based tasks will require greater monitoring for the target cue and be more demanding of attentional processing. This, in association with normative age-related decline in attentional resources (Hasher & Zacks, 1988), will be reflected in non-focal event-based tasks being more sensitive to the impact of stress compared to the focal tasks. Moreover, it is proposed that time-based prospective memory will be negatively impacted, with stress processes interfering with the cognitive processes necessary for monitoring and self-initiated retrieval of the intended action at the appropriate time.

5.3 Hypotheses for Study 2

Study 2 seeks to address the following hypotheses:

1. There will be an effect of stress, as measured by salivary cortisol levels, on event-based prospective memory performance such that older adults with higher cortisol levels will show greater deficits on prospective memory tasks. Specifically,

1.1 Higher daily basal cortisol levels ($AUC_{cortisol}$: area under the $curve_{cortisol}$) will predict lower performance on event-based prospective memory tasks when compared to lower daily basal cortisol levels.

1.2 Higher intra-individual variability (IIV) in cortisol ($iSD_{cortisol}$: intra-individual $standard\ deviation_{cortisol}$) will predict lower performance on event-based prospective memory tasks when compared to lower IIV.

1.3 Higher cortisol awakening responses (CAR) will predict lower probability of proficiency on event-based prospective memory tasks when compared to lower cortisol awakening responses.

1.4 Higher deviation in cortisol level ($Deviation_{cortisol}$) from the individual's mean /time level co-occurring with task enactment will predict lower performance on event-based prospective memory tasks when compared to lower deviation in cortisol at task enactment.

2. The effect of stress on prospective memory tasks requiring more attentional resources will be larger, than for prospective memory tasks requiring fewer attentional resources. Specifically, the effect of higher $AUC_{cortisol}$, higher $iSD_{cortisol}$, larger CAR, and greater $Deviation_{cortisol}$ will be larger for non-focally cued event-based prospective memory tasks compared to focally cued event-based prospective memory tasks.

3.There will be an effect of stress on time-based prospective memory performance such that, higher $AUC_{cortisol}$, higher $iSD_{cortisol}$, larger CAR, and greater $Deviation_{cortisol}$ co-occurring with task enactment will predict lower probability of proficiency on the time-based prospective memory task.

5.4 Method

The method for Study 2 was basically as described in Study 1. As such the following section will only detail variables and measures unique to the current study.

5.4.1 Participants. Data were taken from the ALSA Daily Life Time Sampling study (ADuLTS). Participants were as described in Study 1 of this thesis (see Table 3.1, Chapter 3). The sample comprised 75 adults between the ages of 83 and 102 years, fluent in written and verbal English, with acceptable visual and auditory acuity, and cognitive functioning.

5.4.2 Design. The study was a mixed design, using a seven-day time burst measurement protocol. Outcome variables for the current study were focal (a series of 11 tasks) and non-focal (9 tasks) event-based prospective memory tasks, and a single time-based prospective memory task (as measured in Study 1).The predictor variables were basal cortisol secretion measured as area under the curve for each individual (AUC), the cortisol awakening response (CAR), cortisol lability calculated as the intra-individual standard deviation (iSD), and the person time/mean deviation in cortisol level. Covariate predictors and control factors included age, gender, education level, depression, number of thyroid conditions affecting cortisol secretion and whether a participant was taking medication known to affect cortisol secretion.

5.5 Materials.

5.5.1 Baseline measures. The present study employed pertinent baseline descriptive and demographic variables for inclusion in the statistical models. Depressive symptoms, as measured with the short version of the Centre for Epidemiological Studies Depression Scale (CES-D 10; Andresen et al., 1994; Radloff, 1977) were included as a covariate predictor in the current study. Depressive symptoms have been associated with increased basal cortisol levels

(Gomez et al., 2009) and as a contributing factor to cognitive decline with increasing age (Luszcz, Bryan, & Kent, 1997).

Control variables known to affect salivary cortisol assays were also recorded, including alcohol and caffeine consumption, and smoking status. Possible physiological confounding variables were assessed for each subject, including the number of confirmed medical diagnoses of chronic conditions known to affect basal cortisol levels, as reported in Study 1. The total number of possible confounding physical conditions was recorded for each subject. Use of medications known to influence cortisol assays (Almeida, Piazza & Stawski, 2009) were also assessed. These included steroid and corticosteroid medications and topical preparations, steroidal inhalers, hormonal medications (e.g., hormone replacement medication), and anti-anxiety and anti-depressant medications (Granger, Hibel, Fortunato, & Kapelewski, 2009). Few participants recorded taking medications in this category (*n* = 10), therefore the outcome was dichotomized as either not taking medication known to affect cortisol assays, coded (0) or taking such medication, coded (1).

5.5.2 Time sampling measures.

5.5.2.1 ***Morning and daily questionnaires.*** Participants completed seven daily questionnaires (numbered from 1 to 7) over the course of the week long study as previously described. Self-reported cortisol control variables were recorded with each questionnaire.

The first two morning questionnaires provided measures of affect, salivary cortisol levels and self-reported sleep and sleep medication data. Saliva samples were provided concurrently with each subsequent daily questionnaire (numbers 3 to 7) at approximately three hourly intervals across the day. Daily questionnaires assessed an

individual's affect and location, presence of others, and activities since the last questionnaire.

5.5.2.2 ***Prospective memory items.*** Prospective memory items were interspersed within the daily questionnaires and prospective memory outcomes and data were the same as used for analyses in Study 1. The full prospective memory assessment protocol is previously reported in Study 1 and Appendices D.1 and D.2 list specific examples and scheduling of items. Performance for all prospective memory tasks was represented in terms of either a correct response (1) or incorrect (0) response for each individual measurement occasion across the week. A written prompt for both the event-based tasks was presented on the morning questionnaire each day. No written prompt was given for the time-based prospective item on the morning of task execution.

5.5.2.3 ***Cortisol.*** Salivary cortisol samples were obtained using synthetic Salivettes (Sarstedt, Sevelen, Switzerland). Guideline instructions for saliva collection were provided to all participants (presented in Appendix B.2). Saliva samples were stored in participant's refrigerators and then frozen at -20ºC until shipment for bio-analysis. Upon return from participants, saliva samples were checked against each questionnaire, re-labeled and numbered with cold-resistant labels for shipping to Germany for assay. Cortisol concentrations in saliva samples display stability over time when subjected to changing environmental conditions, with reported large, positive correlation between frozen and non-frozen samples of $R^2 = .92$, $p < .001$ (Clements & Parker, 1998). Salivary free cortisol was analysed by chemi-luminescence immunoassay (LIA) at the Kirschbaum Laboratory at the Technical University of Dresden, Germany. The intraassay coefficient of variation has typically been found to less than 5%, with intraassay variability less than 10%

with this method of analysis (Kirschbaum, Kudielka, Gaab, Schommer, & Hellhammer, 1999).

5.6 Procedure

The full procedural protocol for the ADuLTS study was reported in Study 1 of this thesis. Following collection of baseline descriptive and demographic data, and cognitive and personality measures, participants undertook an intensive introductory session with their research assistant. Training in saliva sample collection, notation and storage was provided, along with procedural instruction for questionnaire completion (including envelope sealing and stamping requirements), and alarm beeper and timer use. Participants completed seven daily questionnaires over the course of seven consecutive days, providing concurrent saliva samples with each questionnaire. An exit session the day following study completion facilitated collection of materials and saliva samples, along with collection of participant feedback data. Upon receipt of materials and samples, envelopes and questionnaire were screened for corresponding times and dates with items scored and recorded.

5.7 Overview of cortisol variables

5.7.1 Cortisol sample completion rate. The ADuLTS protocol was structured to obtain 49 cortisol and ecological momentary assessment pairs from each participant across seven consecutive days. Full cortisol data (i.e., 49 samples) were recorded for 43.8% (n = 32) of the completing participants. Overall, there were 3,584 potential cortisol samples (73 participants x 49 samples, in addition to 7 samples returned from one participant who withdrew from the study). Cortisol data was obtained for 3,471 samples, giving a return and compliance rate of 96.8%, with only 3.2% of samples either missing or invalid (e.g., salivette not impregnated with saliva, or contaminated with food or blood at collection). This represents high

compliance to the saliva sampling protocols in this sample of oldest-old adult, comparable to compliance rates found in previous research (Jacobs et al., 2005).

5.7.2 Cortisol measures. Prior to analyses of cortisol measures, cortisol values were screened. Outlying cortisol levels greater than three standard deviations above the sample mean were substituted with the individual's mean cortisol value for that time of day, given there was a valid first cortisol sample for the day and at least three other cortisol samples for that day were recorded (Chui et al., 2013; Wrosch, Miller, Lupien, & Pruessner, 2008). Cortisol samples associated with evidence of back-filing, that is questionnaires completed or saliva samples suspected of being obtained in advance or long after the alarmed time, were also treated as missing. There was no evidence of back-filing for 91% of the samples obtained. Four discrete cortisol variables were calculated for further analyses.

5.7.2.1 ***Area under the curve.*** AUC is widely used in endocrinology studies to estimate changes in hormone levels over time and intensity in secretion levels over a specified time period (Pruessner et. al., 2003). Pruessner and colleagues advise use of AUC formulae to, 1) reduce multiple repeated measurements to simplify statistical analyses, and 2) to reduce the number of comparisons in large data sets between groups or individuals in order to minimize α-error probabilities.

AUC with respect to ground (AUCg) was calculated, such that,

$$AUC_g = \sum_{i=1}^{n-1} \frac{(m_{(i+1)} + m_i) . t_i}{2}$$

where, t_i is the time between cortisol measurements, m_i denotes the cortisol measurement at that time, and n denotes the total number of measurement occasions. This formula provides the total AUC of all cortisol measurements for a given time

frame for each individual as the distance from ground (or zero) for each cortisol measurement and the difference between single measurements.

The AUC provides an indication of each participant's basal cortisol secretion. For each participant, total daily AUC of cortisol was calculated using raw cortisol scores. A person-mean AUC score across seven days was also estimated as a stable measure of intraindividual cortisol secretion. As recommended by Wrosch et al., (2007), the AUC was calculated only if 1) there was a valid awakening cortisol measure, and 2) there were a specified percentage of samples across the day, determined as at least three samples in the current study. Person-mean cortisol substitution was employed in cases with one to three missing measurements.

5.7.2.2 ***Deviation in cortisol at measurement occasion.*** The deviation in cortisol was calculated for each individual measurement occasion across days as a measure of momentary fluctuation in cortisol secretion at the time of questionnaire completion. The deviation in cortisol ($Deviation_{Cortisol}$) was determined as an individual's deviation in cortisol secretion for that measurement occasion from their person-mean cortisol value for that time of day, (i.e., their centered score), such that,

$$\text{Deviation in cortisol} = \text{Person-mean Cortisol (D1T}n\text{…..D}n\text{T}n\text{)} - \text{Cort (D1T}n\text{…..D}n\text{T}n\text{)}$$

5.7.2.3 ***Intra-individual standard deviation.*** The *i*SD was calculated for each participant as a measure of the deviation in cortisol at each measurement occasion around the mean secretion for that time of day to account for the diurnal pattern in cortisol secretion.

The *i*SD in cortisol level was determined using the method reported by Ram and colleagues (2011). For each individual (*i*) the *i*SD is the square root of the intra-individual variance in cortisol such that,

$$iSD = \sqrt{\sigma_i^2} = \sqrt{\frac{1}{T-1}\sum_{T=1}^{T}\left(y_{ti} - \overline{y}_i\right)^2}$$

where the *iSD* is the sum of the squared daily deviations in cortisol t = 1 to T and daily deviations in cortisol (y_{ti} = cortisol on occasion t, subtract $\overline{y}_i$ = individual mean cortisol at that time of day) divided by 1 less the total number of measurement occasions.

The daily *i*SD was calculated for each participant. A person-mean *i*SD value was then calculated to represent a stable index for each participant and variability in cortisol levels across seven days, allowing examination of inter-individual differences in this construct.

5.7.2.4 ***Cortisol awakening response***. The CAR represents the normative peak in cortisol secretion occurring approximately 30 to 45 minutes post-awakening. The daily CAR for each participant was calculated using natural log transformed cortisol values, as the difference between the two morning cortisol samples divided by the difference in time between the two samples (Almeida, Piazza, & Stawski, 2009), namely,

CAR = (lnMorning2 Cortisol – lnMorning1 Cortisol) / (Time sample 2 – Time sample 1).

A person-average CAR across seven days was then computed for each person as a stable measure of inter-individual variation for this measure.

5.8 Results

5.8.1 Overview. Demographic and descriptive results are presented in Chapter 3, Table 3.1. Full data were collected from 74 participants, 49 female and 25 male, ranging in age from 83 to102 years (*M* = 88.13, *SD* = 3.15). Participants had received an average of 10.6 years of education with 58.1% leaving school at 15 years of age or more and reported good overall health (*M* = 2.38, *SD* = .77).

5.8.1.1 Prospective memory descriptive results. Prospective memory performance for the focal and non-focal event-based tasks, and the time-based task were presented in Study 1 and are summarised in Chapter 3, Table 3.2. Performance for both of the event-based tasks was similar with 72.9% of participants recording a correct response across trials for the focal (circle capital) EBPM tasks, with 82.8 % of responses on the non-focal (initial box) task answered correctly. Performance on the time-based prospective memory task (call your research assistant) was in contrast to that recorded for the event-based tasks. Only 16 participants remembered to call their research assistant at the specified time giving an overall percentage of correct response on this task of 21.6 %.

5.8.1.2 Cortisol descriptive results. Descriptive results for cortisol assays are presented in Tables 5.1 and 5.2. The overall sample mean cortisol levels across measurement occasions over the seven day protocol displayed a robust diurnal pattern of secretion with younger-old adults as reported in the literature (Kudielka and Kirschbaum, 2003; Piazza et al., 2010). Moreover the diurnal pattern of secretion was shown to be maintained in this cohort of oldest-old as recently reported by Chui et al. (2013) and substantiated in the current study. Sample mean cortisol levels are

represented in Figure 3 and individual means for three participants representing interindividual differences in basal and diurnal cortisol levels are shown in Figure 4. Diurnal cortisol levels are comparative to mean levels obtained from older adults (*M* = 72.27 years of age) over a three day period (Wrosch et al., 2009) and demonstrate a distinct peak 30 minutes post awakening (refer to Table 5.1 for current results and comparative figures from previous studies). Participant mean daily AUC, CAR, and *i*SD of cortisol secretion were computed for each day separately and are presented in Table 5.2. Day-to-day correlations for each of these measures are presented in Table 5.3. Single day measures of AUC were significantly correlated, *r'*s = .27 to .51, ρ's < .01, with correlations for the CAR ranging from *r's* = .34 to .51, ρ's < .01, and for the *i*SD, *r's* = .27 to .90, ρ's < .01.

5.8.1.3 Preliminary analyses of major variables. Preliminary correlation analyses between the major cortisol and descriptive variables are presented in Table 5.4. Cortisol AUC was significantly associated with waking cortisol levels, $r = .52$, $\rho < .01$, and the *i*SD, $r = .46$, $\rho < .05$. The morning rise in cortisol from time of awakening to the second cortisol sample was correlated with waking levels, $r = -.45$, $\rho < .05$, and the *i*SD. The diurnal cortisol slope across the day displayed a significant correlation with waking cortisol level, $r = -.26$, $\rho < .05$, the morning rise, $r = .75$, $\rho < .01$, and with the CAR, $r = -.38$, $\rho < .01$. Of the descriptive variables, education was positively correlated with waking cortisol levels and the morning rise. Interestingly, depression also showed a positive association with the morning rise in cortisol, $r = .24$, $\rho < .05$, and with age $r = .31$, $\rho < .05$. Age was not correlated with the major cortisol measures or with education level.

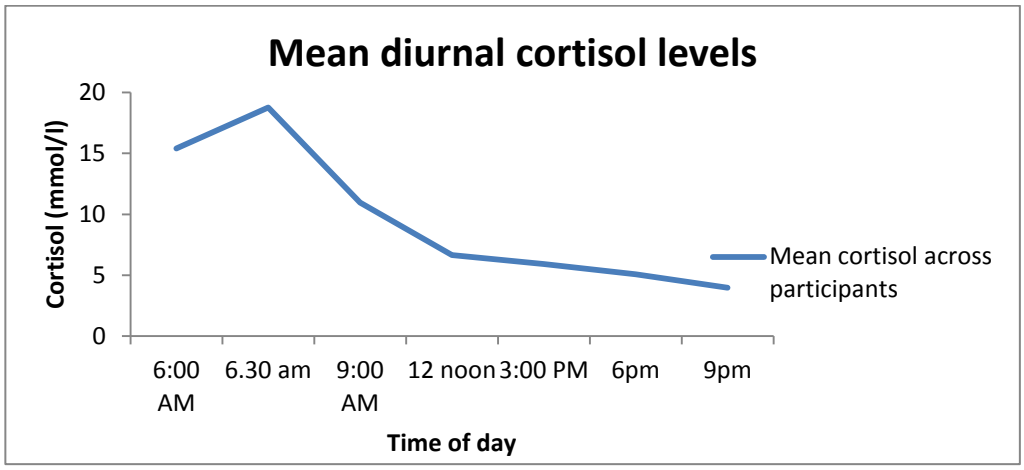

Figure 3. *Mean diurnal cortisol secretion levels across ADuLTS participants.*

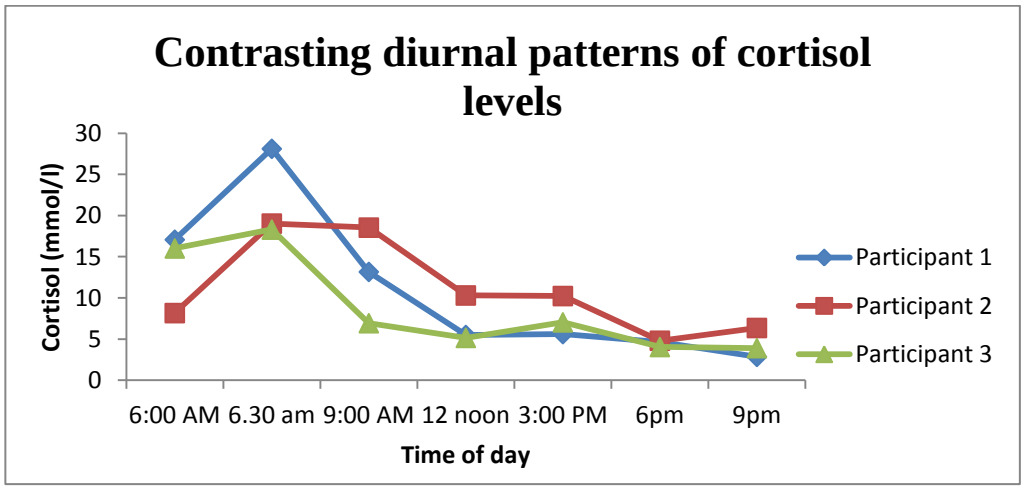

Figure 4. *Individual diurnal patterns of cortisol secretion for three ADuLTS participants.*

Table 5.1

Comparative Table of Mean Diurnal Cortisol Levels for all Participants in the Current Study with Levels Previously Reported

		Cortisol (mmol/lt) Current Study		Cortisol (mmol/lt) Wrosch et al., (2009)	Cortisol (mmol/lt) Kudielka & Kirschbaum (2003)
Quest No.	Default Time	M (SD)		Ms (SDs) Range across days	M (SDs) Range across days
1	Awakening	15.61	(7.10)	12.01 to 15.02 (7.53 – 8.84)	3.15 to 3.89 (3.11 – 5.15)
2	30 minutes post awakening	19.03	(7.74)	15.41 to 20.64 (10.15 – 13.36)	16.51 to 17.60 (10.70 – 11.38)
3	9 am	11.12	(5.60)		
4	12 noon	6.74	(2.94)		
5	3 pm[1]	5.99	(2.77)	5.34 to 6.77 (3.55 – 4.48)	5.32 to 6.26 (3.29 – 4.42)
6	6 pm[2]	5.15	(2.87)	4.78 to 5.63 (3.20 – 4.20)	4.87 to 5.07 (3.19 – 3.99)
7	9 pm	4.03	(2.54)	3.15 to 3.89 (3.11 – 5.15)	3.03 to 3.88 (2.59 – 5.52)

Note: SD = Standard deviations. Default times for Wrosch et al., and Kudielka & Kirschbaum studies were [1] = 2 pm and [2] = 4 pm.

Table 5.2

Sample Mean AUC, CAR and iSD Cortisol Levels Across Days

Day	AUC (Total) M (SD)		CAR M (SD)		iSD M (SD)	
1	106.54	(58.36)	.22	(1.71)	4.99	(3.24)
2	115.27	(52.29)	1.48	(8.67)	4.34	(2.78)
3	115.26	(51.26)	.32	(1.69)	3.75	(2.19)
4	108.95	(46.09)	.25	(1.44)	4.67	(9.25)
5	111.01	(50.76)	.05	(2.00)	3.91	(2.01)
6	115.76	(58.43)	.50	(1.18)	3.83	(2.33)
7	103.93	(43.78)	.47	(2.17)	4.64	(5.32)

Note: Standard deviations are in parentheses.

Table 5.3
Between Day Correlations of Average AUC, CAR, and iSD

	AUC Day 1	AUC Day 2	AUC Day 3	AUC Day 4	AUC Day 5	AUC Day 6	AUC Day 7
AUC Day 1	1						
AUC Day 2	.51**	1					
AUC Day 3	.45**	.62**	1				
AUC Day 4	.46**	.44**	.67**	1			
AUC Day 5	.42**	.50**	.51**	.69**	1		
AUC Day 6	.46**	.27**	.45**	.55**	.47**	1	
AUC Day 7	.46**	.25	.39**	.55**	.60	.43**	1

	CAR Day 1	CAR Day 2	CAR Day 3	CAR Day 4	CAR Day 5	CAR Day 6	CAR Day 7
CAR Day 1	1						
CAR Day 2	-.02	1					
CAR Day 3	.12	.09	1				
CAR Day 4	.26	.26	.38**	1			
CAR Day 5	-.01	.11	.04	.37**	1		
CAR Day 6	.23	.34*	.21	.36**	.34**	1	
CAR Day 7	.10	.04	-.02	.16	.22	.18	1

	*i*SD Day 1	*i*SD Day 2	*i*SD Day 3	*i*SD Day 4	*i*SD Day 5	*i*SD Day 6	*i*SD Day 7
*i*SD Day 1	1						
*i*SD Day 2	.41**	1					
*i*SD Day 3	.23	.27**	1				
*i*SD Day 4	.05	.35**	.31*	1			
*i*SD Day 5	.24	.25*	.44**	.21	1		
*i*SD Day 6	.17	.29*	.19	.11	.27*	1	
*i*SD Day 7	.10	.40**	.30*	.90**	.30*	.15	1

Note: AUC is Area under the Curve, CAR is Cortisol Awakening Response, *i*SD is the intra-individual Standard Deviation. * $\rho < .05$, ** $\rho < .01$, *** $\rho < .001$

Table 5.4

Correlations of Sample Mean Cortisol and Descriptive Variables

	AUC	Wake Cortisol	CAR	iSD	Wake Cortisol (ln)	MR	DCS	Education	Age	CES-D
AUC	1									
Wake Cortisol	.52**	1								
CAR	.03	-.22	1							
iSD	.46**	.35*	.01	1						
Wake Cortisol (ln)	.45**	.87**	-.20	.23*	1					
MR	.15	-.41**	-.01	.06*	-.50**	1				
DCS	-.13	-.26*	-.38**	.07	-.40**	.75**	1			
Education	.17	.32**	-.09	-.04	.23*	-.06	-.04	1		
Age	.18	.19	.07	-.08	.13	.12	.00	.14	1	
CES-D	.05	-.08	.16	-.16	-.08	.24*	.15	.05	.31*	1

Note: AUC = average area under the curve, Wake cortisol = average waking cortisol level, CAR = average cortisol awakening response, iSD = average intra-individual standard deviation, Wake cortisol (ln) = average log transformed waking cortisol level, MR = average morning rise slope cortisol, DCS = average diurnal cortisol slope, Education = years of schooling, Age = age at interview, CES-D = depressive symptoms. *** $\rho < .001$, ** $\rho < .01$, * $\rho < .05$

5.8.2 Statistical model and analytic approach. The research questions proposing a negative association between stress and prospective memory proficiency were examined using a variety of statistical analyses. This section will review the rationale and approach behind the choice of analyses employed. Direct logistic regression was used to examine the relationship between the time-based prospective memory task and stress. However, the repeated and clustered nature of the event-based prospective memory measures necessitated a multi-level approach to analyses. Multi-level modelling (MLM) was therefore used for the statistical analyses to examine the extent of variability in event-based prospective memory outcomes within and between-individuals. MLM is recommended for use when 1) there is sufficient variability at each level of the model, and 2) there is a hierarchical system of clustered data (Heck, Thomas, & Tabata, 2012). As MLM is an emerging class of statistical analysis techniques, a brief outline of the rationale for use in this thesis and general parameters of the models used will be discussed.

5.8.2.1 ***Overview of multi-level modelling and generalised linear mixed models*****.** Event-based prospective memory variables in the current study, namely 1) the EBPM focal task (capital question), and 2) the EBPM non-focal task (initial box question), are defined as dichotomous, categorical outcomes, coded as either an incorrect or correct response. MLM generally assume outcome variables to be continuous in nature with normal error distributions. Dichotomous outcomes on the other hand, do not assume a normal distribution but exhibit a binomial probability distribution. In such cases, data are commonly estimated using Generalised Linear Models in preference to classical analytical techniques such as repeated measures ANOVA. Such traditional techniques transform non-normally

distributed data prior to analyses. However, it is widely recognised that categorical data cannot be successfully transformed into a normal distribution (Hox, 2010). Generalised Linear Models overcome this problem by inclusion of an appropriate transformation of the data coupled with an appropriate error distribution into each model (Hox, 2010, p.113). Further, GLMs are recommended for categorical data where subjects are nested within groups or where repeated measures are nested within individuals and/or then within group structures (Heck et al., 2012).

The event-based prospective memory research questions were therefore examined using a two-level Generalised Linear Mixed Model (GLMM) to accommodate the dichotomous, repeated measures data. The mixed effects model allowed inclusion of fixed effects for the predictor variables and also estimation of variability in specified random effects (variability across higher level units or across time).

At Level-1, the model describes outcomes in terms of intra-individual change in the dependent variable over time, that is, repeated measures are clustered within individuals at this level. At Level-2, inter-individual change in the dependent variable is described, that is variability between individuals. In a two-level model, the fixed effects are unstandardised β coefficients and indicate the change in the log odds of the variate, (η_{it}) per unit change in the predictor. There is no residual variance term at level-1in a GLMM, as the variance of a dichotomous predictor is dependent upon the mean value, and the underlying probability distribution is not normally distributed. At this level the observed variance in the proportion is determined by the estimated value of the population proportion (π_{it}). At higher levels, GLMMs are specified as for other multi-level

models with a between-subject variance in random effects. At Level-2, residual terms are estimated as for models with continuous dependent variables (Raudenbush, Bryk, Cheong, & Congdon, 2004, cited in Heck, Thomas, & Tabata, 2012).

5.8.2.2 ***Model definition.*** Separate models were estimated for both the focally cued and non-focally cued prospective memory outcomes, utilising the same statistical modelling approach for both prospective memory dependent variables. The sequential models used are outlined below.

Model A. Model A was an unconditional, empty model to examine the expected probability (*E*) of an individual (*i*) at time (*t*) correctly answering the prospective memory task. At Level-1, model A is represented as,

1.0 $$E(\gamma_{ti}) = \pi_{ti}$$ where,

- π_{ti} is the probability that $\gamma_{ti} = 1$ (a correct response) and
- 1 - γ_{ti} is the probability of an incorrect response.

The initial model gave the population-average estimate for the dependent variable and is represented by the equation,

1.1 $$\eta_{ti} = \log\left(\frac{\pi_{ti}}{1-\pi_{ti}}\right) = \beta_0$$ where

- β_0 is the intercept (log odds of response at t = 1) when any of the variables in the model are held constant at 0 and there are no predictors added to the model.

Model B. Model B estimated the extent of variability in EBPM separately for the focal (capital question) and non-focal (initial box) tasks, across subjects (Level-2 units) and across repeated measurement occasions.

This model gave the population-average estimate for the dependent variable across measurement occasions and is represented by the equation,

1.2 $$\eta_{ti} = \log\left(\frac{\pi_{ti}}{1-\pi_{ti}}\right) = \beta_0 + \beta_1 time$$ where

- β_0 is the intercept (log odds of response at t = 1) when any of the variables in the model are held constant at 0 and there are no predictors added to the model.
- β_1 is the rate of change on a logit scale in the fraction of correct responses in the population of subjects per unit time.

Model C. Model C was a random coefficients model, estimated as a two level model. At Level-1, *t* measurements were nested within subjects *i* such that

1.3 $$\eta_{ti} = \log\left(\frac{\pi_{ti}}{1-\pi_{ti}}\right) = \beta_{0i} + \beta_{1i} time_{ti}$$ where

- $\beta_{0i} = \gamma_{00} + \mu_{0i}$ (with γ_{00} being the population-average intercept, and μ_{0i} being the random subject effect assuming a normal and independent distribution [0, σ^2], that is the difference between the population-average intercept and the actual intercept for an individual (*i*)
- $\beta_{1i} = \gamma_{10}$ (with γ_{10} the slope or time related variable fixed between subjects)
- With substitution, the log odds (η_{ti}) of a positive response then becomes

1.4

$$\eta_{ti} = \gamma_{00} + \gamma_{10} time_{ti} + \mu_{0i}$$

This results in three parameters to estimate in this model, firstly two fixed effects, namely the intercept (γ_{00}) and the fixed slope for time ($\gamma_{10}time_{ti}$), and one random effect (μ_{0i}), being the slope variance between individuals at level-2.

Model D. A two-level random coefficients model was estimated at this step, with two groups of time-invariant baseline predictors added to the model. Age, gender, and education (dichotomised to leaving school under 15 years of age, or at 15 years of age or older) were predictors added to the model along with covariate predictors including depressive symptoms, physiological conditions affecting cortisol levels, and use of medication known to affect cortisol (dichotomised as either yes or no). The resulting model equation derived from the intercept (β_{0i}) and time slope (β_{1i}) became:

- $\beta_{0i} = \gamma_{00} + \gamma_{01\,age} + \gamma_{02\,gender} + \gamma_{03\,education} + \gamma_{04\,dep\,symptoms} + \gamma_{05\,phys\,cond} + \gamma_{06\,med} + \mu_{0i}$
- $\beta_{1i} = \gamma_{1o} + \gamma_{1i\,age} + \gamma_{12\,gender} + \gamma_{13\,education} + \gamma_{14\,dep\,symptoms} + \gamma_{05\,phys\,cond} + \gamma_{06\,med}$

With substitution the equation for Model D becomes,

1.5 $$\eta_{ti} = \gamma_{0o} + \gamma_{01\,age} + \gamma_{02\,gender} + \gamma_{03\,education} + \gamma_{04\,dep\,symptoms} + \gamma_{05\,phys\,cond} + \gamma_{06\,med} + \gamma_{1o}time_{ti} + \mu_{0i}$$

resulting in fixed effects for the intercept, time slope, age, gender, education, depressive symptoms, physiological conditions, and medication. The model also estimates one random effect (i.e., the randomly varying subject intercept), and one residual effect (the structure of the within subjects covariance matrix).

Model E. This random coefficients model was estimated sequentially from the previous model with the addition of time-varying cortisol predictor variables.

Individual daily basal cortisol (AUC), daily cortisol awakening response (CAR), daily intra-individual standard deviation in cortisol (*i*SD), and deviation in cortisol at measurement occasion from the person-average for that time were added. Between-person (BP) effects were estimated using the person mean across days for the AUC, CAR, and *i*SD (e.g., person-mean AUC across days). Within-person (WP) effects were estimated using the deviation from the mean for the measurement time or occasion for the AUC, CAR, and *i*SD (e.g., person-mean AUC less AUC for that day). The deviation in cortisol represented a within person effect. The resulting model equation derived from the intercept (β_{0i}) and time slope (β_{1i}) became:

- $\beta_{0i} = \gamma_{00} + \gamma_{01\,age} + \gamma_{02\,gender} + \gamma_{03\,education} + \gamma_{04\,dep\,symptoms} + \gamma_{05\,phys\,cond} + \gamma_{06\,med} + \gamma_{07\,AUC\,cort\,BP} + \gamma_{08\,AUC\,cort\,WP} + \gamma_{09CAR\,cort\,BP} + \gamma_{010CAR\,cort\,WP} + \gamma_{011\,iSD\,cort\,BP} + \gamma_{012\,iSD\,cort\,BP} + \gamma_{013\,iSD\,cort\,WP} + \gamma_{014\,Dev\,cort} + \mu_{0i}$
- $\beta_{1i} = \gamma_{1o} + \gamma_{11\,age} + \gamma_{12\,gender} + \gamma_{13\,education} + \gamma_{14\,dep\,symptoms} + \gamma_{15\,phys\,cond} + \gamma_{16\,med} + \gamma_{17\,AUC\,cort\,BP} + \gamma_{18\,AUC\,cort\,WP} + \gamma_{19CAR\,cort\,BP} + \gamma_{110CAR\,cort\,WP} + \gamma_{111\,iSD\,cort\,BP} + \gamma_{112\,iSD\,cort\,BP} + \gamma_{113\,iSD\,cort\,WP} + \gamma_{114\,Dev\,cort}$

With substitution the equation for Model E becomes,

1.6 $$\eta_{ti} = \gamma_{0o} + \gamma_{01\,age} + \gamma_{02\,gender} + \gamma_{03\,education} + \gamma_{04\,dep\,symptoms} + \gamma_{05\,phys\,cond} + \gamma_{06\,med} + \gamma_{07\,AUC\,cort\,BP} + \gamma_{08\,AUC\,cort\,WP} + \gamma_{09CAR\,cort\,BP} + \gamma_{010CAR\,cort\,WP} + \gamma_{011\,iSD\,cort\,BP} + \gamma_{012\,iSD\,cort\,BP} + \gamma_{013\,iSD\,cort\,WP} + \gamma_{014\,Dev\,cort} + \gamma_{1o}time_{ti} + \mu_{0i}$$

This model therefore has fixed effects for the intercept, time slope, age, education, depressive symptoms, physiological conditions, medication, $AUC_{BP\ and\ WP}$, $CAR_{BP\ and\ WP}$, $iSD_{BP\ and\ WP}$, and deviation in cortisol. One random effect (the randomly varying subject intercept), and one residual effect (the structure of the within subjects covariance matrix) were also estimated with this model.

5.8.2.3 ***Software.*** All models were estimated using a Generalized Linear Mixed Model in IBM SPSS Version 21.0.

5.8.2.4 ***Covariance structure.*** An autoregressive [AR(1)] matrix covariance was specified in analyses as the optimal correlation matrix (Heck et al., 2012). This matrix has a simplified error structure and is widely used for repeated measures data. The residual error variance is assumed to be correlated within subjects, but independent between subjects, with a correlation between adjacent repeated measures of ρ, with ρ constrained to $-1 < \rho < 1$.

5.8.2.5 ***Estimation of logit coefficients and probabilities.*** The predicted log odds determined by the regression equation were linked by a canonical link function for a binomial distribution as recommended by Hox (2010). The logit transformation, $\log [\pi / (1-\pi)]$, specifies the estimated odds of the outcome event occurring versus not occurring. For example, if the probability of being proficient (a correct response) at a prospective memory task is .80 (80%), then the probability of not being proficient is .20 (20%), with the associated odds of 80:20 or 4:1. Formulas used for transforming logits and odds into odds and probabilities as recommended by Singer and Willet (2003, p. 376) are presented in Table 5.5.

Table 5.5

Formulae for Transforming Logits and Odds to Probabilities

Scale	Formula
Logit	Odds = e^{logit}
Odds	Probability = $\frac{odds}{1+ odds}$
Logit	Probability = $\frac{1}{1+ e^{-(logit)}}$

5.8.2.6 ***Model estimation***. The purpose of model estimation is to determine how well the model represents the data in predicting the outcome variable. Maximum likelihood estimation is recommended for general linear models with categorical outcomes and provides the model deviance statistics (-2*log likelihood: -2LL). By default, GLMMs in SPSS are estimated with the 2*pseudo-log likelihood (-2PLL) which is based on Pearson χ^2 residuals. Generally, convergent models with lower deviance better represent the data and can be compared between models. However, Hox (2010) argues to use the pseudo-deviance statistic with caution when evaluating models using a logistic distribution.

5.8.3 Results for EBPM focal models. Two-level GLMMs assessed the effects of stress upon focally cued event-based prospective memory performance. It was expected that prospective memory performance would be negatively related to stress, as measured by salivary cortisol levels. Results for the focal EBPM models are presented in Table 5.6 (also see Appendix G.3 for selected SPSS output). Model A estimated log odds of η of 0.99 (ρ < .001, 95% CI [0.66, 1.35]). The intercept represents the predicted log odds of successful performance

on the focal EBPM task for all subjects across the course of the study (grand mean). This gives an odds ratio of 2.69 ($e^{\beta} = e^{0.988} = 2.69$) and transforms to an estimated population-average probability of successful performance on this task of 72.9%, calculated as,

$$\pi_{ti} = \frac{\exp\ (x'_{ti}\,\beta)}{1+\exp\ (x'_{ti}\,\beta)} = e^{0.99}/(1 + e^{0.99}) = 2.69 / (1 + 2.69) = 0.729$$

Time, representing measurement occasion was added to Model B. The estimated log odds of η were 0.50 ($\rho < .05$, 95% CI [0.03, 0.97]), giving an odds ratio of 1.65 and a probability of successful performance of 0.623 (62.3%). The time variable suggested that over each measurement occasion the likelihood of successful performance increased significantly ($\rho < .01$) across subjects, (β = 0.08), from 62.3% at measurement occasion 1, to 80.5% at the final measurement (see Appendix G.1).

Model C was a random coefficients model with the subject level intercept of estimated log odds of 0.46 ($\rho > .05$, 95% CI [-0.25, 1.16]), giving an average subject level probability of successful performance of 61.2%. The estimated log odds for the time slope were 0.16 ($\rho < .001$, 95% CI [0.07, 0.25]). Random effects represented by the slope variance between individuals in this model was a coefficient of 3.82 ($\rho < .001$, 95% CI [2.4, 6.06]).

