INTERACTION BETWEEN MOOD DISORDER AND AGING IN EMOTION PROCESSING

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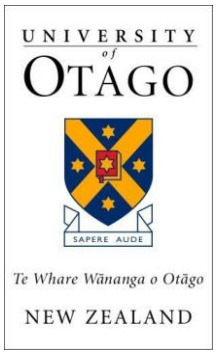


Abstract

Background

Understanding changes in emotion processing in mental health conditions, in aging, and at the nexus of both, is important for contributing to knowledge about our expanding aging population. Effective processing of emotions is an important contributor to wellbeing. Consequently, disruptions and changes to such likely lead to reduced wellbeing and may contribute to the development and maintenance of significant mental health conditions. While some research has been conducted in emotion processing in older adults and aging, the evidence base for this in mental health conditions is limited.

Objectives

- To examine changes in emotion processing with aging in healthy adults over 45 years.
- To examine changes in emotion processing with aging in individuals 16-64 years old with mood disorders and healthy participants.
- To highlight areas and directions for future explorations of emotion processing in aging and mental health.

Methods

A cross-sectional study of emotion processing and non-emotional cognition in four age bands of healthy participants (between 45 and 84 years) was conducted. Differences in emotion processing were examined across the four age bands, as was the impact of non-emotional cognitive function on emotion processing. A second study involved an exploratory pooled analysis of facial emotion recognition in adults between 16 and 64 years with major depressive disorder, bipolar disorder, or healthy control participants. The impact of age and non-emotional cognition on emotion processing was investigated, alongside the influence of mood disorder diagnosis.

Results

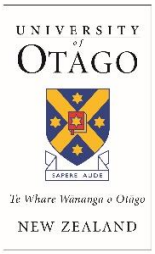
In the analysis of the healthy older sample, a decrease in accuracy of facial emotion recognition was found with increasing age for the emotions of fear and sadness. No age-

related changes were found for other emotions. An increase in reaction time with increasing age was present across all emotions and the performance index showed a reduction in efficiency with age for all emotions. Further analysis exploring misidentification bias showed that participants were less likely to misidentify neutral faces as sadness, anger, or fear as age increased. Significant correlations were also found in the healthy sample consistently between fear/sadness/anger and age, when controlled for non-emotional cognition.

In the mood disorder sample, no effect of diagnosis or current depression was found. Reduced accuracy with aging was found for processing of anger, disgust, fear, sadness, and surprise alongside an increase in recognition accuracy for happiness with increasing age. An increase in reaction time with age was found across all emotions except happiness, and the performance index showed a reduction in efficiency with age for all emotions except happiness.

Conclusion

Positivity bias was demonstrated with increasing age, across an age range of 16-84 years, in healthy participants and participants with mood disorders. The positivity bias was seen here by late middle age. The positivity bias shown here in people with mood disorders is surprising given that findings in mood disorder samples have generally shown a negativity bias compared with healthy controls. A clear future direction would be to examine the relationship between mood disorder, age, and emotion processing across the age range.



Co-Authorship Form

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Expectations of theses including publications:

The thesis must be an integrated and coherent body of work. The body of the thesis may include entire publications verbatim, but these need to be reformatted to a consistent chapter style, and commentary may need to be added to link the publications together. If the thesis contains multiple publications, candidates need to ensure that they have: included an introductory chapter; demonstrated their ability to critically engage with the literature; carefully considered their research design and justified choices of methodology and methods where necessary; and synthesised and discussed the findings from the publications. It is the candidate's responsibility to ensure that any published work (or parts thereof) included in the thesis comply with the copyright provisions of the publisher and that any guidelines with regard to self-citation are followed.

Details of publications included in and/or appended to this thesis (please add rows as needed)**.**

Chapter/ Append.	**Paper title**	**Authors**	**Contribution of candidate and co-authors – please detail the nature and extent (%)**	**Journal**	**Status (e.g. under review, forthcoming, published)**
Chapter Six	Emotion processing in depression and anxiety disorders in older adults: systematic review	Vanessa Gray, Katie M Douglas, Richard J Porter	V.G. conducted the systematic review of papers and prepared the first draft of the manuscript. R. J.P. and K.M.D. supervised the systematic review and reviewed and updated subsequent drafts.	BJ Psych (Open)	Published
Chapter Nine	The Effect of Age on Emotion Processing in Mood Disorders and Healthy Participants	Vanessa Gray, William Moot, Chris Frampton, Katie Douglas, Peter Gallagher , Jennifer Jordan, Janet D Carter,	VG, WM, CF, and RP contributed to conception and design of the analysis. VG and WM organized the database. VG, WM, CF, and RP performed	Frontiers Psychology	Under Review

		Maree Inder, Marie Crowe, Virginia V McIntosh, Richard J Porter	the statistical analysis. VG and RP wrote the first draft of the manuscript. VG, WM, RP, and PG wrote sections of the manuscript. JJ, JC, MI, MC, VM and RP contributed to design of the original studies and collection of the data. All authors contributed to manuscript revision, read, and approved the submitted version.		

Certification by Primary Supervisor:
The undersigned certifies that the above table correctly reflects the nature and extent of the candidate's contribution to this co-authored work

Name: Richard Porter Signature:  Date: *24.07.23*

Preface

The research presented in this thesis was conducted between May 2016 and June 2023 while I was enrolled as a PhD candidate in the Department of Psychological Medicine at the University of Otago, Christchurch. Professor Richard Porter was my primary supervisor and Associate Professor Katie Douglas co-supervised the project, both of whom are from the Department of Psychological Medicine. Alongside my PhD I completed a Postgraduate Diploma in Clinical Psychology from the University of Canterbury and have worked as a Clinical Psychologist for Te Whatu Ora (Health New Zealand). This research was supported by the Gilbert M Tothill Scholarship in Psychological Medicine.

Data for the study were collected between March 2019 and October 2022. Participants were recruited from the general population in Christchurch and assessment took place at the Department of Psychological Medicine. Ethical approval for the study was obtained prior to recruitment from the University of Otago Human Ethics Committee (Health).

The following people contributed to the study:

Professor Chris Frampton (biostatistician) provided statistical expertise to study analyses.

Bridget Kimber (research nurse) assisted with training on cognitive testing procedures and Andrea Bartram (data manager) assisted with the creation of data management systems.

I co-ordinated all aspects of the study which involved:

- applying for ethical approval,
- development of the cognitive testing battery,
- recruiting, screening, and obtaining informed consent from participants from the general population in Christchurch,
- conducting cognitive assessments for all participants, in total, 137 cognitive assessments.

Aspects of this research have been presented at the New Zealand College of Clinical Psychologists National Conference (2020 and 2023), Department of Psychological Medicine Research Meetings, University of Otago Graduate Research Festival, Department of Psychological Medicine (Wellington) Student Symposium, Christchurch Postgraduate Research Symposium, Otago Spotlight Series- Mental Health Research

(poster), and as a webinar for the New Zealand Special Interest Group in Neuropsychology. Findings have also been published or are in the process of being published in scientific peer reviewed journals.

Following submission of this PhD, I intend to prepare several further manuscripts for publication, including analysis of data not included in this thesis. Details of completed publications and presentations from the thesis are presented in the following section.

List of Publications

Papers directly related to this thesis

Gray, V., Douglas, K., & Porter, R. (2021). Emotion processing in depression and anxiety disorders in older adults: Systematic review. *BJPsych Open, 7*(1), E7. doi:10.1192/bjo.2020.143

Papers under review

Gray, V., Moot, W., Frampton, C., Douglas, K., Gallagher, P., Jordan, J., Carter, J. D., Inder, M., Crowe, M., McIntosh, V.V., & Porter, R. J. The effect of age on emotion processing in mood disorders and healthy participants. Submitted to *Frontiers Psychology*.

Conference presentations of results related to this thesis

Gray, V., Douglas, K., & Porter, R. J. (2023). *Interaction Between Mood Disorder and Aging in Emotion Processing.* Presentation at the New Zealand College of Clinical Psychologists Annual Conference, Wellington, New Zealand.

Gray, V., Douglas, K., & Porter, R. J. (2023). *Emotion Processing in Depressed Older Persons*. Presentation at the Department of Psychological Medicine (Wellington) Student Symposium, Wellington, New Zealand. Awarded for Best Communicator.