Model C allows for the intraclass correlation (ICC) to be calculated from the scale factor at Level-1, and is defined as the proportion of variance that lies between units ($\sigma^2_{\text{Between}}$) relative to the total variance ($\sigma^2_{\text{Between}} + \sigma^2_{\text{Within}}$). Hox

Table 5.6
Results of GLMM Analysis of Focal EBPM (Circle Capital Task)

Model	Model A	Model B	Model C	Model D	Model E
	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff.(SE)	Coeff.(SE)
Fixed effects					
Intercept	.988 (.19)***	.503 (.36)*	.459 (.36)	13.37 (8.66)	17.35 (9.62)
Time		.084 (.03)**	.159 (.05)***	.16 (.05)***	.16 (.05)**
Age				-.15 (.10)	-.21 (.11)
Gender [1]				-.39 (.61)	-.37 (.67)
Education [2]				1.43 (.56)**	1.14 (.66)*
Depression				-.11 (.08)	-.07 (.10)
Thyroid conditions				.71 (.64)	.93 (.78)
Thyroid medication[3]				1.03 (1.10)	1.12 (1.17)
AUC cortisol BP					.01 (.01)
AUC cortisol WP					.00 (.01)
CAR cortisol BP					-.07 (.06)
CAR cortisol WP					- .05 (.02)**

	Model A	Model B	Model C	Model D	Model E
iSD cortisol BP					.13 (.15)
iSD cortisol WP					.05 (.05)
Deviation Cortisol					.04 (.03)
Random effects					
Variance intercept			3.82 (.90)***	3.69 (.91)***	4.10 (1.03)***
AR1 Diagonal	.10 (.07)***	.10 (.07)***	.72 (.04)***	.74 (.04)***	.71 (.04)***
AR1 Rho	.62 (.03)***	.62 (.03)***	.20 (.05)***	.19 (.05)***	.19 (.05)***
Goodness of fit					
-2*pseudo log-likelihood	3124.77	3158.32	3948.04	3987.87	3728.92
AIC	3128.78	3162.33	3910.24	3993.90	3742.44
BIC	3138.07	3171.62	3924.16	4007.80	3722.88

Note: Standard errors are in parentheses. AUC is area under the curve. CAR is cortisol awakening response. *i*SD is intraindividual standard deviation. BP is the between person mean of the measure. WP is the within person deviation from the mean. AIC is Akaike Information Criterion and BIC is Bayesian Information Criterion.[1] is Gender coded as male. [2] is Education coded as left school > 15 years. [3] is Thyroid medication coded as yes, taking thyroid related medication. *$\rho < .05$, **$\rho < .01$, ***$\rho < .001$

determined the variance in a logistic distribution with a scale factor of 1.0 to be $\pi^2/3$ or approximately 3.29 (Hox, 2002). The ICC for Model C is estimated as $\rho = \sigma^2_{\text{Between}} / \sigma^2_{\text{Between}} + \sigma^2_{\text{Within,}}$ (3.82 / (3.82 + 3.29) = 0.537). This suggests 53.7% of the variance in the probability of successful performance on the EBPM (focal task) lies between individuals, with 46.3% variance lying within individuals. The Wald test for statistical significance (z = 4.23, ρ < .001), indicates that the intercept variance varies significantly between Level-2 units, thereby justifying the development of a Multilevel Model.

After adding predictive factors for age, gender and education, and covariates for depressive symptoms, physiological conditions known to affect the thyroid, and cortisol affecting medication use, the fixed effects in Model D estimated an intercept with log odds of 13.35 (ρ > .05, 95% CI [-3.64, 30.34]). The main effect of measurement occasion remained significant with estimated log odds of β =.16 (ρ < .001, 95% CI [0.07, 0.26]).

Education emerged as a significant predictor in the probability of being correct on the EBPM (focal task) with estimated log odds of β = 1.43 (ρ < .01, 95% CI [0.34, 2.53]) for those with higher levels of education (i.e., participants who left school at 15 or more years of age). The exponent coefficient, or odds ratio of 4.20, suggests that the odds of successful performance over the eleven measurement occasions were almost four times higher for those with greater years of schooling compared to those with fewer years of schooling across the study, holding the holding the other predictors constant. These results are reflected in the estimated means of .924 for those who left school after the age of 15 years, compared to .796 for those who left school before the age of 15 years.

Neither age nor gender, were significantly associated with the probability of a correct response for the focal EBPM tasks. Similarly, depressive symptoms, physiological conditions affecting the thyroid, and use of cortisol confounding medication were not predictive of prospective memory proficiency in this model.

Random effects estimated an intercept for the covariance parameters for Model D of log odds of 3.69, with a statistically significant variance across subjects ($z = 4.05$, $\rho < .001$, 95% CI [2.28, 5.99]).

As in the previous model, Model E found that education level remained a significant predictor of focal EBPM proficiency, (estimated log odds $\beta = 1.14$, $\rho < .05$, 95% CI [-.16, 2.45]). The odds ratio of 3.14 for education was slightly lower in this model, indicating that those with more years of schooling were almost 3 times more likely to be proficient compared to their counterparts. The estimated means for those who left school after 15 years of age compared to those who left before 15 years were similar to those produced in the previous model (.934 and .805 respectively).

The full model directly assessed the relationship of stress upon focal EBPM performance. Basal cortisol levels (AUC), individual lability in cortisol secretion (*i*SD), and the co-occurrence of stress with prospective memory tasks (person/time mean deviation in cortisol) showed no significant association with prospective memory performance at the between or within-person level. Thus the research questions postulating these three stress indices to be predictive of individual differences in focal event-based prospective memory performance were not supported by the data.

Within-person differences in the cortisol awakening response (CAR) did however emerge as a significant predictor of focal event-based prospective memory performance. The estimated log odds for the CAR were $\beta = -.05$, ($\rho < .01$, 95% CI [-0.09, 0.02]), with an odds ratio of 1.05 and corresponding probability of 49.9%. The model estimated the slope coefficient for this predictor of $\beta = 1.05$. Thus the CAR contributed to explaining the dependent variable such that the odds of successful performance were decreased by a factor of 1.05 for each unit increase in the CAR, with all other predictors held constant. Tabachnick and Fidell (2007, p 463) suggest the odds ratio can be interpreted as a measure of effect size, with a ratio closer to one having a smaller effect. Thus the effect size of the CAR in this model is small and should be interpreted with caution.

The random effects in the full model produced a covariance parameter intercept with estimated log odds of 4.45, and again results were similar to the previous model with a statistically significant variance across subjects at Level-2 ($z = 3.89$, $\rho < .001$, 95% CI [2.69, 7.36]) or 54.2%.

Model E as a whole produced better fit than previous models with a lower -2PLL estimate. Therefore the addition of cortisol predictors as a group improved the model beyond considering just demographic and cortisol covariate variability within and between individuals. The full model representing the data shows a moderate, significant effect of formal education upon focal event-based prospective memory performance in this cohort of elderly participants. There was a very small effect on the outcome measure of an individual's CAR, but no effect for the other cortisol predictors. As such the data provides only modest support for the hypotheses predicting a relationship between stress and focal event-based prospective memory.

5.8.4 Results for EBPM non-focal models. Results for the non-focal event-based prospective memory models are presented in Table 5.7(with selected SPSS output in Appendix G.4). Model A was the intercept only model and produced estimated log odds of successful performance on the non-focal event-based prospective memory task across all subjects of $\beta = 1.57$ ($\rho < .001$, 95% CI [1.14, 2.01]). The odds ratio was 4.81, giving an estimated population-average probability of a correct response on this task of 82.7%.

When time was added to Model B, the estimated log odds of η were 1.21 ($\rho < .001$, 95% CI [0.78, 1.65]), giving an odds ratio of 3.36. The time intercept $\beta = .08$ indicated that across the seven measurement occasions, the likelihood of successful performance on this task increased across subjects (slope coefficient $\beta = 1.08$, $\rho < .05$, 95% CI [0.01, 0.14]). The initial probability of correct performance at the first measurement occasion was estimated at 77% increasing to approximately 95.95% at the final measurement occasion (Appendix G.2).

The fixed effects for Model C produced a subject level intercept with estimated log odds of 1.70 ($\rho < .001$, 95% CI [1.05, 2.35]). The odds ratio was 5.47 giving an average participant-level probability of successful performance of 84.5%. The time slope for this model was 0.12 ($\rho < .05$, 95% CI [0.02, 0.22]).

Model C provided random effects for measurement occasion in terms of the slope variance between individuals, with a coefficient of 4.24. The intraclass correlation from Model C is estimated as $\rho = \sigma^2_{\text{Between}} / \sigma^2_{\text{Between}} + \sigma^2_{\text{Within,}}$ (4.24 / (4.24 + 3.29) = 0.56). This equates to the variance in the probability between individuals of being correct on the non-focal EBPM task of 56.7%, with 43.7% of the variance within individuals. The intercept variance between Level-2 units (individuals) reached significance ($z = 4.33$, $\rho < .001$, 95% CI [2.70, 6.67]),

thereby justifying the development of a MLM for this outcome variable.

Model D added predictor variables for age, gender and education, and covariates for depressive symptoms, physiological conditions affecting the thyroid, and thyroid medication use known to affect cortisol levels. Fixed effects were estimated log odds of $\beta = -13.47$ ($\rho = .16$, 95% CI [-32.31, 5.37]), with a significant main effect of measurement occasion, log odds of $\beta = .12$ ($\rho < .05$, 95% CI [0.02, 0.22]). There was no relationship for age, gender or education on the probability of successful performance on the non-focal EBPM tasks. Similarly depressive symptoms, physiological conditions, and use of cortisol confounding medication were not significant.

The random effects in this model produced covariance parameters with estimated log odds intercept of 4.27, which varied significantly across subjects ($z = 4.07$, $\rho < .001$, 95% CI [2.64, 6.92]) or 55.3%.

As in previous models, Model E found no significant effects for any covariates. The estimated log odds for measurement occasion ($\beta = .09$, $\rho > .05$, 95% CI [-0.02, 0.20]) became non-significant. The addition of cortisol predictors to this model slightly improved model fit, however none of the cortisol variables were significantly associated with non-focal EBPM performance (see Table 5.7 for full results).

Table 5.7
Results of GLMM Analysis of Non-focal EBPM (Initial Box Task)

Model	Model A	Model B	Model C	Model D	Model E
	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)
Fixed effects					
Intercept	1.57 (.22)***	1.21 (.22)***	1.70 (.33)***	-13.47 (9.60)	-11.63 (10.53)
Time		.08 (.03)**	.12 (.05)*	.12 (.05)*	.09 (.09)
Age				.17 (.11)	.15 (.12)
Gender [1]				.55 (.64)	.29 (.70)
Education [2]				.37 (.56)	.51 (.67)
Depression				-.09 (.11)	-.08 (.11)
Thyroid conditions				- .75 (.89)	-.83 (.89)
Thyroid medication[3]				1.00 (.74)	1.31 (.89)
AUC cortisol BP					.00 (.01)
AUC cortisol WP					.01 (.05)
CAR cortisol BP					.39 (.29)
CAR cortisol WP					.01 (.11)

	Model A	Model B	Model C	Model D	Model E
*i*SD cortisol BP					.09 (.13)
*i*SD cortisol WP					-.05 (.07)
Deviation cortisol					.03 (.04)
Random effects					
Variance intercept			4.24 (.98)***	4.27 (1.05)***	4.15 (1.04)***
AR1 Diagonal	1.01 (.07)***	1.01 (.07)***	.53 (.03)***	.55 (.03)***	.54 (.06)***
AR1 Rho	.53 (.04)***	.53 (.04)***	.09 (.05)	.09 (.05)	.11 (.05)*
Goodness of fit					
-2*pseudo log-likelihood	2860.09	2874.13	3343.18	3371.72	2882.45
AIC	2864.11	2878.15	3349.22	3377.76	2888.50
BIC	2872.99	2887.02	3362.52	3391.03	2901.18

Note: Standard errors are in parentheses. AUC is area under the curve. CAR is cortisol awakening response. *i*SD is intraindividual standard deviation. BP is the between person mean, WP is the within person deviation from the mean. AIC is Akaike Information Criterion and BIC is Bayesian Information Criterion. [1] is Gender coded as male. [2] is Education coded as left school > 15 years. [3] is Thyroid medication coded as yes, taking thyroid related medication. *$\rho < .05$, ** $\rho < .01$, *** $\rho < .001$

The covariance parameters intercept for this final model produced estimated log odds of 4.12. The Wald test for statistical significance ($z = 3.84$, $\rho < .001$, 95% CI [2.65, 7.36]), suggested that there remained significant variation between individuals at this level of approximately 53.9%. However the individual cortisol covariates and factors tested within this and previous models clearly showed no significant association with performance on the non-focal EBPM outcomes. As such the hypotheses predicting a negative association between stress levels and non-focally cued prospective memory were not supported by the data.

5.8.5 Results of TBPM analyses. To assess the association between the time-based prospective memory task and stress, a direct logistic regression was undertaken. It was predicted there would be a negative relationship between performance on the time-based prospective memory measure and an individual's stress levels. The model contained five demographic and descriptive covariate predictor variables for age, gender, education level, depressive symptoms, and use of medication known to affect cortisol levels. Stress levels were assessed through the addition of independent variables to the model for area under the curve for cortisol secretion (AUC: person-average across days), the cortisol awakening response (CAR: person-average across days), and the intraindividual standard deviation in cortisol (*i*SD: person-average across days) at Step 1. To examine the co-occurrence of stress with the time-based PM task, independent variables for an individual's AUC, CAR and *i*SD on the day of task execution (Day 4) were modelled at Step 2. In addition, the deviation in an individual's cortisol level from

their average time-mean cortisol level, were modelled at the time during the window of opportunity for task execution (Day 4, Questionnaires 3 and 4).

The results for the full model estimated with all predictor variables, is presented in Table 5.8 (refer to Appendix G.5 for selected SPSS output). Overall, the model approached significance, χ^2 (13, N = 567) = 21.11, $\rho < .07$, distinguishing respondents who were proficient at the TBPM task from those who were not. The model correctly classified 80.7% of cases and explained between 31 % (Cox and Snell R square) and 47 % (Nagelkerke R square) of the variance in proficiency. Only three of the predictor variables tested, namely depressive symptoms, the person-average basal cortisol secretion (AUC) across days, and total basal cortisol secretion on the day of task execution (AUC Day 4), made statistically significant contributions to the model.

The odds ratio of .50 (95% CI [.29, .84]) for depression was less than 1, indicating that for every unit increase in the CES-D score, the odds of a participant calling their research assistant decreased by a factor of .50, with all other predictors held constant. Similarly the odds ratio for the person-average AUC in cortisol secretion was reported as 1.10 (95% CI [1.01, 1.18]), suggesting that with every unit increase in AUC cortisol basal levels, the odds of calling the research assistant increased by a factor of 1.10, controlling for all other predictors. The model showed a negative relationship between daily basal cortisol levels and time-based prospective memory performance on the day of task enactment with an odds ratio of .93 (95% CI [.88, 1.00]). This suggests that for every unit increase in total basal cortisol level, the odds of successful performance on the time-based task decreased by a factor of .93. Performance was not associated with an individual's awakening cortisol levels, individual lability in cortisol secretion,

or with deviation in cortisol from the person-time mean at the time of task enactment.

Thus the hypotheses predicting poor time-based prospective memory performance to be associated with elevated stress levels were only partially supported. Interestingly, depressive symptoms emerged as predictive of prospective memory with higher baseline CES-D scores associated with poorer performance on the time-based task.

5.8.6 Summary of results.

Focal event-based prospective memory and stress. Of the predictor and covariates modelled, the cortisol awakening response showed a small, significant effect upon prospective memory. Larger CAR estimates at the individual level were associated with lower odds of task proficiency, with other predictors and covariates held constant. Similarly, higher levels of education were also predictive of better performance on the focal event-based task, after adjusting for other covariates and predictors.

The models estimated found no association between the demographic factors of age and gender with performance. Similarly, covariate control variables for depressive symptoms, physiological conditions affecting thyroid hormone secretion, and medication use known to affect cortisol assays, were not associated with prospective memory performance.

The cortisol indices of basal cortisol levels (AUC), individual lability in cortisol secretion (iSD), and the deviation in cortisol levels from the person/time mean (Deviation) were not predictive of performance on this task.

Results indicated performance on the focal event-based tasks improved over the course of the study with a population-average increase in the probability of being proficient of 18% between item one and item eleven. Variance between individuals (54.2%) also remained significant when all predictors were controlled in the full model.

Non-focal event-based prospective memory and stress. Analyses indicated none of the demographic factors, covariate control variables, or cortisol indices fitted to the models estimated, were predictive of performance on the non-focal prospective memory tasks. As for the focal event-based tasks, there was indication of improvement in sample-average performance across the week ranging from 77% proficiency for item one to 85.9% proficiency for item nine. In the full model, there remained significant unexplained variation between individuals (55.3%) when all selected predictors were controlled.

Time-based prospective memory and stress. Time-based prospective memory was associated with depressive symptoms, higher levels of which corresponded with lower probability of successful task performance. Similarly, higher weekly mean individual basal levels of cortisol were associated with better probability of task performance. However, increased levels of cortisol secretion on the day of the time based task reduced the probability of task proficiency.

Demographic factors of age, gender and education, and cortisol predictors of basal cortisol levels, individual lability and the size of the cortisol awakening response, failed to predict performance on the time-based prospective memory task.

Table 5.8

Logistic Regression Predicting Likelihood of Proficiency on TBPM Task

	B	(SE)	Wald	Odds Ratio	95% CI for Odds Ratio	
					Lower	Upper
Age	.18	(.21)	.70	1.19	.79	1.00
Gender[1]	-.01	(.87)	.00	.99	.18	5.46
Education[2]	-1.11	(1.09)	1.02	.33	.04	2.80
Depression	-.70	(.27)	6.76**	.50	.29	.84
Medication[3]	-1.79	(1.70)	1.10	.17	.01	4.70
AUC	.09	(.04)	4.86*	1.10	1.01	1.18
CAR	-.26	(.81)	.10	.77	.16	3.80
iSD	-.37	(.45)	.67	.69	.29	1.70
AUC Day 4	-.07	(.03)	4.12*	.93	.88	1.00
CAR Day 4	.41	(.49)	.72	1.51	.58	3.93
iSD Day 4	.11	(.12)	.81	1.12	.88	1.41
Cortisol Deviation D4 Q3	-.35	(.21)	2.95	.47	.47	1.05
Cortisol Deviation D4 Q4	.12	(.25)	.21	1.12	.69	1.84
Constant	-15.03	(18.39)	.69	.00		

R^2 = .66 (Hosmer & Lemeshow), .31 (Cox & Snell), .47 (Nagelkerke).
Model χ^2 (13) =21.11, ρ = .07

Note: [1] Gender reference category is Female, [2] Education reference category is left school at ≥ 15 years, AUC is person-average area under the curve cortisol across days, CAR is person-average cortisol awakening response across days, *i*SD is person-average intra-individual standard deviation cortisol across days, AUC Day 3 & 4 is area under the curve cortisol that day, CAR Day 3& 4 is cortisol awakening response that day, *i*SD Day 3 & 4 is intra-individual standard deviation cortisol that day, Cortisol Deviation is deviation in cortisol level from person-average for that measurement occasion. Standard Errors are shown in parentheses. * $\rho < .05$, ** $\rho < .01$, *** $\rho < .001$,

5.9 Discussion

The primary aim of this study was to examine the relationship between prospective memory and daily stress processes in oldest-old adults. Prospective memory tasks were classified according to the characteristics of the task, namely as either event-based or time-based tasks. The event-based tasks were differentiated according to the nature of the target cue signal as either focal (double circle a capitalised question) to the on-going task or non-focal (initial box at bottom of page). It was argued that focally cued targets would elicit spontaneous retrieval processes due to association and detectability of the target cue with the intended action. Non-focal cues on the other hand, would require higher levels of cognitive processing directed toward cue monitoring and be more demanding of limited attentional resources, as would be the case for the time-based prospective memory task. It was postulated that higher stress levels would be associated with impaired performance on all of the prospective memory tasks administered in this study. Moreover, higher stress levels were proposed to exert a larger effect on prospective memory tasks more demanding of attentional resources, that is non-focally cued event-based tasks and the time-based prospective memory task.

In summary, the results demonstrated that individual variability in stress levels and co-occurrence of stress at task execution did not predict performance on either focal or non-focal event-based prospective memory and concurs with findings recently reported by Walser et al. (2013). An elevated CAR was associated with reduced performance on the focal tasks but this effect was small. There was evidence for a small effect of stress on time-based prospective memory performance. Embedded within the data are several substantive findings with

respect to ageing and diurnal cortisol profiles. These will be discussed prior to considering the theoretical implications arising from analyses of the research questions proposed in this study.

Cortisol bio-markers indicated that the distinct diurnal cortisol profile of early morning increase in concentration followed by the peak awakening response and gradual flattening in secretion during the day was well maintained in the study participants. Intra-individual differences in the CAR were quite stable with daily measures positively correlated. Moreover, mean cortisol concentrations were comparable to those obtained in earlier studies with young-old adults (Wrosch, Miller, & Schultz, 2009). As such this study provides valuable additional normative data of cortisol secretion in very advanced older age obtained within naturalistic environments and over a substantial time period. However the data has returned unexpected and equivocal findings in relation to the effect of stress on cognition. The following section will consider the results in respect to both event- and time-based prospective memory and propose explanatory mechanisms for the current findings.

The CAR and education emerged as significant predictors of focally cued event-based prospective memory. The CAR is distinct from the circadian rise in HPA activity during the early hours of the morning and reflects psychobiological processes associated with the transition between sleep and waking (Wilhelm et al., 2007). The CAR is also considered a reliable indicator and measure of the reactivity of the HPA axis and function (Hellhammer et al., 2007). However the role of the CAR remains contentious and elevated cortisol and heightened CAR early in the day has been linked to different mechanisms and outcomes. Research has shown a blunted CAR to be indicative of chronic fatigue, burn-out (Pruessner

et al., 2003), and post-awakening sleepiness. In contrast, elevated CAR's have been related to cardiovascular pathology and other illness (McEwen et al., 1998; Girod & Brotman, 2004) and to be predictive of depression. For example, Steptoe et al. (2007) found the CAR to be elevated in less happy individuals, consistent with a protective effect of lower neuroendocrine dysregulation in pathology. In addition higher CAR's are associated with chronic stress (Adam, Hawkley, Kudielka, & Cacioppo, 2006), job stress (Chida & Steptoe, 2009), and in anticipation of the demands of the forthcoming day. Within-person differences have been reported with higher CAR measures recorded on weekdays compared to weekends (Hellhammer et al., 2007; Kunz-Ebrecht, Kirschbaum, & Steptoe, 2004; Schlotz, Hellhammer, Schulz, & Stone, 2004; Smyth et al., 1998), and in ballroom dancers measured on competition days compared to non-competition days (Rohleder et al., 2007). Thus the empirical evidence suggests day-to-day variation in the CAR and diurnal cortisol profiles reflects changing secretion levels in response to daily situational factors, including daily demands and stress. Additionally, older adults have generally been shown to have an attenuated CAR in comparison to younger adults. It was predicted therefore that participants experiencing a higher CAR in comparison to their average, would display prospective memory decrements due to the adverse effects of cortisol associated with cognitive functioning as discussed in Chapter 4. It was further predicted that the effects would be larger for non-focally cued compared with focally cued event-based tasks. The current results lend some support to this prediction but not in the direction hypothesised.

A higher CAR and thereby a higher diurnal cortisol profile lend support to the assumption of stress-induced depletion of higher-order cognitive processes

involved in more complex prospective memory tasks. The focal nature of the cue in the ‘double circle the capitalised question’ task was predicted to support spontaneous retrieval of the intended action-target cue association and thereby require less allocation of cognitive resources. This is in comparison to predicted allocation of resources directed toward environmental monitoring for the non-focally cued tasks. As such the focally cued event-based prospective memory tasks were theorised to be less sensitive to the deleterious effects of stress in comparison to the non-focally cued tasks. However as exemplified by the attention deficit hypothesis, the dual-task nature (Marsh, Hicks, & Cook, 2005; Smith, 2003), of the focal item could arguably divide attention between the on-going and prospective memory question, necessitating switching of mental sets and inhibition of pre-potent responses. On the other hand, the non-focal task, once detected, represented a single-item task, well habituated to and practised across the life-span (initialling a box). It is therefore possible that higher cortisol concentration associated with a larger CAR and higher diurnal profile may have reduced performance on the more complex focal event-based task. In consideration of the small effect size and lack of significant association with additional cortisol indices, this explanation is speculative. The findings do however provide an initial grounding for future research to examine stress-induced depletion of higher level cognition in relation to dual-task and complex prospective memory paradigms.

Results indicated that education was predictive of better performance on focal event-based prospective memory but was not associated with non-focal performance. This concurs with findings from previous research in which higher levels of education were related to prospective memory performance (Cherry &

Le Compte, 1999; Crawford et al., 2000). Higher IQ has also been found to be related to higher executive functioning, posing a feasible explanation for the current results. Although the current study did not measure global intelligence, it could be extrapolated that higher levels of education could reflect higher general intelligence and better executive functioning. Executive functioning is a multi-dimensional construct attributed with attentional control, switching and inhibition. As such executive functioning supports prospective memory processes and would be integral to successful completion of the focal task, facilitating allocation of attentional control involved in switching between on-going and prospective tasks and inhibiting pre-potent responses. The association between executive function and prospective memory will be examined in Study 2, controlling for the effect of education. Thus while there was some indication of small effects related to the CAR and education in predicting performance, overall performance on the event-based tasks was unrelated to the majority of physiological indices of stress incorporated in this study.

Non-focal prospective memory performance was notably unaffected by any of the biological indices of stress after controlling for the covariate predictors of interest. This provides support for the Walser et al. (2013) study in which laboratory-based stress induction resulted in no observable decrements in time-based or event-based prospective memory performance. As previously discussed a likely explanation lies in the nature of the non-focal task. As single and arguably simple tasks, the non-focal prospective memory items may not have been sufficiently sensitive to stress induced depletion of cognitive resources for significant effects to emerge.

In contrast to the results obtained for non-focal event-based tasks, decrements in time-based prospective memory performance were related to higher levels of cortisol concentration during the opportunity for task execution, and to the presence of higher depressive symptoms. Major depression has not only been associated with increased cortisol levels but has also been shown to affect cognition in late life (Het et al., 2005; Li et al., 2006; Mitchell, 1995; Thomas & O'Brien, 2008). Gomez et al. (2009) examined diurnal cortisol profiles, verbal memory and executive function in participants with diagnosed major depression (n = 37) and healthy controls (n = 18). They found increased cortisol significantly reduced verbal memory performance in both groups, and was correlated with executive function (r = -.48, ρ < .05) in the healthy controls. Another study found that among 62 younger adults (M = 25.07 years, SD = 4.12), those who responded to a sad mood induction had significantly poorer prospective memory performance compared with non-responders to the mood induction and those in a neutral mood control group (Kliegel et al., 2005). Moreover, reduced clock monitoring and prospective task response times were evident in the sad mood group. The authors concluded that intrusive thoughts associated with negative emotional states reduce processing resources available to cognitive tasks and also affect forward planning processes. Such studies corroborate the link shown in the current data between depressive symptoms and performance deficits on the time-based prospective task. This finding is of particular interest, given the low overall incidence of depressive symptoms reported by participants. An elevation of depressive symptoms below a clinical threshold was associated with poorer performance, indicating that major depression was not requisite for an effect to be observed on demanding cognitive processes in adults of advanced older age.

In comparison to event-based prospective memory, it was predicted that time-based intended actions would be more demanding of strategic self-initiated monitoring and more sensitive to the adverse effects of stress. This was supported by the current data with increased cortisol concentrations on the morning of task execution associated with a 48% reduction in the likelihood of participants calling their research assistant. The current findings therefore challenge the findings of Nater et al. (2006) with reported improvement in time-based performance following laboratory-based stress induction. However it is possible the improvement in the Nater study was not due to stress induced decrements in cognitive processing but to a shift in processing strategy. Participants increased the number of optional clock checks when under stress in the time-based prospective memory condition thereby facilitating better time monitoring. The current results provide initial support for co-occurring stress related decrements in time-based prospective memory performance.

Despite the foregoing results, overall the study's findings did not point to stress associated pathways in prospective memory performance in oldest-old adults. This is in accord with the recent work of Walser and colleagues (2013). In their laboratory-based investigation with younger adults, stress-related increases in salivary cortisol were induced in order to assess HPA axis reactivity. Prospective memory performance in terms of accuracy and response times was unaffected under acute stress activation. In the present study, basal cortisol levels (AUC) and intra-individual lability (iSD) failed to show consistent associations with proficiency. Although some significant effects were obtained on some select measures, the overall findings could be explained by insufficient statistical power due to the relatively small sample size. This was off-set however by the study's

repeated measures design with a relatively large number of event-based prospective memory time-point measurements. As previously alluded to, this is not applicable to the single time-based task. Of the few studies that have investigated the relationship between prospective memory and stress, the evidence to date suggests that this memory process is well-preserved even under states of stress and physiological arousal.

A plausible explanation for the present findings emerges from biological models of ageing and stress processes that propose reduced, rather than heightened (Seeman et al., 2001; Simpson et al., 2007), reactivity to stress and emotion through normative age-related dysregulation of the HPA axis. Although cortisol levels have been associated with stress in numerous studies (Kendler et al., 2001; Sliwinski, 2009; Stawski, Mogle, & Sliwinski, 2011) the lack of supporting evidence in the current study could reflect this model. For instance, a study investigating stress, affect and social networks in a sample of 48 older adults (mean age = 74.4, SD = 5.8) found that stressful events, daily hassles and life event history were not associated with cortisol levels (Ice, 2005). This concurs with findings from Nicholson et al. (1997) who found no relationship between current stress, past life stress, or diurnal levels of cortisol secretion in older adults. Reduced physiological reactivity to negative events associated with biological ageing has also been reported (Panksepp & Miller, 1996). Indeed participants in the current study represented a select group of relatively healthy adults prospering longer than the average life expectancy. It follows that reduced physiological and age-driven reactivity to stressors may be characteristic of older ‘survivors’ in such a select sample, thereby obscuring effects that may be evident in younger-old adults or in a wider sample of oldest-old adults.

Further, the associations reported between acute stress and cortisol, have predominantly been found in laboratory based studies rather than naturalistic based studies. Induced stress in laboratory studies may affect neuroendocrine reactivity through 1) increasing participant stress simply by being in a 'testing' situation, and 2) the induced stressors being perceived as novel. In naturalistic settings, older adults are exposed to similar stressors and daily hassles over time, the habituation to which may reduce overall reactivity and hence cortisol response. Flattening of the HPA axis may therefore partially explain the current findings with stress not impinging sufficiently on the cognitive resources and attentional control processes required for successful prospective memory outcomes.

The current data however shows intra-individual fluctuations and inter-individual differences in cortisol concentration levels across the week which could arguably co-occur with a physiological response to either biological or psychosocial stress. Given this is the case, and in view of the relationship between reduced cognitive function and cortisol concentrations discussed in Chapter 4, stress processes may not have emerged as significant predictors of prospective memory function due to increased resilience and reduced emotional reactivity to stress (Carstensen et al.,1999; Charles, 2010). Contrary to the prediction of increased age-related reactivity to stress, older adults in the current study may have had the capacity to re-appraise their subjective perception of stress in spite of any physiological arousal. This is consistent with the Socioemotional Selectivity Theory (SST: Carstensen et. al., 1999) and the life-course developmental model of Selective Optimization with Compensation developed by Baltes and Baltes (SOC: 1990). SST theory contends older adults become more flexible, insightful and

skilled in adjusting to their unmet needs, in dealing with their feelings, and in prioritizing goals. The SOC model furthers the SST, recognising physiological ageing is associated with reduced flexibility and increased vulnerability brought about by changes in social, cognitive and biological function. Despite these unavoidable changes, the tenets of the model suggest older adults allocate functional resources and optimize behaviours in pursuit of realistic and salient goals. Compensatory behaviours and activities are employed if goals cannot be realised. Thus, participants may have regulated their subjective response and appraisal to events or situations, even if experiencing physiological stress and heightened cortisol secretion. As suggested by SST, older adults cope with stress and emotional experiences by reducing negative reactivity through practice, experience, and self-knowledge accumulated over the life-span. Re-appraisal of situations and events, implementation of adaptive behaviours, and strategic attention provide older adults with strength in overcoming increased vulnerabilities associated with age and compromised physiological function. In addition, the older adults participating in the current study were a select sample of higher functioning oldest-old adults who through experience and self-knowledge may have attained an enhanced ability to attenuate emotional negativity and reactivity to daily hassles.

Alternatively, the lack of evidence for stress processes impacting upon prospective memory could be due to participants being proficient at reducing their exposure to potentially stressful and negative situations and experiences. Such reduced exposure to daily stress could also result from physical and health constraints limiting the opportunity for exposure to stressful events. Thus the current findings may emanate from either participants reducing their exposure to

daily stressors or regulating their subjective response and appraisal to events or situations even if experiencing physiological stress and heightened cortisol secretion. As momentary self-reported stressors and appraisals were not measured in this study, these explanations cannot be tested, but propose an interesting avenue for further research into stress processes in the oldest-old.

5.9.1 Limitations and future directions. There are limitations to this study that need to be considered in the interpretation of results and to inform future research. The first concerns the nature and complexity of the prospective memory tasks. The tasks may have had insufficient complexity to require demanding monitoring and processing, especially the non-focal 'initial box' task. More complex tasks necessitating higher levels of recruitment of prefrontal attentional control processes may be more sensitive to stress induced cognitive depletion. Incorporation of complex prospective tasks needing higher levels of maintenance between the intended action-target cue association, and more non-salient non-focal target cues could better delineate the effect of acute stress on proficiency. Dual-tasks and tasks necessitating greater inhibitory processing may also contribute to this end. In addition there was some evidence of improvement in performance for all tasks across the study, argued to result from habituation or practice effects. The inclusion of non-regular tasks and a higher number of time-based tasks may attenuate such concerns and thereby enhance reliability of the current results.

The second area of concern relates to the compliance of participants in collection of salivary cortisol samples, especially with respect to the measurement and calculation of the CAR and therefore the diurnal cortisol slope. Accurate assessment of the CAR depends upon there being no delay between wake-time

and collection of the first saliva sample, otherwise the CAR can appear blunted (Kunz-Ebrecht et al., 2004). In the current study it has been assumed the first saliva sample was collected immediately upon awakening but it is difficult to know if participants complied with the protocol. Inadvertent delays could have occurred between wake-time, saliva collection, and stamping of the first morning questionnaire. For instance participants may have lain in bed for a period after waking, visited the bathroom prior to questionnaire retrieval and completion, or may have been slow 'getting going'. To allow for comparison of actual wake-up time with saliva collection time, 'smart-cap' salivettes that record the time of opening, combined with objective measures of actual wake-time (e.g., via wrist actigraphy) could be incorporated into future studies.

Third, in the current study it is difficult to delineate the processes responsible for elevated cortisol concentrations. Elevated cortisol may have been related to psychosocial stress processes or have reflected intra-individual fluctuations in biological processes. Although the study was designed to control for as many biological confounds, all of which were controlled for in analyses, self-report of the experience of stress co-occurring at the time of questionnaire completion or short-term retrospective report (i.e., stress or hassles experienced within the last hour) would aid in validating results. Inclusion of such measures would support the utility of using ecological momentary assessment (EMA) to examine within person momentary subjective stress co-varying with physiological arousal and function. Future research directed at replication of the current study, in conjunction with laboratory-based experimental paradigms assessing stress and prospective memory in the oldest-old will better clarify the relations between the constructs employed in this study.

Additionally, the present study was limited to a select sample of generally healthy older adults. Generalising results to the wider population of oldest-old adults is therefore problematic. In particular, research has shown age-related benefits in affective well-being are associated with those in good health, defined as fewer than four health conditions. In comparison, older adults with four or more health complaints displayed decreased affective well-being, and increased reactivity to stressors comparable to younger adults (Piazza, Charles, & Almeida, 2007). It follows that older adults in poorer health may be more susceptible to stress induced depletion of cognitive resources. This prediction awaits future research with testing conducted using more diverse population samples, and would necessitate re-structuring of the current study protocol to reduce burden accompanying a seven-day study on less able and healthy participants.

5.10 Conclusion

The present study contributes to the growing body of research elucidating HPA activity and cortisol profiles across the life-span and has established that the normative diurnal profile is well-maintained into advanced older age. Being conducted in naturalistic environments, the ADuLTS time-burst study has ecological validity and adds a valuable perspective to data collected within the umbrella of the ALSA. Studies such as the ADuLTS, allow for multiple time trajectories to be examined, complimenting and extending cross-sectional research and presenting future research capacity for reciprocal benefits between longitudinal and time-burst data. The major contribution of the current study has been to examine the association between stress processes and prospective memory performance for the first time in the oldest-old. The study provides new insight into age, bio-psycho-social stress and reactivity of the HPA axis in the context of

cognition and day-to-day prospective memory function. Overall, the study provided weak evidence for an association between concurrent stress and reductions in time-based prospective memory. However stress did not appear to attenuate proficiency on less demanding event-based prospective memory. Increased capacity in older age to re-appraise stressors and emotional reactivity to stress in spite of physiological arousal may contribute to preserved function in this vital memory domain.

Chapter 6

Study 3: The association of executive function, working memory, and retrospective memory with prospective memory in the fourth age.

6. Overview

Study 3 examines the role of cognitive processes in prospective memory in oldest-old adults. The study will present evidence from the ADuLTS study in determining the effect of executive function, working memory, and retrospective memory on prospective memory performance in oldest-old adults. Testing hypotheses derived from the Multiprocess Framework, the effect of the three cognitive predictors on prospective memory will be examined in terms of task characteristics and cue focality.

6.1 Introduction

Individual differences in cognitive function and age-related change in various domains of cognition have informed a substantial body of research. As reviewed in Chapter 4, executive function, working memory, and retrospective memory are cognitive constructs, each with an influential role in supporting prospective memory processes. The age-prospective memory paradox introduced in Chapter 2, captures the complexity of prospective memory processes and highlights the equivocal findings reported in age-related effects associated with this construct. Individual differences in cognitive processes may well serve as explanatory factors in the prospective memory paradox. Whilst research has addressed the relationships between executive function, working memory, and retrospective memory in prospective memory proficiency, very few studies to date have considered this with respect to oldest-old adults in real world settings. The major focus of Study 3 is to determine the effect of the level of controlled

attentional processes, namely executive function and working memory capacity, and to a lesser extent, retrospective memory on prospective memory performance. Each construct will be briefly reviewed in relationship to prospective memory and the rationale and hypotheses for Study 3 presented.

6.2 Rationale for Study 3.

6.2.1 Executive function. Executive function is a complex, multi-dimensional process, fundamental to optimal cognition, memory and functional status (Lezak et al., 2012) and is responsible for the integration, regulation and co-ordination of higher order cognitive processes (Daniels, Toth, & Jacoby, 2006; Luszcz, 2011). Although distinguished as either a unitary control process or as an interaction of multiple sub-processes, executive function is broadly subsumed under three sub-processes, inhibition, shifting, and updating (Friedman & Miyake, 2004). Inhibition refers to the ability to control interference from task-irrelevant stimuli. Shifting is the ability to shift attentional control between different tasks or mental sets in response to changing situational demand, with updating involved in the moment to moment monitoring and updating of working memory representations. Although conceptualized as multi-dimensional, demand on any one sub-process is theorized to reduce attentional and cognitive resources available to the other sub-processes (Friedman & Miyake, 2004). As such, executive control processes can be viewed as partially interdependent but unitary in concept, sharing a common functionality (Blair, 2006; Luszcz, 2011; Shallice & Burgess, 1993).

Executive function exhibits robust age-related decline with normative ageing (Luszcz & Bryan, 1999) thought to accompany changes in the neurological integrity of brain regions associated with the ageing process (Crawford, Bryan,

Luszcz, Obonsawin, & Stewart, 2000; Luszcz & Bryan, 1999). This is exemplified by the frontal-executive hypothesis of cognitive ageing (West, 1996) whereby the frontal cortex region is assumed to support executive function processes. Evidence supporting this viewpoint stems from imaging studies in which neurological control of executive function processes has been located primarily in the prefrontal cortex region of the brain (Alvarez & Emory, 2006; Phillips & Della Sala, 1998). Neurophysiological studies citing structural atrophy and reduced white matter density (Charlton et al., 2010; Head, Rodrigue, Kennedy, & Raz, 2008; Raz 2005), and compromised neurotransmitter integrity with age (Salat, Kaye, & Janowsky, 2002) augment support. Evidence from clinical studies also provides convergent evidence for executive function deficits to present with prefrontal morbidity and structural change (Damasio, Anderson, & Tranel, 2011; Davidson et al., 2008; Henry & Crawford, 2004, 2004b, 2006; Rainville et al., 2002).

Executive function decline with age has therefore been well documented in the literature. Behavioural studies indicate older adults are compromised on tests sensitive to executive function in comparison to younger adults (Luszcz & Lane, 2008). In addition, executive function has been shown to mediate age effects on tests of episodic memory and strategic retrieval (Bryan & Luszcz, 2000; Crawford et al., 2000). Given this substantial body of evidence, it is feasible that executive function decline may predict prospective memory performance in older age with age-related effects dependent on the degree of frontal recruitment required of the task. However, the association between these two constructs has not always yielded definitive results with some early studies finding no relationship between the two processes (Bisiacchi, 1996; Mi et al., 2000). In

contrast, other laboratory based investigations have produced consistent evidence for executive function support of prospective memory processes with respect to older adults (Glisky, 1996; Martin, Kliegel and McDaniel, 2003; McDaniel et al., 1999; Salthouse, Berish, & Siedlecki, 2004). Neurophysiological studies have contributed converging findings, showing activation of prefrontal regions during prospective memory tasks consistent with recruitment of executive function processes supporting prospective memory (Burgess et al., 2008; Burgess, Qualye, & Frith, 2001; Martin et al., 2007; Okuda et al., 1998; Simons et al., 2006; Uretzky & Gilboa, 2010).

Executive function is therefore implicated in prospective memory performance. However, a central feature of executive control is the dissociation between controlled and automatic processing under differing demand conditions. As discussed in Chapter 3, the dual-process theory (Shriffrin & Schneider, 1977) defines controlled processing as the active control of attentional processes, during which the prefrontal cortex is activated (Liebermann, Jarcho, & Sapute, 2004). This is arguably analogous to executive function. Automatic processing on the other hand is involuntary, reflexive processing with unlimited capacity supported by sub-cortical regions (Liebermann et al., 2004). Automatic processing is largely spared in biological ageing, considered to reflect declines in inhibitory and controlled processing ability associated with executive function decline (Braver and Barch, 2002). Thus, older adults with executive function deficits could show differential performance on cognitive tasks demanding either automatic or controlled processing.

The Multiprocess Framework (McDaniel & Einstein, 2000) differentiates prospective memory processes in terms of task and cue characteristics. Time-

based tasks require greater self-initiated strategic monitoring of time intervals and are more demanding of cognitive resource allocation through controlled processing than event-based tasks. Performance on event-based prospective tasks has been associated with the characteristics of the target cue, with non-focal cues requiring greater resource allocation and controlled processing compared to focal cues. The Multiprocess Framework would therefore predict older adults with poorer executive functioning to show poorer performance on demanding prospective memory tasks compared to those with better preserved executive function.

Confirmatory findings for this theoretical viewpoint have been recently reported. Schnitzspahn et al., (2013) examined the effect of controlled attention on non-focal event-based prospective memory using measures capturing three factors of executive function, shifting (a semantic category-switch task and colour-shape task), updating (keep-track task and letter-memory task) and inhibition (antisaccade task and Simon task). In addition, working memory and speed of cognitive processing were assessed as control variables. Participants were 285 younger (mean age = 23.16, range = 18-39 years) and older adults (mean age = 66, range = 57-77 years). The study provided clear evidence for mediation of prospective memory by two factors of executive function, namely switching and inhibition, across adulthood, both of which were also predictive of age-related effects in performance. Updating and working memory did not predict prospective memory performance in this study.

Complimentary to this study, a recent meta-analysis investigated the effect of task order specificity on age-related effects across the prospective memory literature (Ihle et al., 2013). Studies involving 5,590 younger (M = 26.4 years) and

older (*M* = 71.4 years) participants revealed a main effect for cue type with greater age-effects in tasks with non-focal target cues compared with focal target cues. Age-effects were also more prominent for prospective memory tasks in which the task order was specified during the experimental protocol. Specified task order places increased demand on cognitive control processes associated with task switching and inhibition of performance in line with task instruction upon cue detection. The authors concluded that cue focality and response management are independent moderators of age-effects in prospective memory tasks. Age-effects are therefore more prominent for non-focal target cues requiring greater strategic environmental monitoring and allocation of cognitive resource compared with focal target cues (Rendell et al., 2007).

Functional evidence for the neural correlates of cue focality has also been provided in two recent studies. Gordon et al. (2011) determined focal prospective memory performance to be positively correlated with the volume of the medial temporal regions, in particular the hippocampus, regions supporting automatic retrieval processes. Interestingly there was no such correlation evident for non-focal prospective memory performance. This line of research was furthered by Cona, Bisiacchi, and Moscovitch (2013) who examined event-related potential (ERP's) concomitant with focal and non-focal prospective memory. Twenty-four participants (*M* = 22.83, range = 19-30 years) were tested over 3 conditions (baseline, focal prospective memory tasks, non-focal prospective memory tasks) using a lexical decision paradigm as the ongoing activity. Response times were slowed in both prospective memory conditions in comparison to baseline but more so for the non-focal condition, verifying a prospective memory interference effect (Marsh et al., 2002). Importantly, the amplitude of the frontal and parietal

ERP modulations were influenced by cue focality with greater amplitude evident in the non-focal trials, reflecting recruitment of preparatory resources required for monitoring of non-focal cues. The frontal FN400, argued to be associated with automatic memory and familiarity recognition, displayed higher amplitude in the focal trials, suggesting more automatic recognition and retrieval of focal target cues.

Drawing from the Multiprocess Framework and the evidence accumulated to date, it is apparent that adults with low executive functioning show poorer performance on more demanding prospective memory tasks requiring controlled and strategic cognitive processing, namely time-based tasks and non-focal event-based tasks. It is predicted similar effects would be apparent in oldest-old adults. Using data from the ADuLTS study, the current study will investigate the effect of executive function on prospective memory under differing demand conditions. Executive function resources in the context of a prospective memory task will be examined from an individual differences approach as used by Schnitzspahn et al. (2013), rather than directly manipulating executive function load.

Closely related to executive function is the concept of working memory. The effect of working memory on prospective memory performance has been widely investigated during the last three decades, again with few studies applicable to the oldest-old. Whilst most commentators acknowledge shared components between executive function and working memory processes, there is sufficient evidence to suggest they are partly dissociable. As such the current study has been designed to capture the effects of both executive function and working memory as related but independent, predictors in prospective memory.

6.2.2 Working memory. Working memory is a limited capacity system responsible for the manipulation and maintenance of information, and provides an interface between short-term memory storage and long-term memory (Baddeley, 2003). Working memory is characterised as a dynamic construct related to higher level cognition and executive and attentional processes, including general fluid intelligence, episodic memory and attentional capacity (Colom et al., 2004; Kane & Engel, 2000, 2004). Thus, working memory is fundamental to memory, controlled attention, and to moment to moment monitoring and updating of ongoing activities. Prospective memory performance depends upon activation and recognition of a relevant cue at the appropriate time to enable retrieval of an intended action from long-term memory. Working memory is therefore implicated in the strategic monitoring required in time-, and some event-based, prospective memory tasks.

As is the case with executive function processes, working memory is sensitive to age-related changes and exhibits well documented decline with advancing age. Age-effects have been attributed to reduced speed of perceptual processing accompanying ageing (Salthouse, 1996), and to older adults having lower ability to inhibit irrelevant information (Hasher & Zacks, 1988). Anatomical studies suggest age-related declines in structural (Raz, 2005) and functional integrity (Baddeley, Eysenck, & Anderson; 2009) of the prefrontal region are implicated in reduced working memory efficiency. This is verified in neuroimaging studies confirming recruitment of a network of prefrontal cortex and parietal regions of the brain during working memory tasks (Bopp & Verhaeghen, 2005; Braver & Bongiolatti, 2002; Cabeza & Nyberg, 2000; Dolan et al., 1997; Henon, 2001; Paulesu, Frith, & Frackowiak, 1993; West, 1996; Zeintl &

Kliegel, 2007). In addition, the prefrontal cortex is recruited in working memory tasks involving attentional control, strategy selection, inhibition of irrelevant stimuli and interference, and manipulation of information (Conway et al., 2003). The literature substantiates working memory declines to be consistent with the frontal-executive hypothesis of cognitive ageing (West, 1996).

Given successful prospective memory depends upon an intended action being active in working memory during the window for task execution, it follows that working memory capacity and attentional control support proficiency in this memory process. The association between working memory and prospective memory however, remains contentious. Numerous studies have failed to find evidence of working memory mediating age-effects in prospective memory proficiency (Einstein et al., 2000, Experiment 3; Einstein et al., 1997; Kliegel & Jäger, 2006; Marsh & Hicks, 1998; Schnitzspahn et al., 2013; West & Craik, 2001). In particular, some early dual-task studies showed inconclusive results of the effect of working memory demand on prospective memory performance suggesting working memory load was not associated with poorer performance (Einstein et al., 1995; Otani et al., 1997). Marsh & Hicks (1998) looked at the role of working memory in prospective memory by manipulating the type and demand of secondary tasks. They found prospective memory deficits were prominent with tasks recruiting executive function processes of planning and monitoring but not with working memory tasks occupying the phonological loop, a sub-system of working memory.

Challenging these results are studies clearly delineating working memory support in prospective memory processes (Cherry & Le Compte, 1999; Einstein et al., 2000; Logie et al., 2004; Reynolds, West and Braver, 2009; Smith, 2003).

Logie and colleagues (2004) examined the effect of working memory on prospective memory. Participants were 40 young and 40 older adults tested on a high and low demand arithmetic task, both alone and in combination with event- and time-based tasks. Retrospective memory was also assessed using three tests, namely, forward digit span, last-word sentence span, and verbal free recall. Older adults were less successful than the younger participants in the high demand working memory condition and displayed slower responding times. This was interpreted as being indicative of reduced working memory efficiency. In another study, Kidder et al. (1997) compared the performance of 90 young (mean age = 19.6 years, SD = 2.1) and 80 older (mean age = 70.9 years, SD = 6.2) on prospective memory tasks in which task load and working memory demand were manipulated. Decrements in performance were associated with higher engagement and load in the on-going working memory task for both age groups but poorer performance was evident for the older adults.

As presented in Chapter 3, there is mounting evidence for working memory involvement in prospective memory with differential effects depending on the demands of an on-going task. Prospective memory tasks combined with on-going activities typically show slowed response times (Marsh et al., 2003; Smith, 2003; Smith & Bayen, 2004a) due to allocation of working memory resources away from the ongoing task toward environmental monitoring for the prospective target event and cue. West, Bowry, and Krompinger (2006) found that demanding working memory load and tasks presented during the opportunity for noticing a target cue were associated with reduced detection of prospective memory target cues. Such studies provide confirmatory evidence for working memory support in prospective memory processes and posit a case for working

memory demand associated with the prospective task to affect overall performance.

Consistent with the Multiprocess Framework of prospective memory McDaniel& Einstein, 2000) the degree of automatic or controlled processing allocated to environmental monitoring for prospective events and target cues is dependent upon the task context, cue characteristics and individual differences. As such it is predicted that higher levels of working memory would facilitate allocation of attentional resources required for successful performance on more demanding prospective memory tasks, namely time-based and non-focal event-based tasks. In comparison, lower levels of working memory would be associated with detrimental effects on performance for demanding prospective memory tasks. As for executive function, working memory resources will be assessed in the context of prospective memory performance using an individual differences approach.

6.2.3 Retrospective memory. Retrospective memory is a neurocognitive process intimately associated with successful prospective memory performance. As a form of episodic declarative memory, retrospective memory is memory for past events and experiences, usually personal in nature with temporal reference (Tulving, 1972). Chapter 2 presented evidence indicating that although retrospective memory is an integral component of prospective memory, the two processes are partially dissociable constructs (Raskin et al., 2011; Salthouse, 2004; Zeintl, Kliegel, & Hofer, 2007). Using factor analysis, Maylor and colleagues (2002) found retrospective and prospective memory to be separate constructs, and weak associations between the two constructs have also been reported (Maylor et al., 2002). Be this as it may, remembering the ‘what’ and

'where' of an intended future action is paramount to successful retrieval and performance of the action.

Effortful retrospective memory, as in recall from long-term memory, is sensitive to age-related decline (Craik, 1986; Lin & Craik, 2009). This being the case, it could be argued that advanced age would be associated with more retrospective failures in prospective memory processing. However, a review of the literature has revealed inconclusive outcomes. Henry et al., (2004) found larger age-related impairment in the retrospective memory component of tasks in comparison to the prospective component. This concurs with results reported by Kidder and colleagues (1997) who examined retrospective task load and working memory demand on prospective memory performance. Increased retrospective memory load differentially affected performance with older adults having more difficulty with prospective memory tasks with more event-based cues to remember. However, diverging results have been shown in studies reporting fewer age-related deficits associated with retrospective memory compared to prospective memory (Cohen et al., 2003; Cohen, West & Craik, 2001). Indeed, several studies suggest that retrospective memory is not a significant predictor of prospective memory performance in adulthood (Kliegel, MacKinlay, & Jäger, 2008; McDaniel & Einstein, 2007; Zimmermann & Meier, 2006).

Retrospective memory has therefore been incorporated into the current study design to ascertain if spared ability in this memory domain is predictive of successful prospective memory outcomes. Although a substantial body of the empirical evidence to date suggests that retrospective memory is a component of the prospective memory process it does not appear to a major determinant in successful performance. However, given the age of the cohort participating in the

ADuLTS study, it is feasible that age –related decline in retrospective memory ability may be more evident in this age group and any negative impact upon retrieval of the content of the prospective tasks more pronounced. Currently, few studies have examined the role of retrospective memory in prospective memory in the oldest-old. This being the case, the current study has been designed to assess if those with poorer retrospective memory are less likely to successfully complete the prospective memory measures for both event-based and time-based tasks. The degree of automatic or controlled processing allocated to retrieval of the intended action may also be dependent upon the task demand and cue characteristics (Mäntylä, 1994). As such it is predicted that higher levels of retrospective memory would be required for successful retrieval of the time-based and non-focal event-based tasks in comparison to focal event-based tasks with differential effects on performance. The effect of individual differences in retrospective memory resources upon prospective memory performance will be examined (Kliegel, MacKinlay, & Jäger, 2008), in comparison to studies which have directly manipulated retrospective task load (Kidder et al., 1997; Mäntylä, 1994; Zimmermann & Meier, 2006).

6.3 Summary.

The Multiprocess Framework (McDaniel & Einstein, 2000) provides a conceptual model for predicting age-related effects in prospective memory in which the degree of controlled attentional processes required to successfully retrieve an intended action depends on multiple factors. These include the nature of the task, target cue characteristics, difficulty of the ongoing task, and individual differences. Empirical evidence has shown age-related effects are greater with prospective memory tasks requiring strategic and controlled attentional processes

(Henry et al., 2004; Kliegel et al., 2008). This study has been designed to examine controlled attentional processes and retrospective memory in prospective memory performance, across tasks differentiated by task type and cue characteristics. Specifically, the effect of working memory and executive function on prospective memory will be assessed in order to disentangle the influence of different factors of controlled attention on performance. The current study offers a unique opportunity to further the recent work of Schnitzspahn and colleagues (2013) in examining facets of controlled attentional processing in focal and non-focal event-based, and in time-based, prospective memory. Moreover, the study extends the current literature in exploring the constructs of interest in a sample of oldest-old adults.

6.4 Aim of Study 3

The major aim of the current study is to examine prospective memory performance in a sample of oldest-old adults, and to test the influence of controlled attentional processes in the form of executive function and working memory, on prospective memory performance in terms of cue type and task characteristics. As in Studies 1 and 2, prospective memory cue type will be defined as either time-based or event-based. Event-based target cues will be defined as either focal or non-focal, to elucidate the effects of the cognitive predictors on prospective memory under contrasting strategic demand and task characteristics. The second aim of Study 3 is to examine the effect of retrospective memory ability on prospective memory proficiency.

6.5 Hypotheses for Study 3

The following research questions are proposed for Study 3. It is hypothesised that:

1. There will be an effect of executive function on prospective memory performance such that,
    - 1.1 Older adults with lower levels of executive function will show greater deficits on event-based prospective memory tasks compared to those with higher levels of executive function.
    - 1.2 The effect of lower levels of executive function on prospective memory will be greater for non-focal event-based tasks compared to focal event-based tasks.
    - 1.3 Older adults with lower levels of executive function will show greater deficits on time-based prospective memory tasks compared to those with higher levels of executive function.
2. There will be an effect of working memory on prospective memory performance such that,
    - 2.1 Older adults with lower levels of working memory will show greater deficits on event-based prospective memory task compared to those with higher levels of working memory.
    - 2.2 The effect of lower levels of working memory on prospective memory will be greater for non-focal event-based tasks compared to focal event-based tasks.
    - 2.3 Older adults with lower levels of working memory will show greater deficits on time-based prospective memory tasks compared to those with higher levels of working memory.

3. There will be an effect of age-related declines in retrospective memory on prospective memory performance such that,
    - 3.1 Older adults with lower levels of retrospective memory will show greater deficits on event-based prospective memory task compared to those with higher levels of retrospective memory.
    - 3.2 The effect of lower levels of retrospective memory on prospective memory will be greater for non-focal event-based tasks compared to focal event-based tasks.
    - 3.3 Older adults with lower levels of retrospective memory will show greater deficits on time-based prospective memory tasks compared to those with higher levels of retrospective memory.

6.6 Method

The method and procedure for Study 3 was as described in Study 1. The following section will briefly review previously presented variables. Executive function, working memory, retrospective memory, and speed of perceptual processing measures unique to the current study will be discussed in detail in the subsequent Materials section.

6.6.1 Participants. Data were taken from the ALSA Daily Life Time Sampling study (ADuLTS) and from Wave 11of the ALSA. Participants were identical to those for Studies 1 and 2, and comprised 74 older adults who ranged in age from 83 to 102 years. They were recruited and screened for suitability in the same manner as in Study 1.

6.6.2 Design. The current study was a mixed design, using a seven-day time burst measurement protocol. The dependent variables were focal and non-focal event-based prospective memory tasks, and a single time-based prospective

memory task. The predictor variables were composite measures for executive functioning, working memory, and retrospective memory.

6.6.3 Materials.

6.6.3.1 Baseline and covariate measures. The present study included relevant baseline demographic variables for inclusion as covariate predictors in analyses examining the effect of neurocognitive function on prospective memory performance. These included age, education level and depressive symptoms, the rationale and justification for which was overviewed in Studies 1 and 2. As such the rationale for inclusion of these covariates in the present study will be briefly addressed.

Education has been identified as a factor predictive of performance on a executive function measure used in the current study, namely the FAS fluency task (refer to Section 6.6.3.4.1 for a full description of the FAS). Studies have shown older adults with higher levels of education (≥ 13 years) produced twice as many words when compared to those with lower levels of education (0 to 6 years: Crossley et al., 1997) and accounted for significant variance in FAS performance (21.7%) over and above variance attributable to age (11.85%), (Tombaugh et al., 1999). From this evidence the level of a participant's education will be controlled for in analyses.

Depressive symptoms were measured using the short version of the Centre for Epidemiological Studies Depression Scale (CES-D 10; Andresen et al., 1994; Radloff, 1977). Depressive symptoms have previously been reported as a contributing factor to cognitive decline with increasing age (Bryan, Luszcz, &

Kent, 1997), and to deficits associated with verbal fluency performance (see Henry & Crawford, 2005a for a meta-analysis of 42 studies). Depression will therefore be incorporated as a covariate predictor.

6.6.3.2 Digit Symbol Substitution Test. Perceptual speed of processing was measured using the Digit Symbol Substitution Test (DSST). Perceptual speed has been shown to mediate the relationship between age and memory in older adults (Bryan & Luszcz, 1996; Bunce & Macready, 2005) and is implicated as a limiting factor in cognitive ageing (Baudouin et al., 2009; Salthouse, 1996, 2000). As such perceptual speed of processing is included in the present study as a covariate predictor to control for possible mediation between age, and executive function and working memory performance.

The DSST is a componential test measuring speed of processing and incidental learning. It is a sub-test of the Weschler Adult Intelligence Test (Wais-111, 1981) suitable for administration to those aged 16 to 89 years. This task involved participants substituting symbols paired with the digits 1 to 9 into a table of paired boxes. One hundred digits (seven of which were for practice prior to the timed task) were presented randomly in rows with an empty corresponding box below each digit. Participants were instructed to draw the correct symbol in the corresponding boxes as rapidly as possible (see Appendix E.2), working consecutively from left to right across the table. The score for the DSST was the number of correct substitutions in a ninety second time limit, with higher scores indicative of faster processing speed. Robust correlation of $r = .78$ has been reported between the DSST and other measures of perceptual speed (Salthouse, 1996). The DSST also demonstrates high test-retest reliability, Cronbach's alpha of .80 to .89 (Barr, 2003).

6.6.3.3 Time sampling and prospective memory measures. Time sampling measures and prospective memory items used in the current study were identical to those used in studies previously described in this thesis. Prospective memory data and outcomes were the same as used in analyses for Study 1. Participants completed two morning and five daily questionnaires over the course of the seven day study. The morning and daily questionnaires and associated protocol are fully described in Study 1.

The prospective memory items were interspersed within the daily questionnaires and can be reviewed in Appendix D.1 for specific examples and scheduling of items. Prospective memory measures were represented in terms of 1) the proportion of correct responses, and 2) forgetting and recovery ratios for each category of event-based prospective memory (i.e., focal and non-focal tasks: Maylor, 1996; Vogels et al., 2002). The time-based prospective memory item was represented as either a correct or incorrect response.

6.6.3.4 Tests of executive function. Well-established measures were used to assess cognitive function in the ADuLTS protocol and Wave 11 of the ALSA. The following section will detail three measures used to assess executive functioning in the current study, namely two tests of verbal fluency, the Initial Letter Fluency test and the Excluded Letter Fluency test, and a clock drawing task (CLOX 1). The measures are presented in Appendices E.4 to E.6.

6.6.3.4.1 *Initial Letter Fluency Test*. The Initial Letter Fluency Test (IFL) is a test of phonemic memory retrieval sensitive to crystallized verbal knowledge (Bryan & Luszcz, 2000), adapted from the Controlled Oral Word Association test (COWA: Benton, 1968; Spreen & Benton, 1969). Most commonly used letters in the Initial Letter Fluency test are F, A, and S as developed by Benton (1968). The

task involves participants verbally generating as many words as possible of four letters or more in three 60 second trials beginning with nominated letters. Proper nouns were prohibited as were variations including word extensions, perseverations including recurrent or ideational perseverations, repetitions, and incorrect words. In the current study, two trials only were administered. In trial one, words were required beginning with the letter *f* and in trial two, words beginning with *a*. The number of admissible words generated in each trial was summed to give a total score (see Appendix E.4). The FAS is sensitive to cognitive disturbances in the domains of language, executive function (Alvarez & Emory, 2006; Frith et al., 1995; Henry & Crawford, 2004; Parks et al., 1988), attention and speed of processing, and has a demonstrated alternate form reliability co-efficient of r = .69 (Anastasi, 1988).

6.6.3.4.2 ***Excluded Letter Fluency Test (ELF).*** The excluded letter fluency test was developed by Bryan, Luszcz & Crawford (1997) as an alternative test to the FAS. It is a test of phonemic memory retrieval sensitive to executive control processes (Bryan & Luszcz, 2000; Henry & Crawford, 2004; Phillips, 1997). The task involved participants generating as many words as possible in two 60-second trials that did not include nominated letters. Trial 1 asked for words without the letter *a*, and in trial 2, the letter *e* was excluded. Word generation rules were the same as for the FAS test. Moderate alternate form reliability between the *a* and *e* trials (Pearson correlation of .61) has been obtained with this test (Bryan et al., 1997). Scoring of the ELF was the same as for the FAS test, with correctly generated words for both the *a* and *e* trials summed to give a total EFL score.

Tests of phonemic fluency, as represented by the FAS and ELF tests, are regularly used to assess executive dysfunction, in particular following

neurological insult. Phonemic fluency is thought to place demand on cognitive processes including the efficient organization of word retrieval and recall based on non-habitual lexical search strategies (Perret, 1974). The tests also demand self-monitoring of responses, self-initiation of search strategies, flexibility, and inhibition of incorrect or previously presented responses (Henry & Crawford, 2004) all of which are integrated cognitive processes of executive functioning.

Further evidence for the validity of verbal fluency tests as measures of executive function stems from neuroanatomical and neuropathological studies. Increased activation of the left prefrontal cortex (Gourovitch et al., 2000) and in particular the left dorsolateral prefrontal cortex (Alvarez & Emory, 2006; Frith et al., 1995; Parks et al., 1988) during tests of verbal fluency is evident in neuroimaging studies. Verbal fluency deficits are commonly reported in clinical populations with involvement of the frontal cortex region (Baldo, Schwartz, Wilkins, & Dronkers, 2006; Miller, 1984). Indeed a meta-analysis of 31 studies examining the effects on verbal fluency associated with different cortical regions in clinical and non-clinical populations, concluded that phonemic fluency was a sensitive measure of frontal dysfunction with high specificity (Henry & Crawford, 2004). Across the studies analysed, those with frontal lobe lesions displayed larger deficits in phonemic verbal fluency than healthy controls (r = .52). Alvarez and Emory (2006) in a subsequent meta-analysis of executive measures concur with this position, reporting sensitivities of three tests, the WCST, the FAS, and the Stroop test of d's = -.97, -.80, and -30 respectively, with larger effect sizes evident for younger and older adults in comparison to middle-aged adults. Thus the FAS and the ELF were used in the current study along with a clock drawing task (CLOX 1), as reliable and valid measures of executive function.

6.6.3.4.3 *CLOX 1.* The CLOX 1 (CLOX 1; Royall, Mulroy, Chiodo, & Polk, 1999) was administered in conjunction with the MMSE to assess executive control function. There are numerous versions of the clock drawing test. These include a clock drawing task as part of a 7-minute cognitive screening test (Soloman et al., 1998) and a test requiring participants to indicate a time of 2:45 on a pre-drawn clock (Sunderland, 1989). In the current study the free-drawn CLOX 1 version was used (Royall et.al.).

Participants were given a blank piece of paper and instructed to draw an analogue clock that says 1:45, with the hands and numbers drawn on the face so that a child could read them. No assistance was provided once drawing commenced. Performance was scored to a maximum total of 15 points, with a cut-off point of 10 representing the 5th percentile in young adult subjects (Royall et al., 1999). The CLOX 1 has a demonstrated significant correlation (r = .78) with measures of executive control function after scores are adjusted for age, education and MMSE scores (Royall et al., 1998, 2004). In addition, the CLOX 1 is associated with performance on verbal fluency tasks (Suhr & Jones, 1998), executive function tests of competing programs (Go-No-Go test: Libon et al., 1993), and has demonstrated high correlation with tests of global cognition (MMSE: *r*'s = .41 to .80). Longitudinal research in which 1208 participants over the age of 65 years were tested every two years over a decade demonstrated a small decline in performance on the CLOX 1 with advancing age (Ratcliff et al., 2003). Thus the CLOX 1 is considered to be a sensitive measure of executive function in older adults.

In the current study a composite measure comprised of the executive function tests reviewed was computed to assess executive function, namely the

total of correct words produced on both the FAS and the ELF from the verbal fluency tests, and scores from the CLOX 1 test.[1] The total number of correct responses for each of the verbal fluency tests was scored excluding incorrect responses, rule break errors, and perseverative errors. The three measures were z-scored prior to computing a composite measure. Preliminary analyses indicated that the FAS and the ELF measures were significantly correlated (r = .67, ρ < .001). The CLOX 1 was not associated with the FAS but had a correlation with the ELF that approached significance (ρ = .06).

6.6.3.5 Tests of Working Memory.

6.6.3.5.1 *MMSE: Spelling backwards, serial sevens and 3-stage command.*

Working memory was examined in the ADuLTS study using a composite score derived from items assessed in the Mini-Mental State Examination (MMSE: Folstein, Folstein, & McHugh, 1975). There is empirical support for items within the MMSE to be categorised as to the underlying construct of measurement (Banos & Franklin, 2002; Jones & Gallo, 2000). These constructs are defined as orientation, attention, memory, and working memory. In addition, the MMSE has been found to be a sensitive instrument of measurement applicable to both normative ageing and those experiencing pathological cognitive ageing (Hill & Bachman, 1995; Nilsson et al., 2002; Tombaugh et al., 1996; Wells et al., 1992).

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[1] Factor analysis (FA) of the neurocognitive measures employed in the ADuLTS study was contraindicated due to the small sample size. Tabachnick & Fidell (2007) suggest sample sizes of 300 to 500 to be optimal for FA. Small sample sizes (<100) produce less reliable estimation of correlation coefficients. Composite neurocognitive measures in this study were therefore based upon theoretical frameworks and previous research

The sensitivity of items in the MMSE has been demonstrated in research indicating that most errors occur on the following tasks, the recall of 3 words, spelling *WORLD* backward, serial sevens, orientation to time, and the drawing of intersecting pentagons task, for both participants without pathology and those with dementia (Hill & Bachman, 1995; Nilsson, Fastbom, & Wahlin, 2002; Tombaugh & McIntyre, 1992; Tombaugh et al., 1996; Wells et al., 1992).

Previous research has utilized two items in particular from the MMSE to compute composite measures of working memory, namely spelling *WORLD* backward and serial sevens (Espino et al., 2004). Although serial sevens and spelling backwards have been conceptualised as measures of attention and concentration (Ganguli et al, 1990), contemporary research has delineated these items as factors of memory. Espino and colleagues (2004) argue that both measures are differential, componential measures of working memory. However, they contend serial sevens to be a better indicator of overall cognition in comparison to spelling backward, and the preferred measure for assessing global cognition. In contrast to this argument, spelling backward has been posited to be a valid measure of working memory and contemporary studies have investigated the validity of spelling backward as a measure of the working memory construct. Jefferson et al. (2002) indexed this item from the MMSE and found a moderate correlation between the spelling backward items with memory, as measured on the Boston revision of the Weschler Memory Scale – Mental Control Subtest (WMS-MC). A similar relationship was found for this measure with free recall, as measured on the 9-word dementia version of the California Verbal Learning Test (CVLT: Delis et al., 1987).

In the current study working memory was assessed using a composite measure of two items from the MMSE, namely serial sevens and spelling backward. Serial sevens required participants to engage in a mental arithmetic task in which they were asked to subtract the number 7 from 100, and then continue subtracting 7 from the answer over five trials Serial sevens was scored as either a correct (1) or incorrect (0) subtraction for each of the five trials. If a subtraction error was recorded and subsequent answers were 7 less than the error, only one error was counted. During the spelling backward task, participants were asked to spell the word WORLD backward, having first been spelled forward by the research assistant. Spelling backward was scored as either correct (1) or incorrect (0) for each of the five letters identified. The two working memory measures were z-scored to standardise the measures to the same metric prior to creating the composite score, for consistency with the executive function and retrospective memory measures used in analyses.

6.6.3.5.2 ***Working memory, the MMSE, and covariate predictors.***

Composite measures from the MMSE have been shown to be valid measures of working memory. However, numerous studies examining the validity of the use of the MMSE with older adults highlight factors other than cognitive function as influencing test results. In particular, inter-individual differences in demographic variables are theorized to impact results. Espino and colleagues (2004) examined the coefficients of variation associated with the MMSE, defined as the within-group variability associated with an instrument. Greater variability indicates better ability of the test to discriminate between individuals upon a trait of interest. They argued that a relatively homogenous community sample of older adults with intact cognition may be insufficient to produce heterogeneity on MMSE test results and

that other factors may have greater impact on results, namely education level, language, age and neighbourhood. Education in particular was cited as an important factor in both the distribution of MMSE scores and internal consistency, in population based studies. A Tasmanian community-based study of 269 older adults concurs with these findings (Jorm et al., 1991). Participants with a primary education only were found to have an α co-efficient of .65 (n = 146) compared with those with a secondary education, α = .54 (n = 123). Thus when using items from the MMSE, it is prudent to control for factors influencing the distribution of scores. In Study 3, education and age will therefore be included as covariate control variables along with speed of perceptual processing, in all analyses.

6.6.3.6 Tests of retrospective memory. Retrospective memory was assessed using a composite measure of items taken from the Digit Symbol Subtest and the Mini-Mental State Examination (MMSE: Folstein, Folstein, & McHugh, 1975). The measure comprised two items, the free recall of symbols regardless of placement from the Digit Symbol Subtest, with a score range of 0-9, and the recall of three items from the MMSE (penny, table, and apple) with a score range of 0-3. The items were summed following conversion to standardised z-scores. The following section presents empirical evidence for inclusion of the selected items as measures of retrospective memory.

6.6.3.6.1 ***The MMSE and retrospective memory.*** The recall of three items task within the MMSE has previously been employed in longitudinal research with older adults as a valid measure of memory recall performance (Jorm et al., 2001). The task involves the naming of three objects, usually penny, table, and apple, by the test administrator. The respondent is asked to name the objects with each item scored as correct or incorrect. The respondent is then asked to repeat the

objects until learned, with the number of required trials recorded. A subsequent item is then tested (e.g., spelling *WORLD* backward and/or serial sevens) after which the respondent is asked to recall and name the three objects. A correct score is given for each object accurately named. The recall of three items was therefore used in the current study to compute a composite measure of retrospective memory in conjunction with a free recall item from the Digit Symbol Subtest.

6.6.3.6.2 ***The Digit Symbol Subtest and retrospective memory***. The Digit Symbol Subtest was administered to participants following completion of the DSST (refer to Section 6.6.3.2 for a full description of the DSST and Appendix E.3 for the Digit Symbol Subtest). The Digit Symbol Subtest assesses both incidental learning and free recall memory (Strauss, Sherman, & Spreen, 2006, 3rd Ed.). Participants were requested to recall and draw the corresponding symbol for each digit between 1 and 9 presented in the DSST test (Salthouse, 1985). The Subtest is scored as the (a) total number of symbols correctly recalled and matched with the corresponding digit (incidental learning), and (b) the number of symbols recalled irrespective of digit/symbol pairing (free recall). Current research has demonstrated the validity and clinical utility of these measures. Strauss and colleagues found a moderate significant correlation (r = .37) between the free recall and pairing scores on the DSST with memory index scores on the WMS-111. Further, Joy, Kaplan, and Fein (2003) investigated results from 1167 participants who completed the free recall component of the DSST, of whom 195 were aged between 70 and 79 years and 136 were aged between 80 and 89 years. The overall sample was stratified on descriptive and demographic factors. Good construct validity was reported, with the correlation between free recall and WMS-111 general memory index of r = .38. The probability of memory

impairment as a function of free recall was also examined. For older adults (50 to 89 years) scores of ≤ 5 on free recall were associated with an increased frequency of memory impairment, measured as a score of < 85 on at least one of the four memory indexes of the WMS-111, $\chi^2(1) = 49.83$, $\rho < .001$. Joy and colleagues also found older adults with perfect free recall scores to have a very low associated risk of memory impairment. The free recall component from the Digit Symbol Subtest was employed in the current study as a measure of retrospective memory.

6.7 Procedure

The full procedural protocol for the ADuLTs study was reported in Study 1 of this thesis. Measurement of prospective memory performance can be reviewed in the method section of Study 1 (Chapter 3, Section 3.4.5.4).

The ADuLTS study was conducted between September 2010 and October 2011. Baseline descriptive, demographic, and cognitive data were obtained at Wave 11 (between September and November 2010) for ALSA participants, 50 of whom subsequently participated in the ADuLTS study. For the 25 non-ALSA participants, these data were collected concurrently at the ADuLTS study baseline assessment.

At Wave 11, the ALSA participants undertook the MMSE (Folstein et al., 1975) which was embedded within the Household questionnaire. Following completion, participants were invited to further participate in the ALSA via a Clinical Assessment that included a Cognitive component. Measures of pertinence to the current study assessed within the Clinical Assessment were the DSST, including the Digit Symbol Subtest, the FAS, the ELF, and the CLOX 1 clock drawing task.

Baseline descriptive and cognitive data were obtained from the 25 non-ALSA participants at an introductory session with a trained research assistant. Participants were interviewed and household demographic measures recorded, including type of dwelling, country of birth, marital status, and education. Cognitive tests were then administered and included the MMSE, the CLOX 1, the DSST and Digit Symbol Subtest, the FAS and finally the ELF. Upon collection and scoring of the baseline interview and tests, the non-ALSA participants were screened for suitability to undertake the ADuLTS study using scores on the MMSE. No participants in this group were precluded from participation, all scoring above the cut-off score of 24 points (Folstein, Anthony, Parhad, Duffy & Gruenberg, 1985).

6.8 Analytic Approach

6.8.1 Prospective memory measures. Prospective memory tasks were calculated as a dichotomous response, either correct (1) or incorrect (0), for each individual measurement occasion across the week. The proportion of correct responses for each category of event-based prospective memory tasks was calculated (i.e., focal and non-focal tasks), and subsequently represented in terms of forgetting and recovery ratios (Maylor, 1996; Vogels et al., 2002). Time-based prospective memory was represented as either correct or incorrect. Calculations and measures of prospective memory items as described in Study 1 (Chapter 3) were employed in the current study.

6.8.2 Software. All data were analysed using the Statistical Package for the Social Sciences (IBM SPSS: Version 21).

6.9 Results

6.9.1 Overview. Demographic and descriptive results for study participants are presented in Chapter 3, Table 3.1. As a brief overview, 74 participants completed the week-long ADuLTS protocol (female *n* = 49, male *n* = 25). Participants were aged between 83 and 102 years (*M* = 88.13, *SD* = 3.15) and had an average of 10.6 years of education.

Prospective memory results were presented in Study 1and are summarized in Chapter 3, Table 3.2. Correct responses were recorded for 72.9% of participants for the focal (circle capital) EBPM tasks across trials, and for 82.8% of participants for the non-focal (initial box) EBPM tasks. Correct responses were recorded for 21.6% of participants for the TBPM (call research assistant) task.

6.9.2 Preliminary analyses of prospective memory performance and executive function, working memory, and retrospective memory. Prior to hypothesis testing, all major variables were screened for normal distribution and linearity as recommended by Tabachnick and Fidell (2000). The data displayed approximately normal distribution for all major variables with no evidence of nonlinearity, or homoscedasticity, thus all variables met criteria for parametric testing. In addition, no outlying cases were identified.

Composite measures for the executive function, working memory, and retrospective memory tasks were computed for use as independent predictor variables in regression analyses for hypothesis testing. Measures were z-transformed prior to computing composite scores. Predictor variables were operationalised as follows:

1. Executive Function = FAS total correct + ELF total correct + CLOX 1
2. Working Memory = Spell WORLD backward + Serial Sevens

3. Retrospective Memory = DSS free recall + 3-item Recall

Preliminary results of descriptive statistics for major executive function and covariate variables are presented in Table 6.1. Major variables were within normative parameters for older adults reported in previous literature.