Porter, R., Gray, V., & Douglas, K. (2021). Emotion processing in late life depression. *Bipolar Disorders, 23*(S1). Presentation at the 23rd Annual Conference of the International Society for Bipolar Disorders.

Gray, V., Douglas, K., & Porter, R. J. (2021). *Emotion Processing in Depression and Anxiety Disorders in Older Adults.* Presentation at the New Zealand College of Clinical Psychologists Annual Conference, Christchurch, New Zealand.

Gray, V., Douglas, K., & Porter, R. J. (2019). *Emotion Processing in Depressed Older Persons*. Presentation at the University of Otago Graduate Research Festival, Dunedin, New Zealand.

Gray, V., Douglas, K., & Porter, R. J. (2019). *Emotion Processing in Depressed Older Persons*. Presentation at the Christchurch Postgraduate Research Symposium, Christchurch, New Zealand.

Gray, V., Douglas, K., & Porter, R. J. (2019). *Emotion Processing in Depressed Older Persons*. Poster presented at Otago Spotlight Series- Mental Health Research, Wellington, New Zealand.

Acknowledgements

I am very grateful to all the people who have supported me in my studies, and on this particular part of that journey. Firstly, to my supervisors Professor Richard Porter and Associate Professor Katie Douglas. This thesis would not have been possible without you both. While I am sure research and PhD's in general encounter difficulties along the way, this thesis seemed to have many obstacles, many of which were out of anyone's control. You have both guided me through these difficult times and encouraged me to find solutions and keep my focus on the end goal. Richard, your knowledge and wisdom has made pulling together the overall picture of this piece of work smoother and you have guided me through many ups and downs with the study design and other obstacles thrown in my way. Katie, you have guided and supported me to become (hopefully!) a better writer, and to remember to ask questions and clarify what I really need to say.

The support from Psych Med overall has made this journey a lot more pleasant and the lunchtime banter made the days much more delightful. In particular, thanks go to Bridget Kimber for getting me started on all of the testing, and Andi Bartram for assisting me with the set-up of the data storage systems. I am further indebted to Professor Chris Frampton for his support in all matters statistics and data analysis. You have been so kind and supportive and made me feel that analysing data is something I am capable of, which made the overall process much easier!

I would like to extend thanks to the Tothill family for their provision of the Gilbert M Tothill Scholarship in Psychological Medicine which provided financial support during the tenure of this thesis. Taking away some of the financial pressure allowed me to focus more fully on the task at hand.

Massive thanks go to my friends and family who have supported me in this journey. To my fellow clinical classmates, the bond we were able to form during our time studying together took some of the stress out of the whole process and allowed me to still function as rational human being over these many years. Special thanks goes to Sam Groves for her support, proof reading, and reassurance, through both the clinical and PhD journeys. Through this friendship we have both managed to come out the other side and I am so grateful to have had you alongside me for this entire process.

To my family, I appreciate your support and interest in this whole journey. While I might not have always appreciated questions about finishing dates, I feel so lucky to have a family that cares enough to be interested in what I am doing, even if it is a bit abstract at times!

Biggest thanks must go to Matt, my partner in life and someone who has put up with everything this journey has involved, financially and emotionally. You (and Rosie!) have made our home my safe space and coming home from long days to a place where I feel safe and supported has been the bedrock of these past years.

Finally, my thanks go to all the people who participated in this study. You were all so kind and generous with your time and the interest you showed in this research has made it all feel worthwhile.

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List of Abbreviations

ABM	Aging Brain Model
AD	Alzheimer's Disease
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
BD	Bipolar Disorder
CANTAB	Cambridge Neuropsychological Automated Test Battery
COWAT	Controlled Oral Word Association Tests
DIT	Dynamic Integration Theory
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders 4th Edition
DSM-5	Diagnostic and Statistical Manual of Mental Disorders 5th Edition
DSST	Digit Symbol Substitution Test
ERP	Event Related Potential
eStroop	Emotional Stroop
FER	Facial Emotion Recognition
GAD	Generalised Anxiety Disorder
GMLT	Groton Maze Learning Test
IQ	Intelligence Quotient
LLD	Late Life Depression
MADRS	Montgomery-Asberg Depression Rating Scale
MCI	Mild Cognitive Impairment
MDD	Major Depressive Disorder
MDE	Major Depressive Episode
MINI	Mini International Neuropsychiatric Interview
MMSE	Mini-Mental State Examination
MoCA	Montreal Cognitive Assessment
MPFC	Medial Prefrontal Cortex
NART	National Adult Reading Test
PCA	Principal Components Analysis
PI	Performance Index
PTSD	Post Traumatic Stress Disorder
QIDS-C	Quick Inventory of Depressive Symptoms- Clinician Rated
RAVLT	Rey Auditory-Verbal Learning Test
RMET	Reading the Mind in the Eyes Test
SAD	Social Anxiety Disorder
SD	Standard Deviation
SPSS	Statistical Package for Social Science
SST	Socioemotional Selectivity Theory
STAI	Sate Trait Anxiety Inventory
ToM	Theory of Mind

Chapter 1 - Thesis Outline and Overview

This chapter briefly outlines the background (Section 1.1) and rationale and aims (Section 1.2) of this thesis. Section 1.3 includes an outline of the remaining chapters of the thesis.

1.1 BACKGROUND

Aging is an inevitable fact of life and current estimates suggest that the proportion of people considered to be of older age is increasing globally (United Nations, 2019). Accordingly, it behoves researchers to explore what is happening to people as they age and to investigate ways that wellbeing can be improved for this increasingly significant portion of society.

Regulation and effective processing of emotions is an important contributor to wellbeing. Consequently, disruptions and changes to such likely lead to reduced wellbeing and can contribute to the maintenance of significant mental health conditions such as major depression. While some research has been conducted in the area of emotion processing in older adults and aging, the evidence base for this in mental health conditions is limited (Gray et al., 2021). As such, the initial conceptualisation for this thesis was to explore emotion processing in older adults with depression compared with healthy control participants and to examine the interaction between mood disorders and aging.

Difficulties with recruitment of appropriate participants within the mental health system (i.e., old age depression) and the time limited nature of a PhD thesis eventually led to the decision to redirect the focus to explore emotion processing in the context of aging, particularly during the period from middle adulthood to older adulthood. It was noticed that often studies compare a group of younger adults (usually 18-65 years) with a group of older adults (over 65 years), with little consideration of the heterogeneity likely present within the younger adult sample. Using a sample of adults from middle adulthood (45-65 years) may clarify changes occurring in emotion processing in the lead up to older adulthood and may determine whether previously documented changes might be happening earlier in the aging process. This desire to explore changes in middle adulthood also influenced the decision to examine the interaction between age and facial emotion processing in a slightly younger group of participants with mood disorders for whom data had already been collected.

1.2 RATIONALE AND AIMS

Understanding changes in emotion processing in mental health conditions, aging, and at the nexus of both, is important for contributing to knowledge about our expanding aging population.

The rationale behind this thesis was to examine emotion processing in aging and in mood disorders using two different methodologies and analyses with each shedding light on different aspects of this research area. These contributions to this body of research, alongside a discussion of what they might mean in the context of the current knowledge base (see Chapters Eight and Nine), will highlight areas and directions for future explorations in aging and mental health.

The two analyses presented in the thesis are:

1. A naturalistic cross-sectional study of emotion processing (facial and verbal) in healthy participants aged over 45 years. This sample was recruited from the general population in Christchurch, New Zealand. Participants completed cognitive tasks, which encompassed both emotional and non-emotional cognition.
2. An exploratory pooled analysis of facial emotion recognition (FER) in adults between 18 and 64 years with either major depressive disorder (MDD), bipolar disorder (BD), or healthy control participants. This analysis was designed to examine FER across this age span, in particular, examining the interaction between age and mood disorders, and considering the impact of non-emotional cognition on these variables.

1.3 THESIS OUTLINE

This thesis has the following structure:

Chapter Two presents an introduction to mood and anxiety disorders, including their classification and life course.

Chapter Three introduces the concept of emotion processing and the interaction between emotion processing and non-emotion-based processing. A summary of cognitive paradigms used in the thesis is also provided.

Chapter Four provides a literature review of emotion processing in mood and anxiety disorders in adults.

Chapter Five explores emotion processing and aging and introduces theories which explain changes in emotion processing with age.

Chapter Six presents a systematic review of emotion processing in older adults with MDD and anxiety (published).