6.9.2.1 ***Correlation between major variables***. Bivariate correlations between the major variables were examined and are presented in Table 6.2. The demographic and covariate variables examined revealed several interesting relationships. Digit Symbol Substitution Test scores exhibited a positive relationship with executive function (r = .32, ρ < .01) and with education level (r = .24, ρ < .05). This measure was also positively associated with performance on the focal EBPM task, with a negative association with the non-focal EBPM forgetting ratios. However speed of processing was not related to either working memory or retrospective memory, or to the other prospective memory items in the current data. Education was not associated with age or depression. In addition there was no correlation evident in the current data between education level and executive function, working memory, or retrospective memory performance.

Age showed a small positive association with depressive symptoms, but neither age nor depressive symptoms were correlated with the executive function, working and retrospective memory measures, or the prospective memory measures. Participants in the current study recorded low scores on the CES-D 10 scale with a mean of 4.77 (SD = 3.4, Range = 0 – 16). Due to lack of correlation with the cognitive variables, depressive symptoms were not included as a covariate predictor in further analyses.

Table 6.1.
Mean and Standard Deviations for Cognitive and Covariate Variables

	Mean	SD	Observed Range	
			Min	Max
Cognitive Variables				
Executive function				
FAS total[1]	22.25	8.27	4	47
ELF total[2]	15.32	6.37	2	31
CLOX 1[3]	10.65	2.95	2	14
zExecutive function (total)[4]	.00	2.24	-6.00	5.00
Working memory				
Spell backward[5]	4.58	.91	2	5
Serial sevens[6]	4.35	1.03	1	5
zWorking memory (total)[7]	.00	1.42	-5.14	1.09
Retrospective memory				
DSS free recall[8]	7.14	1.72	0	9
3-item recall[9]	2.70	.64	0	3
zRetrospective memory (total)[10]	.00	1.72	-8.41	1.55
Covariate Variables				
Age[11]	88.22	3.13	84	102
Education[12]	4.04	1.40	1	7
Depressive symptoms[13]	4.78	3.47	0	16
DSST total[14]	33.82	8.99	9	54

Note: [1] is total correct on Initial Letter Fluency test, [2] is total correct on Excluded Letter Fluency test, [3] is total score on Clock Drawing Test, [4] is total z-score Executive function, [5] is Spelling World Backward from MMSE (range 1-5), [6] is Serial sevens from MMSE (range 0-5), [7] is total z-score Working memory, [8] is Free recall from Digit Symbol Sub-test (range 0-9), [9] is 3-item recall from MMSE (range 0-3), [10] is total z-score Retrospective memory, [11] is age at interview, [12] is Education (coded as age left school), [13] is Depressive Symptoms (CES-D 10, range 0-30), [14] is total correct in 90 seconds on Digit Symbol Substitution Test

Table 6.2 *Correlation Matrix of Major Variables with Focal and Non-focal EBPM*

	fEBPM PC	fEBPM FR	fEBPM RR	nfEBPM PC	nfEBPM FR	nfEBPM RR	EF	WM	RM	Age	Educ	Dep	DSST total
fEBPM PC[1]	1												
fEBPM FR[2]	-.83**	1											
fEBPM RR[3]	-.06	-.15	1										
nfEBPM PC[4]	.21	-.11	-.06	1									
nfEBPM FR[5]	-.23	.22	.05	-.89**	1								
nfEBPM RR[6]	.15	-.25*	.07	-.28*	.10	1							
EF[7]	.37**	-.28*	-.08	.07	-.15	.24*	1						
WM[8]	.10	-.05	-.06	.35**	-.40**	.10	.37**	1					
RM[9]	.21	-.29*	.20	.25*	-.33*	.08	.26*	.33**	1				
Age[10]	-.22	.15	-.13	.01	-.11	-.12	-.12	-.05	-.06	1			
Educ[11]	-.04	.15	-.05	.11	-.08	-.01	.12	.11	.06	.13	1		
Dep[12]	-.15	.06	.10	-.14	.11	-.15	-.12	-.07	.02	.30*	.05	1	
DSST total[13]	.31**	-.15	-.06	.21	-.25*	.14	.32**	.15	.08	-.20	.24*	-.19	1

Note: [1] is focal EBPM proportion correct, [2] is focal EBPM forgetting ratios, [3] is focal EBPM recovery ratios, [4] is non-focal EBPM proportions correct, [5] is non-focal EBPM forgetting ratios, [6] is non-focal EBPM recovery ratios, [7] is Executive function, [8] is Working Memory, [9] is Retrospective Memory, [10] is Age at interview, [11] is Education coded as age leaving school, [12] is Depressive symptoms (CES-D 10), [13] is Digit Symbol Substitution Test total correct in 90 seconds. * $\rho < .05$, ** $\rho < .01$, *** $\rho <$ -001.

Of the three composite cognitive measures examined, executive function was related to working memory (r = .37, ρ < .01) and with retrospective memory (r = .26, ρ < .05). Working memory and retrospective memory also showed a positive association (r = .33, ρ < .05).

The proportion correct of the focal event-based prospective memory (circle capital) tasks showed a significant positive correlation with executive function, r = .37, ρ < .01. This relationship was further highlighted with focal prospective memory forgetting ratios having a negative association with executive function, r = -.28, ρ < .05. However this association did not extend to the recovery ratios for the focal tasks. Retrospective memory was associated with the forgetting ratios for the focal event-based task, r = -.29, ρ < .05. Working memory was not correlated with the focal event-based prospective memory measures.

Non-focal event-based prospective memory displayed correlations with all three cognitive measures. Executive function was positively correlated with the recovery ratios on these tasks, r =.24, ρ < .05.Working memory was significantly related to both the non-focal EBPM proportion correct, r =.33, ρ < .05, and to the non-focal EBPM forgetting ratios, r = -.40, ρ < .001. Retrospective memory also displayed a significant relationship with the non-focal EBPM proportion correct, r = .25, ρ < .05, and forgetting ratios, r = -.33, ρ < .05.

Preliminary examination of the data suggested that higher levels of executive function were associated with better performance on the focally cued event-based prospective memory tasks and that working memory was associated with non-focal event-based prospective memory performance. Retrospective memory was associated with lower forgetting ratios for both the focal and non-focal event-based tasks across

the focal event-based tasks and with better overall performance on the non-focal event-based tasks.

Preliminary analyses were also undertaken to examine if there were differences in performance on the cognitive scores between the ALSA and non-ALSA participants, given the difference in time-points of data collection for these measures. As previously discussed, cognitive measures for the 25 non-ALSA participants were collected concurrently with the ADuLTS study, whereas cognitive data for ALSA participants were obtained at Wave 11, giving a time-lag of between 1-11 months until commencement of the ADuLTS protocol. Descriptive statistics for the cognitive measures for both groups are presented in Table 6.3 Results indicated a significant difference in performance between groups on one of the executive function tasks of interest, the Excluded Letter Fluency task (ELF), t (71) = -2.01, $\rho < .05$. Performance on this measure for the non-ALSA group (M = 17.48, SD = 6.22) was significantly better than for the ALSA participants (M = 14.32, SD = 6.23). There were no significant differences between the two groups for performance on executive measures of the FAS, or the CLOX 1. Similarly, there were no significant differences between groups for the working memory measures of spell WORLD backward or serial sevens, nor for the retrospective measures of the 3-item recall and free recall from the Digit Symbol Sub-test. Further analyses revealed no significant differences between the ALSA and non-ALSA groups for descriptive and demographic variables,

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[2.] Hypothesis testing using HMR analyses with separate groups of ALSA and non-ALSA participants on the ELF task, did not substantially alter the results. As such results in the following section are reported for the combined ADuLTS study sample.

including age, education, and depressive symptoms, nor for performance on either the event-based or time-based prospective memory tasks. As such, analyses in the current study were conducted using the combined ALSA and non-ALSA sample.[2]

6.9.2.2 ***Hypothesis testing***. Hypothesis testing was undertaken to test the effect of cognitive predictors on prospective memory performance. The hypotheses proposed a negative relationship between executive function and prospective memory performance. It was predicted that,

1) Lower levels of executive function, working memory, and retrospective memory would be associated with lower levels of performance for both focal and non-focal event-based prospective memory
2) Lower levels of executive function, working memory, and retrospective memory would be associated with lower performance on the event-based non-focal prospective memory tasks compared with performance on the event-based focal prospective memory task
3) Lower levels of executive function, working memory, and retrospective memory would be associated with poorer performance on the time-based prospective memory task compared to higher levels of executive function.

For hypothesis testing to examine the variance attributable to each of the cognitive predictors, independent of the covariates of age, education, and speed of processing, a series of HMR analyses were conducted for both focal and non-focal

Table 6.3.

Mean and Standard Deviations for Cognitive and Covariate Variables for ALSA and Non-ALSA Participants

	ALSA		Non-ALSA	
	M	SD	M	SD
Cognitive Variables				
Executive function				
FAS total[1]	21.17	7.61	24.42	9.25
ELF total[2]	14.32	6.25	17.48	6.22
CLOX 1[3]	10.38	3.19	11.17	2.41
Working memory				
Spell backward[4]	4.48	.97	4.79	.72
Serial sevens[5]	4.24	1.12	4.58	.78
Retrospective memory				
DSS free recall[6]	6.92	1.85	7.58	1.35
3-item recall[7]	2.68	.73	2.75	.44
Covariate Variables				
Age[8]	88.87	2.62	87.50	3.96
Education[9]	3.81	1.38	4.50	1.35
Depressive symptoms[10]	5.04	3.47	4.15	3.47
DSST total[11]	33.18	8.40	35.13	10.17

Note: [1] is total correct on Initial Letter Fluency test, [2] is total correct on Excluded Letter Fluency test, [3] is total score on Clock Drawing Test, [4] is Spelling World Backward from MMSE (range 1-5), [5] is Serial sevens from MMSE (range 0-5), [6] is Free recall from Digit Symbol Sub-test (range 0-9), [7] is 3-item recall from MMSE (range 0-3), [8] is age at interview, [9] is Education (coded as age left school), [10] is Depressive Symptoms (CES-D 10, range 0-30), [10] is total correct in 90 seconds on Digit Symbol Substitution Test

prospective memory measures correlated with the cognitive measures (refer to the correlation matrix presented in Tables 6.2). Depressive symptoms were not included in analyses due to lack of correlation with the predictor and independent variables. Logistic regression analysis was then used to investigate the effect of executive function, working memory, and retrospective memory on time-based prospective memory performance.

6.9.3 Results of HMR analysis for focal EBPM and executive function, working memory, and retrospective memory.

6.9.3.1 ***Focal EBPM proportion correct and executive function, working memory, and retrospective memory.*** The first model using HMR analysis, regressed executive function, working memory and retrospective memory scores with the focal EBPM proportion correct (refer to Table 6.4 and Appendices H.1 to H.6 for selected SPSS output of HMR analyses for this study). At Step 1 of the model, covariate predictors of age, education, and speed of processing accounted for 12 % (R^2 = .124) of the variance in focal EBPM proportion correct scores. At Step 2, executive function, working memory and retrospective memory were entered. Overall, the model accounted for a total variance in prospective memory of 21% (R^2 = .212), reaching statistical significance F (6, 62) = 2.78, ρ < .05. The model suggested that the three neurocognitive measures explained an additional 9% (R^2_{change} = .088) of the variation in scores which did not reach statistical significance, F_{change} (3, 62) = 2.31, ρ = .085. However, executive function was a significant independent predictor of performance on the focal EBPM tasks, recording a beta value of .30. The beta value associated with the executive function score (M = .08, SD = 2.20) indicates that for each 1 SD increase in the executive function score, performance on the focal

prospective memory task improved by .30 standard deviation. The standard deviation for the focal EBPM proportion correct is 33.62. This constitutes an increase in the proportion correct for focal EBPM of 10% for every unit improvement in executive function (33.62 x .30). Thus, improvement in executive function of 2.20 standard points was associated with an improvement in the proportion correct of focal EBPM of 10%, holding age, education, and speed of processing constant.

6.9.3.2 ***Focal EBPM forgetting ratio and executive function, working memory, and retrospective memory***. The analysis was repeated using HMR analysis to test the effect of cognitive performance on the focal EBPM forgetting ratios (refer to Table 6.5). Executive function, working memory, and retrospective memory were the predictor variables, and focal EBPM forgetting ratio was the dependent variable. At Step 1, age, education, and speed of processing accounted for only 7% (R^2 = .068) of the variation in prospective memory performance. Following entry of the predictor variables at Step 2, the model accounted for 19% (R^2 = .189) of the variation in scores on the focal EBPM forgetting ratios, F (6,62) = 2.40, ρ < .05. The predictor variables accounted for an additional 12% (R^2_{change} = .12) of the variance in scores. At Step 2, the final model was statistically significant, F_{change} (3, 62) = 3.06, ρ < .05. Retrospective memory made a significant independent contribution to the model with a beta value of -.24 (ρ < .05). An increase of 1 SD in retrospective memory was associated with a decrease in the focal EBPM forgetting ratio (M = .17, SD = .31) of .07 units (.31 x -.24) or 7%, holding all other predictors constant. Executive function approached significance as an independent predictor of the forgetting ratios, with a beta value of -.26 (ρ = .058). Thus every increase of 1 SD in executive function was associated with a decrease in the focal EBPM forgetting ratio (M = .17, SD = .31) of

.08 units (.31 x -.26) or 8%, holding all other predictors constant. As with the previous regression analysis, working memory did not predict performance on the focally cued event-based prospective memory tasks.

6.9.3.3 ***Focal EBPM recovery ratio and executive function, working memory, and retrospective memory***. HMR analysis was to test the effect of cognitive performance on the focal EBPM recovery ratios (refer to Table 6.6). Focal EBPM recovery ratio was the dependent variable and executive function, working memory, and retrospective memory were predictor variables. Age, education, and speed of processing accounted for only 4% (R^2 = .038) of the variation in recovery ratios at Step 1. At Step 2, after entry of the predictor variables, 11% (R^2 = .107) of the variation in recovery scores was explained by the model, which failed to reach significance, F (6, 62) = 1.24, ρ = .299. The predictor variables accounted for an additional 7% (R^2_{change} = .069) of the variance in scores and the final model was not statistically significant, F_{change} (3, 62) = 1.60, ρ =.199. Retrospective memory was a significant independent predictor of the recovery ratio, with a beta value of .27 (ρ < .05). Thus every increase of 1 SD in executive function was associated with a small increase in the focal EBPM recovery ratio (M = .08, SD = .09) of .02 units (.09 x .27) or 2%, holding all other predictors constant. Working memory and executive function did not predict performance on the focally cued event-based recovery scores.

Table 6.4.

Results of HMR Analysis of Focal EBPM Proportion Correct Across Days with Executive Function, Working Memory, and Retrospective Memory

	B	SE (B)	β	CI (B)	
Step 1					
Constant	177.97	123.68		-.69.03	424.97
Age	-1.52	1.37	-.12	-4.24	1.21
Education	-2.32	2.89	-.10	-8.10	3.46
DSST[1]	1.14	.48	.30	.18	2.11
Step 2					
Constant	198.30	120.73		-43.03	439.63
Age	-1.58	1.33	-.14	-4.24	1.08
Education	-2.24	2.84	-.09	-7.87	3.40
DSST	.68	.51	.18	-.33	1.70
EF[2]	4.53	2.03	.31*	.48	8.59
WM[3]	-2.25	2.95	-.10	-8.15	3.61
RM[4]	2.52	2.53	.12	-2.53	7.57

$R^2 = .12$ for Step 1. $\Delta R^2 = .09$ for Step 2, $\rho = .085$

Note: [1] DSST is Digit Symbol Substitution Test, [2] EF is Executive Function, [3] WM is Working Memory, [4] RM is Retrospective Memory.
$^{*}\rho < .05$, $^{**}\rho < .01$, $^{***}\rho < .001$

Table 6.5.

Results of HMR Analysis of Focal EBPM Forgetting Ratio Across Days with Executive Function, Working Memory, and Retrospective Memory

	B	SE (B)	β	CI (B)	
Step 1					
Constant	-.81	1.17		-3.14	1.53
Age	.01	.01	.11	-.01	.04
Education	.03	.03	.17	-.02	.09
DSST[1]	-.01	.01	-.16	-.02	.00
Step 2					
Constant	-.92	1.12		-3.17	1.33
Age	.01	.01	.11	-.01	.04
Education	.04	.03	.17	-.02	.09
DSST	-.00	.01	-.05	-.01	.01
EF[2]	-.04	.02	-.26*	-.07	.00
WM[3]	.02	.03	.13	-.03	.08
RM[4]	-.05	.02	-.24*	-.09	.00

$R^2 = .07$ for Step 1. $\Delta R^2 = .12$ for Step 2, $\rho < .05$

Note: [1] DSST is Digit Symbol Substitution Test, [2] EF is Executive Function, [3] WM is Working Memory, [4] RM is Retrospective Memory.
$^{*}\rho < .05$, $^{**}\rho < .01$, $^{***}\rho < .001$

Table 6.6.

Results of HMR Analysis of Focal EBPM Recovery Ratio Across Days with Executive Function, Working Memory, and Retrospective Memory

	B	SE (B)	β	CI (B)	
Step 1					
Constant	.64	.36		-.07	1.35
Age	-.01	.00	-.19	-.01	.00
Education	.00	.01	.00	-.02	.02
DSST[1]	-.00	.00	-.10	-.00	.00
Step 2					
Constant	.59	.35		-.12	1.30
Age	-.01	.00	-.18	-.01	.00
Education	.00	.01	.01	-.02	.02
DSST	-.00	.00	-.08	-.00	.00
EF[2]	-.01	.01	-.08	-.02	.01
WM[3]	-.01	.01	-.12	-.03	.01
RM[4]	.02	.01	.27*	.00	.03

$R^2 = .04$ for Step 1. $\Delta R^2 = .07$ for Step 2, $\rho = .20$

Note: [1] DSST is Digit Symbol Substitution Test, [2] EF is Executive Function, [3] WM is Working Memory, [4] RM is Retrospective Memory.
$^{*}\rho < .05$, $^{**}\rho < .01$, $^{***}\rho < .001$

6.9.4 Results of HMR analysis for non-focal EBPM and executive function, working memory, and retrospective memory.

6.9.4.1 ***Non-focal EBPM proportion correct and executive function, working memory, and retrospective memory***. HMR analysis was used to test the effect of the correlation between the proportion of correct responses on the non-focally cued EBPM tasks and the cognitive predictor variables (refer to Table 6.7). For consistency with previous analyses, age, education, and speed of processing were included in the models as covariate predictors. At Step 1, the covariate variables did not predict prospective memory performance, with R-square of .06. At Step 2, after the addition of executive function, working memory and retrospective memory, the model explained a significant variation in scores of 22% (R^2 = .216), F (6, 63) = 2.89, ρ < .05. The independent variables explained an additional variation in scores of 16%, R^2_{change} = .156, F_{change} (3, 63) = 4.17, ρ < .05. The significant beta values associated with working memory (β = .35, ρ < .01) confirmed that overall performance on the non-focal EBPM was predicted by the level working memory, but not by executive function and retrospective memory ability. An increase in working memory (M = .00, SD = 1.43) performance of 1.43 standard units predicted a 9% (26.79 x .35), increase in the non-focal proportion correct (M = 84.26, SD = 26.79), with other predictors held constant.

6.9.4.2 ***Non-focal EBPM forgetting ratio and executive function, working memory, and retrospective memory.*** Analysis of the effect of the cognitive predictor variables on non-focally cued EBPM forgetting ratios was further analysed using HMRA (refer to Table 6.8). As in the previous analysis, age, education, and speed of processing predicted a variation in prospective memory of 10% (R^2 = .10) at Step 1.

At Step 2, after the addition of the predictor variables, the overall model was significant F (6, 63) = 4.22, ρ < .001, explaining 29 % (R^2 = .287) of the variation in scores. The predictor variables accounted for 19% of the additional variance at Step 2, with the change in R square of .186, F_{change} (3, 63) = 5.46, ρ < .01. The final model found working memory, retrospective memory, and speed of processing were significant independent predictors of the non-focal EBPM forgetting ratios (M = .11, SD = .23). The beta value associated with working memory (-.37, ρ < .01) indicated that an increase in working memory (M = .00, SD = 1.45) performance of 1.45 points predicted a decrease in the forgetting ratio of 9% (.23 x -.37, .085 units), with other predictors held constant. Speed of processing (M = 33.26, SD = 8.69) and retrospective memory (M = .04, SD = 1.43) each made comparable independent contributions to performance, with beta values of -.25 and -.24 respectively. Thus every standard unit increase in retrospective memory and speed of processing was associated with a reduction in the non-focal EBPM forgetting ratios of approximately 6%.

6.9.4.3 ***Non-focal EBPM recovery ratio and executive function, working memory, and retrospective memory.*** The relationship between cognitive predictor variables and non-focally cued EBPM recovery ratios was analysed using HMRA (refer to Table 6.9). At Step 1, age, education, and speed of processing predicted a variation in prospective memory of only 3% (R^2 = .026). At Step 2, the overall model was not significant F (6, 62) = .77, ρ = .60, explaining 7 % (R^2 = .069) of the variance, with predictor variables explaining only 4% of the additional variance, R^2_{change} = .043, F_{change} (3, 62) = .95, ρ = .42. The final model indicated that executive function,

working memory, and retrospective memory were not significant independent predictors of the non-focal EBPM recovery ratios.

6.9.5 Results of logistic regression analyses for TBPM and executive function, working memory, and retrospective memory. Logistic regression analysis was used to examine the effect of executive function, working memory, and retrospective memory on time-based prospective memory performance (refer to Table 6.10 and Appendix H.7 for selected SPSS output). It was predicted that lower levels of each of the independent variables would predict poorer performance on a time-based prospective memory task. The dependent variable was time-based prospective memory (did they call their RA) and the predictor variables were the executive function, working memory, and retrospective memory. Covariate predictors were age, education level, and speed of processing.

Covariate predictors were entered at Step 1of the logistic regression, with executive function, working memory, and retrospective memory measures entered at Step 2. Although the model correctly classified 77.5% of participants, the full model failed to reach significance, χ^2 (3, N = 71) = 3.42, ρ = .75, explaining only between 5% (Cox and Snell R^2 = .047) and 7% (Nagelkerke R^2 = .073) of the variance in TBPM scores. Further, none of the independent variables made statistically significant contributions to the model as a whole. Thus, contrary to the hypothesised research questions, the model indicated that executive functioning, working memory, and retrospective memory, were not predictive of performance on a time-based prospective memory task.

Table 6.7.

Results of HMR Analysis of Non-focal EBPM Proportion Correct Across Days with Executive Function, Working Memory, and Retrospective Memory

	B	SE (B)	β	CI (B)	
Step 1					
Constant	-23.31	101.91		-.226.77	180.15
Age	.91	1.13	.10	-1.33	3.16
Education	.93	2.37	.05	-3.78	5.66
DSST[1]	.70	.39	.23	-.08	1.49
Step 2					
Constant	-33.79	95.60		-.224.10	164.52
Age	1.08	1.05	.12	-1.12	3.17
Education	.44	2.22	.02	-4.09	4.94
DSST	.63	.39	.21	-.13	1.46
EF[2]	-2.31	1.52	-.19	-5.20	.98
WM[3]	6.51	2.33	.35**	2.40	11.57
RM[4]	2.91	2.00	.17	-3.12	5.12

$R^2 = .06$ for Step 1, $\Delta R^2 = .16$ for Step 2, $\rho < .01$

Note: [1] DSST is Digit Symbol Substitution Test, [2] EF is Executive Function, [3] WM is Working Memory, [4] RM is Retrospective Memory.
* $\rho < .05$, ** $\rho < .01$, *** $\rho < .001$

Table 6.8.

Results of HMR Analysis of Non-focal EBPM Forgetting Ratio Across Days with Executive Function, Working Memory, and Retrospective Memory

	B	SE (B)	β	CI (B)	
Step 1					
Constant	1.71	.87		-.03	3.45
Age	-.02	.01	-.19	-.03	.00
Education	.00	.02	.02	-.04	.04
DSST[1]	-.01	.00	-.31	-.02	-.00
Step 2					
Constant	1.78	.80		.18	3.36
Age	-.02	.01	-.21	-.03	.00
Education	.01	.02	.05	-.03	.05
DSST	-.01	.00	-.26*	-.02	.00
EF[2]	.01	.01	.08	-.02	.04
WM[3]	-.06	.02	-.34**	-.09	-.02
RM[4]	-.04	.02	-.24*	-.07	-.00

$R^2 = .10$ for Step 1. $\Delta R^2 = .19$ for Step 2, $\rho < .01$

Note: [1] DSST is Digit Symbol Substitution Test, [2] EF is Executive Function, [3] WM is Working Memory, [4] RM is Retrospective Memory.
* $\rho < .05$, ** $\rho < .01$, *** $\rho < .001$

Table 6.9.

Results of HMR Analysis of Non-focal EBPM Recovery Ratios Across Days with Executive Function, Working Memory, and Retrospective Memory

	B	SE (B)	β	CI (B)	
Step 1					
Constant	.31	.35		-.39	1.01
Age	-.00	.00	-.10	-.01	.02
Education	-.00	.01	-.02	-.02	.02
DSST[1]	.00	.00	.10	-.00	.00
Step 2					
Constant	.36	.35		-.34	1.05
Age	-.00	.00	-.11	-.01	.00
Education	-.00	.01	-.02	-.02	.02
DSST	.00	.00	.01	-.00	.00
EF[2]	.01	.01	.23	-.00	.02
WM[3]	-.00	.01	-.02	-.02	.02
RM[4]	6.545E-5	.01	.00	-.02	.02

$R^2 = .03$ for Step 1. $\Delta R^2 = .04$ for Step 2, $\rho = .42$

Note: [1] DSST is Digit Symbol Substitution Test, [2] EF is Executive Function, [3] WM is Working Memory, [4] RM is Retrospective Memory.
$^{*}\rho < .05$, $^{**}\rho < .01$, $^{***}\rho < .001$

Table 6.10.

Results of Logistic Regression for TBPM and Executive Function, Working Memory and Retrospective Memory

	B	SE	z	Exp (B)	95 % CI Exp (B)	
					Lower	Upper
Age	.09	.10	.81	1.09	.90	1.32
Education[1]	-.17	.23	.58	.84	.54	1.31
DSST total[2]	-.03	.04	.43	.98	.90	1.05
Executive function	.00	.16	.00	1.00	.73	1.37
Working memory	.14	.24	.32	1.15	.71	1.83
Retrospective memory	-.18	.18	.93	.84	.59	1.20
Constant	-7.62	8.86	.74	.00		

Note: [1] is Education coded as age left school, [2] is Digit Symbol Substitution Test total correct in 90 seconds. $^{*}\rho < .05$, $^{**}\rho < .01$, $^{***}\rho < .001$

6.10 Discussion

Informed by the Multiprocess Framework of prospective memory, this study examined the role of attentional control processes and retrospective memory in prospective memory performance in the oldest-old. Attentional control processes were represented by executive function and working memory. As in Studies 1 and 2, event-based prospective memory tasks were classified according to the focality of the target cue and the associated degree of attentional control incumbent upon detection and processing of the cue and intended action. Focal cues for instance, were posited to require less attentional control and environmental monitoring directed toward cue detection in comparison to non-focal cues.

In summary, a major finding of this study was that frontally mediated attentional control processes predicted several facets of prospective memory proficiency in oldest-old adults. This converges with evidence implicating a role for frontal process in supporting prospective memory (Einstein et al., 2000, Experiment 2; Mäntylä, 2003; Schnitzspahn et al., 2013). Overall there was a small effect demonstrating that executive function ability influenced performance. However this was not in the direction hypothesised. Higher executive function was associated with better performance on focal event-based prospective memory but was not related to performance for the non-focal tasks, contrary to the study predictions. In contrast, and as hypothesised, working memory ability was a significant predictor of the non-focal event-based proportion correct and forgetting ratio proficiency. Further, neither executive function ability nor working memory capacity influenced proficiency on the time-based task.

An additional finding of particular interest was the association found between retrospective memory and components of event-based prospective memory performance. Retrospective memory was a small but significant independent predictor of recovery ratios for the focal event-based prospective memory tasks. Lower forgetting ratios for both focal and non-focal event-based tasks were also associated with higher scores on the retrospective memory measures. These results diverge with much of the current research that has demonstrated little association between the two memory constructs, a finding that has been widely demonstrated in the literature to date in younger old adults (Kliegel, MacKinlay, & Jäger, 2008; McDaniel & Einstein, 2000). However, retrospective memory did not predict performance on the time-based prospective memory task. Importantly, the current results provide preliminary

evidence for retrospective memory being a determinant of successful event-based prospective memory performance into advanced older age.

Prior to discussing the conceptual implications of the current study, the relationships between prospective memory performance, control variables, and the cognitive constructs of interest will be considered. A moderate correlation was found between executive function and working memory, indicating better ability in one domain of attentional control was associated with better performance in the other. This is not surprising in light of the frontal-executive hypothesis of cognitive ageing (West, 1996) which suggests that age-related declines in higher level cognition are related to declines in structural and functional integrity (Raz, 2005) of the frontal lobes. Neurological imaging studies show working memory and executive function to be supported by frontal lobe functioning (Braver & Barch, 2007) and recent factor analysis has established shared attentional components between the two constructs (McCabe et al., 2010). The current data therefore support these documented changes in cognitive ageing in the oldest-old, with sparing of function in one domain associated with sparing of function in the other. A finding of moderate correlations between retrospective memory with executive function and working memory, lends empirical support for attentional control process support of episodic memory. This is consistent with studies in which working memory (Oberauer, 2005) has been shown to predict performance on recollection tasks and in executive function mediation of age-related effects in episodic memory (Crawford & Bryan, 2002).

Education was not associated with the attentional control measures or with retrospective memory. Consistent with the cognitive reserve hypothesis (Stern, 2002), it has been argued that a higher level of education in early development exerts a

protective effect on cognitive decline in later years. This would be particularly evident in resource demanding processes, for instance the executive, working memory, and recall tasks used in the current study. It could be speculated that the protective effects of education and cognitive reserve on attentional control become less evident into late life in the context of more pervasive biological vulnerabilities. In particular, age-related neuro-anatomical and functional changes in the pre-frontal cortical regions implicated in attentional control may attenuate benefits from education and cognitive reserve. Although degradation of areas supporting retrospective memory, namely the hippocampus and cortical regions, is not as pronounced as for the pre-frontal cortex, age-related declines in these areas have been documented (Erickson et al., 2010). As such education may not have exercised a protective effect on the cognitive processes of interest. Although the foregoing argument is speculative at best, future research could be directed toward clarifying the mechanisms through which education and socio-demographic differences influence differing domains of memory performance in advanced older age.

In considering participant age, the current data found no relationship between chronological age and executive function, working memory, retrospective memory, or speed of processing in this cohort of oldest-old adults. Although not representative of a homogenous group of older adults, the differences observed in the higher-order cognitive processes examined in the current study may reflect intra-individual differences in function rather than being an artefact of chronological age within the narrow age band under consideration. Consistent with this viewpoint, speed of processing was not related to age but was strongly correlated with executive function. This is consistent with the work of Salthouse (1996) and colleagues (Salthouse et al.,

2004), whereby processing speed was found to mediate performance on higher order cognitive tasks. However, the lack of association between working memory and processing speed diverges from research demonstrating age-related reduction in processing speed as predictive of working memory decline (Hasher & Zacks, 1988; Park et al., 1996; West & Bowry, 2005). The working memory measures in the current study could account for the observed differences. Age-related decline in working memory and controlled attention has been demonstrated in resource demanding dual-task paradigms in cross-sectional research (March & Hicks, 1998; Smith & Bayen, 2003; Verhaeghen & Ceralla, 2002) and may reflect the inherent demand of a task rather than age-related effects. Reduced processing speed has been proposed to constrain working memory performance through limiting time for task completion, elaboration and rehearsal, and retrieval processes associated with the task, whilst also limiting the amount of information available for simultaneous processing (Salthouse, 1996). The working memory measures employed in the ADuLTS study (i.e., spelling WORLD backward and serial 7's from the MMSE) represented single task items. As suggested by the current data, it could be argued that processing speed would not be a dominant determinant of performance with such tasks with age-effects more likely with tasks requiring maintenance and manipulation of two or more distinct sets of stimuli.

An inspection of the relationships between the measures of interest in the current study has therefore revealed some interesting findings with respect to overall cognitive processes in the oldest-old sample under consideration. However the main goal of Study 3 was to determine the effect of cognitive processes on prospective memory performance. The data support an involvement of executive function,

working memory capacity, and retrospective memory in different aspects of event-based prospective memory performance. The relationship and effect of the three individual constructs upon prospective memory performance in terms of the nature of the task and cue focality will be discussed.

Executive function emerged as a significant predictor of performance on the focally cued event-based prospective memory tasks. Hierarchical regression analyses for both the focal EBPM proportion correct and forgetting ratio, showed that inclusion of executive function, working memory and retrospective memory led to a higher amount of variance in performance on this task over and above that attributable to age, education and speed of processing. In both analyses, executive function was the only significant predictor of performance and accounted for almost all of the observed variance. This is contrary to the hypothesis that higher levels of executive function would predict performance on the non-focally cued event-based tasks in comparison to the focal event-based tasks. Non-focal cues were anticipated to require allocation of higher levels of cognitive resources to facilitate strategic environmental monitoring directed toward cue detection and intended action retrieval. Focal cues on the other hand were expected to support spontaneous cue detection and retrieval.

The present findings suggest that focality of the target cue may not have been the central factor determining the allocation of executive function processes to the focal event-based tasks. Under the noticing-plus-search model of prospective memory (Einstein & McDaniel, 19**9**6), the occurrence of a focal target cue elicits a sense of familiarity associated with automatic and spontaneous retrieval of an intended action, also consistent with the Multiprocess Framework (McDaniel & Einstein, 2000). This in turn stimulates a strategic search to attribute meaning to the cue and differentiate

between target and non-target cues, necessitating allocation of attentional control processes. In the current study, the focally cued tasks embedded in the ongoing questionnaire may have facilitated automatic detection. The subsequent strategic search for the content of the intended action could then have been supported by the updating component of executive processes. This would be consistent with participants having better executive function ability exhibiting better overall performance on this task. In contrast, although detection of the non-focally cued tasks may have been supported by strategic environmental monitoring, as suggested by the correlation between these tasks and working memory capacity, the simplicity of the actual task may have negated recruitment of executive processes for task completion. Arguably, the non-focal task of initialling a box is a simple and over-practised task across the life-span, drawing on fairly automatic response sets. Indeed signatures rarely show signs of perseveration or deficit with age or in prefrontal cortex impaired clinical populations (Lezak et al., 2012). As such executive function processes may not have factored in these tasks as is suggested by the current data.

In considering the complexity of the tasks undertaken by the ADuLTS' participants, an alternative explanation for executive function association with focal event-based prospective memory performance emerges. In comparison to the non-focal tasks, the focal tasks were more complex and may have taxed executive function as a result of the interplay between the demands of the prospective task whilst providing the affect ratings. These tasks required participants to shift their mental set from the on-going task, and inhibit the demands of the on-going task, toward the prospective task upon cue detection. Successful completion of the task therefore hinged on the ability of the participant to notice the target cue, retrieve the

requirements of the intended action, and then engage in completing the intended action. The ability to control attention and switch between activities during goal-oriented tasks is central to executive function (Diamond, 2006). The present findings therefore endorse the contention that higher levels of executive function enabled participant's to more readily switch between the on-going task and prospective task and inhibit interference from the disparate demands of the on-going and prospective task, thus facilitating better performance. This provides convergent evidence with several studies. Martin, Kliegel and McDaniel (2003) found executive function ability to be positively related to performance on event- and time-based prospective memory tasks and strongly associated with complex prospective tasks, in older but not younger adults. In contrast, executive function was not associated with a very simple event-based task (i.e., remembering a belonging after study completion) in either age group. Moreover, Schnitzspahn et al. (2013) found inhibition and switching to be two executive function factors predictive of prospective memory performance in both younger and older adults. The current findings lend tantalising convergent evidence for executive function involvement in complex event-based prospective memory in advanced older age.

Working memory was also found to play a role in prospective memory, and was shown to be differentially associated with cue focality. Working memory capacity was correlated with overall performance, that is, the proportion correct across the week, and with the forgetting ratios for the non-focal event-based tasks. There was no evidence of working memory association with proficiency on the focal tasks. The preliminary analyses therefore lend support to the hypothesised relationship between working memory and prospective memory. Hierarchical regression analyses found

working memory to predict performance on the non-focal task, after controlling for age, education and speed of processing, explaining a small but significant amount of the variance in the non-focal task proportion correct and forgetting ratios. As such the hypothesised involvement of working memory in prospective memory was partially supported by the current data.

Working memory is a dynamic system attributed with the manipulation and maintenance of information, and in providing an interface between short and long term memory storage (Baddeley, 2003). It is these factors in combination with controlled attentional processes and environmental monitoring for target cues that suggest a plausible explanation for the present results. The correlation of working memory with non-focal event-based tasks, compared to no association with the focal tasks, posits a case for working memory involvement in environmental monitoring for the non-focal cues. The Multiprocess Framework proposes that non-focal cues demand extra monitoring for cue detection outside of the periphery of an on-going activity. The PAM theory (Smith, 2003; Smith & Bayen, 2004) concurs, proposing working memory as integral to environmental monitoring for prospective memory stimuli. That being the case, the relationship between working memory and performance on the non-focal tasks is in keeping with the theoretical approach underpinning the current study.

Another parsimonious explanation for the observed results stems from a meta-analysis of studies examining working memory and general intelligence, conducted by Ackerman, Beier, and Boyle (2005). They concluded that working memory showed greater convergence with “narrow measures of elementary information-processing” (p. 48), than with tests of reasoning, verbal, spatial, or numerical abilities. Initialling a

box could be described as a well-practised, singular task demanding only superficial information-processing upon target cue detection. This would contrast with the dual-task and more complex focal prospective items, which as discussed, demonstrated greater sensitivity to deficits in executive control processes than with working memory.

Working memory also emerged as a small but significant predictor of the forgetting ratios associated with the non-focal tasks, accounting for 9% of the variance in performance. Higher levels of working memory ability therefore predicted a decrease in forgetting ratios associated with these tasks. It could be concluded that working memory ability not only influenced the degree of cognitive resource available to environmental monitoring for the target cue as discussed above, but also facilitated the maintenance and retrieval of the intended action into working memory from long term storage at the correct opportunity. Although working memory may have provided a similar function for the focal prospective memory task, it is feasible that the greater complexity of these items obscured the involvement of working memory, with successful task completion more reliant on executive processes as demonstrated in the current findings.

In addition to working memory, speed of processing emerged as significant predictor of the non-focal task forgetting ratios, explaining around 6 % of the variance in performance. This finding converges with that of Groot, Wilson, Evans, and Watson (2002) in which prospective memory was found to be correlated with processing speed. Speed of processing is a key process influencing adult age differences in cognition (Salthouse et al., 2004) and is a mediator of age-related effects in prospective (Salthouse, Berish, & Siedlecki, 2004) and retrospective

memory (Salthouse, 1996). Results indicated that speed of processing supported older adults in remembering the non-focal event-based tasks. It is plausible that efficient speed of mental processing may have facilitated retrieval and recollection of the intended prospective action, thereby reducing the incidence of forgetting across trials. Taken together, results indicate that attentional control processes are important predictors of event-based prospective memory performance in oldest-old adults above and beyond chronological age and education.

The attentional control mechanisms of interest in the current study were proposed to influence performance on the time-based prospective memory task. Contemporary models of prospective memory suggest time-based prospective memory to require greater self-initiated environmental monitoring and strategic attentional control (Shriffin & Schneider, 1977) for successful outcomes. It was therefore hypothesised that higher levels of executive function and working memory would support better performance on this task. After controlling for non-executive covariate predictors, a logistic regression analysis found no evidence of executive or working memory processes predicting performance. Several studies have found robust age-related decline in time-based prospective memory both within the laboratory and in naturalistic environments (d'Ydewalle, Bouckaert, & Brunfaut, 2001; Henry et al., 2004). Indeed d'Ydewalle and colleagues (1999) compared time-based performance between younger and older adults, concluding that age-effects were associated with general cognitive slowing rather than deficits in strategic monitoring. This being the case, strategic monitoring and controlled processing inherent in executive function and working memory may not have factored in performance. It is also plausible that the retention period between cue encoding and the opportunity for task execution (i.e.,

12 to 15 hours overnight) was simply too long for older adults resulting in forgetting of the task. The mechanisms involved in forgetting remain unclear but include autonomous decay of the memory trace due to physiological and/ or metabolic erosion at the synapse (Bauer, 2000). Poor encoding and fixation of the memory have also been implicated in forgetting (Howieson & Lezak, 2002b). The time-based task instruction was presented to participants at the end of the final questionnaire on Day 3 of the study protocol. This may have resulted in poor encoding and fixation due to fatigue at the end of the day, or alternatively, the instruction may have gone undetected. However, this is speculative as no retrospective data was collected specific to participant recollection of the time-based task. As time-based prospective memory was only assessed on one occasion the presented results offer only a preliminary glimpse of the role of executive function and working memory in this complex and demanding memory process.

A subsidiary focus of the current study was to explore the role of retrospective memory in prospective memory performance. Retrospective memory was correlated with the attentional control mechanisms of interest, and predicted recovery performance on focally cued event-based prospective memory in the cohort of oldest-old under consideration. Moreover, better retrospective memory predicted a lower incidence of forgetting for both the focal and non-focal event-based tasks across the study. Einstein and McDaniel (1990) defined the retrospective component of prospective memory as the ability to retain information about the intended action and the context for the action. As such, prospective memory failure could result not only from failure of a target cue to elicit a response and retrieval of an intended action, but also from the retrospective component if there is a lapse in association between the

target cue and intended action. The findings from the current study point to a small variance in prospective memory responses emanating from the retrospective component of the task. This is in contrast to much of the reported research demonstrating age-related differences in prospective memory as largely independent of retrospective memory (Cohen, West, & Craik, 2001; Kliegel, MacKinlay, & Jäger, 2008; Mäntylä, 1994; McDaniel & Einstein, 2000).

The current findings suggest that in advanced older age, performance on event-based tasks is enhanced for those adults able to recall the content and requirements of the intended action. The repetitive nature of prospective memory 'actions' used over multiple trials in the current study could have potentially attenuated reliance on retrospective memory for successful task completion. The current findings suggest this was not the case. Both the focal and non-focally cued tasks benefitted from participant's remembering the requirements of the task across trials, and remembering the target-cue association, accounting for lower forgetting ratios. Further, better retrospective memory predicted higher recovery ratios for the more demanding, dual- tasks, as epitomised by the focally cued event-based prospective memory tasks. This lends empirical support to studies in which retrospective memory mechanisms have been shown to explain differences in prospective memory performance (Groot et al., 2002). The current study partially supports the hypothesised relationships in demonstrating that retrospective memory contributes to various components of event-based prospective memory in advanced older age, in particular remembering the *what* demanded of a task and ostensibly the *when.* It could be argued that higher levels of retrospective memory function may have facilitated better memory for the prospective tasks, enhancing vigilance and

environmental monitoring at each questionnaire for the target cue. This would be in keeping with the tenets of the PAM theory of prospective memory (Smith, 2003; Smith & Bayen, 2004), and could be reflected in lower forgetting of tasks and better recovery in performance. The question remains as to whether retrospective memory support in prospective memory processes emanates from either facilitating recall of a task consequent to target cue detection, or from augmenting monitoring in anticipation of a task. This contention awaits further investigation to disentangle the mechanisms through which retrospective memory contributes to the various components of prospective memory.

It can be concluded from the current study that executive function, working memory, and retrospective memory have distinct and partially independent influence on different aspects of prospective memory performance in oldest-old adults. As previously alluded to, the study provides preliminary evidence for the reported effects, and several limitations of the present data concern the cognitive measures used and the generalisation of results. Throughout this thesis, participants in the ADuLTS study represented a select group of higher functioning, healthy older adults. As discussed in Study 1, selection bias into longitudinal studies and self-selection into one-off studies is often non-random, and could have impacted on the results with mean trends in the sample confounding the data using conventional analyses. Thus generalisation to the wider cohort of over 85 year olds is difficult. Moreover, although the sample size in the ADuLTS study was consistent with those found in similar studies involving substantial participant burden, the relatively small sample meant that statistical power to detect modest effects was limited.

6.11 Limitations.

Methodological issues with respect to the prospective memory measures as considered in Study 1 are pertinent to this study, and include possible habituation and practice effects associated with repeated presentation of event-based tasks possibly exaggerating proficiency. The administration of a single time-based task is also problematic and future research would benefit from the incorporation of multiple time-based prospective memory items and non-repetitive event-based tasks. Specific to the current study is the potential limitation attributable to the differences in collection of cognitive data between the ALSA and non-ALSA participants. Time differences of up to eleven months between collection of cognitive and prospective memory data between participants could have potentially confounded results, although in the current study this was not the case. Concurrent collection of data for all measures of interest would strengthen future research in this field.

Limitations of the current study also concern the specific nature of the attentional control measures used to operationalise executive function, working memory, and retrospective memory. Cognitive measures emanated from measures contained in the ALSA. As such they were not necessarily representative of the multi-dimensional constructs embodied within each of the mechanisms. Executive function for instance was defined as a unitary construct and measured as a composite score extracted from three tasks, two of which assessed verbal fluency. Verbal fluency tasks such as the FAS and ELF are sensitive to executive function (Bryan & Luszcz, 2000; Henry &Crawford, 2004; Phillips, 1997) and assess executive sub-processes such as switching between semantic categories, inhibition of perseverative responses, flexibility, self-initiated search strategies, and updating of responses. The third

component of the executive function measure, the CLOX 1, also has demonstrated sensitivity as a measure of executive function (Suhr & Jones, 1998; Ratcliff et al., 2003; Royall et al., 1999). Similarly, working memory and retrospective memory data were comprised from underlying constructs collected within the MMSE with each composite measure having previously reported validity. The cognitive measures employed in the current study were construed based on theory and reported validity and reliability studies. The inclusion in future studies of more comprehensive tests of cognitive functioning for each construct would strengthen research in this field and facilitate defining the factors specifically related to the different phases of the prospective memory process (Kliegel et al, 2011).

6.12 Conclusion.

The results of Study 3 point toward attentional control processes, namely executive function and working memory, as integral cognitive abilities supporting prospective memory in oldest-old adults. The retrospective memory component of prospective memory processes was a small predictor of proficiency, aligned with a specific component of an event-based prospective task and cue. The current study does supports recent research in which the executive sub-processes of shifting between the demands of an on-going task and a concomitant prospective task, and the inhibition of prepotent responses, were found to be predictive of prospective memory performance in both younger and older adults (Schnitzspahn et al., 2013). As such, findings concur with the premises of the Multiprocess Framework of prospective memory (McDaniel & Einstein, 2000) whereby controlled attention is argued to support various components of prospective memory. Further, the current study provides initial evidence for working memory support of environmental monitoring

and manipulation of relevant stimuli to be accessible in working memory during prospective memory tasks undertaken by those in advanced older age. A role for retrospective memory support of prospective memory processes in advanced older age is also an important finding in the current study. Study 3 therefore contributes to contemporary models of prospective memory processes in delineating the fundamental role of executive function, working memory, and retrospective memory in this complex memory process under ecologically relevant experimental conditions. In so doing, the study lays the foundation for future research to further the exploration of both controlled attentional processes and episodic memory in prospective memory in the oldest-old in both laboratory controlled and naturalistic studies.

Chapter 7.

Discussion and Conclusion

7. Overview

This chapter begins with a brief overview of the findings. The interpretation of the pattern of results will be considered from alternative conceptual frameworks and contemporary theories of prospective memory. The implications of several limitations identified in the current research will be discussed prior to considering future directions for prospective memory research in the oldest-old.

7.1. Introduction

The essence of psychological research on cognitive ageing is to delineate the bio-psycho-social mechanisms and pathways determining function in cognitive and behavioural processes. Based on this tenet, the purpose of the current research was to address the influence of several theoretically relevant inter- and intra-individual correlates of the unique construct of prospective memory. The thesis aimed to present empirical evidence of prospective memory performance in a group of oldest-old adults in an ecologically valid investigation. Taken together, the three studies presented identified cognitive, situational, and physiological resources available to an individual that may modify performance in this memory domain and highlighted the complex and multi-dimensional nature of prospective memory. Informed by the Multiprocess Framework, results demonstrated that prospective memory performance is associated with the nature of the task, be it event- or time-based, and with the degree of cognitive resource allocation requisite to successful task outcomes. The major finding of this thesis showed that event-based prospective memory performance is generally well

maintained into advanced older age, but clear deficits are apparent with time-based prospective memory tasks.

Drawing from the Multiprocess Framework (McDaniel & Einstein, 2000) as a theoretical scaffold, prospective memory items throughout this thesis were categorised according to functional factors. Event-based tasks were classified dependent upon the nature of the task as either event- or time-based. These tasks were further delineated according to the focality of the target cue signal. Eleven focally cued items were presented across the week of the micro-longitudinal study, these cues hypothesised to educe spontaneous retrieval processes. Participants were also presented with nine non-focally cued items, predicted to demand greater strategic monitoring, resulting in larger performance deficits on these tasks. A single time-based task required participants to telephone their Research Assistant on a particular morning of the study. As time-based prospective memory is demanding of self-initiated strategies and high levels of environmental monitoring for successful completion, poor performance on this task was predicted in comparison to the event-based tasks. Performance across trials was scored as successful for both the focal and non-focal event-based items if a correct response was recorded, or if participants remembered to make the telephone call during the nominated morning.

7.2 Review of major findings from Studies 1, 2, and 3.

7.2.1. Study 1. Inter-individual differences in prospective memory performance were examined in Study 1, the aims of which were to identify possible age-related effects across a narrow age-band of older adults, and to unravel the nature and direction of performance in real-world environments. Results were consistent with functional factors, namely the nature of the task, and the focality of the target cue,

differentially impacting upon performance. Consistent with findings of previous studies in naturalistic environments, event-based prospective memory was largely spared in the majority of oldest-old participants (Henry et al., 2004; Hertzog, Park, & Morell, 2000; Maylor, 1990; Rendell & Thomson, 1999). In fact a number of participants recorded perfect, or near perfect scores for both focal and non-focal prospective memory. In contrast, time-based prospective memory performance was compromised for the majority of participants, providing convergent evidence with previous research (Einstein & McDaniel, 1996; Einstein et al., 1995; Henry et al., 2004; Park, 1997). The findings are consistent with the theoretical approach of the Multiprocess Framework (McDaniel & Einstein, 2000) in which time-based tasks are posited to demand higher levels of self-initiated monitoring and strategy use for successful completion in comparison to event-based tasks. This also supports the theoretical underpinnings of the PAM (Smith, 2003; Smith & Bayen, 2004) in which higher levels of environmental monitoring are proposed to be associated with more complex prospective tasks. The current results therefore highlight the fundamental parallels between these two contemporary models of prospective memory and attest to the utility of incorporating multiple theoretical approaches when considering research design.

The distinction between the observed results for event-based and time-based prospective memory performance lends support to the age-prospective memory paradox. The paradox encompasses a substantial body of research in which the performance of older adults shows age-related benefits in naturalistic studies compared to age-related deficits in laboratory-based studies (Rendell & Craik, 2000). This is particularly evident for event-based tasks. Based upon the high proportion of

successful event-based responses, it was apparent that the paradox was substantiated. As event-based performance in laboratory-based conditions was not assessed for participants in the ADuLTS study, it is difficult to know how this particular sample of oldest-old adults would have fared in such circumstances. It is reasonable to surmise however, that performance may have been less exemplary under more artificial, experimental conditions. Time-based prospective memory performance was poor for the majority of participants and was in contrast to results for the event-based tasks. This finding diverges from naturalistic studies in which older adults have been shown to outperform their younger counterparts (d'Ydewalle, Bouckaert, & Brunfaut, 2001) on time-based tasks. However, these results are generally in keeping with those reported by Henry et al. (2004) whereby age-related benefits conferred in naturalistic settings do not necessarily transfer to time-based tasks.

Age effects associated with prospective memory were also examined in Study 1. There was preliminary evidence of linear age having an association with declines on focal EBPM performance, a relationship not observed for the non-focal event-based tasks or for time-based prospective memory. The effect however, was small and it can be inferred that age was not a major determinant of prospective memory within this narrow age-band of the oldest-old. Contrary to previous research (Cherry & Le Compte, 1999; Duncan et al., 1996), the results were independent of covariate predictors of gender, education, and depressive symptoms. Overall Study 1 provided evidence for variation and differential effects in prospective memory processes in the oldest-old that were largely independent of age and the included demographic covariates. With a small sub-set of individuals clearly displaying deficits with

prospective memory tasks, the subsequent studies in the thesis were developed to examine potential key correlates of prospective memory.

7.2.2 Study 2. The effect of stress upon prospective memory performance was investigated in Study 2 from an inter-individual differences and intra-individual variability perspective. It was postulated that age-related elevations in basal cortisol levels and increased physiological reactivity to stress would compromise memory processes. As few studies had directly examined the effect of stress processes on prospective memory in oldest-old adults, this study presented an opportunity to add valuable insight into the mechanisms and correlates supporting performance in this memory domain.

There were two key contributions from Study 2. Firstly, the ADuLTS study was among the first to examine diurnal cortisol secretion in the oldest-old. Cortisol bio-markers indicated that the pattern of diurnal cortisol secretion is maintained for the majority of individuals in advanced age, with a distinct early morning increase in concentration, peaking approximately 30 minutes post-awakening, and diminishing across the course of the day. Intra-individual differences in the cortisol bio-markers were relatively stable across the study with evidence of positive correlations between many of the daily measures. The study therefore added additional normative data of cortisol secretion in very old adults to the literature.

Secondly, some significant but small effects were obtained on several select stress bio-markers with prospective memory. A higher within-person CAR was associated with poorer performance on focally cued prospective memory but there were no observed effects of stress upon non-focal prospective tasks. An elevated mean basal cortisol level at the individual level predicted a higher probability of

successfully completing the requirements of the time-based task. Also at an individual level, an increased cortisol concentration on the morning of the time-based task was associated with a reduction in the likelihood of participants calling their research assistant.

The CAR is a reliable indicator of reactivity of the HPA axis and function (Hellhammer et al., 2007) and the boost hypothesis suggests higher CAR levels are associated with anticipatory demands of the forthcoming day (Hellhammer et al., 2007; Kunz-Ebrecht, Kirschbaum, & Steptoe, 2004; Rohleder et al., 2007; Schlotz, Hellhammer, Schulz, & Stone, 2004; Smyth et al., 1998). The current data suggested that a higher CAR was associated with better time-based performance. However, higher levels of cortisol during the window of opportunity to complete the time-based task were associated poorer performance. This suggested that stress co-occurring with the task, depleted higher-order cognitive processes requisite for more complex prospective memory. Time-based intended actions were argued to be more demanding of strategic self-initiated monitoring and more sensitive to the adverse effects of stress. It was consistently demonstrated across the three studies that successful completion of the dual-task and more complex focally cued prospective tasks was associated with higher levels of cognitive resources, in comparison to the non-focal tasks, over and above the influence of cue focality. This captures the observed relationship between an elevated CAR and decrements in focal event-based performance.

However, the lack of significant association between prospective memory performance and the additional cortisol indices, and the small effect sizes that were observed imply that prospective memory processes may be generally resistant to stress

and daily hassles experienced in everyday life. In fact the evidence to date, although sparse, gives reason to believe that prospective memory is spared under stress and heightened cortisol secretion (Walser et al., 2013). Study 2 provides confirmatory evidence for sparing of prospective memory under stress, specific to the oldest-old outside of the laboratory and artificially induced stress. These findings are consistent with the current research in the field (Walser et al., 2013).

A subsidiary finding of interest embedded within Study 2 illustrated that higher levels of depressive symptoms were associated with a reduced probability of phoning the Research Assistant. Intuitively this would not be unexpected in major depressive illness in which flattened affect reduces motivation and self-initiated behaviours. The current findings identified depressive symptoms below a clinical diagnostic threshold as being predictive of deficits in cognition. This concurs with studies in which depressive symptoms have been shown to predict cognitive decline (Bielak, Gerstorf, Kiely, Anstey, & Luszcz, 2011), and with deficits on cognitive tasks and forward planning processes (Kliegel et al., 2005). Drawing from these findings, there is grounding for future research to examine the association of mood and affect in stress-induced depletion of higher level cognition with complex prospective memory.

Study 2 highlighted some important insights into the relationship between age-driven stress processes and prospective memory in the oldest-old. Although some significant findings were observed on select measures, overall effects were small. It is feasible that the relatively small sample size in the ADuLTS study resulted in insufficient statistical power to detect subtle relationships. Further, as Saxbe (2008) points out, naturalistic studies do not always find a strong association between stressors and cortisol due to statistical noise or sampling error obscuring small effects.

However several aspects of the study design challenge these assumptions. For example, behaviours possibly affecting cortisol secretion, such as smoking, caffeine consumption, eating, and drinking were controlled factors in the study design. The application of ambulatory assessment enabled repeated measures of event-based tasks and cortisol sampling at multiple time-points, and multi-level analysis enabled use of all available data points. Moreover, sampling compliance was generally very good. Through the incorporation of these design strengths (see Section 7.3 for further discussion), Study 2 provided preliminary evidence for stress processes being associated with prospective memory. Future research may further delineate this relationship and provide more definitive results.

7.2.3. Study 3. Study 3 focused on the influence of cognitive variables on prospective memory performance. Given documented age-related declines in executive function and working memory and the age of the ADuLTS' participants, it was proposed that deficits in these attentional control processes would be associated with poorer prospective memory. Because any given prospective memory task necessarily involves retrospective recall of specific content, and in view of equivocal findings regarding the relationship between prospective and retrospective memory, it was also considered as a possible correlate.

Study 3 provided empirical evidence for attentional control processes predicting performance in several components of event-based prospective memory after controlling for the effects of age and speed of processing. These findings supported much of the contemporary literature in the field (Einstein et al., 2000, Experiment 2; Mäntylä, 2003; Schnitzspahn et al., 2013), but have not previously been shown among oldest-old adults. Higher levels of executive function were

associated with better performance on the focal event-based tasks compared to the non-focal tasks. This was contrary to the direction of results hypothesised. It was argued that better executive function supported performance on the more complex focal event-based tasks in comparison to the non-focal tasks. On the other hand, working memory predicted performance on the less complex non-focal event-based tasks. Working memory was proposed to be integral to environmental monitoring required for detection of non-focal cues, consistent with both the Multiprocess Framework (McDaniel & Einstein, 2000) and the PAM theory (Smith, 2003; Smith & Bayen, 2004). Study 3 contributed to empirical findings reported in the literature, confirming that attentional control processes are associated with prospective memory into advanced older age. Importantly, the results indicate that different cognitive mechanisms support different components of prospective memory substantiating the multi-dimensional nature of this memory construct (Kliegel et al., 2002). The empirical evidence presented in Study 3 therefore offers a basis for future research to further delineate the cognitive factors involved in the various components of prospective memory in the oldest-old under more controlled experimental conditions.

An important result from Study 3 was the observed relationship between retrospective memory and a lower incidence of forgetting on the event-based tasks. This result diverged from much of the literature examining the role of retrospective memory in prospective processes undertaken with younger adults (Kliegel, MacKinlay, & Jäger, 2008; McDaniel & Einstein, 2000). The delineation of the retrospective and prospective components in prospective memory processes has not been substantially addressed in recent research. The current results provide preliminary evidence for retrospective memory support of prospective memory in

advanced age and in so doing suggests an opportunity for future studies to further this line of inquiry. Study 3 findings have practical implications for older adults experiencing even mild deficits in episodic memory and attentional control processes in maintenance of prospective memory function. Interventions (discussed in Section 7.6.4) aimed at supporting these underlying cognitive processes have the potential to improve functional capacity and facilitate independence into later years. As such the results from Study 3 inform prospective memory research from both a theoretical and applied perspective.

Surprisingly, speed of processing was only associated with the non-focal event-based prospective memory forgetting ratios. This was unexpected given that processing speed has been described as a cognitive primitive, shown to mediate age-related decrements in a number of memory domains (Bryan & Luszcz, 1996; Bryan et al., 1997; Salthouse, 1996). Slower information processing may limit efficient processing and execution of other cognitive functions, including encoding and retrieval of information (Bryan et al., 1997) and inhibitory responses (Hasher et al., 2007), negatively impacting both working and episodic memory performance. Prospective tasks in the current study were not timed, with participants having as long as they wanted to complete each questionnaire. This may be why speed of processing did not generally mediate the effects of attentional control processes on prospective memory. Under time constraints, speed of processing may have emerged as a significant covariate and this supposition remains to be clarified in future studies.

7.3 Review of the design and strengths of the ADuLTS study.

This thesis used a range of methods to examine prospective memory and address important questions relative to performance in the oldest-old. A number of

theoretically relevant bio-psycho-social variables of interest were incorporated into the studies in an attempt to delineate the processes and mechanisms underpinning this construct. In addition, central features of the ADuLTS study added strength to the design, including ecological validity, and advantages associated with micro-longitudinal design and ambulatory assessment. Each of these aspects of the study design will be critiqued in the following section.

7.3.1 Ecological validity. The real-world environment in which participants were tested provided greater ecological validity to the studies than would otherwise be possible in laboratory-based studies. This is particularly so for Study 2 whereby stress co-occurring with natural events and situations provides a more accurate picture of day-to-day stress dynamics in an elderly population in comparison to acute laboratory-based inductions of stress (Saxbe, 2008). Beyond being a naturalistic study, the nature and design of the ADuLTS study allowed for a degree of experimental control to be maintained. Prospective memory items were developed to incorporate the core characteristics of intended actions in the real-world as proposed by Kliegel, Martin, McDaniel, and Einstein (2002). Following encoding of the tasks, retention intervals preceded presentation of the target cues and tasks. The window of opportunity to execute each task was restricted to, 1) the time required to complete the questionnaire and seal it in an envelope for the event-based tasks, and 2) the allocated morning to make a phone call for the time-based task. There were no further explicit prompts given at the opportunity for task execution and participants were engaged in on-going activities (i.e., answering the questionnaire and cortisol sampling) at the time for target cue detection and task execution. In comparison to most laboratory-based studies, task retention periods were quite long and may have affected outcomes,

especially for the time-based task. However, long retention periods mimic real-life prospective memory tasks which may entail retention periods from seconds, to days or weeks and provide further ecological validity to the study. This is a major strength of the ADuLTS study and the current results add valuable information on prospective memory processes observed in cross-sectional laboratory-based studies.

7.3.2 Micro-longitudinal design. The micro-longitudinal design of the ADuLTS study facilitated the examination of the day-to-day interplay between everyday cognitive processes and diurnal cortisol secretion as examined in Study 2. In so doing, associations between performance on the focally cued event-based tasks with the CAR and education level, and between stress and time-based performance, were observed. This represents a unique approach in the current literature examining prospective memory and cognitive processes in general. Much insight can be gained from incorporating micro-longitudinal studies and multi-level modelling into study designs, presenting an exciting direction for future research. Moreover, the ADuLTS study incorporated a micro-longitudinal study embedded within longitudinal research, further augmenting the strength of the study. In the future, studies such as this will allow researchers to conceptualise complex bio-psycho-social processes associated with ageing and individual trajectories across differing time-scales. Unfortunately, prospective memory was not assessed across the many waves of the ALSA study, and as such longitudinal change in this domain could not be included in the thesis studies. However, although beyond the scope of this thesis, the ADuLTS study provides the opportunity for reciprocal research with a sub-set of the ALSA participants, for instance an examination of longitudinal trajectories in cognition (e.g., attentional

control, episodic memory, and speed of perceptual processing) as predictors of current prospective memory.

7.3.3 Ambulatory assessment. Participants in the ADuLTS study were assessed in their everyday environments using ambulatory assessment sometime known as ecological momentary assessment (EMA). Ambulatory and diary methods are a methodological approach applicable to many populations with the advantage of being easily modified to the needs of a sample and the context of a study. EMA permits intra-individual variability and change to be measured through repeated, short-term fluctuations, but in so doing, often places significant burden on participants. Although EMA has been applied to research with older adults to assess medication adherence, activities of daily living, and affect, "cognitive performance has rarely been investigated in daily-life studies" (Hoppmann and Riediger 2009, p. 104). There are many advantages to time-sampling methods identified by Hoppmann and Riediger (2009). Processes can be obtained in naturalistic environments, improving ecological validity of studies, and the degree of experimenter control can be varied, for example, time-stamped assessments in the current study allowed an examination of participant compliance. EMA facilitates the examination of the co-occurrence of momentary experiences, cognitions, and physiological processes, controlling for the problems often inherent in self-report measures such as retrospective bias and memory elaboration or distortions (Hoppmann & Riediger, 2009). EMA also has the advantage of allowing alternative measurements to self-reports, such as performance based tasks or physiological measures, to be incorporated as done here. EMA is undoubtedly a significant strength of the current

studies which offer a unique and novel perspective on prospective memory processes in advanced age.

7.3.4 Summary. When considered together, the three studies demonstrated that although prospective memory processes were generally well preserved into advanced older age, especially for event-based tasks, there was never-the-less a sub-set of individuals who struggled with the tasks. Thus there was evidence for differential effects in prospective memory across the narrow age-band of the oldest-old. It can be concluded that aspects of the age-prospective memory paradox are supported in advanced older age, at least in a select group of higher functioning individuals, under ecologically valid conditions. From a theoretical perspective an interesting observation concerned the effect of cue focality on results. Focal event-based prospective memory showed the poorer performance although it was predicted to be less demanding of strategic monitoring and to facilitate spontaneous retrieval in comparison to the non-focal task. This was argued to reflect the complexity and dual-task nature of the focal tasks, consistent with the attention-depletion hypothesis and dual-process theory (Shriffrin & Schneider, 1977). Although this is a parsimonious explanation, there are plausible alternative conceptual frameworks from which to interpret the current results.

7.4 Alternative explanations for the current findings.

Alternative explanations for the pattern of results emanate from at least three sources related to the componential and multi-dimensional nature of prospective memory processes and theory. The first concerns the operationalisation of the focality of the event-based prospective memory target cues. Second, the role of perceptual and semantic processing, and valence of the focal cues may contribute to interpretation of

results. Third, contextual factors including motivation, control over task execution, meta-cognitive awareness, and competing activities (Phillips et al., 2008) may offer an alternative conceptualisation of results.

7.4.1 Categorisation of the focality of event-based cues. Across this thesis, the categorisation of the focality of the event-based cues was a recurring issue that may have impacted upon the observed results. From the Multiprocess Framework (McDaniel & Einstein, 2000), focal cues were proposed to elicit spontaneous retrieval processes supporting better prospective memory performance on these tasks in comparison to non-focal cues. Non-focal target cues were posited to be more demanding of cognitive resources allocated toward environmental monitoring for the target cue, culminating in poorer performance. However, poorer performance on the focal tasks was evident in all three studies. Thus, the focality or otherwise of the event-based cues may be a contentious issue and it is difficult to ascertain whether the definition of these cues was optimal. Target cues were operationalised based on theoretical applications applied in previous research with pencil- and- paper tasks and definitions proposed by eminent theorists in the field (McDaniel & Einstein, 2000).

It was argued in Study 1 that better performance on non-focal EBPM compared with focal EBPM was plausible when considering the tenets of the PAM model (Smith, 2003; Smith & Bayen, 2004b) and the Multiprocess Framework (McDaniel & Einstein, 2000). It was proposed that better performance on the non-focal tasks was due to attentional resources being directed to environmental monitoring for the target cue, rather than toward maintenance of an on-going task, as was the case with the focally cued prospective memory items. The literature has confirmed that working memory is involved in strategic monitoring processes and

supports prospective memory processes (Smith, 2003; Smith & Bayen, 2004b). Study 3 found convergent evidence, with working memory predicting performance on the non-focal EBPM tasks, posited to require higher monitoring for detection. This was not evident with the focal EBPM tasks. Because the box to be initialled was at the bottom of the page with other questions several centimetres away, detection of the non-focal cue may have demanded higher levels of environmental monitoring for successful detection, reflected in the association between better working memory and lower forgetting ratios on these tasks.

It is also reasonable to deduce that the focal target cues may have been detected spontaneously but the inherent complexity associated with the dual-task may have imposed detrimental effects on performance. Given the evidence from Study 3 showing differential associations between executive function and working memory with the event-based tasks, it could be argued that the cues were correctly categorised. As argued in Studies 2 and 3, the different levels of complexity characterising the two event-based prospective memory tasks provides a contextual basis for explaining the observed effects in performance over and above the influence of target cue focality. However, as costs in terms of response time latencies associated with monitoring and task switching were not measured, the operationalisation of target cue focality challenges a definitive interpretation.

7.4.2 Perceptual and affective processing of cues. An additional aspect of the methodology warranting some discussion is the potential influence on successful cue detection arising from differences in the salience and emotional valence of the focal and non-focal cues. The perceptual distinctiveness of the cue, and hence the salience, in comparison to the on-going task is a factor identified in attenuating age-

related differences. As applied in the current research, Einstein, McDaniel, Manzi, Cochran and Baker (2000) presented cues in upper-case font embedded within an on-going task presented in lower case font. In so doing, performance was better for both younger and older adults in comparison to cues presented in the same font. Further, the effect of cue salience occurred for both age groups during cue detection (i.e., the prospective component) but not recall of content (i.e., the retrospective component).

Emotional valence of a cue has also been shown to increase cue salience, with attention drawn toward emotional information. This culminates in better retention of emotional information compared with neutral information, with enhanced long-term memory for the information shown in both younger and older adults. A recent study manipulated the emotional valence of cues presented to young adults (Clark-Foos, Brewer, Marsh, Meeks, & Cook, 2009). In Experiments 1a to 1c, positive cues embedded within a neutral on-going task were detected more often than negative cues. In Experiment 2, neutral cues were embedded within positive, negative, and neutral sentences. Cues within the neutral sentences had the highest detection frequency, followed by those in the positive sentences. In other research, Altgassen et al. (2010) tested 41 younger (M = 24.95, SD = 3.74 and 41 older adults (M = 68.85, SD = 4.54) using an on-going working memory task and prospective task (i.e., pressing a key at the detection of specific stimuli). The stimuli were pictures rated on salience and emotional valence from negative, to neutral, to positive. They found older adults to be more impaired in detection of the neutral cues but not the emotionally valenced cues.

These studies add empirical support to the Multiprocess Framework which predicts emotionally valenced and highly salient cues to support performance and reduce age-related differences. However such evidence does little to explain the

results in the current thesis. The non-focal cues were of neutral valence and not highly distinctive. In contrast the focal cues were distinctive, and by definition 'salient'. Moreover the focal cues were adjectives describing positive and negative emotional states (i.e., content, proud, lively, relaxed, still, angry, afraid, hostile, upset, tired, and bored). The Multiprocess Framework and the work by Altgassen and colleagues would therefore predict better performance on the focal task due to increased emotional valence and distinctiveness of the cue. However this was not the case, with performance on the focal task not as robust as that on the non-focal task.

An alternative explanation to cue salience and valence stems from theory differentiating data-driven and conceptually- driven processes in perception (Cohen, West, & Craik, 2001). Performance on data-driven processes is dependent on the perceptual information presented with a cue. This is in contrast to conceptually-driven processes which are associated with the semantic meaning of stimuli presented with a cue. Cohen, West, and Craik (2001) found that data- driven processing positively affected perceptual performance but that semantic relatedness between an on-going task and cue had a greater effect. The authors concluded that cues distinctive to a task and relevant to existing knowledge capture an individual's attention and aid in perceptual processing. In this respect a box for initialling should have readily been processed as a task-cue association familiar across the life-span. This provides a reasoned explanation for the high level of proficiency on the non-focal tasks.

Drawing from this work, the perceptual distinctiveness (i.e., a capitalised item) and the semantic relatedness of the focal cues (i.e., emotionally valenced adjectives assessing affect) should have aided detection and performance on this task. It is apparent that this was not the case. In spite of semantic relatedness between the focal

cues presented across trials and the on-going task, attentional resources may have been diverted to semantic processing of the cue. In addition, regulation of emotional response induced by the affective demand of the cue may have shifted resource allocation at the expense of the on-going prospective memory task. The dual-process theory (Shriffrin & Schneider, 1977) discussed in Chapter 2, and the association between executive function and focal event-based performance reported in Study 3, lend some credence to this contention.

The dual-process theory (Shriffrin & Schneider, 1977) demonstrates the dissociation between controlled and automatic processing of information. Braver and Barch (2002) contend that inhibitory and controlled processing deficits associated with age-related executive function decline increase propensity to engage in automatic processing. The ability to suppress automatic pre-potent stimulus-response associations with controlled processing is therefore compromised, and is particularly evident under high cognitive or affective demand, or when performance constraints are placed upon working memory (Hess et al., 2009). Payne (2003) suggests this places greater reliance on automatic processing, increasing susceptibility to contextual distortions, and a reduction of episodic memory. It is feasible that the valence associated with the focal cues may have activated semantic processing for cue meaning and induced an affective or emotional response. This concept is consistent with Socio-emotional Selectivity Theory (SST; Charles, et. al., 2003) according to which older adults focus on the emotional meaning of information in an effort to optimize and regulate their emotional experience. It follows those older adults with executive function decrements could have experienced more difficulty inhibiting pre-potent automatic responses associated with activation of an affective response,

reducing explicit memory recall of the prospective task. In this case, resources would have been redirected from attentional control processes toward amelioration of the affective response and semantic processing leaving fewer resources for prospective task requirements, the consequence being degradation of executive resources under load with poorer memory performance. Older adults experiencing executive function decline may therefore have been more susceptible to the interplay of age-related attentional decline and depletion of cognitive resources associated with affective regulation induced from target cue valence. In Study 3, executive function was found to be associated with focal EBPM performance. Older adults with higher levels of executive functioning displayed better overall performance and lower forgetting ratios on these tasks. Enhanced mental set shifting and inhibition of the demands of the on-going task were components of executive function posited to support performance on the more complex and dual- focal tasks. However the interplay between attentional control processes, target cue valence, and differential effects associated with data- or conceptually-driven perceptual processing are plausible explanations for the current findings. The opportunity exists for these constructs to be incorporated into future study paradigms to assess their contribution to prospective memory mechanisms in the oldest-old.

7.4.3 Contextual theories of prospective memory. Due to its complex and multi-dimensional nature, consideration should be given to the validity of portraying prospective memory processes from unitary conceptual perspectives. Whilst the Multiprocess Framework and the PAM give theoretical credence to cue focality, environmental monitoring, and the nature of prospective tasks, especially within a laboratory type investigation, it may now be pertinent to complement current theory

with a focus on contextual mechanisms and factors underpinning the age-prospective memory paradox.

7.4.3.1 Contextual factors and prospective memory. It has been proposed by several researchers that older adults' effective use of cues and reminders may provide a parsimonious explanation for the age-prospective memory paradox. For example, Maylor (1990) and Moscovitch (1982) suggested that older adults are more likely to use external reminders in naturalistic settings, supporting performance. Better use of external aids has also been attributed to older adults (d'Ydewalle & Brunfaut, 1996; Rendell & Thompson, 1999) compared with younger adults. The feedback from participants in the ADuLTS study challenges this argument with only one report of self-initiated use of an external reminder (i.e., "I wrote myself a note"). Indeed, reliance on external cues and reminders may not be the only mechanism supporting prospective memory performance in older age.

Recently Phillips and colleagues (2008) identified four mechanisms that could account for age-related preservation of function with everyday tasks in real world environments. These are 1) motivation, 2) control over cues, 3) metacognitive awareness, and 4) activity level between intention formation and the opportunity for task execution. Motivation for task accomplishment is proposed to be enhanced for naturalistic as opposed to laboratory tasks, as tasks are usually embedded within familiar activities and everyday life. By comparison laboratory-based studies often present abstract tasks with little meaning or context, thought to reduce an individual's motivation to complete the task. Further, Phillips et al. suggest that older adults have greater situational control over memory cues in real-world environments, choosing when, where, and how to complete a task rather than responding to spontaneous

environmental cues. This contention is in line with the Selective Optimization with Compensation (SOC) model of ageing (Baltes & Baltes, 1990). Meta-cognition refers to awareness of one's own strengths and weaknesses in cognitive ability and functioning. Those with higher awareness usually outperform those with lower levels of cognitive awareness through an enhanced ability to direct knowledge acquired across the life course to a particular task. The level and demands of competing and intervening activities undertaken in naturalistic environments are also thought to impinge upon performance. As older adults are more likely to be retired with more flexibility and time to hand, it is proposed that they have greater opportunity to plan and attend to prospective tasks in comparison with younger adults.

The association between the four mechanisms proposed by Phillips et al. (2008) to influence paradoxical age-related findings in prospective memory were examined in a recent cross-sectional study (Schnitzspahn et al., 2011). Importantly the study re-affirmed the age-prospective memory paradox with older adults performing better than younger adults on tasks set in naturalistic settings. In comparison, younger adults out-performed their older counterparts in the laboratory tasks. Level of control over the task did not predict performance, and motivation and metacognitive awareness reduced age-effects in the naturalistic performance by 36% and 9% respectively. Younger adults reported substantially higher immersion in their daily activities and thus experienced higher levels of interference from competing activities, compared to older adults. This was a significant co-varying predictor of performance, eliminating age-related effects on the naturalistic task. Level of activity absorption also explained age-deficits in the laboratory task. In line with these findings, prospective memory performance in ADuLTS may have been linked with the level of

competing activities experienced by participants. An examination of concurrent activities, location, and presence of others on prospective memory performance would be of interest, in particular the role of social, physical, and cognitive activities either preceding, concurrent with, or subsequent to questionnaire completion.

The salience of prospective memory tasks and motivation to complete them as identified by Phillips et al. (2008) is of particular interest when examining prospective memory processes in advanced age. Very old adults may experience a reduced or limited window of opportunity for task execution. This may result from functional limitations (health, mobility), social and functional support inside and outside of the home, or limitations with transport as examples. Thus everyday tasks may have high salience and older adults may be more motivated to allocate resources toward successful outcomes. For example, older adults in assisted living and reliant on the community bus for transportation to the shops, may be highly motivated to purchase all of their necessities and to undertake prospective tasks at the shopping centre (e.g., post a letter, buy a birthday card, go to the bank). In comparison, younger adults may be afforded a wider opportunity to redress a forgotten task, for instance quickly returning to the shop if an essential item was forgotten. Future research assessing differences in motivation for real-world prospective memory tasks would add valuable insight to the mechanisms contributing to the age-prospective memory paradox.

The four mechanisms therefore offer a compelling avenue for examining the contextual factors influencing prospective memory processes in older age outside of task and cue characteristics. In addition, the relationship between perceived stress and HPA axis reactivity and cognitive deficits hypothesised in Study 2 may be mediated by an individual's level of activity absorption and competing cognitive demands.