Chapter Seven describes the methodology used in Chapter Eight.

Chapter Eight presents cross-sectional cognitive findings (traditional cognitive tasks and facial emotion processing tasks) in the healthy older sample, followed by a discussion of the results.

Chapter Nine presents the pooled analysis examining facial emotion processing and the effect of age in mood disorders and healthy control participants and discussion of the findings.

Chapter Ten presents an overall summary and discussion of the study findings, their implications, and directions for future research.

Chapter 2 - Mood and Anxiety Disorders

This chapter will provide an overview of mood disorders including MDD and BD, and then anxiety disorders relevant to the thesis. Classification, clinical characteristics, and life course and prognosis will then be discussed.

2.1 MOOD DISORDERS

2.1.1 Major Depressive Disorder

In the Diagnostic and Statistical Manual of Mental Disorders 5th Edition (DSM-5), MDD falls under the classification of "depressive disorders" (American Psychiatric Association, 2013). This section includes MDD, persistent depressive disorder, and premenstrual dysphoric disorder.

2.1.1.1 Clinical Classification

Major depressive disorder is characterised by the presence of a major depressive episode (MDE). A MDE is described as a period lasting two or more weeks in which a person feels low in mood and/or experiences a loss of interest or pleasure in almost all activities, most of the day, nearly every day. Alongside this, the person must experience four or more of the following symptoms and these symptoms must represent a change from previous functioning: significant weight or appetite disturbance, insomnia or hypersomnia, psychomotor agitation or retardation, fatigue, feelings of worthlessness or guilt, diminished concentration, suicidality. Additionally, these symptoms must cause clinically significant distress or impairment in everyday functioning (American Psychiatric Association, 2013).

2.1.1.2 Life Course and Prognosis

The average age of onset of MDD is approximately 26 years old (Bromet et al., 2011; Kessler et al., 2005) and women are twice as likely to be affected than men (Van de Velde et al., 2010). The number of MDD cases is steadily rising with an estimated increase in cases of 50% in the past 30 years, with currently more that 264 million people are experiencing MDD (Liu et al., 2020). In New Zealand, the Ministry of Health reported a prevalence rate of depression of 19% in 2021/2022, representing 801,000 adults over the age of 15 (Ministry of Health, 2022).

In a study of inpatients and outpatients with MDD, 85% of patients experienced a recurrence of symptoms over a 15-year period (Keller & Boland, 1998), whereas a community-based study found a recurrence rate of 35% with a similar 15 year follow-up (Eaton et al., 2008). Steinert et al. (2014) conducted a systematic review of studies of participants with MDD in the community and general practice. They found that in these studies, between 35% and 60% of participants had no further recurrence of symptoms. They noted a finding of 10-17% of participants with a chronic course of illness. From the National Epidemiologic Study of Alcohol Related Conditions, using a nationally representative sample, Skodol et al. (2011), found rates of persistence/recurrence of MDD over three years of 15% and 7%, respectively. Smaller studies have reported one-year recurrence rates of 23% (Sargeant et al., 1990) and 28% (Spijker et al., 2001). From those studies, predictors of recurrence included severity, duration of episode, family history, co-morbid physical illness, and personality disorder.

Recent research suggests that over half of people who have had a MDE do not experience another episode (Monroe et al., 2019; Monroe & Harkness, 2011). Early interventions for MDD may therefore be an important way to reduce the life course outcomes and impacts of this disorder. However, due to the knowledge that there is a subset of people who will experience a more repeated and disabling course of MDD, who are more likely to be treated in specialist mental health settings, it is also important to know what might happen to this group over time.

Predicting outcomes of MDD in older adults is difficult. Older adults have many of the factors which are known to be poor predictors of outcome, such as smaller social networks and family support, physical health conditions, and cognitive decline (Schaakxs et al., 2018). Alongside this, it is known that having previous episodes of depression is associated with a worse prognosis, and due to having lived more life, older people have a higher chance of having had previous episodes (Borza et al., 2015; Steinert et al., 2014). The burden of MDD during the life course may be linked to premature mortality. As such, those most affected may not be included in older age studies, or conversely, those affected during their lifetime may have developed coping strategies by this life stage and as such may not show up as so strongly impacted by MDD (Schaakxs et al., 2018). Schaakxs et al. (2018) conducted a large study including people from 18-88 years old and examined the naturalistic course of MDD over two years. They found a linear worsening of MDD with age, meaning in the oldest participants, there was a two to three times higher likelihood of symptoms remaining at a diagnostic level after two years and a smaller likelihood of remission.

2.1.1.3 Late Life Depression

Age of onset of depressive symptoms is important in older adults. People who experience depression throughout their lifetime are generally considered to have early onset depression, and those for whom depression makes its initial appearance in older age are considered to have late onset depression. A large body of literature has examined differences in aetiology and presentation between these two types of depression. In-depth discussion of this is not pertinent to the thesis as a whole and so will not be discussed in detail. Studies in older persons with depression do not always report whether participants have early or late onset depression and oftentimes the samples used have a mixture of both. As such, during this thesis, a distinction will not be made between these two populations and depression in older adults will be examined as a whole.

2.1.2 Bipolar Disorder

According to diagnostic manuals, BD can be subdivided into bipolar I and bipolar II disorder. While these two divisions are suggested to be distinct in their presentations, both require the presence of an elevation in mood as the defining feature of the disorder. This requirement has resulted in the suggestion that the categorisation of these two subtypes as different disorders is fundamentally flawed and not consistent with presentations seen in clinical practice (Malhi, 2021). Difficulties in distinguishing differences between hypomania and mania, and the subjective nature of defining the levels of functional impairment to make this distinction, are noted as reasons why these two subtypes should not be considered separate (Malhi et al., 2016).

Bipolar disorder is a general term to describe both subgroups and in research, the two subtypes are often studied together. This will be the approach taken in this thesis, as in Chapter Nine. Below, a brief description of the features of BD is provided, grouped into subgroups as per the DSM-5 (American Psychiatric Association, 2013).

2.1.2.1 Clinical Characteristics

2.1.2.1.1 Manic Episode

A manic episode is characterised by a period (one week or more) of abnormally elevated or irritable mood, alongside persistent goal-directed behaviour, or energy. It reflects a significant change from usual behaviour and includes three or more of the following symptoms: increased self-esteem or grandiosity, pressured speech, racing thoughts or flight of ideas, distractibility, increased goal-directed activity, and excessive involvement in risky behaviour.

This change in behaviour must be significant enough to cause impairment in social or occupational functioning.

2.1.2.1.2 Hypomanic Episode

A hypomanic episode involves elevated or irritable mood for at least four consecutive days. This episode must also consist of three of the following symptoms: reduced need for sleep, excessive or pressured speech, racing thoughts, distractibility, grandiosity, increase in goal-focused behaviour, and excessive pleasurable activities. In hypomania, the change in behaviour is usually observable to others but is not severe enough to cause interference with functioning.

2.1.2.1.3 Major Depressive Episode

Criteria for an MDE are the same as mentioned in the MDD section (see Section 2.1.1.1)

2.1.2.2 Bipolar I Disorder

Bipolar I disorder requires the presence of one or more manic episodes. Major depressive episode and hypomanic episodes may also be present during the life course but are not required for diagnosis.

2.1.2.3 Bipolar II Disorder

Bipolar II disorder requires the current or past presence of both a hypomanic episode and a MDE. There must not be a history of a manic episode.

2.1.2.4 Life Course and Prognosis

Lifetime prevalence of BD from a worldwide survey was found to be 0.6% for BD I and 0.4% for BD II (Merikangas et al., 2011). A 2011 study by Novoli et al. found that BD I is present equally across genders, however BD II is more prevalent in women (Nivoli et al., 2011). Alongside the DSM-5 diagnostic criteria, psychotic symptoms are seen in about 75% of patients in an acute manic episode (Goodwin & Jamison, 2007). Prevalence rate in New Zealand for BD in 2021/2022 have been reported as 1% (Ministry of Health, 2022). The Ministry of Health has also reported ethnicity data for those with BD, showing prevalence rates of 2% for Māori, 4% for Pacific people, and 1% of NZ European (Ministry of Health, 2022).

In a longitudinal study with follow-up of 15 years, it was found that participants with BD were euthymic for 50% of the time (Judd et al., 2003; Judd et al., 2002). Further, depression was prevalent for 31% of the time in participants with BD I and 52% for those with BD II.