7.5 Limitations

There are several limitations and methodological issues that should be considered when examining the results of this thesis. The first concerns the size and nature of the ADuLTS sample. Potentially, sample size in the study (N = 74) may have provided insufficient power to detect subtle relationships. This is particularly relevant to Study 2 in respect to cortisol measures. A recent meta-analysis examining 107 stress and cortisol-based studies found there was an average of 80 participants per study (Miller, Chen, & Zhou, 2007). The authors concluded that most of the studies were insufficiently powered to assess between-subjects effects, and required at least twice the number of participants. It is acknowledged that a larger sample would have improved statistical power. However, it is questionable whether a larger sample in this age demographic could have been successfully recruited, particularly in view of the considerable demand placed on participants by the study protocol.

Moreover, participants were a select group of healthy, high-functioning community-dwelling individuals in the fourth age and represented a relatively homogeneous group of older adults. As with much ageing research, females comprised approximately 67% of the sample, but there were no significant differences attributable to gender across the studies. Due to the select and somewhat homogeneous nature of the sample, small effects may have been difficult to detect with effect sizes underestimated (Anstey & Luszcz, 2002). Generalisation to the wider cohort of oldest-old may therefore be problematic due to the characteristics of the ADuLTS' participants.

Second, consideration of the measures used across the studies raises some potential confounds. Measures were selected as valid and reliable instruments

commonly used in ageing research and all were administered in accordance with standardised instructions. However, as previously discussed, differences between the focal and non-focal event-based cues in terms of task complexity (i.e., dual-task versus single task) and repetition (i.e., different target cue versus identical cues) may have blurred the distinction between cue focality. In addition the categorisation of target cue focality may not have been ideal and is a potential shortcoming in this thesis. Future research would benefit from altering the nature of the cues to comparative task difficulty and demand. Another methodological issue concerns the single task used to assess time-based prospective memory. The inclusion of multiple time-based tasks would have strengthened the confidence with which the effects could be interpreted.

When considering the choice of measures to assess distinct executive function, working memory, and retrospective memory constructs, task impurity may have impacted upon results (Lee et al., 2012). For example the DSST measures speed of cognitive processing and necessitates the recruitment of more complex cognitive functions for successful completion (Baudouin et al., 2009). The test also imposes upon both psychomotor speed and perceptual speed of processing. Although verbal fluency tests such as the FAS and ELF are valid measures of executive function, they are also timed tests incorporating a speed of processing component. Task impurity could therefore have impacted upon the interpretation of the results as independent measures of the constructs of interest. Future research could include a more comprehensive battery of executive and speed tasks. This would permit analysis of latent variables to reduce possible overlap between tests and confirm measurement of the underlying constructs of interest. As previously acknowledged, differences in

timing in cognitive assessment between the ALSA and non-ALSA participants had potential to affect results. Analyses conducted in Study 3 between the groups on the cognitive variables of interest found this not to be significant confounding limitation.

Third, salivary cortisol sampling conformed to established field-based protocols (Saxbe, 2008) and cortisol sampling was generally well-tolerated, with an acceptable rate of compliance. However, the ADuLTS study placed a significant burden on participants. Shortening the protocol could reduce participant demand and facilitate more research of this nature. However, researchers suggest a minimum of two to three days of multiple cortisol measures are required for the reliable assessment of the diurnal pattern (Saxbe, 2008), and the CAR in particular. In addition to the length and burden imposed by the study design, timing of the first morning cortisol sample is a potential confounding factor in determining cortisol output. Accurate computation of the CAR and daily slopes hinges upon the first morning cortisol sample being given within 5 to 10 minutes of awakening. The current literature suggests a flattening of the diurnal cortisol slope with age, which could be an artefact of delay between actual awakening time and saliva collection across studies. The inclusion of actigraphy to accurately measure sleep/wake times and the use of time-indicating saliva collection tubes would help to control for effects of non-compliance in future studies. In view of the limitations discussed it is important to interpret the findings in this thesis with prudence and with an appreciation for the methodological issues raised.

7.6 Future directions for research on prospective memory processes in the oldest-old.

Future research on prospective memory, and indeed stress processes, in the oldest-old presents some exciting opportunities and challenges, some examples of which include: 1) prospective memory research with frail oldest-old adults, 2) cross-sectional studies examining stress reactivity in the oldest-old in conjunction with more naturalistic studies, 3) research to clarify the role of social partners in supporting prospective memory performance, and 4) research examining the effect of interventions to support prospective memory including cognitive and behavioural programs. Possible avenues for future studies in these areas are outlined in the subsequent sections.

7.6.1 Prospective memory in frail oldest-old adults. Participants in the ADuLTS study represented a sample of relatively healthy, positively ageing older adults and were essentially a group of select survivors from their cohort. As such, generalisation of results to the wider oldest-old population presents a dilemma. Although our knowledge of prospective memory processes in older adults is increasing, little is known about prospective memory in frail populations. Of necessity, research with high participant demand targets high functioning, healthy older adults. In parallel, other research clearly delineates memory processes in clinical populations. For example, studies of clinical populations indicate that those with Alzheimer's disease display early and significant problems with prospective memory, in particular for focal tasks (McDaniel, Shelton et al., 2012). However, there is little research directly applicable to those older adults who are experiencing increasing frailty, but who do not fit the criteria for diagnosis with widely studied clinical

syndromes reported in the literature such as Parkinson's disease, Alzheimer's disease, Mild Cognitive Impairment, Multiple Sclerosis and other dementias. Future research is therefore needed to explore prospective memory constructs in both physically and cognitively frail populations of older adults. In so doing, identification of difficulties and early implementation of intervention and support strategies may delay early dependency in these groups.

7.6.2 Stress reactivity in the oldest-old in laboratory studies. A future focus on laboratory based research into stress and reactivity in the oldest-old would bolster findings from micro-longitudinal research such as that in this thesis. Augmenting longitudinal and naturalistic studies with laboratory studies provides researchers with the opportunity to gain greater understanding of basic processes, with the potential strengths afforded by such research through random assignment and experimental manipulation. For example, laboratory-based studies would enable stress-related processes and HPA activity and reactivity to be examined in controlled environments and to observe differences between age-groups.

For example, it may well be that acute induced psycho-social stress may have quite different effects on prospective memory performance compared to stress and elevated cortisol co-occurring with normally encountered everyday hassles and events. A novel stressor may highlight age-related physiological changes in reactivity to stress in terms of higher spike and longer recovery latency, with concurrent decrements in prospective memory accuracy and response time latencies (Saxbe, 2008). This would only be possible under controlled experimental conditions, but from a practical viewpoint, recruiting a suitable sample in terms of size from the oldest-old cohort may be problematic. The ethical implications of experimentally

manipulating acute stress in an older population are also debatable (Adam, Hawkley, Kudielka, & Cacioppo, 2006). Additionally, such research may have little ecological relevance with respect to the associations between naturally occurring stressors and real-world memory tasks. Although laboratory-based studies would engender a deeper theoretical understanding of stress processes in the oldest-old, the inherent limitations in such research poses challenges to future researchers to weigh incumbent costs and benefits.

7.6.3 The influence of social partners in prospective memory performance. The social context of prospective memory is another factor that may support performance in older age. Collaboration between dyads, and the support or otherwise of friends, relatives or significant others is pertinent to determining the mechanisms underpinning successful performance. End of life proximity and advanced older age bring greater stressors and losses in functional and social terms. The theory of SOC (Baltes & Baltes, 1990) posits compensation strategies are often used by older adults if their normal strategies and behaviours fail to attain selected goals and outcomes. Significant others may attenuate memory deficits and provide cognitive scaffolding to the other, acting as compensatory, external memory aids. This possibility was recently examined by Margrett, Reese-Melacon, and Rendell (2011). Verbal dialogue between a sample of five middle-aged (M = 52.15 years) and six older (M = 73.24 years) couples was assessed, as one partner of the dyad played the Virtual Week board game developed by Rendell and Craik (2000). Results indicated that couples collaborated in supporting prospective memory performance, specifically with respect to encoding, monitoring and tutoring. In the current research, three couples completed the ADuLTS protocol. Two of these dyads successfully completed

the time-based prospective memory task. Given poor performance on this task for the greater majority of participants, it is feasible to speculate that collaboration between the couples may have aided performance. Thus, the role of significant others in supporting prospective memory in advancing age remains to be determined and is an issue awaiting future research.

7.6.4 The role of cognitive training and interventions to support prospective memory.

7.6.4.1 The use of interventions and emerging technologies to support prospective memory. The research presented in this thesis was primarily developed around contemporary theoretical models and interpretations of prospective memory processes. Theoretical perspectives are important aspects of research but the practical application of prospective memory theory and knowledge is also important given the significant impact deficits in this memory domain can exert in the everyday lives of older adults (Kinsella et al, 2007). Although age-related decline in a number of domains is inevitable, a life-span perspective suggests older adults are able to compensate for losses through the application of accumulated knowledge and experience facilitating maintenance of independent functioning (Baltes & Baltes, 1990). In the face of prospective memory deficits such as those observed in some of the ADuLTS' participants, interventions to provide supportive environments and healthy choices may attenuate the rate of decline and facilitate longer independent functioning. Moreover, provision of assistance and interventions to high functioning oldest-old adults may enable them to participate as long as possible and reach their full potential during their advanced years.

Over recent decades consideration has been given to measures to promote comfort, safety and mobility of older adults, and to housing design geared toward independent home care models which facilitate interaction and social engagement (Morris et al., 2012). Similarly measures to reduce social isolation through the provision of digital technologies geared toward accessing social networking and health and welfare information is receiving increasing attention in aged care sectors (Kapur, Glisky & Wilson, 2004). While not directly targeting memory ability, these measures none-the-less provide instrumental and material support that may bolster mechanisms thought to assist prospective memory performance, for instance enhancing control over tasks and reinforcing meta-cognitive awareness (Phillips et al., 2008). With the advancement of emerging technologies, the opportunity exists to provide older adults with compensatory devices to enhance functional capacity and maintain independence. Examples of emerging technologies include alarms, paging devices, electronic communication devices, and personal tablet computers/organisers that can be programmed to deliver reminders or cues signalling everyday activities (Kapur, et al., 2004). Medication adherence can be supported through the use of labelled pre-packaged blister packs available through most pharmacies, and through the use of automated pill dispensers. However although new technologies and devices may attenuate the effects of cognitive losses, the utility of these measures remains to be clarified, especially for those individuals experiencing memory declines. Studies measuring the efficacy of intervention measures and the effects of instrumental and socio-demographic variables on sustaining this memory process in older populations would provide contextual frameworks for future evidence-based intervention programs.

7.6.4.2 Cognitive training and prospective memory. In addition to instrumental and material support, cognitive training has become the focus of many recent interventions aimed at supporting independent functioning in older age. According to the 'use it or lose it hypothesis' (Salthouse, 2004), the rate of mental aging is posited to be moderated by the amount of stimulating mental activity in which an individual engages. Distal and proximal effects of cognitive training undertaken by a large (N = 2,832) representative sample of older adults (*M* = 73.6 years) were recently reported by Rebok and colleagues (2014). An hour of training was conducted weekly over 5 to 6 weeks with some participants later receiving 4 sessions of booster training. Memory, reasoning, and speed of processing were targeted abilities. At baseline, there was immediate improvement in performance but this was highly domain specific. At the 10 year review, Rebok et al. concluded that the effects of training were maintained for reasoning and speed of processing, but this was not observed for memory training, the effects of which dissipated after five years. Importantly, there was long-term transfer of training effects to daily functioning in the trained groups, with participants reporting better preserved functional status at the 10 year mark.

Training has also been shown to improve working memory. Zinke et al. (2014) conducted training with adults aged between 65 and 95 years (*M* = 77.2, *SD* = 8.1) incorporating three components of working memory, namely verbal, visuo-spatial, and executive control processes. Beneficial effects of training were apparent at post-test assessment, which were maintained at a 9-month follow-up assessment. There was also evidence for transfer effects for verbal working memory, executive control, and fluid intelligence at follow-up. Further, as reviewed by Fish, Wilson, and Manly

(2010), successful training and rehabilitation targeting prospective memory has been conducted with adults with neurological disorders. Given these encouraging findings, the questions awaiting future researchers is whether cognitive training would benefit prospective memory in non-clinical populations of older adults, and if so, are there specific cognitive domains that should be targeted. Executive function, working memory, and retrospective memory were all found to predict different components of prospective memory. Training in any or all of these domains may transfer to prospective memory and functional ability. However as suggested by Salthouse (2006) empirical evidence for the mental-exercise hypothesis and age-related benefits of cognitive training is still in its infancy, with much work required to document consistent findings in this area.

7.7 Conclusion.

Informed by the Multi-process Framework this thesis endeavoured to examine several key correlates of prospective memory performance in the oldest-old. Understanding the association between prospective memory and ageing is a vital issue in cognitive psychology, both from theoretical and practical viewpoints. Prospective memory failures can have a severe impact on normal everyday functioning, the implications of which have the potential to compromise independent functioning in advanced older age. It is clear from the evidence presented in this body of work that prospective memory processes in older adults are complex and multi-dimensional. Much work therefore remains to clarify the circumstances and conditions facilitating optimal prospective memory performance in both healthy and compromised ageing.

In addition to the influence of functional factors inherent in a prospective task, sparing of prospective memory into advanced age is likely to result from diverse bio-

psycho-social influences such as health, cognitive capacity and reserve, and social and instrumental support available to an individual. Studying prospective memory in isolation from these cognitive and contextual factors provides limited opportunity to unravel the mechanisms involved in this cognitive domain. However, advancements in research techniques and statistical analyses will facilitate exploration and integration of multiple factors and complex day-to-day dynamics in longitudinal and time-burst studies. This thesis encompassed several of these emerging techniques and provided a preliminary glimpse of the utility of using ambulatory assessment to examine interconnections between daily experiences and cognitive processes. For new ideas to emerge, imagination and intuition need to be integrated with sound theoretical models and empirical evidence. In so doing, the mechanisms and processes supporting prospective memory in the oldest-old can be delineated and perhaps, the age-prospective memory paradox clarified.

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Appendix A

Preliminary forms for participants in the ADuLTS study.

Appendix A.1

ADuLTS Recruitment letter for ALSA participants

Dear Mr/Mrs

Re: ADuLTS (ALSA Daily-Life Time-Sampling) Study

We are writing to you as part of your on-going involvement in the Australian Longitudinal Study of Ageing (ALSA). We would like to thank you for recently undertaking an Interview and Clinical Assessment as part of Wave 11 of this important research. Your contribution is extremely valuable and greatly appreciated.

We are now about to embark on a sub-study of ALSA (known as the **ADuLTS Study**) which aims to discover more about the day-to-day functioning of people over the age of 80. We would like to invite you to be a part of this exciting new project. This research will provide some very important information about the aspects of older people's lives that impact on their daily well-being.

The procedure for the ADuLTS Study is as follows:

- A Research Assistant will visit you in your own home and complete a questionnaire to assess your health status and other measures relating to your social activities. Following this the Research Assistant will take you through the procedure for the ADuLTS study which you will follow over a 7 day period. This initial session will take approximately 2.5 hours.

- You will begin the following day. Each day when you wake up, and at 6 more regular intervals throughout the day, you will chew on a salivette (we will provide you with instructions on how to use these); and be prompted by an alarm to respond to a short questionnaire about how you are feeling, what activities you have been doing etc. The salivettes will later be analysed to look at stress-related substances.

- The next day the Research Assistant will again visit to check on your progress and answer any questions that you may have.

- At the end of the 7 days, the Research Assistant will collect the study materials and ask you some questions about your thoughts on the study. This final session will take approximately 1 hour.

An information Sheet which outlines the purpose of the study is included.

Over the next few weeks a Research Assistant from the Flinders Centre for Ageing Studies will be contacting you to ask if you would like to participate and to arrange a time to visit which is convenient for you. In the meantime we encourage you to discuss your involvement in this project with your family and friends. If you have any questions or would like to discuss any aspects of the study, please contact the Study coordinators on 8201 7567 or 8201 2041.

Please note that whether or not you decide to participate in this sub-study will in no way affect your on-going participation in ALSA. We would like to take this opportunity to again thank you for the very valuable contribution you are making to the health and welfare of older Australians, through your participation in our research.

With kindest regards

Professor Mary Luszcz
Director
Flinders Centre for Ageing Studies

Appendix A.2

ADuLTS Recruitment letter for non-ALSA participants

Flinders Centre for Ageing Studies

Social Sciences North Building

School of Psychology
GPO Box 2100
Adelaide SA 5001

Tel: 08 8201 2041
Fax: 08 8201 3877
fcas@flinders.edu.au

http://www.flinders.edu.au/sabs/fcas/

CRICOS Provider No. 00114A

Dear Mr/Mrs

Re: ADuLTS (ALSA Daily-Life Time-Sampling) Study

We are writing to you as you have previously participated in research undertaken by the Flinders Centre for Ageing Studies and have indicated that you may be willing to be involved in further projects. Your contribution is extremely valuable and greatly appreciated.

We are now about to embark on a study known as the ADuLTS Study which aims to discover more about the day-to-day functioning of people over the age of 85. We would like to invite you to be a part of this exciting new project. This research will provide some very important information about the aspects of older people's lives that impact on their daily well-being.

The procedure for the ADuLTS Study is as follows:

A Research Assistant will visit you in your own home and complete a questionnaire to assess your health status and other measures relating to your social activities. Following this the Research Assistant will take you through the procedure for the ADuLTS study which you will follow over a 7 day period. This initial session will take approximately 2.5 hours.

You will begin the following day. Each day when you wake up, and at 6 more regular intervals throughout the day, you will chew on a salivette (we will provide you with instructions on how to use these); and be prompted by an alarm to respond to a short questionnaire about how you are feeling, what activities you have been doing etc. The salivettes will later be analysed to look at stress-related substances.

The next day the Research Assistant will again visit to check on your progress and answer any questions that you may have.

At the end of the 7 days, the Research Assistant will collect the study materials and ask you some questions about your thoughts on the study. This final session will take approximately 1 hour.

An information Sheet which outlines the purpose of the study is included.

Over the next few weeks a Research Assistant from the Flinders Centre for Ageing Studies will be contacting you to ask if you would like to participate. In the meantime we encourage you to discuss your involvement in this project with your family and friends. If you have any questions or would like to discuss any aspects of the study, please contact the Study coordinators on 8201 7567 or 8201 2041.

We would like to take this opportunity to again thank you for the very valuable contribution you are making to the health and welfare of older Australians, through your participation in our research.

With kindest regards,

Professor Mary Luszcz
Director
Flinders Centre for Ageing Studies

Appendix A.3

ADuLTS information Sheet for ALSA participants

Flinders Centre for Ageing Studies
School of Psychology
Finders University
Telephone: 8201 7567
or 8201 2041

The University of British Columbia
Department of Psychology
Vancouver, BC, V6T 1Z4
Phone: 604.822.2755
Fax : 604.822.6923

ADuLTS (ALSA Daily-Life Time-Sampling) Study

INFORMATION SHEET:

Why is there is so much variability in how we age?

Why do some people age relatively well, while others experience declines in their health and well-being?

We are interested in examining these questions and others with the help from participants of the Australian Longitudinal Study of Ageing (ALSA).
Few studies looking at these research questions have involved participants above age the age of 85 years. Hence, little is known about very old age.

What is needed is a more in-depth look at what is happening, on a day-to-day level.

The ADuLTS Study aims to explore how the health of older adults like you is impacted by the emotions that you experience in your day-to-day life, the people that you see and the activities in which you partake. If you decide to participate in our study, you will be asked to complete seven brief questionnaires each day over the course of seven days. In addition, we will ask you to provide saliva samples to measure stress hormones. This in depth look at the daily lives of older adults will give us insight into how situational circumstances, activities, cognitive functioning and well-being change over the day, and affect long-term health.
If you have any questions, please contact the Study Coordinators on **8201 7567** or **8201 2041**

Appendix A.4

Information sheet for non-ALSA participants

Flinders Centre for Ageing Studies
School of Psychology
Finders University
Telephone: 8201 7567
or 8201 2041

The University of British Columbia
Department of Psychology
Vancouver, BC, V6T 1Z4
Phone: 604.822.2755
Fax : 604.822.6923

A
ADuLTS (ALSA Daily-Life Time-Sampling) Study

INFORMATION SHEET:

Why is there is so much variability in how we age?

Why do some people age relatively well, while others experience declines in their health and well-being?

We are interested in examining these questions and others. Few studies looking at these research questions have involved participants above age the age of 85 years. Hence, little is known about very old age.

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The ADuLTS Study aims to explore how the health of older adults like you is impacted by the emotions that you experience in your day-to-day life, the people that you see and the activities in which you partake. If you decide to participate in our study, you will be asked to complete seven brief questionnaires each day over the course of seven days. In addition, we will ask you to provide saliva samples to measure stress hormones. This in depth look at the daily lives of older adults will give us insight into how situational circumstances, activities, cognitive functioning and well-being change over the day, and affect long-term health.

If you have any questions, please contact the Study Coordinators on **8201 7567** or **8201 2041**

Appendix A.5

Consent form and information sheet

Flinders Centre for Ageing Studies
School of Psychology
Finders University
Telephone: (08) 8201 7567
or: (08) 8201 2041

The University of British Columbia
Department of Psychology
Vancouver, BC, V6T 1Z4
Phone: 604.822.2755
Fax : 604.822.6923

CONSENT FORM

ADuLTS (ALSA Daily-Life Time-Sampling) Study

Investigators:
Dr. Mary Luszcz
School of Psychology
Flinders University
(08) 8201 2481

Dr. Christiane Hoppmann
Department of Psychology
The University of British Columbia
Telephone: 1 (604) 822-8428

Dr. Ruth Walker
School of Psychology
Flinders University
(08) 8201 3064

Dr. Denis Gerstorf
Human Development & Family Studies
The Pennsylvania State University
1 (814) 867-2131

Purpose:

The ADuLTS Study aims to explore how older people's health is impacted by the emotions that they experience in day-to-day life, the people they see and the activities they partake in. Throughout the course of each day, over a 7 day period, you will be asked to complete seven short questionnaires. In addition, we will ask you to provide saliva samples. We will use the saliva to measure cortisol and amylase, two stress-related hormones. We will store the saliva samples for 5 years after the end of the study. Should new assays become available, we may also use the saliva samples to look at other stress-related substances, for example oxytocin or cytokines. We anticipate that approximately 70 people over the age of 80 will participate in this study.

Study Procedures:

This study consists of 4 parts:

1. First (Day 1), a Research Assistant will visit you in your own home where you will be asked to complete a questionnaire to assess your health status, cognitive functioning and other measures relating to your social activities and goals. We will then show you how and when to complete a series of daily questionnaires, and how to collect the saliva samples. We don't want to alter your usual routine, so we will work out a schedule that suits your typical activities. You will receive a written copy of the schedule, a summary of all instructions, data collection envelopes, and a contact mobile telephone number for any further questions you might have during the study. This initial session will take approximately 2.5 hours.
2. Second, starting the next day (Day 2), you will enter a daily life questionnaire phase for the next 7 days. Each day when you wake up you will start by providing a saliva sample by chewing on a cotton swab, and also reporting on your sleep; 30 minutes later you will chew a second swab and indicate what you've done since the first measurement.

You will also be asked to respond to a short questionnaire seven times per day. You will follow the schedule we worked out with you on the first day as closely as you can. To help you remember, you will receive a device which will 'beep' when you need to complete the questionnaire. The questionnaires will ask you about how you are feeling, about what you are doing at that time, and will involve a short cognitive task. Each questionnaire will take

about 10 minutes to complete. While completing these questionnaires, you will again provide saliva samples. In summary, saliva samples will be taken 7 times daily: after waking up, 30 minutes later, and in conjunction with the 5 daily questionnaires. We will be available by mobile phone if you have any questions during this part of the study.
3. The next day the Research Assistant will again visit to check on your progress and answer any questions you may have.
4. At the end of this week, the Research Assistant will visit your home again to collect the study materials and ask you some questions about your thoughts on the study. This final session will take approximately 1 hour.

How much of my time is required?
If you agree to participate in this study, your time involvement will be 10 hours over 9 days.

Potential Risks:
There are no risks known risks associated with your participation in this study.

Potential Benefits:

Although there is no direct benefit to you by participating, you will help us to better understand day-to-day changes in functioning as we grow older. This knowledge will be used in the future to improve the health of older adults.

Confidentiality:
All records containing personal information will remain confidential and no information which could lead to identification of you, or any other individual, will be released. Data files will be protected, and all records will be kept locked in secure areas.

Compensation:
You will receive a 'thank you' gift as a token of our appreciation for your participation in this study.

Contact for information about the study:
Should you require further details about this research, or wish to discuss any issues raised as a result of your involvement in the study, please contact the Study Coordinators (Ph: 8201 7567 or 8201 2041), or Professor Mary Luszcz, (Ph: 8201 2481). If the questionnaires raise any issues that you would like to discuss confidentially with someone, we suggest you consult your medical practitioner, the 24-hour Lifeline telephone counselling service (131 114) or the Centacare Family Relationships Counselling Service (8210 8200). Please note that the counselling services listed are free. If you prefer, you may also contact the researchers for other suggestions.

Funding:
This study is funded by the Australian Research Council and Canadian Institutes of Health Research and the has been reviewed and approved by the Flinders Clinical Research Ethics Committee and the University of British Columbia's Behavioural Research Ethics Board.

Contact for concerns about the rights of research subjects:
Should you wish to discuss the project with someone not directly involved, in particular in relation to matters concerning policies, your rights as a participant, or should you wish to make a confidential complaint, you may contact the Manager – Flinders Research Ethics Committee, Mr Harry Randhawa on 8204 6453 or 0422 687 087. You may also contact the Research Subject Information Line in the UBC Office of Research Services with any concerns about your treatment or rights as a research subject via email: RSIL@ors.ubc.ca.

Consent:
Your involvement in this study is entirely voluntary and your non-participation will not affect you in any way. Should you decide to withdraw from the study you may do so freely and without prejudice at any time.

Your signature on the following page indicates that you have received a copy of this consent form for your own records.

Your signature on the following page indicates that you consent to participate in this study.

Consent Form

Flinders Centre for Ageing Studies
ALSA DAILY LIFE TIME-SAMPLING (ADuLTS) STUDY

CONSENT TO PARTICIPATE IN RESEARCH 2010
SURNAME: .....
GIVEN NAMES: .....
SEQUENCE NUMBER: /___/___/___/___/___/

I.....
(Given names) *(Surname)*

agree to participate in a confidential interview with a representative of the research project.

ALSA DAILY LIFE TIME-SAMPLING (ADuLTS) STUDY

- I acknowledge that the nature and purpose of this interview has been explained to my satisfaction.
- I have been provided with an ***Information Sheet***, which has detailed the aims and objectives of this research project
- I understand that this study, which will involve my participation over a 9-day period, may not be of any direct benefit to me.
- I understand that I may withdraw my consent at any stage without affecting my rights or the responsibilities of the researchers in any respect.
- I understand that all records containing personal information will remain confidential and no identifying information will be released.
- I have been given a copy of the consent form.
- I declare I am over 18 years of age.

Signature of research participant: ..... Date:.....

Signature of Witness: .....Date:.....

Printed name of Witness: .....

I ..... have described to..... the research project. In my opinion he/she understands the explanation and has freely given his/her consent.

Signature: ..... Date:.....

Status in project.....

Appendix B.1

Participant guidelines and instructions.

Appendix B.1

Participant guidelines and instructions.

Participant Guidelines

ALSA Daily-Life Time-Sampling (ADULTS) Study

Please refer to these Guidelines as often as necessary during your participation in the ADuLTS study.

Thank you for agreeing to participate in this important study.

The ADuLTS Study aims to explore how older people's health is impacted by the emotions that they experience in day-to-day life, the people they see and the activities they partake in.

During this study you will be asked to complete seven brief questionnaires each day over the course of seven days. In addition, we will ask you to provide saliva samples to measure cortisol and amylase, two stress-related hormones.

Your Research Assistant will also visit you once you have commenced the study to check on your progress and answer any questions you may have.

After 7 days have passed, your Research Assistant will visit you for a third time and ask you to answer some questions about your thoughts on the study.

Because people are different from each other, each person responds to daily situations in his or her own way. Therefore, all responses to the questions in this study are correct responses. There are no incorrect answers. All of your responses are valuable to us. We hope that taking part in this study is an enjoyable experience for you and once again we thank you for your generous participation.

Summary Procedure for Morning questionnaires

Please refer to your SAMPLE MORNING QUESTIONNAIRE for detailed information regarding specific questions

- Morning Questionnaire #1 is to be completed when you first wake up and **before** you get out of bed, even if you feel that you are not quite functioning yet. While you are completing this Questionnaire you will also chew on your first salivette. (Please see the separate guidelines for detailed salivette instructions).
- If your mouth is dry when you wake it is OK to have water before the first salivette.

- At this time you will also set the kitchen timer for 30 minutes
- After you have completed Morning Questionnaire # 1, please take the first salivette out of your mouth and place it back in the vial. You can set the questionnaire aside until the kitchen timer goes off.
- **It is very important that you DO NOT: exercise, take a cold shower, brush your teeth, have breakfast, smoke, or consume caffeine or alcohol or fall back asleep before you answer Morning Questionnaire # 2 and use the second salivette. This is important to us because all of these things can influence the cortisol results. It is OK to have water; juice, decaf and stay in bed as long as you do not fall back asleep.**
- **It is very important that you DO continue to follow your usual medical regime and any instructions which a doctor has given you.**
- When the 30-minute **kitchen timer alarm goes off** please use the second salivette while answering Morning Questionnaire #2.
- When you have completed Morning Questionnaire #2, please fold the questionnaire and put it back into its envelope, seal the envelope and stamp across the seal. The envelope can then be returned to your kit.
- After 2 minutes the salivette can be returned to its vial and then placed in its Glad Bag.

Summary Procedure for Daily Questionnaires

Please refer to your SAMPLE DAILY QUESTIONNAIRE for detailed information regarding specific questions

- Throughout the day your alarm device will prompt you to respond to short questionnaires. This will happen 5 times per day over the course of seven days. Your Research Assistant will organize a schedule for your alarm (beep) so that it will fit in with your usual activities as much as possible.
- At each of these beeps we would like to ask you to put a salivette in your mouth and roll it until it is saturated with saliva. This will be approximately the length of time that it takes to fill out the questionnaire (Please see the separate guidelines for detailed salivette instructions).
- Some of the questions ask about how you are feeling. If you were unable to complete the questionnaire immediately at the beep you need to ensure that you answer these questions based on how you feel at the time when you are answering them. For example, if you need to wait 30 minutes to fill out the questionnaire then answer based on how you feel at the moment in time when you are actually answering the question; don't try to recall how you were feeling 30 minutes ago.
- There are some questionnaires that will have questions written in capital letters. **Please make two circles around your answer choice whenever you see a question that is written in capital letters.**
- There are some questionnaires that will have a box  on the bottom right of the page. **Please write your initials in this box whenever you have a questionnaire with a box on the bottom right corner of the page.**
- When you have completed each Daily Questionnaire, please fold the questionnaire

and put it back into its envelope, seal the envelope and stamp across the seal. The envelope can then be returned to your kit.

- After you have completed the Daily Questionnaire the salivette can be returned to its vial and placed in its Glad Bag. At the end of each day please place the Glad Bag with the used salivettes in the fridge or freezer.

Important Points to Remember

- The purpose of this study is to find out as much about your daily lives as possible but NOT to interfere with your usual activities. Therefore, if you need to miss a beep because it would be too intrusive (for example if you are at church, at a doctor's appointment, having a nap) then that is OK.

- If you are not able to complete a questionnaire at the time the alarm goes off then please just do so as soon as possible. If more than 2 hours have passed since the beep, then please just skip that questionnaire and corresponding salivette and complete the next one when the next alarm goes off.

- If you need to go out and you know a beep and questionnaire are coming up soon, it is fine to complete it before you leave home.

- If you will be able to respond to a beep when you are away from home, please take the necessary equipment (questionnaire, salivette, time stamp and alarm device) with you in the bag provided.

- Please answer the questionnaire as soon as possible after the beep. If you are with a group of people; please try to fill it out without chatting in-between questions.

- Please use the time stamp to record the date and time in the spaces indicated at the beginning and end of each questionnaire. To ensure that the stamp works correctly, roll it towards you and press down firmly until the noise stops.

- When you have completed the questionnaire, put it in the envelope provided and stamp the envelope across the seal with the time stamp. To ensure that the stamp works correctly, roll it towards you and press down firmly until the noise stops.

- Once the envelope has been sealed please do not re-open it.

- If you are concerned that you may not be able to produce enough saliva to saturate the salivette, you may chew gum beforehand to assist.

- It is important to us that you use the correct salivette. However, if you do accidentally use the wrong one, it is more important that you enter the actual Day and Number of the salivette that you did use.

- In the case where something unanticipated occurs (e.g. sickness) please call your Research Assistant as soon as possible and she will arrange a different schedule to suit you. This could mean re-scheduling for another week or pausing for a few days before continuing.

Do not hesitate to call your Research Assistant whenever you have any questions.

Appendix B.2

Saliva Collection Instructions

ALSA Daily-Life Time-Sampling (ADULTS) Study

Please refer to these Instructions as often as necessary during your participation in the ADuLTS study.

We will provide supplies for you to collect 7 samples of your saliva (spit) each day for 7 days. We are collecting saliva to learn about stress hormones and how they differ between people.

PLEASE READ THESE INSTRUCTIONS COMPLETELY BEFORE YOU HANDLE THESE SUPPLIES.

Each day you will use 7 salivettes (this is similar to cotton-like gauze used at the dentist). The salivettes are used for collecting saliva. Each salivette is in a small plastic tube. For each day that you are in the study, we will provide a separate plastic bag. One bag for Day 1, one bag for Day 2, etc. Each bag contains all of the salivettes that you will use for that day.

DO NOT open the tubes until it is time to collect saliva.

Your kit contains these items:

- 1 plastic bag per day, each with 7 tubes.
- Tubes are labeled from 1 to 7 on the top and the Day and Number on the side. There is a coloured sticker on the top of each salivette which corresponds with the same coloured sticker on the Questionnaire envelopes. Each day has its own colour.
- For example, on Day 1 you will use the bag labeled Day 1. This bag contains salivettes numbered 1 through 7. **Please use them in order.** If you ever miss a beep and therefore did not complete the questionnaire and collect your saliva please just leave that salivette and corresponding questionnaire unused. At the next beep you would use the next salivette and questionnaire. For example if you miss Day 3 Number 4, that would remain unused and you would use Day 3 Number 5 at the next beep.
- The label on the side of the salivette also has your unique ID# . This is for office use only and does not need to be recorded by you.
-

What You Need To Be Careful About

We appreciate your help in collecting unspoiled saliva specimens. We ask that you:

- **Do not** open the tubes until you are ready to collect saliva samples. Dampness in the air may affect the samples.
- While chewing on the salivette, **do not simultaneously:** eat, drink any liquids including water, chew gum or sweets. You may chew gum **prior** to chewing on the salivette to aid saliva production.
- In the morning please **do not**: exercise, take a cold shower, brush your teeth, have breakfast, smoke, consume caffeine or alcohol or fall back asleep before you use the second salivette. This is important to us because all of these things influence the interpretation of the cortisol results. It is OK to have water, juice or **decaffeinated** drinks. For example, in the morning, wait to brush your teeth until after you have collected both morning saliva samples. You may brush your teeth after the second morning sample is collected.

- DO CONTINUE TO FOLLOW YOUR USUAL MEDICATION REGIME

Collection Guidelines

The first saliva sample will be collected in the morning, after waking. The next will be collected 30 minutes later. The next 5 samples will be collected based on when your alarm device alerts you that it is time to fill out the questionnaire. Please collect the sample when you fill out the questionnaire.

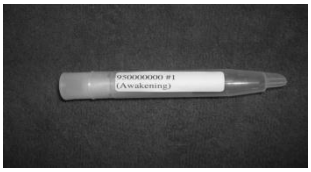
Each Day:

- 1st saliva sample—upon waking up. Please collect the saliva sample as soon as you wake up and **before you get out of bed & before you brush your teeth.**
- 2nd saliva sample—30 minutes after waking up; **before you brush your teeth.**
- 3rd saliva sample through 7th saliva sample will be at approximately 3 hr intervals during the day. These times will have been set into your alarm device by your Research Assistant and the corresponding times recorded on your summary sheet.

1. Carefully remove one tube from the correct plastic bag for that day. (They are numbered on the top and the side in order #1 - #7 for each day).
   - Remove the tube's cap and place the salivette into your mouth.
2. Chew each salivette for **2 minutes**, until it is soaked.
3. Put the salivette back into the small tube and put the cap back on the tube
4. Properly store your sample, as follows.

Figure B

   - Put the small tube into the longer tube. [Fig. B]
   - Press down firmly on the cap, until it clicks. [Fig. C]
   - Place the closed tube back into the Glad Snap Lock bag.
   - Repeat these steps for the remaining saliva samples
   - At the end of each day please put the Glad Snap Lock bag with your used salivettes into the fridge or freezer.



5. Enter the Day and Number of your sample on the questionnaire.

   Each time you fill out a questionnaire, it will ask you to enter the day and number of the salivette you have used on the questionnaire.

   Day____ Number_____

   This is important for our analyses so that we know which salivette was used at which time.

6. Put the long tubes back into the Glad Snap Lock bag. At the end of each day please put the Glad Snap Lock bag with your used salivettes into the freezer. If you do not have a freezer, please place in a refrigerator.

Thank you for your assistance and cooperation.

Appendix C

Questionnaires and assessment forms for the ADuLTS study.

Appendix C.1. Baseline assessment form.

ADuLTS Study - Baseline Assessments

Participants Sequence Number: ☐☐☐☐ Date: ☐☐/☐☐/☐☐

Date of Birth: ☐☐/☐☐/☐☐ Gender: Male/Female

Interviewer: _____

I need to ask you some questions regarding your health and lifestyle.

1. Do you currently have a medical condition that is related to thyroid dysfunction?

   Yes 1 No 0

2. Have you ever been diagnosed with any of the following:

2a. Post-Traumatic Stress Disorder Yes 1 No 0

2b. Parkinson's Yes 1 No 0

2c. Alzheimer's Yes 1 No 0

2d. Cushing's Yes 1 No 0

2e. Addison's Yes 1 No 0

3. Have you ever received any other psychiatric or neurological diagnosis in your life?

   Yes 1 No 0

3a. (If yes), please specify?_____

3b. (If yes), are you currently undergoing treatment?

   Yes 1 No 0

   The next 2 questions use the following scale with 4 options:

   not at all several days more than half the days nearly everyday

   Should I go over it one more time?

4. Over the last 2 weeks, how often have you been bothered by any of the following problems?

4a. Little interest or pleasure in doing things

Not at all	1
Several Days	2
More than half the days	3
Nearly every day	4

4b. Feeing down, depressed or hopeless

Not at all	1
Several Days	2
More than half the days	3
Nearly every day	4

5. In the last 4 weeks, have you had an anxiety attack – suddenly feeling fear or panic?

Yes 1 No 0

6a. Do you often feel that you can't control, what or how much you eat?

Yes 1 No 0

6b. Do you often eat, within any 2 hour period, what most people would regard as an unusually large amount of food?

Yes 1 No 0

6c. (If yes), has this been as often, on average, as twice a week for the last three months?

Yes 1 No 0

7. Do you ever drink alcohol (including beer or wine)?

Yes 1 No 0 *If No please go to Q8*

7a. Have any of the following happened to you more than once in the last 6 months?

7b. You drank alcohol even though a doctor suggested that you stop drinking because of a problem with your health?

Yes 1 No 0

7c. You drank alcohol, were intoxicated, or hung over while you were taking care of family or other responsibilities?

Yes 1 No 0

7d. You had a problem getting along with other people while you were drinking?

Yes 1 No 0

7e. You drove a car after having several drinks or after drinking too much?

Yes 1 No 0

8. How many cigarettes do you smoke? _____ cigarettes

(circle 1 of the following time frames)

8a. N/A 0
Per day 1
Per week 2
Per month 3

9. How many cups of coffee do you drink? _____ cups

(circle 1 of the following time frames)

9a. N/A 0
Per day 1
Per week 2
Per month 3

The following height & weight info will be on the Participant Information Form and can be prefilled below.

10. Record height from clinical? _____

11. Record weight from clinical? _____

If the participant has not had a clinical assessment recently please obtain these measures today.

12. During the last 2 weeks, how much have you been bothered by any of the following problems?

	Not bothered	Bothered a little	Bothered a lot
a. Stomach pain	[ ]	[ ]	[ ]
b. Back pain	[ ]	[ ]	[ ]
c. Pain in your arms, legs, or joints (knees, hips, etc.)	[ ]	[ ]	[ ]
d. Headaches	[ ]	[ ]	[ ]
e. Chest pain	[ ]	[ ]	[ ]
f. Dizziness	[ ]	[ ]	[ ]
g. Fainting spells	[ ]	[ ]	[ ]
h. Feeling your heart pound or race	[ ]	[ ]	[ ]
i. Shortness of breath	[ ]	[ ]	[ ]
j. Constipation, loose bowels, or diarrhea	[ ]	[ ]	[ ]
k. Nausea, gas, or indigestion	[ ]	[ ]	[ ]

13. Over the last 2 weeks, how often have you felt this way?

Show Display Card 1

		Rarely or none of the time	Some of the time	Quite a bit of the time	Most or all of the time
a.	I was bothered by things that don't usually don't bother me	[ ]	[ ]	[ ]	[ ]
b.	I had trouble keeping my mind on what I was doing	[ ]	[ ]	[ ]	[ ]
c.	I felt depressed	[ ]	[ ]	[ ]	[ ]
d.	I felt that everything I did was an effort	[ ]	[ ]	[ ]	[ ]
e.	I felt hopeful about the future	[ ]	[ ]	[ ]	[ ]
f.	I felt afraid	[ ]	[ ]	[ ]	[ ]
g.	My sleep was restless	[ ]	[ ]	[ ]	[ ]
h.	I was happy	[ ]	[ ]	[ ]	[ ]
i.	I felt lonely	[ ]	[ ]	[ ]	[ ]

j.	I could not get going	[ ]	[ ]	[ ]	[ ]

14. In the past 12 months, has a Medical Doctor ever told you that you suffer from any of these chronic conditions

		NO	YES
a.	Arthritis	[ ]	[ ]
b.	Cancer	[ ]	[ ]
c.	Chronic Bronchitis or emphysema	[ ]	[ ]
d.	Diabetes	[ ]	[ ]
e.	Fractured Hip	[ ]	[ ]
f.	Heart Attack	[ ]	[ ]
g.	Heart Condition	[ ]	[ ]
h.	Hypertension	[ ]	[ ]
i.	Myocardial Infarction	[ ]	[ ]
j.	Osteoporosis	[ ]	[ ]
k.	Other (please specify)_____		

15. Medication

We are interested in any medicines (prescription and non prescription) that you have taken or were supposed to take in the last two weeks. These medications might include aspirin, headache pills, laxatives, cough and cold medicines, vitamins, minerals and dietary supplements.

Please list Name of each.

_____

_____

16. Over the last 2 weeks, how often have you been bothered by any of the following problems?

		Not at all	Several days	More than half the days
a.	Feeling nervous, anxious, on edge, or worrying a lot about different things	[ ]	[ ]	[ ]
17. If answered "Not at all", go to Question 17.		[ ]	[ ]	[ ]
b.	Feeling restless so that it is hard to sit still	[ ]	[ ]	[ ]
c.	Getting tired very easily	[ ]	[ ]	[ ]

d.	Muscle tension, aches, or soreness	[ ]	[ ]	[ ]
e.	Becoming easily annoyed or irritable	[ ]	[ ]	[ ]

17. During the last 2 weeks, how much have you been bothered by any of the following problems

		Not bothered at all	**Bothered a little**	**Bothered a lot**
a.	Worrying about your health	[ ]	[ ]	[ ]
b.	The stress of taking care of children, grandchildren or other family members	[ ]	[ ]	[ ]
c.	Stress at work or outside of the home or at school	[ ]	[ ]	[ ]
d.	Financial problems or worries	[ ]	[ ]	[ ]
e.	Having no one to turn to when you have a problem	[ ]	[ ]	[ ]
f.	Something bad that happened recently	[ ]	[ ]	[ ]
g.	Thinking or dreaming about something terrible that happened to you in the past - like your house being destroyed, a severe accident, being hit or assaulted,etc	[ ]	[ ]	[ ]

18. In the last year, have you been hit, slapped, kicked or otherwise physically hurt by someone?

Yes 1 No 0

19. What is the most stressful thing in your life right now?

_____

_____

_____

20. Are you taking any medicine for anxiety, depression or stress?

Yes 1 No 0

Personality Characteristics

Show Display Card 2

I am going to read a number of characteristics that may or may not apply to you and ask you which response on the Display Card indicates the extent to which you agree or disagree with that statement. For example, do you agree that you are someone who likes to spend time with others. For each statement, please tell me the *number* corresponding to the answer that best represents *your opinion*.

There are no "right" or "wrong" answers. The purpose of this will be best served if you describe yourself and state your opinions as accurately as possible.

All questions answered on a 5 point Likert scale where:

1	2	3	4	5
Disagree strongly	Disagree a little	Neither agree not disagree	Agree a lot	Agree strongly

I see myself as someone who

1. Does a thorough job
2. Is depressed, blue
3. Can be somewhat careless
4. Is relaxed, handles stress well
5. Is a reliable worker
6. Can be tense
7. Tends to be disorganized
8. Worries a lot
9. Tends to be lazy
10. Is emotionally stable, not easily upset
11. Perseveres until the task is finished
12. Can be moody
13. Does things efficiently
14. Remains calm in tense situations
15. Makes plans and follows through with them
16. Gets nervous easily
17. Is easily distracted

Personal Growth, Positive Relations with Others, Purpose in Life

I am going to read some statements to you. For each statement, please tell me the **number** corresponding to the answer that best represents **your opinion**.

Show Display Card 3

1. I think it is important to have new experiences that challenge how you think about yourself and the world.

1	2	3	4	5	6
Strongly disagree	Moderately disagree	Slightly disagree	Slightly agree	Moderately agree	Strongly agree

2. For me, life has been a continuous process of learning, changing, and growth.

1	2	3	4	5	6
Strongly disagree	Moderately disagree	Slightly disagree	Slightly agree	Moderately agree	Strongly agree

3. I gave up trying to make big improvements or changes in my life a long time ago.

1	2	3	4	5	6
Strongly disagree	Moderately disagree	Slightly disagree	Slightly agree	Moderately agree	Strongly agree

4. Maintaining close relationships has been difficult and frustrating for me.

1	2	3	4	5	6
Strongly disagree	Moderately disagree	Slightly disagree	Slightly agree	Moderately agree	Strongly agree

5. People would describe me as a giving person, willing to share my time with others.

1	2	3	4	5	6
Strongly disagree	Moderately disagree	Slightly disagree	Slightly agree	Moderately agree	Strongly agree

6. I have not experienced many warm and trusting relationships with others.

1	2	3	4	5	6
Strongly disagree	Moderately disagree	Slightly disagree	Slightly agree	Moderately agree	Strongly agree

7. I live life one day at a time and don't really think about the future.

1	2	3	4	5	6
Strongly disagree	Moderately disagree	Slightly disagree	Slightly agree	Moderately agree	Strongly agree

8. Some people wander aimlessly through life, but I am not one of them.

1	**2**	**3**	**4**	**5**	**6**
Strongly disagree	Moderately disagree	Slightly disagree	Slightly agree	Moderately agree	Strongly agree

9. I sometimes feel as if I've done all there is to do in life.

1	**2**	**3**	**4**	**5**	**6**
Strongly disagree	Moderately disagree	Slightly disagree	Slightly agree	Moderately agree	Strongly agree

Personal Goals

R.A.: Take time with section – give plenty of time for the participant to absorb and think about what you are explaining.

We are interested in studying the kinds of activities and concerns that people have at different stages of their life. We call these **personal projects**. All of us have a number of personal projects at any given time that we **think** about, **plan** for, carry out, and sometimes (though not always) **complete**.

Personal projects can be related to many different life domains such as: partnership, family, friends, health, memory, leisure, finances, work etc.

We are particularly interested in those projects

- that you are planning to actively pursue within the **upcoming weeks**
- that are important for you **right now**
- that influence your **daily** life and the **activities** in which you engage

Please take a moment to think about your personal projects and goals that you would like to work on within the next 2 weeks and when you are ready share them with me.

If they are having problems getting started give some examples (these could differ and grow after you have visited a few participants).

Previous participants have mentioned physical activity goals like walking twice a week, staying in touch with the grandchildren by emailing or calling them once a week.

These can be things you are hoping for, priorities, something that may help you organise your daily life activities, concerns you may have…….

If they suggest something abstract, e.g., a good wife or good person – try to make it more concrete – What does it mean 'you want to be a good wife?' – what does that entail?, *e.g.,, might mean taking time to sit and chat with husband or play a game with them, or go for a walk when they suggest, show interest in activities.*

If they are still struggling show Display Card 4 to see if that prompts them.

Encourage them to name at least four. If they only think of a couple initially once you have asked the questions about specific goals ask again if that has given them ideas about any more. If a participants comes up with more than four goals, let him/her choose which ones are most important and ask the follow-up questions for each of these most important goals. Write down goals as detailed as possible to allow for later content coding.

We are interested in finding out a little bit more about the role that these goals play for you at this moment. We will therefore ask you several questions **with respect to each of these goals separately**.

Project A (*R.A. – Please reiterate goal)*_____

_____

1. **Which life domain does this belong to?** Select <u>all</u> that apply from Display Card 4. *Interviewer: Please tick below.*

__	partnership	__	cognition or memory	__	family
__	religion	__	friends	__	productive activities
__	health/physical activities	__	home management	__	finances
__	mobility	__	leisure	__	other

Interviewer: Explain scale

	NOT AT ALL				VERY MUCH
How important is this goal to you?	1	2	3	4	5
How likely do you think it is that you will be able to achieve your goal?	1	2	3	4	5
To what extent does this goal refer to something you hope for?	1	2	3	4	5
To what extent does this goal refer to something you fear? (or rather not happen?)	1	2	3	4	5

Project B

_____

2. **Which life domain does this belong to?** Select <u>all</u> that apply from Display Card 4. *Interviewer: Please tick below.*

__	partnership	__	cognition or memory	__	family
__	religion	__	friends	__	productive activities
__	health/physical activities	__	home management	__	finances
__	mobility	__	leisure	__	other

Interviewer: Explain scale

	NOT AT ALL				VERY MUCH
How important is this goal to you?	1	2	3	4	5
How likely do you think it is that you will be able to achieve your goal?	1	2	3	4	5
To what extent does this goal refer to something you hope for?	1	2	3	4	5
To what extent does this goal refer to something you fear? (or rather not happen?)	1	2	3	4	5

Project C

---

3. **Which life domain does Project C belong to?** Select <u>all</u> that apply from Display Card 4. *Interviewer: Please tick below.*

__ partnership	__ cognition or memory	__ family
__ religion	__ friends	__ productive activities
__ health/physical activities	__ home management	__ finances
__ mobility	__ leisure	__ other

Interviewer: Explain scale

	NOT AT ALL				VERY MUCH
How important is this goal to you?	1	2	3	4	5
How likely do you think it is that you will be able to achieve your goal?	1	2	3	4	5
To what extent does this goal refer to something you hope for?	1	2	3	4	5
To what extent does this goal refer to something you fear? (or rather not happen?)	1	2	3	4	5

Project D

---

4. **Which life domain does this belong to?** Select <u>all</u> that apply from Display Card 4. *Interviewer: Please tick below.*

__ partnership	__ cognition or memory	__ family
__ religion	__ friends	__ productive activities
__ health/physical activities	__ home management	__ finances
__ mobility	__ leisure	__ other

Interviewer: Explain scale

	NOT AT ALL				VERY MUCH
How important is this goal to you?	1	2	3	4	5
How likely do you think it is that you will be able to achieve your goal?	1	2	3	4	5
To what extent does this goal refer to something you hope for?	1	2	3	4	5
To what extent does this goal refer to something you fear? (or rather not happen?)	1	2	3	4	5

Well-being (PGCMS)

Now here are some statements about **how you feel about life**. Could you indicate to me whether you agree or disagree with each statement. We are interested in **your own opinion**, not your judgment of what others think.

		Agree	Disagree
1.	Little things bother you more than they used to.	1	0
2.	Things keep getting worse as you get older	1	0
3.	You fell lonelier than you used to feel.	1	0
4.	You have a lot to be happy about.	1	0
5.	You are as happy now as when you were younger.	1	0
6.	You get upset easily.	1	0
7.	You have as much energy as you had last year.	1	0
8.	You get angry more than you used to.	1	0
9.	You sometimes feel life isn't worth living.	1	0
10.	As you get older you are less useful.	1	0
11.	You take things to heart.	1	0
12.	Life is difficult for you much of the time.	1	0
13.	You are nervous about a lot of things.	1	0
14.	You are satisfied with your life these days.	1	0
15.	As you get older, things are better than you thought they would be.	1	0

Appendix C.2. Morning Questionnaire

ALSA Daily-Life Time-Sampling Study – Morning Questionnaire- # 1

Please remember to make two circles around your answer choice when you see questions that are written in capitals and also to write your initials whenever there is a box on the bottom right of the page. These items are not on all questionnaires.

Date & Timestamp: _____

*Please take the **first cotton stick** out of the vial and roll it in your mouth while answering the following questions. Please also **set the kitchen timer** to **30 minutes** for the second saliva sample.*

1. How are you **feeling** at **this moment**?

How **happy** are you?	not at all 1----2----3----4----5 very much
How **sad** are you?	not at all 1----2----3----4----5 very much
How **calm** are you?	not at all 1----2----3----4----5 very much
How **sleepy** are you?	not at all 1----2----3----4----5 very much
How **anxious** are you?	not at all 1----2----3----4----5 very much
How **alert** are you?	not at all 1----2----3----4----5 very much
How **quiet** are you?	not at all 1----2----3----4----5 very much
How **irritated** are you?	not at all 1----2----3----4----5 very much
How **excited** are you?	not at all 1----2----3----4----5 very much

2. **Who** are you **with**?

☐ Service Provider ☐ Other family member ☐ Other
☐ Formal Carer ☐ Friend
☐ Spouse ☐ Alone

3. Please tell us about your **sleep**

When did you go to bed last night?	___/___hour/min
How long did it take you to fall **asleep** last night?	___/___hour/min
When did you **wake up** this morning?	___/___hour/min
How many hours of actual sleep did you get?	___/___hour/min

Last night, how many times did you have **trouble sleeping** because you…"

Could not get to sleep within 30 minutes?	never---once---twice--- >3 times
Woke up in the middle of the night or early morning?	never---once---twice--- >3 times
Had to get up to use the bathroom?	never---once---twice--- >3 times

Coughed or snored loudly? never---once---twice--- >3 times
Felt too cold? never---once---twice--- >3 times
Felt too hot? never---once---twice--- >3 times
Had bad dreams? never---once---twice--- >3 times
Had pain? never---once---twice--- >3 times
Were disrupted by bed partner or spouse never---once---twice--- >3 times
Had any other reasons for disturbing sleep? never---once---twice--- >3 times

Did you **take medicine** to help you sleep? yes/no

Overall, how was your **sleep quality**? very good 1---2---3---4---5 very bad

4. **Since you woke up this morning** have you had or done any of the following

☐ Nicotine	☐ Medicine or drugs	☐ Cold shower
☐ Caffeine	☐ Food	☐ Brushed teeth
☐ Alcohol	☐ Exercise	☐ None

5. What is the **day & number** on your **saliva sample**? Day____ Number_____

Please take the first saliva sample out of your mouth and place it back in the vial. You can set the questionnaire aside until the kitchen timer goes off.

Morning - Questionnaire # 2

When the 30-minute **kitchen timer alarm goes off**…

*Please take the **second cotton stick** out of the vial and roll it in your mouth for **2 minutes** while answering the following questions.*

6. Please stamp the following field:_____

7. Since the last questionnaire have you had or done any of the following

☐ Nicotine	☐ Medicine or drugs	☐ Cold shower
☐ Caffeine	☐ Food	☐ Brushed teeth
☐ Alcohol	☐ Exercise	☐ Gone back to sleep

8. What is the **day & number** on your **saliva sample**? Day____ Number_____

9. Please stamp the following field :_____

Please fold the questionnaire and put it back into its envelope, seal the envelope and stamp across the seal. After 2 minutes the cotton stick can be returned to its vial.

ALSA Daily-Life Time-Sampling Study – Daily Questionnaire # 3

Date & Timestamp: _____

*Please take the **cotton stick** out of the vial and roll it in your mouth while answering the following questions.*

1. How are you **feeling** at **this moment**?

How **happy** are you?	not at all 1----2----3----4----5 very much
How **sad** are you?	not at all 1----2----3----4----5 very much
How **calm** are you?	not at all 1----2----3----4----5 very much
How **sleepy** are you?	not at all 1----2----3----4----5 very much
How **anxious** are you?	not at all 1----2----3----4----5 very much
How **alert** are you?	not at all 1----2----3----4----5 very much
How **quiet** are you?	not at all 1----2----3----4----5 very much
How **irritated** are you?	not at all 1----2----3----4----5 very much
How **excited** are you?	not at all 1----2----3----4----5 very much

2. **Where** are you at the moment?

☐ Outside
☐ Other person's house
☐ Home
☐ Travelling
☐ Public building

3. **Who** are you **with**? (tick any that apply)

☐ Service Provider
☐ Formal Carer
☐ Spouse
☐ Other family member
☐ Friend
☐ Alone
☐ Other

Please turn over.

4. Now we are going to ask you about your **activities since the last questionnaire**.

*Please **only** complete the boxes for the times **since your last** questionnaire up to the present time. If you did more than one activity within the 30 minutes please enter only the activity code that occupied the majority of your time.*

From	To	What did you do? *(Please insert **only one** activity code)*	With other people? *Please circle Yes or No*	Personally meaningful? *Please insert from 1 "not at all" to 5 "very much"*	How challenging? *Please insert from 1 "not at all" to 5 "very much"*	Had planned to do something else instead? *Please circle Yes or No*
5:00	5:30		Yes No			Yes No
5:30	6:00		Yes No			Yes No
6:00	6:30		Yes No			Yes No
6:30	7:00		Yes No			Yes No
7:00	7:30		Yes No			Yes No
7:30	8:00		Yes No			Yes No
8:00	8:30		Yes No			Yes No
8:30	9:00		Yes No			Yes No
9:00	9:30		Yes No			Yes No
9:30	10:00		Yes No			Yes No
10:00	10:30		Yes No			Yes No
10:30	11:00		Yes No			Yes No
11:00	11:30		Yes No			Yes No
11:30	12:00		Yes No			Yes No

Code	Activity	Examples
1	Social Activities	meeting friends, talking to family, going to senior centre
2	Physical Activities/Health	going on a walk, gardening, exercising
3	Home Management	housework, cooking, shopping
4	Cognition	cross-word puzzles, reading, finances
5	Self-care	body care, resting/napping, eating, doctor's visits
6	Productive Activities	helping others, volunteering
7	Leisure Activities	watching TV, listening to music

5. **Since the last questionnaire** have you had or done any of the following

☐ Nicotine ☐ Medicine or drugs ☐ Cold shower
☐ Caffeine ☐ Food ☐ Brushed teeth
☐ Alcohol ☐ Exercise ☐ None

6. What is the **day & number** on your **saliva sample**? Day____ Number_____

7. Please stamp the following field:_____

Please fold the questionnaire back into its envelope, seal the envelope and stamp across the seal. Please take the saliva sample out of your mouth and place it back in the vial.

Sequence #

ALSA Daily-Life Time-Sampling Study – Daily Questionnaire # 4

Date & Timestamp: _____

*Please take the **cotton stick** out of the vial and roll it in your mouth while answering the following questions.*

1. How are you **feeling** at **this moment**?

How **happy** are you?	not at all 1----2----3----4----5 very much
How **sad** are you?	not at all 1----2----3----4----5 very much
How **calm** are you?	not at all 1----2----3----4----5 very much
How **sleepy** are you?	not at all 1----2----3----4----5 very much
How **anxious** are you?	not at all 1----2----3----4----5 very much
How **alert** are you?	not at all 1----2----3----4----5 very much
How **quiet** are you?	not at all 1----2----3----4----5 very much
HOW ANGRY ARE YOU?	not at all 1----2----3----4----5 very much
How **irritated** are you?	not at all 1----2----3----4----5 very much
How **excited** are you?	not at all 1----2----3----4----5 very much

2. **Where** are you at the moment?

☐ Outside
☐ Other person's house
☐ Home
☐ Travelling
☐ Public building

3. **Who** are you **with**?

☐ Service Provider
☐ Formal Carer
☐ Spouse
☐ Other family member
☐ Friend
☐ Alone
☐ Other

Please turn over.

4. Now we are going to ask you about your **activities since the last questionnaire**.

*Please **only** complete the boxes for the times **since your last** questionnaire up to the present time. If you did more than one activity within the 30 minutes please enter only the activity code that occupied the majority of your time.*

From	To	What did you do? *(Please insert **only one** activity code)*	With other people? *Please circle Yes or No*	Personally meaningful? *Please insert from 1 "not at all" to 5 "very much"*	How challenging? *Please insert from 1 "not at all" to 5 "very much"*	Had planned to do something else instead? *Please circle Yes or No*
8:00	8:30		Yes No			Yes No
8:30	9:00		Yes No			Yes No
9:00	9:30		Yes No			Yes No
9:30	10:00		Yes No			Yes No
10:00	10:30		Yes No			Yes No
10:30	11:00		Yes No			Yes No
11:00	11:30		Yes No			Yes No
11:30	12:00		Yes No			Yes No
12:00	12:30		Yes No			Yes No
12:30	1:00		Yes No			Yes No
1:00	1:30		Yes No			Yes No
1:30	2:00		Yes No			Yes No
2:00	2:30		Yes No			Yes No
2:30	3:00		Yes No			Yes No

Code	Activity	Examples
1	Social Activities	meeting friends, talking to family, going to senior centre
2	Physical Activities/Health	going on a walk, gardening, exercising
3	Home Management	housework, cooking, shopping
4	Cognition	cross-word puzzles, reading, finances
5	Self-care	body care, resting/napping, eating, doctor's visits
6	Productive Activities	helping others, volunteering
7	Leisure Activities	watching TV, listening to music

5. **Since the last questionnaire** have you had or done any of the following?

☐ Nicotine ☐ Medicine or drugs ☐ Cold shower
☐ Caffeine ☐ Food ☐ Brushed teeth
☐ Alcohol ☐ Exercise ☐ None

6. What is the **day & number** on your **saliva sample**? Day____ Number_____

7. Please stamp the following field:_____

Please fold the questionnaire back into its envelope, seal the envelope and stamp across the take the saliva sample out of your mouth and place it back in the vial.

Sequence #

ALSA Daily-Life Time-Sampling Study – Daily Questionnaire # 5

Date & Timestamp: _____

*Please take the **cotton stick** out of the vial and roll it in your mouth while answering the following questions.*

1. How are you **feeling** at **this moment**?

How **happy** are you?	not at all 1----2----3----4----5 very much
How **sad** are you?	not at all 1----2----3----4----5 very much
How **calm** are you?	not at all 1----2----3----4----5 very much
How **sleepy** are you?	not at all 1----2----3----4----5 very much
How **anxious** are you?	not at all 1----2----3----4----5 very much
How **alert** are you?	not at all 1----2----3----4----5 very much
How **quiet** are you?	not at all 1----2----3----4----5 very much
How **irritated** are you?	not at all 1----2----3----4----5 very much
How **excited** are you?	not at all 1----2----3----4----5 very much

2. **Where** are you at the moment?

☐ Outside
☐ Other person's house
☐ Home
☐ Travelling
☐ Public building

3. **Who** are you **with**?

☐ Service Provider
☐ Formal Carer
☐ Spouse
☐ Other family member
☐ Friend
☐ Alone
☐ Other

Please turn over.

4. Now we are going to ask you about your **activities since the last questionnaire**.

*Please **only** complete the boxes for the times **since your last** questionnaire up to the present time. If you did more than one activity within the 30 minutes please enter only the activity code that occupied the majority of your time.*

From	To	What did you do? *(Please insert **only one** activity code)*	With other people? *Please circle Yes or No*	Personally meaningful? *Please insert from 1 "not at all" to 5 "very much"*	How challenging? *Please insert from 1 "not at all" to 5 "very much"*	Had planned to do something else instead? *Please circle Yes or No*
11:00	11:30		Yes No			Yes No
11:30	12:00		Yes No			Yes No
12:00	12:30		Yes No			Yes No
12:30	1:00		Yes No			Yes No
1:00	1:30		Yes No			Yes No
1:30	2:00		Yes No			Yes No
2:00	2:30		Yes No			Yes No
2:30	3:00		Yes No			Yes No
3:00	3:30		Yes No			Yes No
3:30	4:00		Yes No			Yes No
4:00	4:30		Yes No			Yes No
4:30	5:00		Yes No			Yes No
5:00	5:30		Yes No			Yes No
5:30	6:00		Yes No			Yes No

Code	Activity	Examples
1	Social Activities	meeting friends, talking to family, going to senior centre
2	Physical Activities/Health	going on a walk, gardening, exercising
3	Home Management	housework, cooking, shopping
4	Cognition	cross-word puzzles, reading, finances
5	Self-care	body care, resting/napping, eating, doctor's visits
6	Productive Activities	helping others, volunteering
7	Leisure Activities	watching TV, listening to music

5. **Since the last questionnaire** have you had or done any of the following?

☐ Nicotine ☐ Medicine or drugs ☐ Cold shower
☐ Caffeine ☐ Food ☐ Brushed teeth
☐ Alcohol ☐ Exercise ☐ None

6. What is the **day & number** on your **saliva sample**? Day____ Number_____

7. Please stamp the following field:_____

Please fold the questionnaire back into its envelope, seal the envelope and stamp across the take the saliva sample out of your mouth and place it back in the vial.

ALSA Daily-Life Time-Sampling Study – Daily Questionnaire # 6

Date & Timestamp: _____

*Please take the **cotton stick** out of the vial and roll it in your mouth while answering the following questions.*

1. How are you **feeling** at **this moment**?

How **happy** are you?	not at all 1----2----3----4----5 very much
How **sad** are you?	not at all 1----2----3----4----5 very much
How **calm** are you?	not at all 1----2----3----4----5 very much
How **sleepy** are you?	not at all 1----2----3----4----5 very much
How **anxious** are you?	not at all 1----2----3----4----5 very much
How **alert** are you?	not at all 1----2----3----4----5 very much
How **quiet** are you?	not at all 1----2----3----4----5 very much
How **irritated** are you?	not at all 1----2----3----4----5 very much
How **excited** are you?	not at all 1----2----3----4----5 very much

2. **Where** are you at the moment?

☐ Outside
☐ Other person's house
☐ Home
☐ Travelling
☐ Public building

3. **Who** are you **with**?

☐ Service Provider
☐ Formal Carer
☐ Spouse
☐ Other family member
☐ Friend
☐ Alone
☐ Other

Please turn over.

4. Now we are going to ask you about your **activities since the last questionnaire**.

*Please **only** complete the boxes for the times **since your last** questionnaire up to the present time. If you did more than one activity within the 30 minutes please enter only the activity code that occupied the majority of your time.*

From	To	What did you do? *(Please insert **only one** activity code)*	With other people? *Please circle Yes or No*	Personally meaningful? *Please insert from 1 "not at all" to 5 "very much"*	How challenging? *Please insert from 1 "not at all" to 5 "very much"*	Had planned to do something else instead? *Please circle Yes or No*
2:00	2:30		Yes No			Yes No
2:30	3:00		Yes No			Yes No
3:00	3:30		Yes No			Yes No
3:30	4:00		Yes No			Yes No
4:00	4:30		Yes No			Yes No
4:30	5:00		Yes No			Yes No
5:00	5:30		Yes No			Yes No
5:30	6:00		Yes No			Yes No
6:00	6:30		Yes No			Yes No
6:30	7:00		Yes No			Yes No
7:00	7:30		Yes No			Yes No
7:30	8:00		Yes No			Yes No
8:00	8:30		Yes No			Yes No
8:30	9:00		Yes No			Yes No

Code	Activity	Examples
1	Social Activities	meeting friends, talking to family, going to senior centre
2	Physical Activities/Health	going on a walk, gardening, exercising
3	Home Management	housework, cooking, shopping
4	Cognition	cross-word puzzles, reading, finances
5	Self-care	body care, resting/napping, eating, doctor's visits
6	Productive Activities	helping others, volunteering
7	Leisure Activities	watching TV, listening to music

5. **Since the last questionnaire** have you had or done any of the following?

☐ Nicotine ☐ Medicine or drugs ☐ Cold shower
☐ Caffeine ☐ Food ☐ Brushed teeth
☐ Alcohol ☐ Exercise ☐ None

6. What is the **day & number** on your **saliva sample**? Day____ Number_____

7. Please stamp the following field:_____

Please fold the questionnaire back into its envelope, seal the envelope and stamp across the take the saliva sample out of your mouth and place it back in the vial.

Sequence #

Day 1

ALSA Daily-Life Time-Sampling Study – Daily Questionnaire # 7

Date & Timestamp: _____

*Please take the **cotton stick** out of the vial and roll it in your mouth while answering the following questions.*

1. How are you **feeling** at **this moment**?

How **happy** are you?	not at all 1----2----3----4----5 very much
How **sad** are you?	not at all 1----2----3----4----5 very much
HOW STILL ARE YOU?	not at all 1----2----3----4----5 very much
How **calm** are you?	not at all 1----2----3----4----5 very much
How **sleepy** are you?	not at all 1----2----3----4----5 very much
How **anxious** are you?	not at all 1----2----3----4----5 very much
How **alert** are you?	not at all 1----2----3----4----5 very much
How **quiet** are you?	not at all 1----2----3----4----5 very much
How **irritated** are you?	not at all 1----2----3----4----5 very much
How **excited** are you?	not at all 1----2----3----4----5 very much

2. **Where** are you at the moment?

☐ Outside
☐ Other person's house
☐ Home
☐ Travelling
☐ Public building

3. **Who** are you **with**?

☐ Service Provider
☐ Formal Carer
☐ Spouse
☐ Other family member
☐ Friend
☐ Alone
☐ Other

Please turn over

4. Now we are going to ask you about your **activities since the last questionnaire**.
*Please **only** complete the boxes for the times **since your last** questionnaire up to the present time. If you did more than one activity within the 30 minutes please enter only the activity code that occupied the majority of your time.*

From	To	What did you do? *(Please insert **only one** activity code)*	With other people? *Please circle Yes or No*	Personally meaningful? *Please insert from 1 "not at all" to 5 "very much"*	How challenging? *Please insert from 1 "not at all" to 5 "very much"*	Had planned to do something else instead? *Please circle Yes or No*
5:00	5:30		Yes No			Yes No
5:30	6:00		Yes No			Yes No
6:00	6:30		Yes No			Yes No
6:30	7:00		Yes No			Yes No
7:00	7:30		Yes No			Yes No
7:30	8:00		Yes No			Yes No
8:00	8:30		Yes No			Yes No
8:30	9:00		Yes No			Yes No
9:00	9:30		Yes No			Yes No
9:30	10:00		Yes No			Yes No
10:00	10:30		Yes No			Yes No
10:30	11:00		Yes No			Yes No
11:00	11:30		Yes No			Yes No
11:30	12:00		Yes No			Yes No

Code	Activity	Examples
1	Social Activities	meeting friends, talking to family, going to senior centre
2	Physical Activities/Health	going on a walk, gardening, exercising
3	Home Management	housework, cooking, shopping
4	Cognition	cross-word puzzles, reading, finances
5	Self-care	body care, resting/napping, eating, doctor's visits

6	Productive Activities	helping others, volunteering
7	Leisure Activities	watching TV, listening to music

5. **Since the last questionnaire** have you had or done any of the following?

☐ Nicotine	☐ Medicine or drugs	☐ Cold shower
☐ Caffeine	☐ Food	☐ Brushed teeth
☐ Alcohol	☐ Exercise	☐ None

6. What is the **day & number** on your **saliva sample**? Day____ Number_____

7. Please stamp the following field:_____

Appendix C.4. Feedback Assessment

ADuLTS Study – Feedback Interview

Participants Sequence Number: ☐☐☐☐ **Date:** ☐☐/☐☐/☐☐

Please circle the participants' answers.

Alarm device

1. Do you think that the alarm was loud enough?

1 2 3 4 5
not at all very much

General feedback

2. Did the people around you react negatively when you completed the questionnaires?

1 2 3 4 5
not at all very much

3. To what extent did the questionnaire completion interfere with your daily routines?

1 2 3 4 5
not at all very much

4. Did your response to the questions result in you changing your behaviour?

1 2 3 4 5
not at all very much

If so, how? _____

5. How long did it take you to complete the daily questionnaire on average?

_____ minutes

6. Were you able to answer the questions right after the beep?

1 2 3 4 5 never
occasionally some of the time most of the time all the time

If not, why?
_____

7. Did you ever get interrupted when answering the questionnaire?

❒ never ❒ once ❒ twice ❒ 3-5 times ❒ more than 5 times

8. Did you forget to answer any questionnaires?

❒ never ❒ once ❒ twice ❒ 3-5 times ❒ more than 5 times

Why?

_____

9. Were the questions easy to understand?

1 2 3 4 5
not at all very much

10. Do you consider the days you participated in our study as typical of your everyday life?

1 2 3 4 5
not at all very much

If not, why?

_____

11. Would you be willing to participate in another study like this?

❒ yes ❒ no ❒ maybe

12. Do you recall the capitalised questions and the empty box on the page? If so, what strategies did you use to remember “double-circling” the capitalised questions and initialling the box whenever it appeared at the bottom of a page?

_____
_____

13. Did you encounter any major difficulties during the study?

❒ yes ❒ no

If yes: What kind of difficulties did you have?

_____

14. What did you like about the study?

_____

15. Do you have any other comments, critiques, suggestions?

Appendix D

Prospective memory items

Appendix D.1. Schedule of prospective memory items.

	Questionnaire 3	**Questionnaire 4**	**Questionnaire 5**	**Questionnaire 6**	**Questionnaire 7**
Day 1		C **ANGRY**	Box to initial □		C **STILL**
Day 2	C **CONTENT**		C **UPSET**		Box to initial □
Day 3	Box to initial □		Box to initial □	C **RELAXED**	Call RA tomorrow
Day 4		Box to initial □	C **HOSTILE**	C **LIVELY**	
Day 5	C **PROUD**		Box to initial □		
Day 6		C **AFRAID**	C **TIRED** Box to initial □		Box to initial □
Day 7				Box to initial □	C **BORED**

EBPM TRIALS: Focal tasks

1. (**ADJECTIVE**) = HOW ___(**ADJECTIVE**)____ ARE YOU? Inserted in capital letters within Question 1 (How are you feeling at this moment?) Prospective memory task is to double circle response for the questions appearing in capital letters.

   Total number of trials over study = 11 tasks.

2. Stamp time and date across seal of each envelope after questionnaire completion and returning to envelope.

   Total number of trials over study = 46 tasks.

EBPM TRIALS: Non-focal tasks

☐ = Box presented at end of first page of questionnaire. Prospective memory task is to initial the box when it is detected.

Total number of trials over study = 9 tasks.

TBPM TRIALS:

Call RA = "Please call Research Assistant tomorrow" appears at end of Questionnaire 7. Prospective memory task is to call the RA the following day.

Total number of trials over study = 1 task.

Appendix E

Baseline tests administered in the ADuLTS study.

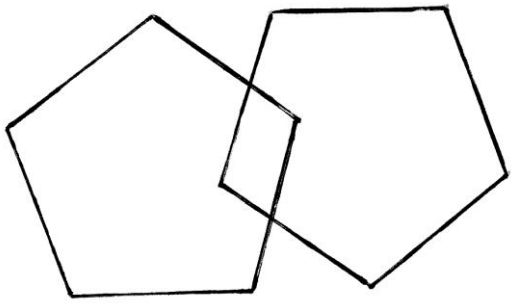
Appendix E.1

The Mini-Mental State Examination

ID #_____

Maximum	Score	
		Orientation
5	( )	What is the (year) (season) (date) (day) (month)?
5	( )	Where are we (state) (country) (town) (building) (floor)?
		Registration
3	( )	Name 3 objects: penny, apple, table; 1 second to say each. Then ask the respondent all 3 after you have said them. Give 1 point for each correct answer. Then repeat them until he/she learns all 3. Count trials and record. Trials_____
		Attention
5	( )	Spell " world" backwards.
		Recall
3	( )	Ask for the 3 objects repeated above. Give 1 point for each correct answer.
		Language
2	( )	Name a pencil and watch.
1	( )	Repeat the following "No ifs, ands, or buts".
3	( )	Follow a 3-stage command: "Take a paper in your hand, fold it in half, and put it on your lap".
1	( )	Read and obey the following: CLOSE YOUR EYES.
1	( )	Write a sentence.
1	( )	Copy the design shown.