As BD often has its initial occurrence in young adulthood, it has a significant effect on the earning population. The WHO World Mental Health Survey reported it to be one of the leading causes of disability in the young adult age group (Alonso et al., 2011). Sequelae of this early onset then results in a high economic cost to society (Gardner et al., 2006). There is also a physical toll to BD, with high levels of comorbidity of diabetes, obesity, and cardiovascular disorders (Fiedorowicz et al., 2008).

2.1.3 Residual Symptoms in Mood Disorders

An important aspect to consider in MDD is that of level of recovery, i.e., if there is the presence of residual/subthreshold mood symptoms when the person is deemed to be in recovery and what effect that may have on future outcomes, including cognition.

A 10-year naturalistic study of individuals with MDD explored the effect of residual symptoms on time to relapse/recurrence (Judd et al., 1999). They found that the presence of residual symptoms at recovery was associated with relapse to MDE more than three times faster than those who were asymptomatic at recovery. Further exploration of this in patients in recovery from a first MDE at 12 year follow-up showed that patients with residual mood symptoms had an illness course which consisted of faster and more frequent recurrences of MDE than asymptomatic patients (Judd et al., 2000).

In BD, those with residual affective symptoms experienced relapse or recurrence of affective episodes more than three times faster than those who were asymptomatic (Judd et al., 2008). In a community cohort of people with BD, again it was found that subsyndromal symptoms predicted time to relapse, with subsyndromal individuals relapsing three times faster than individuals who were euthymic (De Dios et al., 2012).

2.2 ANXIETY DISORDERS

The following sections describe the clinical classification, life course, and prognosis of three anxiety disorders: social anxiety disorder (SAD), generalised anxiety disorder (GAD), and post-traumatic stress disorder (PTSD). These three disorders are introduced in the current chapter as they are examined in the systematic review presented in Chapter Six. No studies eligible for inclusion in the systematic review were found for other anxiety disorders and as such, discussion of those disorders is not included in this thesis.

2.2.1 Social Anxiety Disorder

Social anxiety disorder, previously known as social phobia, is a disorder which is characterised by fear or anxiety in social situations. The annual prevalence of SAD in children and adults in the United States is suggested to be about 7% (American Psychiatric Association, 2013). In a recent Australian national health survey, a 12-month prevalence of SAD was 7% (Australian Bureau of Statistics, 2020-21). Data from the last New Zealand Mental Health survey conducted in 2003/04 reported a 12-month prevalence of 5% (Wells, 2006).

2.2.1.1 Clinical Classification

The DSM-5 identifies the following criteria for a diagnosis of SAD, and these criteria must be present for a minimum of six months and must cause significant distress or impairment in daily functioning: fear or anxiety specific to social settings, concern that this anxiety will be noticed and result in rejection, consistent distress in social situations, avoidance or painful endurance of social interactions, and fear and anxiety grossly disproportionate to the situation (American Psychiatric Association, 2013).

2.2.2 Generalised Anxiety Disorder

Generalised anxiety disorder is reported to have a lifetime prevalence of 4-6% in the general population (American Psychiatric Association, 2013). A New Zealand Mental Health Survey conducted in 2003/04 reported 12-month prevalence rates of 2% (Wells, 2006). A more recent Australian national health survey reported 12-month prevalence rates of 3.8% (Australian Bureau of Statistics, 2020-21).

2.2.2.1 Clinical Classification

According to the DSM-5, GAD is characterised by excessive anxiety and worry, occurring more days that not for at least six months (American Psychiatric Association, 2013). The worry must be about several events or activities, and the person finds it difficult to control the worry. Alongside this, three or more of the following symptoms must be present for more days than not: restlessness, fatigue, difficulty concentrating, irritability, muscle tension, sleep disturbance. Finally, as is usual in most clinical disorders, the symptoms must cause significant distress or impairment in functioning.

2.2.3 Post Traumatic Stress Disorder

Post-traumatic stress disorder is included in this thesis as it was previously classified under the umbrella of anxiety disorders and as such, has been included in much of the research in

the area. The DSM-5 has included a new section entitled Trauma and Stressor-related Disorders under which PTSD now sits (American Psychiatric Association, 2013). A New Zealand mental health survey from 2003/04 reported a 12-month prevalence of 3% (Wells, 2006). A more recent national Australian survey reported 12-month prevalence rates of 6% (Australian Bureau of Statistics, 2020-21).

2.2.3.1 Clinical Characteristics

Necessary for PTSD is exposure to a traumatic event or events either directly or by witnessing the trauma, learning about a relative or close friend being exposed to trauma, or indirect exposure to trauma, usually in the context of professional duties. After this exposure, the person is required to have one of the following persistent experiences: unwanted and upsetting memories, nightmares, flashbacks, emotional distress, or physical reactivity after traumatic reminders. Also required is avoidance of trauma-related stimuli in one of the following ways: avoidance or efforts to avoid either distressing memories, thoughts or feelings associated with the event, or external reminders which prompt distressing memories, thoughts, or feelings associated with the event.

Mood and physical changes are also implicated in PTSD. Negative alterations in mood or cognition are to be evidenced by two or more of: reduced memory of the event itself, persistent negative beliefs about self, others or the world, distorted cognitions about the cause of the event leading to blame, persistent negative emotional state, reduced interest, or participation in significant events, feeling detached from others, or difficulty experiencing positive emotions. Alterations in arousal and reactivity are shown by two or more of: irritable behaviour or outbursts, reckless behaviours, hypervigilance, increased startle response, difficulties concentrating, or sleep disturbance.

These symptoms are required to be present for more than one month and cause clinically significant distress or impairment in functioning. Additionally, PTSD can be experienced with dissociative symptoms usually expressed as either depersonalisation or derealisation.

2.2.4 Life Course and Prognosis of Anxiety Disorders

A systematic review by Bryant et al. (2008) found that in community samples, the prevalence of anxiety disorders is around 1.2% to 1.5%. Clinical samples have a much wider range with suggestions from 1% to 28%. Studies suggest that GAD is the most common anxiety disorder in older adults (Lenze & Wetherell, 2011). A national New Zealand survey reported 12-month prevalence of anxiety disorders in 2021/22 of 14% (Ministry of Health, 2022). A national

Australian survey from 2020/21 reported a 12-month prevalence of anxiety disorders of 17% (Australian Bureau of Statistics, 2020-21).

Lenze and Wetherell (2011) created a representation of their understanding of anxiety across the lifespan as seen Figure 1. It indicates a reduction in phobias (specific and social) and panic with age but similar rates of worry and PTSD in old age and adulthood.

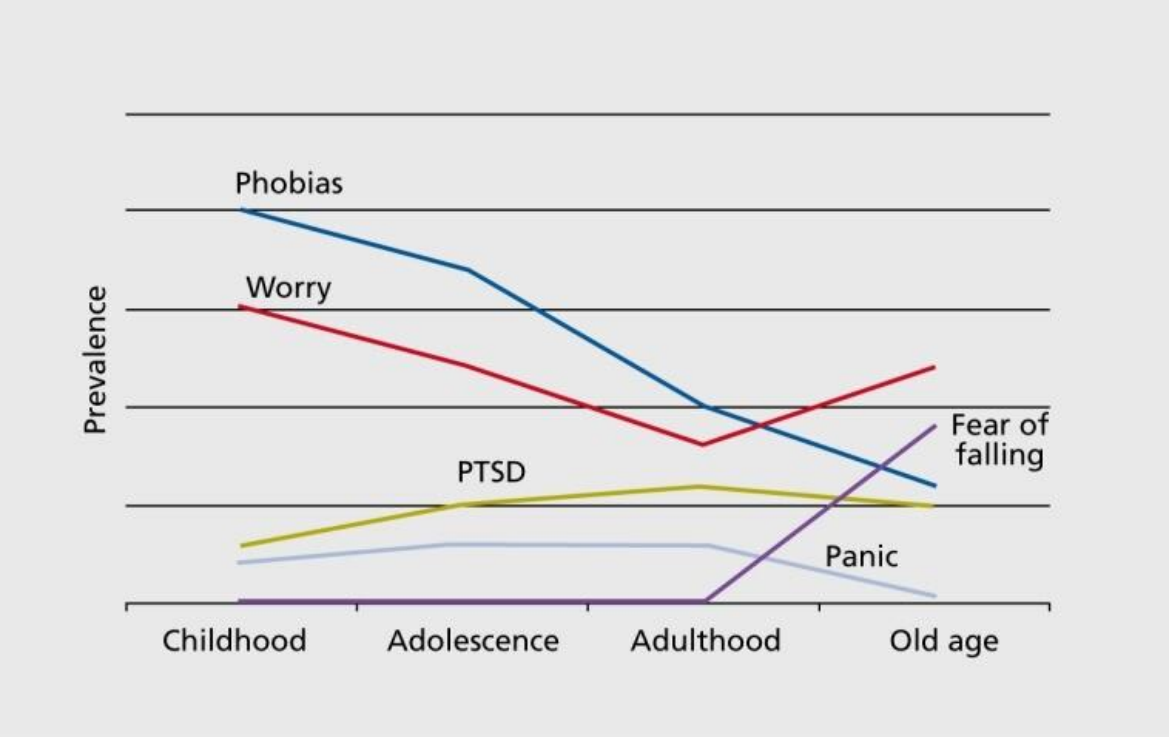

Figure 1 Changes in anxiety disorder presentation across the lifespan.