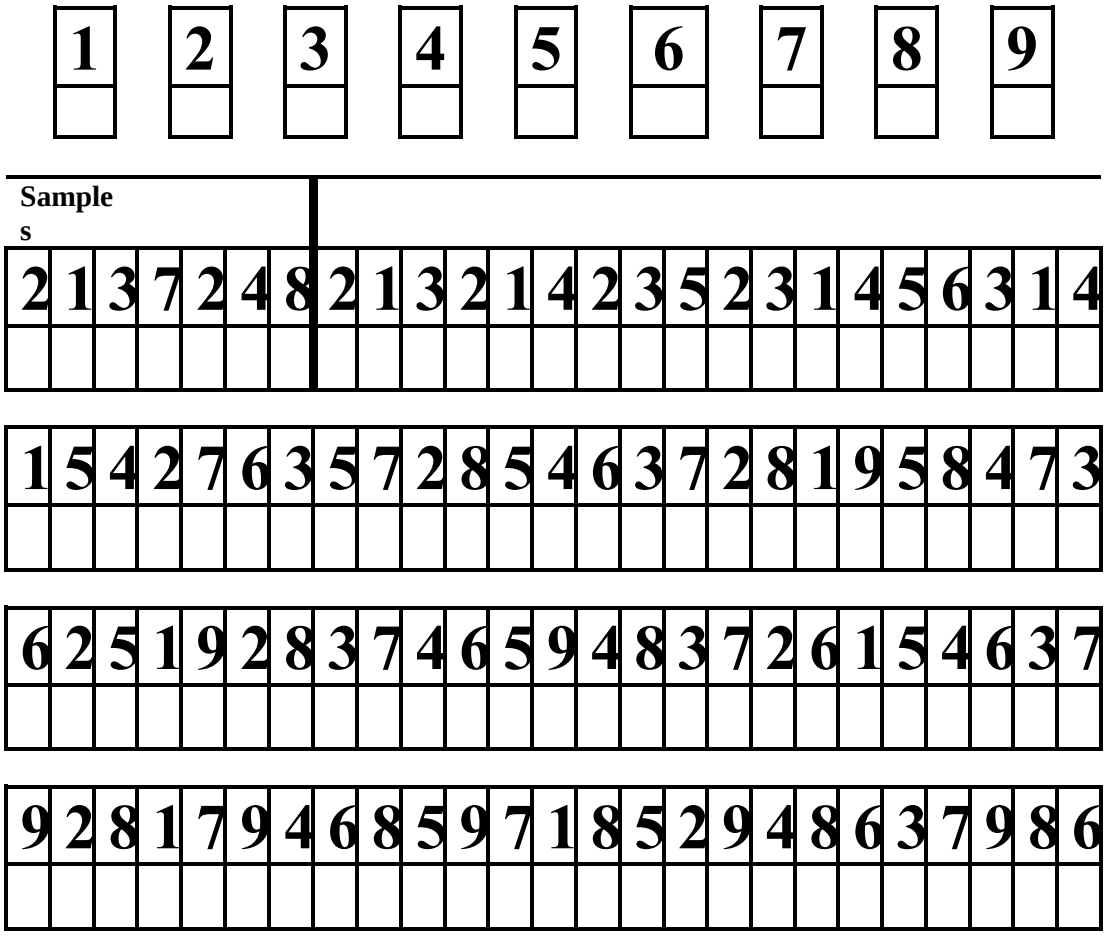
Total score: _____



Appendix E.2

Digit Symbol Substitution Test

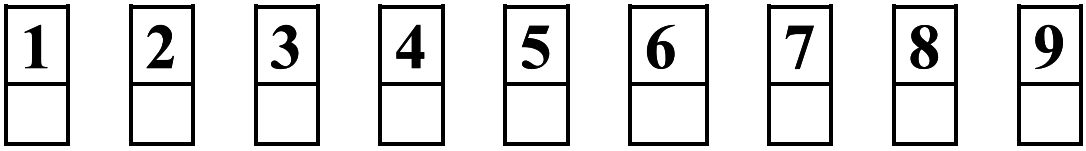
ID #_____ **DIGIT SYMBOL ITEMS**



Appendix E.3

The Digit Symbol Sub-test

DIGIT SYMBOL SUB-TEST



Instructions to interviewer: Place the "Symbol Recall" sheet in front of the respondent and say

Interviewer: "Now I'd like you to see if you can remember the symbols that went with the numbers. Draw them in the appropriate square.

You can do them in any order. If you can remember a symbol, but are not sure where it goes, just have a guess and put it in somewhere".

Number of symbols correctly placed _____

Number of symbols incorrectly placed_____

Appendix E.4

INITIAL LETTER FLUENCY (FAS): SCORING SHEET & TAPED

F		A	
1	21	1	21
2	22	2	22
3	23	3	23
4	24	4	24
5	25	5	25
6	26	6	26
7	27	7	27
8	28	8	28
9	29	9	29
10	30	10	30
11	31	11	31
12	32	12	32
13	33	13	33
14	34	14	34
15	35	15	35
16	36	16	36
17	37	17	37
18	38	18	38
19	39	19	39
20	40	20	40

Appendix E.5

EXCLUDED LETTER FLUENCY (ELF): SCORING SHEET & TAPED

Not 'E'		Not 'A'	
1	21	1	21
2	22	2	22
3	23	3	23
4	24	4	24
5	25	5	25
6	26	6	26
7	27	7	27
8	28	8	28
9	29	9	29
10	30	10	30
11	31	11	31
12	32	12	32
13	33	13	33
14	34	14	34
15	35	15	35
16	36	16	36
17	37	17	37
18	38	18	38
19	39	19	39
20	40	20	40

Appendix E.6

CLOX 1

CLOX: An Executive Clock Drawing Task

Step 1: Turn this form over on a light colored surface so that the circle below is visible. Have the subject draw a clock on the back. Instruct him or her to "Draw me a clock that says 1:45. Set the hands and numbers on the face so that a child could read them". Repeat the instructions until they are clearly understood. Once the subject begins to draw no further assistance is allowed. (CLOX 1).

RATING			
	ORGANISATIONAL ELEMENTS	**POINT VALUE**	**CLOX 1**
1	Does figure resemble a clock?	1	
2	Outer circle present?	1	
3	Diameter >1 inch?	1	
4	All numbers inside the circle?	1	
5a	Spacing intact (symmetry)?	2	
5b	If errors present, are there corrections?	1	
6	Only Arabic numerals?	1	
7	Only numbers 1- 12 present?	1	
8	Sequence 1-12 intact?	1	
9	Only two hands present?	1	
10	All hands represented as arrows?	1	
11	Hour hand between 1 and 2?	1	
12	Minute hand longer than the hour?	1	
13	None of the following?	1	
	1) Hand pointing to 4 or 5 o'clock?		
	2) "1:45" present?		
	3) intrusions from hand or face present?		
	4) any letters, words, or pictures?		
	5) any intrusion from circle below?		
		TOTAL	

Appendix F

Selected SPSS output and analyses for Study 1.

Appendix F.1

HMRA of focal EBPM proportion correct with covariate predictors.

Descriptive Statistics

	Mean	Std. Deviation	N
EBPM Capital proportion correct week	72.94	33.175	72
Age at interview	88.20	3.114	74
Gender	.66	.476	74
education level	1.37	.486	73
CESD Depression	4.77	3.443	69

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.215[a]	.046	.032	32.644	.046	3.164	1	65	.080
2	.231[b]	.053	-.008	33.302	.007	.152	3	62	.928

a. Predictors: (Constant), Age at interview
b. Predictors: (Constant), Age at interview, education level, CESD Depression, Gender
c. Dependent Variable: EBPM Capital proportion correct week

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3371.098	1	3371.098	3.164	.080[b]
	Residual	69265.074	65	1065.617		
	Total	72636.172	66			
2	Regression	3878.068	4	969.517	.874	.485[c]
	Residual	68758.104	62	1109.002		
	Total	72636.172	66			

a. Dependent Variable: EBPM Capital proportion correct week
b. Predictors: (Constant), Age at interview
c. Predictors: (Constant), Age at interview, education level, CESD Depression, Gender

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	275.357	113.877		2.418	.018	47.930	502.784
	Age at interview	-2.295	1.290	-.215	-1.779	.080	-4.872	.282
2	(Constant)	260.267	134.154		1.940	.057	-7.904	528.437
	Age at interview	-2.093	1.534	-.196	-1.364	.178	-5.160	.975
	Gender	-.737	9.540	-.011	-.077	.939	-19.807	18.333
	education level	1.225	8.816	.018	.139	.890	-16.398	18.848
	CESD Depression	-.829	1.260	-.086	-.658	.513	-3.348	1.690

Appendix F.2

HMRA of non-focal EBPM proportion correct with covariate predictors.

Descriptive Statistics

	Mean	Std. Deviation	N
EBPM Box proportion correct week	82.78	27.860	73
Age at interview	88.20	3.114	74
Gender	.66	.476	74
education level	1.37	.486	73
CESD Depression	4.77	3.443	69

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.019[a]	.000	-.015	28.065	.000	.024	1	66	.878
2	.168[b]	.028	-.034	28.323	.028	.601	3	63	.617

a. Predictors: (Constant), Age at interview
b. Predictors: (Constant), Age at interview, education level, CESD Depression, Gender
c. Dependent Variable: EBPM Box proportion correct week

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	18.699	1	18.699	.024	.878[b]
	Residual	51984.333	66	787.641		
	Total	52003.031	67			
2	Regression	1464.087	4	366.022	.456	.767[c]
	Residual	50538.944	63	802.205		
	Total	52003.031	67			

a. Dependent Variable: EBPM Box proportion correct week
b. Predictors: (Constant), Age at interview
c. Predictors: (Constant), Age at interview, education level, CESD Depression, Gender

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	67.814	97.170		.698	.488	-126.193	261.820
	Age at interview	.170	1.101	.019	.154	.878	-2.029	2.368
2	(Constant)	39.365	113.244		.348	.729	-186.935	265.665
	Age at interview	.474	1.295	.053	.366	.716	-2.114	3.062
	Gender	.585	8.053	.010	.073	.942	-15.508	16.677
	education level	5.257	7.442	.092	.706	.483	-9.615	20.128
	CESD Depression	-1.255	1.064	-.155	-1.180	.243	-3.381	.871

Appendix F.3

Selected SPSS output for logistic regression for TBPM with covariate predictors.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	3.218	3	.359
	Block	3.218	3	.359
	Model	3.425	4	.489

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	65.724[a]	.049	.077

a. Estimation terminated at iteration number 5 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	7.902	8	.443

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	AGE	.111	.121	.835	1	.361	1.117	.881	1.417
	GENDER(1)	.206	.683	.091	1	.763	1.228	.322	4.685
	educ_level(1)	.303	.708	.182	1	.669	1.353	.338	5.426
	CESD_total	-.182	.120	2.285	1	.131	.834	.659	1.055
	Constant	-10.648	10.599	1.009	1	.315	.000		

a. Variable(s) entered on step 1: GENDER, educ_level, CESD_total.

Appendix G
Selected SPSS output and analyses for Study 2.

Appendix G.1

Probability of proficiency on the focal EBPM task across measurement occasions.

Time	Log Odds	Coefficient (OR)	Probability (%)
t =1	0.530	β	62.4
t =2	0.587	0.053 + 0.084	64
t =3	0.671	0.053 + (2 * 0.084)	66.2
t =4	0.755	0.053 + (3 * 0.084)	68
t =5	0.923	0.053 + (4 * 0.084)	71.6
t =6	1.007	0.053 + (5 * 0.084)	73.3
t =7	1.091	0.053 + (6 * 0.084)	74.8
t =8	1.175	0.053 + (7* 0.084)	76.4
t =9	1.259	0.053 + (8 * 0.084)	77.8
t =10	1.343	0.053 + (9 * 0.084)	79.3
t =11	1.427	0.053 + (10 * 0.084)	80.5

Appendix G.2

Probability of proficiency on the non-focal EBPM task across measurement occasions.

Time	Log Odds	Coefficient (OR)	Probability (%)
t =1	1.211	β	77
t =2	1.286	1.211 + 0.075	78.3
t =3	1.361	1.211 + (2 * 0.075)	79.6
t =4	1.436	1.211 + (3 * 0.075)	80.8
t =5	1.511	1.211 + (4 * 0.075)	81.9
t =6	1.586	1.211 + (5 * 0.075)	83
t =7	1.661	1.211 + (6 * 0.075)	84
t =8	1.736	1.211 + (7* 0.075)	85
t =9	1.811	1.211 + (8 * 0.075)	85.9

Appendix G.3

Final model (E) of GLMM for focal EBPM, cortisol indices, and covariates.

```
*Generalized Linear Mixed Models.
GENLINMIXED
  /DATA_STRUCTURE SUBJECTS=id REPEATED_MEASURES=CapquTIME
COVARIANCE_TYPE=AR1
  /FIELDS TARGET=twocircles TRIALS=NONE OFFSET=NONE
  /TARGET_OPTIONS REFERENCE=0 DISTRIBUTION=BINOMIAL LINK=LOGIT
  /FIXED  EFFECTS=CapquTIME Age Gender Educ_rec CESDTot ThyCond
MEDThy auc_cortper AUC_WP avgwake_cortper CAR_WP iSD_avg iSD_WP
dev_cort USE_INTERCEPT=TRUE
  /RANDOM USE_INTERCEPT=TRUE SUBJECTS=id
COVARIANCE_TYPE=VARIANCE_COMPONENTS
  /BUILD_OPTIONS TARGET_CATEGORY_ORDER=DESCENDING
INPUTS_CATEGORY_ORDER=DESCENDING MAX_ITERATIONS=100
CONFIDENCE_LEVEL=95 DF_METHOD=RESIDUAL COVB=ROBUST
PCONVERGE=0.000001(ABSOLUTE) SCORING=0 SINGULAR=0.000000000001
  /EMMEANS_OPTIONS SCALE=ORIGINAL PADJUST=LSD.
```

Case Processing Summary

	N	Percent
Included	745	92.7%
Excluded	59	7.3%
Total	804	100.0%

Model Summary

Target: Did they double circle capital question

Target		Did they initial box
Probability Distribution		Binomial
Link Function		Logit
Information Criterion	Akaike Corrected	3,728.915
	Bayesian	3,742.441

Information criteria are based on the -2 log pseudo likelihood (3,722.880) and are used to compare models. Models with smaller information criterion values fit better. When comparing models using pseudo likelihood values, caution should be used because different data transformations may be used across the models.

Fixed Effects

Target: Did they double circle capital question

Reference Category: No

Source	**F**	**Df1**	**Df2**	**Sig.**
Corrected Model	2.992	14	679	.000
CapquTIME	7.968	1	679	.005
Age	3.536	1	679	.127
Gender	0.314	1	379	.575
Educ_level	2.967	1	679	.085
CESDTot	0.559	1	679	.455
ThyCond	1.360	1	679	.244
MEDThy	0.911	1	679	.340
AUC cortisol BP	1.510	1	679	.220
AUC cortisol WP	0.776	1	679	.379
CAR cortisol BP	1.288	1	679	.257
CAR cortisol WP	8.135	1	679	.004
*i*SD cortisol BP	0.694	1	679	.307
*i*SD cortisol WP	1.045	1	679	.307
dev_cort	1.748	1	679	.187

Probability distribution: Binomial
Link function: Logit

Fixed Coefficients

Target: Did they double circle capital question

Reference Category: No

Model Term	Coeff.	SE	t	Sig.	Exp Coeff.	95% Conf. Interval	
						Lower	Upper
Intercept	17.353	9.625	1.803	.072	34,377,956.	-1.545	36.251
CapquTIME	0.155	0.055	2.823	.005	1.168	0.047	0.263
Age	-0.206	0.110	-1.880	.060	0.814	-0.421	0.009
Gender = 2	-0.373	0.666	-0.561	.575	0.688	-1.682	0.935
Gender = 1	0[a]						
Educ_level=2	1.143	0.664	1.722	.040	3.137	-0.160	2.447
Educ_level =1	0[a]						
CESDTot	-0.074	0.099	-0.748	.455	0.929	-0.269	0.120
ThyCond	0.929	0.797	1.166	.244	2.533	-0.635	2.494
MEDThy= 1	1.119	1.173	0.954	.340	3.062	-1.183	3.421
MEDThy= 0	0[a]						
AUC cortisol BP	0.010	0.008	1.229	.220	1.010	-0.006	0.025
AUC cortisol WP	0.004	0.005	0.881	.379	1.004	-0.005	0.013
CAR cortisol BP	-0.065	0.058	-1.135	.257	0.937	-0.179	0.048
CAR cortisol WP	-0.053	0.019	2.852	.004	1.054	0.016	0.089
*i*SD cortisol BP	0.125	0.151	0.833	.405	1.134	-0.170	0.421
*i*SD cortisol WP	0.049	0.048	1.022	.307	1.050	-0.045	0.143
Deviation cortisol	0.037	0.028	1.322	.187	1.037	-0.018	0.091

Probability distribution: Binomial
Link function: Logit
[a] This coefficient is set to zero because it is redundant

Covariance Parameters

Target: Did they double circle capital question

Covariance Parameters	Residual Effect	2
	Random Effects	1
Design Matrix Columns	Fixed Effects	18
	Random Effects	1[a]
Common Subjects		73

Common subjects are based on the subject specifications for the residual and random effects and are used to chunk the data for better performance.

[a] This is the number of columns per common subject

Random Effect	Estimate	SE	z	Sig.	95% Confidence Interval	
					Lower	Upper
Var (Intercept)	4.449	1.144	3.890	.000	2.689	7.364

Covariance Structure: Variance components
Subject Specification: id

Residual Effect	Estimate	SE	z	Sig.	95% Confidence Interval	
					Lower	Upper
AR1 Diagonal	0.723	0.046	15.771	.000	0.639	0.819
AR1 Rho	0.173	0.051	3.392	.000	0.071	0.271

Covariance Structure: First-order autoregressive
Subject Specification: id

Appendix G.4

Final model (E) of GLMM for non-focal EBPM, cortisol indices, and covariates.

```
GET
  FILE='\\userGH\H\hunt0127\prefs\Desktop\MLM box ques  long
.sav'.
DATASET NAME DataSet1 WINDOW=FRONT.
*Generalized Linear Mixed Models.
GENLINMIXED
  /DATA_STRUCTURE SUBJECTS=id REPEATED_MEASURES=boxquTIME
COVARIANCE_TYPE=AR1
  /FIELDS TARGET=Init_Box TRIALS=NONE OFFSET=NONE
  /TARGET_OPTIONS REFERENCE=2 DISTRIBUTION=BINOMIAL LINK=LOGIT
  /FIXED  EFFECTS=boxquTIME Age Educ_level CESDTot ThyCond MEDThy
AUCMPer CarDayMSub iSDDay dev_cort USE_INTERCEPT=TRUE
  /RANDOM USE_INTERCEPT=TRUE SUBJECTS=id
COVARIANCE_TYPE=VARIANCE_COMPONENTS
  /BUILD_OPTIONS TARGET_CATEGORY_ORDER=DESCENDING
INPUTS_CATEGORY_ORDER=DESCENDING MAX_ITERATIONS=100
CONFIDENCE_LEVEL=95 DF_METHOD=RESIDUAL COVB=ROBUST
PCONVERGE=0.000001(ABSOLUTE) SCORING=0 SINGULAR=0.000000000001
  /EMMEANS_OPTIONS SCALE=ORIGINAL PADJUST=LSD.
```

Case Processing Summary

	N	Percent
Included	608	92.4%
Excluded	50	7.6%
Total	658	100.0%

Model Summary

Target: Did they initial box

Target		Did they initial box
Probability Distribution		Binomial
Link Function		Logit
Information Criterion	Akaike Corrected	2,888.501
	Bayesian	2,901.181

Information criteria are based on the -2 log pseudo likelihood (2,882.454) and are used to compare models. Models with smaller information criterion values fit better. When comparing models using pseudo likelihood values, caution should be used because different data transformations may be used across the models.

Fixed Effects

Target: Did they initial box

Reference Category: No, did not initial box

Source	F	Df1	Df2	Sig.
Corrected Model	0.924	14	514	.532
boxquTIME	2.850	1	514	.092
Age	1.540	1	514	.215
Gender	0.170	1	514	.680
Educ_level	0.597	1	514	.440
CESDTot	0.444	1	514	.505
ThyCond	0.888	1	514	.346
MEDThy	2.139	1	514	.144
AUC cortisol BP	0.300	1	514	.584
AUC cortisol WP	0.431	1	514	.512
CAR cortisol BP	1.801	1	514	.180
CAR cortisol WP	0.010	1	514	.920
*i*SD cortisol BP	0.500	1	514	.480
*i*SD cortisol WP	0.432	1	514	.511
Deviation cortisol	0.655	1	514	.419

Probability distribution: Binomial
Link function: Logit

Fixed Coefficients

Target: Did they initial box

Reference Category: No, did not initial box

Model Term	Coeff.	SE	t	Sig.	Exp Coeff.	95% Conf. Interval	
						Lower	Upper
Intercept	-11.630	10.529	-1.105	.270	0.000	-32.316	9.055
boxquTIME	0.092	0.055	1.688	.092	1.097	-0.015	0.200
Age	0.153	0.123	1.241	.215	1.165	-0.089	0.394
Gender = 2	0.290	0.704	0.413	.680	1.337	-1.092	1.673
Gender = 1	0[a]						
Educ_level=2	0.514	0.666	0.773	.440	1.673	-0.794	1.823
Educ_level =1	0[a]						
CESDTot	-0.076	0.114	-0.667	.505	0.927	-0.300	0.148
ThyCond	-0.835	0.886	-0.942	.346	0.434	-2.575	0.905
MEDThy= 1	1.308	0.894	1.463	.144	3.697	-0.449	3.064
MEDThy= 0	0[a]						
AUC cortisol BP	-0.004	0.008	-0.548	.584	0.996	-0.021	0.012
AUC cortisol WP	0.004	0.006	0.657	.512	1.004	-0.008	0.016
CAR cortisol BP	0.385	0.287	1.342	.180	1.469	-0.178	0.948
CAR cortisol WP	0.011	0.114	0.100	.920	1.011	-0.212	0.235
*i*SD cortisol BP	0.094	0.133	0.707	.480	1.099	-0.168	0.356
*i*SD cortisol WP	-0.049	0.074	-0.658	.511	0.952	-0.194	0.097
Deviation cortisol	0.032	0.069	0.809	.419	1.032	-0.045	0.108

Probability distribution: Binomial

Link function: Logit

[a] This coefficient is set to zero because it is redundant

Covariance Parameters

Target: Did they initial box

Covariance Parameters	Residual Effect	2
	Random Effects	1
Design Matrix Columns	Fixed Effects	18
	Random Effects	1[a]
Common Subjects		73

Common subjects are based on the subject specifications for the residual and random effects and are used to chunk the data for better performance.

[a] This is the number of columns per common subject

Random Effect	Estimate	SE	z	Sig.	95% Confidence Interval	
					Lower	Upper
Var (Intercept)	4.416	1.150	3.840	.000	2.650	7.356

Covariance Structure: Variance components
Subject Specification: id

Residual Effect	Estimate	SE	z	Sig.	95% Confidence Interval	
					Lower	Upper
AR1 Diagonal	0.503	0.036	14.047	.000	0.438	0.579
AR1 Rho	0.104	0.061	1.687	.092	-0.018	0.222

Covariance Structure: First-order autoregressive
Subject Specification: id

Appendix G.5

Logistic regression analysis of TBPM, cortisol indices, and covariates.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	2.901	7	.894

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	31.286[a]	.408	.617

a. Estimation terminated at iteration number 8 because parameter estimates changed by less than .001.

Casewise List[b]

Case	Selected Status[a]	Observed	Predicted	Predicted Group	Temporary Variable	
		Did they call RA due to prompt			Resid	ZResid
5	S	Y**	.291	N	.709	1.562
28	S	N**	.762	Y	-.762	-1.789

a. S = Selected, U = Unselected cases, and ** = Misclassified cases.

b. Cases with studentized residuals greater than 3.000 are listed.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	AGE	.402	.320	1.579	1	.209	1.495	.798	2.800
	GENDER(1)	.279	1.308	.045	1	.831	1.322	.102	17.162
	educ_level(1)	2.011	1.707	1.387	1	.239	7.468	.263	212.120
	CESD_total	-1.026	.433	5.610	1	.018	.358	.153	.838
	thymed(1)	.628	1.883	.111	1	.739	1.874	.047	75.083
	auc_cortper	.094	.053	3.182	1	.074	1.099	.991	1.218
	CAR_per	-2.585	1.799	2.064	1	.151	.075	.002	2.564
	iSD_avg	-.150	.568	.070	1	.791	.860	.282	2.621
	auc_cortday3	-.018	.020	.805	1	.370	.982	.943	1.022
	auc_cortday4	-.070	.041	2.838	1	.092	.933	.860	1.011
	CAR_day3	2.018	1.177	2.938	1	.087	7.522	.749	75.574
	CAR_day4	.509	.705	.521	1	.470	1.664	.417	6.632
	iSD_day3	.409	.547	.559	1	.455	1.505	.515	4.395
	iSD_day4	.032	.143	.051	1	.821	1.033	.781	1.366
	cort_dev_A.21	-1.053	.643	2.686	1	.101	.349	.099	1.229
	cort_dev_A.24	-.761	.373	4.152	1	.042	.467	.225	.971
	cort_dev_A.25	.263	.309	.723	1	.395	1.301	.710	2.384
	Constant	-37.197	28.608	1.691	1	.194	.000		

a. Variable(s) entered on step 1: auc_cortday3, auc_cortday4, CAR_day3, CAR_day4, iSD_day3, iSD_day4, cort_dev_A.21, cort_dev_A.24, cort_dev_A.25.

Appendix H

Selected SPSS output and analyses for Study 3.

Appendix H.1

HMRA of focal EBPM proportion correct and executive function, working memory and retrospective memory.

Descriptive Statistics

	Mean	Std. Deviation	N
EBPM Capital proportion correct week	72.88	33.624	69
Age at interview	88.12	3.003	69
Age left school	4.04	1.419	69
W11: DSST total in 90 seconds	33.14	8.698	69
EF total z-score	.08	2.195	69
WM total z-score	.0091762	1.43956755	69
zRM2	.0391502	1.60735004	69

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.352[a]	.124	.083	32.194	.124	3.059	3	65	.034	
2	.460[b]	.212	.136	31.260	.088	2.314	3	62	.085	1.696

a. Predictors: (Constant), W11: DSST total in 90 seconds, Age at interview, Age left school
b. Predictors: (Constant), W11: DSST total in 90 seconds, Age at interview, Age left school, zRM2, WM total z-score, EF total z-score
c. Dependent Variable: EBPM Capital proportion correct week

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	9511.860	3	3170.620	3.059	.034[b]
	Residual	67368.277	65	1036.435		
	Total	76880.136	68			
2	Regression	16294.319	6	2715.720	2.779	.019[c]
	Residual	60585.817	62	977.191		
	Total	76880.136	68			

a. Dependent Variable: EBPM Capital proportion correct week
b. Predictors: (Constant), W11: DSST total in 90 seconds, Age at interview, Age left school
c. Predictors: (Constant), W11: DSST total in 90 seconds, Age at interview, Age left school, zRM2, WM total z-score, EF total z-score

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	177.969	123.676		1.439	.155	-69.030	424.967
	Age at interview	-1.516	1.366	-.135	-1.110	.271	-4.244	1.211
	Age left school	-2.319	2.894	-.098	-.801	.426	-8.100	3.461
	W11: DSST total in 90 seconds	1.143	.482	.296	2.372	.021	.181	2.105
2	(Constant)	198.299	120.726		1.643	.106	-43.029	439.627
	Age at interview	-1.583	1.330	-.141	-1.191	.238	-4.241	1.075
	Age left school	-2.235	2.821	-.094	-.792	.431	-7.873	3.403
	W11: DSST total in 90 seconds	.684	.507	.177	1.350	.182	-.329	1.697
	EF total z-score	4.533	2.030	.296	2.233	.029	.475	8.590
	WM total z-score	-2.253	2.947	-.096	-.765	.447	-8.145	3.638
	zRM2	2.516	2.527	.120	.996	.323	-2.534	7.567

[a] Dependent variable: EBPM capital proportion correct week

Appendix H.2

HMRA of focal EBPM forgetting ratio and executive function, working memory and retrospective memory.

Descriptive Statistics

	Mean	Std. Deviation	N
EBPM Capital Forgetting Ratio	.1729	.30864	69
Age at interview	88.12	3.003	69
Age left school	4.04	1.419	69
W11: DSST total in 90 seconds	33.14	8.698	69
EF total z-score	.08	2.195	69
WM total z-score	.0091762	1.43956755	69
zRM2	.0391502	1.60735004	69

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.262[a]	.068	.025	.30469	.068	1.591	3	65	.200	
2	.434[b]	.189	.110	.29116	.120	3.061	3	62	.035	1.811

a. Predictors: (Constant), W11: DSST total in 90 seconds, Age at interview, Age left school
b. Predictors: (Constant), W11: DSST total in 90 seconds, Age at interview, Age left school, zRM2, WM total z-score, EF total z-score
c. Dependent Variable: EBPM Capital Forgetting Ratio

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.443	3	.148	1.591	.200[b]
	Residual	6.034	65	.093		
	Total	6.477	68			
2	Regression	1.222	6	.204	2.402	.038[c]
	Residual	5.256	62	.085		
	Total	6.477	68			

a. Dependent Variable: EBPM Capital Forgetting Ratio
b. Predictors: (Constant), W11: DSST total in 90 seconds, Age at interview, Age left school
c. Predictors: (Constant), W11: DSST total in 90 seconds, Age at interview, Age left school, zRM2, WM total z-score, EF total z-score

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-.805	1.171		-.688	.494	-3.143	1.532
	Age at interview	.012	.013	.112	.893	.375	-.014	.037
	Age left school	.037	.027	.172	1.365	.177	-.017	.092
	W11: DSST total in 90 seconds	-.006	.005	-.162	-1.257	.213	-.015	.003
2	(Constant)	-.923	1.124		-.821	.415	-3.171	1.325
	Age at interview	.011	.012	.111	.923	.360	-.013	.036
	Age left school	.037	.026	.169	1.400	.166	-.016	.089
	W11: DSST total in 90 seconds	-.002	.005	-.047	-.355	.724	-.011	.008
	EF total z-score	-.037	.019	-.260	-1.934	.058	-.074	.001
	WM total z-score	.029	.027	.133	1.042	.301	-.026	.083
	zRM2	-.047	.024	-.244	-1.989	.051	-.094	.000

Dependent variable: EBPM capital forgetting ratio

Appendix H.3

HMRA of focal EBPM recovery ratio and executive function, working memory and retrospective memory.

Descriptive Statistics

	Mean	Std. Deviation	N
EBPM Capital Recovery Ratio	.0783	.09259	69
Age at interview	88.12	3.003	69
Age left school	4.04	1.419	69
W11: DSST total in 90 seconds	33.14	8.698	69
EF total z-score	.08	2.195	69
WM total z-score	.0091762	1.43956755	69
zRM2	.0391502	1.60735004	69

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.195[a]	.038	-.006	.09289	.038	.857	3	65	.468	
2	.327[b]	.107	.021	.09163	.069	1.597	3	62	.199	1.297

a. Predictors: (Constant), W11: DSST total in 90 seconds, Age at interview, Age left school
b. Predictors: (Constant), W11: DSST total in 90 seconds, Age at interview, Age left school, zRM2, WM total z-score, EF total z-score
c. Dependent Variable: EBPM Capital Recovery Ratio

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.022	3	.007	.857	.468[b]
	Residual	.561	65	.009		
	Total	.583	68			
2	Regression	.062	6	.010	1.239	.299[c]
	Residual	.521	62	.008		
	Total	.583	68			

a. Dependent Variable: EBPM Capital Recovery Ratio
b. Predictors: (Constant), W11: DSST total in 90 seconds, Age at interview, Age left school
c. Predictors: (Constant), W11: DSST total in 90 seconds, Age at interview, Age left school, zRM2, WM total z-score, EF total z-score

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.639	.357		1.791	.078	-.074	1.352
	Age at interview	-.006	.004	-.194	-1.515	.135	-.014	.002
	Age left school	.000	.008	.003	.024	.981	-.016	.017
	W11: DSST total in 90 seconds	-.001	.001	-.101	-.771	.444	-.004	.002
2	(Constant)	.591	.354		1.670	.100	-.117	1.298
	Age at interview	-.006	.004	-.179	-1.412	.163	-.013	.002
	Age left school	.000	.008	.005	.036	.971	-.016	.017
	W11: DSST total in 90 seconds	-.001	.001	-.082	-.590	.558	-.004	.002
	EF total z-score	-.003	.006	-.082	-.584	.561	-.015	.008
	WM total z-score	-.008	.009	-.120	-.890	.377	-.025	.010
	zRM2	.016	.007	.270	2.102	.040	.001	.030

Dependent variable: EBPM capital recovery ratio

Appendix H.4

HMRA of non-focal EBPM proportion correct and executive function, working memory and retrospective memory.

Descriptive Statistics

	Mean	Std. Deviation	N
EBPM Box proportion correct week	84.26	26.789	70
Age at interview	88.11	2.981	70
Age left school	4.03	1.414	70
W11: DSST total in 90 seconds	33.26	8.686	70
EF total z-score	.02	2.253	70
WM total z-score	.0107540	1.42915880	70
zRM2	.0441378	1.59620562	70

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.245[a]	.060	.017	26.556	.060	1.406	3	66	.249	
2	.465[b]	.216	.141	24.827	.156	4.171	3	63	.009	2.151

a. Predictors: (Constant), W11: DSST total in 90 seconds, Age left school, Age at interview
b. Predictors: (Constant), W11: DSST total in 90 seconds, Age left school, Age at interview, zRM2, WM total z-score, EF total z-score
c.. Dependent Variable: EBPM Box proportion correct week

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2974.281	3	991.427	1.406	.249[b]
	Residual	46544.940	66	705.226		
	Total	49519.221	69			
2	Regression	10687.724	6	1781.287	2.890	.015[c]
	Residual	38831.497	63	616.373		
	Total	49519.221	69			

a. Dependent Variable: EBPM Box proportion correct week
b. Predictors: (Constant), W11: DSST total in 90 seconds, Age left school, Age at interview
c. Predictors: (Constant), W11: DSST total in 90 seconds, Age left school, Age at interview, zRM2, WM total z-score, EF total z-score

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	23.308	101.906		-.229	.820	-226.769	180.153
	Age at interview	.913	1.125	.102	.812	.420	-1.334	3.160
	Age left school	.933	2.369	.049	.394	.695	-3.798	5.663
	W11: DSST total in 90 seconds	.702	.394	.228	1.783	.079	-.084	1.488
2	(Constant)	-33.788	95.599		-.353	.725	-224.828	157.252
	Age at interview	1.078	1.054	.120	1.023	.310	-1.028	3.185
	Age left school	.440	2.222	.023	.198	.844	-4.001	4.882
	W11: DSST total in 90 seconds	.634	.391	.206	1.622	.110	-.147	1.416
	EF total z-score	-2.310	1.518	-.194	-1.522	.133	-5.343	.724
	WM total z-score	6.509	2.331	.347	2.792	.007	1.851	11.167
	zRM2	2.914	2.002	.174	1.455	.151	-1.087	6.915

Dependent variable: EBPM box proportion correct week

Appendix H.5

HMRA of non-focal EBPM forgetting ratio and executive function, working memory and retrospective memory.

Descriptive Statistics

	Mean	Std. Deviation	N
EBPM Box Forgetting Ratio	.1076	.23363	70
Age at interview	88.11	2.981	70
Age left school	4.03	1.414	70
W11: DSST total in 90 seconds	33.26	8.686	70
EF total z-score	.02	2.253	70
WM total z-score	.0107540	1.42915880	70
zRM2	.0441378	1.59620562	70

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.318[a]	.101	.060	.22649	.101	2.474	3	66	.069	
2	.535[b]	.287	.219	.20651	.186	5.464	3	63	.002	2.231

a. Predictors: (Constant), W11: DSST total in 90 seconds, Age left school, Age at interview
b. Predictors: (Constant), W11: DSST total in 90 seconds, Age left school, Age at interview, zRM2, WM total z-score, EF total z-score
c. Dependent Variable: EBPM Box Forgetting Ratio

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.381	3	.127	2.474	.069[b]
	Residual	3.386	66	.051		
	Total	3.766	69			
2	Regression	1.080	6	.180	4.220	.001[c]
	Residual	2.687	63	.043		
	Total	3.766	69			

a. Dependent Variable: EBPM Box Forgetting Ratio
b. Predictors: (Constant), W11: DSST total in 90 seconds, Age left school, Age at interview
c. Predictors: (Constant), W11: DSST total in 90 seconds, Age left school, Age at interview, zRM2, WM total z-score, EF total z-score

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.710	.869		1.968	.053	-.025	3.445
	Age at interview	-.015	.010	-.194	-1.584	.118	-.034	.004
	Age left school	.003	.020	.019	.154	.878	-.037	.043
	W11: DSST total in 90 seconds	-.008	.003	-.308	-2.470	.016	-.015	-.002
2	(Constant)	1.769	.795		2.224	.030	.180	3.358
	Age at interview	-.017	.009	-.213	-1.907	.061	-.034	.001
	Age left school	.008	.018	.050	.445	.658	-.029	.045
	W11: DSST total in 90 seconds	-.007	.003	-.245	-2.023	.047	-.013	.000
	EF total z-score	.010	.013	.096	.786	.435	-.015	.035
	WM total z-score	-.055	.019	-.336	-2.832	.006	-.094	-.016
	zRM2	-.035	.017	-.238	-2.096	.040	-.068	-.002

Dependent variable: EBPM box forgetting ratio

Appendix H.6

HMRA of non-focal EBPM recovery ratio and executive function, working memory and retrospective memory.

Descriptive Statistics

	Mean	Std. Deviation	N
EBPM Box Recovery Ratio	.0674	.08991	69
Age at interview	88.12	3.003	69
Age left school	4.04	1.419	69
W11: DSST total in 90 seconds	33.14	8.698	69
EF total z-score	.08	2.195	69
WM total z-score	.0091762	1.43956755	69
zRM2	.0391502	1.60735004	69

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.162[a]	.026	-.019	.09075	.026	.582	3	65	.629	
2	.263[b]	.069	-.021	.09085	.043	.954	3	62	.420	2.151

a. Predictors: (Constant), W11: DSST total in 90 seconds, Age at interview, Age left school
b. Predictors: (Constant), W11: DSST total in 90 seconds, Age at interview, Age left school, zRM2, WM total z-score, EF total z-score
c. Dependent Variable: EBPM Box Recovery Ratio

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.014	3	.005	.582	.629[b]
	Residual	.535	65	.008		
	Total	.550	68			
2	Regression	.038	6	.006	.767	.598[c]
	Residual	.512	62	.008		
	Total	.550	68			

a. Dependent Variable: EBPM Box Recovery Ratio
b. Predictors: (Constant), W11: DSST total in 90 seconds, Age at interview, Age left school
c. Predictors: (Constant), W11: DSST total in 90 seconds, Age at interview, Age left school, zRM2, WM total z-score, EF total z-score

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.310	.349		.888	.378	-.387	1.006
	Age at interview	-.003	.004	-.103	-.801	.426	-.011	.005
	Age left school	-.001	.008	-.022	-.169	.866	-.018	.015
	W11: DSST total in 90 seconds	.001	.001	.103	.782	.437	-.002	.004
2	(Constant)	.362	.351		1.033	.306	-.339	1.064
	Age at interview	-.003	.004	-.112	-.864	.391	-.011	.004
	Age left school	-.001	.008	-.021	-.163	.871	-.018	.015
	W11: DSST total in 90 seconds	.000	.001	.012	.082	.935	-.003	.003
	EF total z-score	.009	.006	.231	1.602	.114	-.002	.021
	WM total z-score	-.001	.009	-.015	-.107	.915	-.018	.016
	zRM2	6.545E-005	.007	.001	.009	.993	-.015	.015

Dependent variable: EBPM box recovery ratio

Appendix H.7

Logistic regression of TBPM and executive function, working memory and retrospective memory.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	1.023	3	.796
	Block	1.023	3	.796
	Model	3.423	6	.754

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	69.797[a]	.047	.073

a. Estimation terminated at iteration number 5 because parameter estimates changed by less than .001.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	AGE	.088	.098	.811	1	.368	1.092	.901	1.323
	educ	-.171	.225	.577	1	.447	.843	.543	1.310
	DSST_tot	-.025	.039	.432	1	.511	.975	.904	1.052
	zEF_tot	.000	.159	.000	1	.998	1.000	.732	1.365
	zWM_tot	.135	.239	.321	1	.571	1.145	.717	1.829
	zRM2	-.176	.183	.932	1	.334	.838	.586	1.199
	Constant	-7.623	8.856	.741	1	.389	.000		

a. Variable(s) entered on step 1: zEF_tot, zWM_tot, zRM2.