Note: Change of prevalence in anxiety disorders across the lifespan. Reprinted from "A lifespan view of anxiety disorders" by E. J. Lenze, 2011, Dialogues in clinical neuroscience, 13:4, 383.Copyright [2011] by LLS. Reprinted with permission.

Current research suggests that the life course of anxiety disorders is particularly heterogeneous. Some people, like in MDD, recover from one episode, and do not experience recurrence. However, studies do suggest that approximately 40% to 60% of people will have a more chronic and persistent course associated with their anxiety disorder (Bruce et al., 2005; Penninx et al., 2011). A two year follow-up study found that 59% of participants with anxiety disorders remitted within the two-year time frame (median time 16 months; (Penninx et al., 2011)). More specifically, rates for individual disorders over the two-year period were 69.7% for GAD and 53.5% for SAD (Hendriks et al., 2013).

Regarding predictors of persistence, a systematic review by Hovenkamp-Hermelink et al. (2021) suggested strong predictors are: having more panic attacks, co-morbid personality disorders, and recent treatment seeking. Psychologically, higher severity, lower extraversion, and behavioural inhibition were also linked with persistence of anxiety disorder.

2.3 KEY POINTS

- Prevalence of mood and anxiety disorders change across the lifespan. However, there does seem to be a subgroup of people for whom the course of these disorders is chronic and persistent.
- Rates of mood and anxiety disorders in older populations may be affected by premature mortality of those with the disorders. Additionally, development of effective coping mechanisms with time may also impact these figures.
- In both mood and anxiety disorders, predictors of this chronic course include severity, duration of episode, family history, co-morbid physical illness, and personality disorder.

Chapter 3 - Emotion Processing and Non-emotional Cognition

3.1 EMOTION PROCESSING

3.1.1 What are Emotions?

The American Psychological Association defines an emotion as "a complex reaction pattern, involving experiential, behavioural, and physiological elements"(VandenBos, 2007). As part of his theory of evolution, Charles Darwin suggested that facial expressions of emotion were universal, biological, and adaptive, giving signals to others around us regarding how to act or react, and through this, enhancing our ability to survive. Classification of emotions has been subject to much debate over the years. There seems to be agreement that there are two types of emotions "basic" and "complex" and that complex emotions are the product of two or more of the basic emotions (Power & Dalgleish, 2016).

Identification of the basic emotions is where much debate lies. Paul Ekman was one of the first to identify what these "basic" emotions might be (Ekman, 2000). He suggested that there were six basic emotions: happiness, sadness, fear, anger, surprise, and disgust. These six basic emotions have been the basis of many studies into emotion processing and form part of many of the cognitive tasks which will be discussed in later chapters. In the 1980s, Robert Plutchik expanded on Ekman's work and conceptualised eight basic emotions, split into four pairs of opposites (Plutchik, 2014). In addition to Ekmans's six emotions, he identified anticipation as an opposite to surprise, and trust as the opposite to disgust. Plutchick compared these pairs to a colour wheel and suggested that different emotions could be combined to make more complex emotions. More recently, a study from the University of Glasgow posited that instead of six or eight basic emotions, there may only be four (Jack et al., 2014). They suggested that the pairs of anger and disgust and fear and surprise share similar facial expressions and that the differences seen in these emotions are a sociological rather than biological difference. Despite some disagreement about what the basic emotions are, the research base does agree that there are basic emotions which are universally recognisable and that these emotions serve a purpose in our ability to survive and negotiate our way through the world.

3.1.2 What is Emotion Processing?

In order to be able to review the literature on emotion processing, it first needs to be defined. One of the difficulties within this literature is a lack of consistency around the language that is used. Emotion perception, processing, regulation, and identification are often used interchangeably, which can make it difficult to identify what process each article is referring to.

Emotion perception has been defined as involving three processes; 1) identification of the emotional significance of a stimulus; 2) production of an affective state in response to (1); 3) regulation of the affective state (Phillips et al., 2003). Emotion regulation has been defined as "goal directed processes functioning to influence the intensity, duration, and type of emotion experienced" (Gross & Thompson, 2007). Considering this in the context of the emotion perception definition may suggest that emotion identification is the initial process and emotion regulation covers the last stage, with development of an emotion in between. Others however, have suggested that emotion regulation consists of both the initial attention and emotion identification as well was the subsequent modulation of emotional arousal (Townsend & Altshuler, 2012). They also suggest that emotion processing is the simpler task of passively viewing an emotion and it becomes emotion regulation when more complex processes, such as modulation, become involved.

Most often, when emotion regulation is discussed conceptually, it is explicit regulation that is mentioned (for example, trying to look outwardly calm when we are anxious or helping another person to breathe when they are scared). The focus in research, however, is often on implicit emotion regulation, that which occurs without being conscious of it. The most prominent model of emotion regulation is presented below.

3.1.3 Process Model of Emotion Regulation

The modal model of emotion regulation describes a sequence of processes: situation, attention, appraisal, and response ((Gross, 2013); see Figure 2). Situation refers to a psychologically relevant situation, either external (i.e., something in the environment like a spider) or internal (i.e., the thought that others are judging me). These situations are then attended to in some way, resulting in the appraisal, which is reflected as a person's assessment of the meaning of the situation, likely in the context of goals (Ellsworth & Scherer, 2003). The final stage is the emotional response which is influenced by the appraisals and involves behavioural and neurobiological response systems. The emotional response

often changes the situation itself, which is represented by the right to left arrow in Figure 2. Gross and colleagues further expanded the modal model by suggesting that each of these stages in the model is an opportunity for emotion regulation (Gross, 2014). The model was thus renamed the process model of emotion regulation. Processes described in the renamed model are referred to as situation selection, situation modification, attentional deployment, cognitive change, and response modulation. These processes encompass both explicit and implicit methods.

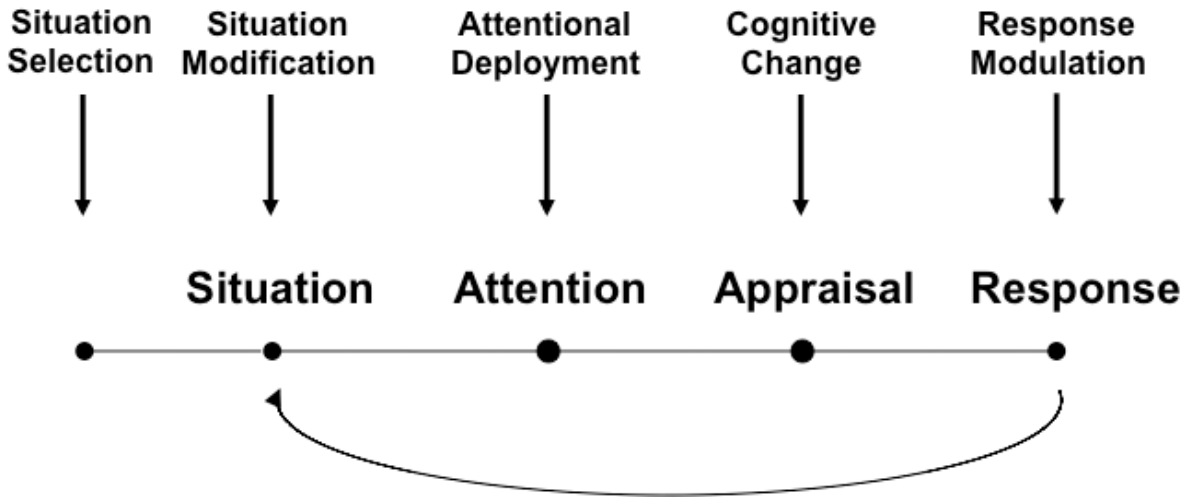

Figure 2 Process model of emotion regulation

Note: The process model of emotion regulation, derived from the modal model of emotion regulation. From Handbook of Emotion Regulation (7), by J.J. Gross, 2014, Guilford Press.

3.2 NON-EMOTIONAL COGNITION AND EMOTION PROCESSING IN MOOD DISORDERS

The previous section of this chapter describes the concept of emotions and introduces a prominent theory as to how emotions are regulated. To understand emotion processing in mood disorders and aging, there must also be an understanding of non-emotion based cognitive processing and how this is impacted by presence of mood disorder. As this is not the primary focus of this thesis, this body of research will be reviewed briefly. Changes in non-emotional cognition in aging will be outlined in Chapter Five.

3.2.1 What is Non-emotional Cognition?

Non-emotional cognition generally refers to any cognitive processing that occurs independent of emotional influence. This type of cognition includes multiple domains, such as verbal processing, attention, memory, processing speed, and executive functioning.

3.2.1.1 Memory

Memory impairment is a clear feature of MDD (Hammar et al., 2022). However, there is debate as to which types of memory are affected and whether these difficulties are present only during an MDE or if they persist post-resolution of depressive mood state. A meta-analysis by Lee et al. (2012) comparing individuals with first-episode depression with healthy control participants, found that participants with depression had significant memory dysfunction compared with controls. In a meta-analysis of studies examining individuals with first-episode depression, Ahern and Semkovska (2017) found that learning and memory, and autobiographical memory normalised when remission had been achieved. Conversely, a meta-analysis by Semkovska et al. (2019) found that impairment in memory persisted after remission from an MDE, and that these deficits worsened with repeated episodes. Authors of the most recent meta-analysis found that number of MDE episodes had a significant effect on some outcomes, including memory tasks, reflecting that an increased number of episodes resulted in poorer performance (Semkovska et al., 2019). This may account for some of the difference seen between the 2019 and 2017 meta-analyses as the earlier analysis was conducted in participants after only one episode.

In BD, a meta-analysis by Bora et al. (2009) showed large verbal memory deficits for patients compared with healthy control participants. Small effect size differences were also found for visual memory and verbal recognition memory. These findings were supported by meta-analysis using individual patient data in euthymic BD compared with healthy control participants, which showed medium effect size differences for verbal memory (Bourne et al., 2013). A meta-analysis of first-episode BD, also showed medium effect size differences in verbal and visual memory between the BD and healthy control participants (Bora & Pantelis, 2015).

3.2.1.2 Attention

Problems maintaining attention and concentration are common in MDD and are part of the diagnostic criteria of an MDE. Attention deficits have been found in MDD both in the acute phase and in remission. A meta-analysis by Lee et al. (2012) suggested that attention may be a

trait marker in MDD as they found no association between mood state and attentional deficit. However, Ji et al. (2020) and Hammar and Årdal (2012) have both conducted small studies in which attention was impaired during the illness phase but was not impaired at both short-term (6 month) and long-term (10 year) follow-up, respectively.

In BD, a meta-analysis by Bora (2009) in euthymic individuals showed large deficits in sustained attention in BD compared with healthy control participants. Further, in those with first-episode BD compared with control participants, a meta-analysis has shown large effect size deficits for sustained attention (Bora & Pantelis, 2015).

3.2.1.3 Processing Speed

Similar to attention, changes in psychomotor functioning are defined as part of the diagnostic criteria of MDD. Processing speed has been shown to be consistently impaired in the acute phases of MDD (Saragoussi et al., 2017; Vasavada et al., 2017). In the first-episode depression meta-analyses presented above (Ahern & Semkovska, 2017; Lee et al., 2012), processing speed deficits were related to clinical state, with this function normalising during remission. The Semkovska et al. (2019) meta-analysis showed that deficits in processing speed were linked to number of episodes, with processing speed becoming slower after more episodes. Original studies by Wekking et al. (2012), Xu et al. (2012), and Shimizu et al. (2013) all showed impairment persisting in remitted patients. Overall, it is possible that after a first episode of depression, processing speed shows some degree of normalisation, but that recurring episodes and age may impact this process later on (Hammar et al., 2022).

A meta-analysis by Bora et al. (2009) showed large deficits in psychomotor speed in BD compared with healthy control participants. Another meta-analysis by Bora and Pantelis (2015) comparing patients with a first episode of BD with healthy control participants found medium effect size deficits in processing speed. This finding was consistent with another meta-analysis in first-episode BD participants (Lee et al., 2014), suggesting that some cognitive changes seen in BD are present even after a first episode.

3.2.1.4 Executive Functioning

Difficulties with higher order cognitive functions are commonly reported by people who have experienced MDD (Porter et al., 2007). Task initiation, inhibition, problem solving, and decision making are all mentioned as areas that people find difficult, and these tasks are generally considered to be examples of executive functioning.

Of these functions, inhibition has been most often studied. In the Lee et al. (2012) meta-analysis, inhibition was impaired in first episode patients, suggesting that this might be a trait marker for depression. Following on from this, Schmid and Hammar (2013) found in their study that impairment in inhibition was present very early in the course of MDD and they also suggested that this might be a trait marker in MDD, referencing findings of inhibition deficits persisting at long-term follow-up (Ronold et al., 2021). Roca et al. (2015) found, improvement in problem-solving performance in remitted patients, however inhibition was still impaired. All of these studies however do acknowledge that without data from MDD participants before their first episode, it is difficult to know if this is truly a trait marker or if it is more likely that the results reflect a scarring effect of the mood episode itself.

A meta-analysis by Bora et al. (2009) showed large deficits in executive functions in BD compared with healthy control participants. This was most prominently seen in response inhibition and set-shifting. Further to this, a meta-analysis using individual patient data also found large effect size deficits in overall executive functioning and response inhibition in BD compared with healthy control participants (Bora & Pantelis, 2015).

Bora and Özerdem (2017) conducted a meta-analysis examining follow-up studies of cognition in participants with BD. They found that there was no significant change in global cognition in BD over time, suggesting that there is not a pattern of global progressive cognitive decline in BD.

3.2.2 Cognition Across Mood Disorders

The National Institutes of Mental Health has closely considered the validity of differentiating between the diagnostic categories of mood disorders and have started to shift their research focus away from traditional diagnostic categories to focus more on overarching domains of functioning (e.g., cognition) and constructs within these (e.g., executive function), thus potentially increasing the size and statistical power of studies. This framework, Research Domain Criteria (RDoC), encourages consideration of combining categorical disorders into larger groups, for example looking at mood disorders e.g., MDD and BD as a whole.

In studies that have compared cognitive change across mood disorder samples, similar impairments have been found between categorical diagnoses. For example, a study by Xu et al. (2012) comparing depressed individuals with MDD or BD, and healthy control participants, found no difference in the profile of cognitive impairment between the clinical groups. Deficits were seen in all clinical groups, compared with control participants, on

processing speed, memory, and executive function. Consistently, Daniel et al. (2013) found that in euthymic individuals, the profile of cognitive impairment did not differ between MDD and BD groups, but both groups differed from healthy control participants in attention and executive function. More recently, Samame et al. (2017) conducted a meta-analysis comparing cognition in various domains (attention/processing speed, verbal memory, executive functions) between MDD and BD participants. In ten studies examining participants in euthymia (MDD = 338, BD = 402), no significant differences were found between the groups across six variables, however a difference was seen for verbal memory on list learning tasks, with BD participants performing significantly worse (Hedges'g = 0.64, $p < .001$). Thirteen studies comparing participants in a depressive mood state (MDD = 665, BD = 462), showed similar outcomes between groups across all eleven variables examined.

Further to this, systematic review by Szmulewicz et al. (2017) found large effect size differences of impaired performance in both MDD and BD groups, compared with healthy control participants, on executive function as a consistent feature of the literature they reviewed. Previous reviews and meta-analyses show that both MDD and BD have cognitive impairment in euthymia as a feature of the disorder (Bourne et al., 2013; Mann-Wrobel et al., 2011; Porter et al., 2015; Rock et al., 2014). In studies considering mood disorders as one group, Gualtieri and Morgan (2008) found cognitive impairment rates of 20-30% in mood disorder samples compared with only 3.6% in healthy control samples. In another study examining four samples of mood disorder participants and healthy controls, it was found that 82%-94% of healthy control participants were not impaired on any cognitive domain using a 1.5 SD cut off, whereas 37.5% of an inpatient depressed sample were impaired in two or more cognitive domains using the same cut-off. Additionally, in the other three samples consisting of participants with outpatient depression, BD depression, and euthymic BD, 9-21% of participants were impaired (Douglas et al., 2018).

Overall, research suggests that MDD and BD do not present with vastly different cognitive profiles. The profile of impairment for both disorders seem to be broad, spanning the major domains of cognitive function (processing speed, memory, and executive functioning). As such, as the evidence stands, it seems reasonable to combine samples with MDD and BD for the purposes of cognitive research, particularly as having larger pools of individuals to recruit from is likely to result in more reliable studies with greater statistical power.

3.2.3 Interaction Between Non-emotional and Emotion-based Cognition

If MDD is conceptualised in the context of emotion dysregulation then it could be suggested that a disconnect between emotion- based and non-emotional cognition may result in less effective emotion regulation (Gotlib & Joormann, 2010). It is further suggested that it is non-emotion-based cognition that influences the process of emotion regulation (Joormann & Vanderlind, 2014). In application, emotional attentional biases divert attention to negative, mood-congruent stimuli in the environment. Therefore, executive functioning deficits may then allow for increased use of maladaptive types of emotional regulation, such as rumination, which are then likely to maintain the negative mood state (Joormann & Gotlib, 2010; Koster et al., 2011).

Executive functions or cognitive control have been most implicated in altering emotion processing. This is due to executive functions being tasked with regulation when presented with task-irrelevant stimuli or automated responses and ensuring that resultant processing and behaviour aligns with current goals (Friedman & Miyake, 2017).

The interaction between cognitive control and emotion processing is complex and rather than viewing the two as separate, somewhat parallel, processes it is imperative that interference of emotion-based processes, which affect motivations and attention, is considered when exploring executive dysfunction (Grahek et al., 2018).

3.3 COGNITIVE TESTING PARADIGMS USED IN THE THESIS

This section presents an overview of the paradigms used to measure both emotion-based and non-emotional cognition in this thesis. These tasks represent the battery of tests used in the cross-sectional analysis presented in Chapters Seven and Eight. Additionally, tasks used in the data analysis presented in Chapter Nine have been included in this overview and are indicated as such. This information is presented in Table 1, below. Cognitive domains tested in each task are indicated and a brief description of the format of the tasks is provided. More detailed description of the tasks used in the cross-sectional analysis, their reasons for inclusion, reliability, and validity is presented in Chapter Seven.

Table 1 *Cognitive Tasks Used in the Thesis*

Domain	**Cognitive Task**	**Task Description**
Executive Functions		
Fluency	**Category Fluency Task^**	Participants are asked to name as many different examples as they can think of belonging to a particular category (e.g., animals) within 90 seconds. The task is then repeated using a second category (e.g., boy's names).
	Controlled Oral Word Association Test (Benton, 1983)*	Participants are asked to generate as many words as possible beginning with a particular letter in 60 seconds. Three trials are completed using letters F, A, and S. Proper nouns, place names, or the same word with a different ending are excluded. Primary outcome is total number of correct words generated across the three trials.
Fluency and Inhibition	**Category Switching Task^**	Participants are asked to name as many different examples as they can think of in two different categories (e.g., fruit and furniture) within 90 seconds. They are required to alternate between saying one example from one category and then an example from the other category.
Visuospatial Learning and Memory		
	Groton Maze Learning Test, immediate recall^	Participants are advised to find a 28-step hidden pathway, one tile at a time. Feedback regarding accuracy of each move is given as the participant progresses through the pathway. Five learning trials are undertaken.

Domain	Cognitive Task	Task Description
	Groton Maze Learning Test, delayed recall^	After a delay period of 10 minutes, participants are asked to find the pathway from the learning trials again.
	CANTAB Spatial Recognition Memory (Sahakian & Owen, 1992)*	Five squares are presented sequentially at different locations on the screen, then participants are presented with a pair of squares in counterbalanced order. They are instructed to identify which square is at a location where one was previously presented. Outcomes recorded are accuracy and speed.
Psychomotor Speed		
	Digit-Symbol Substitution Task(Wechsler, 1997)^	Participants are presented with a printed key that pairs numbers from one to nine with nonsense symbols. The participant is then given a chart that contains blank squares matched with randomly assigned numbers and is required to fill in as many blank squares as possible with the matching symbol in 90 seconds.
	Groton Maze Timed Chase Test^	Participants are instructed to follow a coloured moving tile, as quickly and accurately as they can, by clicking on the coloured tiles one after another. After an untimed practise trial, participants are timed chasing the tile for 30 seconds.
	CABTAB Motor Screening (Sahakian & Owen, 1992)*	Participants are asked to respond to 10 pink or green crosses on the screen as quickly as possible. Outcome recorded is speed of response.

Domain	Cognitive Task	Task Description
Working Memory		
Verbal	**Digit Span Forwards and Backwards (Wechsler, 1997)***	Participants are instructed to repeat increasingly longer strings of numbers either forwards, as presented, or backwards, in the reverse order, after they are read aloud by the examiner. Primary outcome is longest correct number of digits recalled by the participant in each condition.
Visuospatial	**CANTAB Spatial Working Memory (Sahakian & Owen, 1992)***	Participants are asked to search through boxes on the screen to find which one hides a coloured token. In doing this, they are required to remember where the tokens were previously placed. This task begins with four trials of four boxes and progresses to four trials of six, then eight boxes. Repetitious search errors are reported and a performance index for search strategy is generated.
	CANTAB Spatial Span (Sahakian & Owen, 1992)*	Participants are required to remember, then replicate, the order of nine white squares on-screen that change colour one by one. Trials progress from two to nine squares and the task self-terminates after three successive trial failures (incorrect sequence) on a given number of squares. The longest span length correctly recalled is reported.

Domain	Cognitive Task	Task Description
Learning and Memory		
Verbal	**Rey Auditory-Verbal Learning Test (Rey, 1964)***	Participants are presented a pre-recorded list of 15 non-related words over five acquisition trials, followed by recall after each trial. A second distracter list of 15 different non-related words is then presented, and immediately after recall of this list, a sixth recall trial of the first list follows. After 20 minutes (during which other, non-verbal tasks are completed), delayed recall of the first list is tested. Following the delayed recall of the first list, the recognition trial is completed. Primary outcomes are total words recalled in the first five trials and total correct words recalled in the delayed recognition trial.
Visuospatial	**CANTAB Spatial Recognition Memory (Sahakian & Owen, 1992)***	Five squares are presented sequentially at different locations on the screen, then participants are presented with a pair of squares in counterbalanced order. They are instructed to identify which square is at a location where one was previously presented. Outcomes recorded are accuracy and speed.
Emotion Processing		
Complex social	**Reading the Mind in the Eyes Task (Baron-Cohen et al., 2001)^**	Participants are required to identify what the image subject is thinking or feeling for each of 36 images of the eye region of Caucasian individuals. Participants choose their answer from a selection of four adjectives provided.

Domain	Cognitive Task	Task Description
Verbal	**Emotional Stroop Task McKenna & Sharma, 1995^**	Participants are asked to identify the colour of a target stimuli which is presented on the computer screen by pressing the keyboard button of the matching colour. Three different stimuli are presented across the task, single letter strings, emotionally valanced words, colours.
Facial	**Facial Emotion Recognition Task (Harmer et al., 2003)*^**	Participants are presented with successive faces displaying one of five basic emotions or a neutral expression and are instructed to identify the emotion shown by pressing the response key of the emotion which they think best matches the shown face. Participants are asked to do this as quickly and accurately as possible.

Note: ^ denotes task used in Chapter Eight; *tasks used in Chapter Nine; CANTAB: Cambridge Neuropsychological Test Automated Battery

Chapter 4 - Emotion Processing in Mood and Anxiety Disorders

Efficient emotion processing is an important part of interpersonal relationships and social interactions. Interpretation of affective information is vital to these interactions as it influences emotional states and governs behavioural responses in social situations. Difficulties in social situations and avoidance of these, in the context of mental disorders, may maintain clinical levels of distress and hinder attempts to treat the disorder (Godlewska, 2019). Furthermore, emotional material can impair effective cognitive processing by inducing biases in attention or decision-making, thereby impairing other aspects of cognition (Hertel, 2004).

For example, the Cognitive Neuropsychological Hypothesis of Depression (Warren et al., 2015) acknowledges that in depression, there is both behavioural and neurocircuitry evidence of a bias towards negative emotional stimuli. It further suggests that those who are more vulnerable to depression tend to perceive social cues as more negative and attend to and recall more negative information (Disner et al., 2011). These biases may then play a role in precipitating and maintaining depression, and conferring susceptibility to relapse (Godlewska, 2019). Some evidence suggests that antidepressants may reverse this bias relatively quickly, but it takes some time for this change to be translated, via improved social interactions, into a reduction in depressive symptoms (Harmer et al., 2003; Pringle et al., 2011).

The current chapter will overview literature examining the impact of mood and anxiety disorders on emotion processing in younger adults. This will provide context for following chapters focused on older age populations.

4.1 EMOTION PROCESSING IN YOUNGER PEOPLE WITH DEPRESSION

In facial emotion processing research, there are three main approaches to measuring processing changes experimentally: accuracy, misinterpretation, and attentional bias. The following literature review of the data in younger people with depression has been ordered in this way.

4.1.1 Accuracy of Identification of Facial Expressions

Data from studies investigating response accuracy to positive and negative facial expressions is inconsistent. Some studies have found greater inaccuracy and slower reaction times for facial expressions including sadness, happiness, and disgust, in depressed samples compared with healthy control participants (Douglas & Porter, 2010; Gotlib et al., 2004; Leppänen et al., 2004; Mandal & Bhattacharya, 1985; Mikhailova et al., 1996; Rubinow & Post, 1992; Suslow et al., 2004). These effects have been summarised in reviews (Bourke et al., 2010; Leppänen, 2006; Stuhrmann et al., 2011). However, other studies have indicated no significant difference in accuracy between depressed and healthy control groups (Archer et al., 1992; Gollan et al., 2008; Kan et al., 2004; Leppänen et al., 2004; Porter et al., 2016). A small meta-analysis (8 studies) conducted by Demenescu et al. (2010) examining emotion recognition found moderate impairments in emotion recognition in those with depression compared with healthy control participants. A further meta-analysis by Kohler et al. (2011), using 51 studies (31 in bipolar depression, 20 in unipolar depression), also found a moderate deficit in depressed participants compared with healthy control participants. This study also noted no differences in the impairment found between the two diagnostic groups.

Not only is there inconsistency in whether there is a difference in accuracy between healthy and depressed groups, but there is also inconsistency in effects across emotions. Some studies indicate differences in both positive and negative emotions (Asthana et al., 1998; Feinberg et al., 1986; Mikhailova et al., 1996; Persad & Polivy, 1993; Rubinow & Post, 1992) and others just for negative (Mandal & Palchoudhury, 1985). Most recently, an updated meta-analysis of emotion recognition in MDD compared with healthy controls (22 studies) showed impaired emotion recognition for depressed participants overall. Individually, deficits were seen for the emotions of anger, disgust, fear, happiness, and surprise but not for sadness (Dalili et al., 2015). The authors did note that the effect sizes of these outcomes were small and many studies contributing to the analysis were underpowered.

Differences in methodologies across studies such as different paradigms used (static vs dynamic faces), small samples sizes, and variations within clinical groups (i.e., depression severity) may help to explain inconsistency in findings.

4.1.2 Misinterpretation of Facial Expressions

Three different types of misinterpretation are considered in facial emotion processing.

4.1.2.1 Misinterpretation of Ambiguous Facial Expressions

It has been posited that interpretation of ambiguous expressions may be the most affected in people with depression compared with interpretation of non-ambiguous faces (Bouhuys et al., 1999). This aligns with the idea that ambiguous life events are more likely to be interpreted as negative, thus maintaining the depressive episode (Beck, 1979; Fu et al., 2008). A number of studies using drawings of faces conveying mixed emotional states have shown that depressed patients are more likely to interpret these ambiguous expressions as negative compared with faces which clearly denote one emotional state (Bouhuys et al., 1999; Bouhuys et al., 1996; Geerts & Bouhuys, 1998; Hale III, 1998; Hale III et al., 1998; Levkovitz et al., 2003). Only two of these studies (Hale III, 1998; Hale III et al., 1998) included control groups however, with the other studies comparing the same population at two time-points.

4.1.2.2 Misinterpretation of Neutral Facial Expressions

Neutral facial expressions have also been used to examine biases in processing emotional information (Yoon & Zinbarg, 2007). This has been done in studies directly examining misinterpretation of neutral expressions (Leppänen et al., 2004) or in studies which have used neutral faces as a control condition and analysed this bias as a secondary outcome. Irrespective of study design, there is consistent evidence that people with depression are more likely to misinterpret a neutral face as negative (George et al., 1998; Surguladze et al., 2004) or are slower to respond to neutral faces compared with emotional faces (Leppänen et al., 2004; Suslow et al., 2004). Douglas and Porter (2010), comparing a group of inpatients with depression and healthy control participants, found that depressed participants were more likely to misinterpret neutral faces as sad and less likely to misinterpret neutral faces as happy compared with healthy control participants. Despite the small number of studies, the evidence seems consistent that in depression, ambiguous or neutral faces are more likely to be misinterpreted as a negative emotion, as opposed to a positive emotion.

4.1.2.3 Misinterpretation of Emotional Facial Expressions

A study which found participants with depression were less accurate than healthy controls at identifying all six basic emotions subsequently analysed misclassification of emotional faces, finding that depressed participants were more likely to misclassify other emotions as sad than any other emotion (Mandal & Bhattacharya, 1985). Gur et al. (1992) found that depressed individuals were more likely to interpret neutral faces as sad and happy faces as neutral compared with healthy control participants, a result supported by a response bias away from happy faces found by Surguladze et al. (2004). This finding of a negative misinterpretation

bias has subsequently been supported by further studies (Elliott et al., 2011; Harmer et al., 2009; Stuhrmann et al., 2011). Overall, the finding of ambiguous, neutral, or other emotional facial expressions being interpreted as negative is consistently seen in people with MDD.

4.1.3 Attentional Bias Towards or Away from Happy or Sad Faces

Attentional biases away or towards facial expressions of emotion is an alternative approach to assessing facial emotion processing.

In a dot probe task, where attentional bias is measured using direction and latency of initial eye movement and manual reaction times, Mogg et al. (2000) did not find any differences between depressed participants and those with GAD or healthy control participants on attention towards emotional faces. Subsequently however, Gotlib et al. (2004) in a larger study using a similar task, found an attentional bias towards sad compared with happy and fearful, or happy and angry expressions in depressed participants compared with those with GAD and healthy control participants. Joormann and Gotlib (2007) found an avoidance of sad faces in depressed participants alongside increased attention to happy faces in healthy control participants. In a "face in the crowd" detection paradigm, Suslow et al. (2001) showed that depressed participants were slower at responding to happy expressions compared with healthy control participants, but no differences between groups were found for sad expressions. Suslow et al. (2004) later conducted another study using the same paradigm, finding that when depressed participants had co-occurring anxiety disorders, they had slower responses to happy expressions than healthy control participants.

Overall, an attentional bias towards negative and away from positive emotional stimuli is suggested by the literature in people with depression (Bourke et al., 2010; Leppänen, 2006). Again, differences in study methodologies makes direct comparison between studies difficult.

4.1.4 Functional Magnetic Resonance Imaging Studies in Depression

In MDD, dysfunction within fronto-limbic circuits is the mechanism most suggested to be responsible for mood congruent biases and related negative affect (Malhi et al., 2015). More specifically, hyperactivity is found in the amygdala and ventral/rostral anterior cingulate cortex and hypoactivation in the dorsal anterior cingulate cortex and dorsolateral prefrontal cortex (Hamilton et al., 2013; Mayberg, 1997).

As presented in a review by Stuhrmann et al. (2011), a number of studies using functional magnetic resonance imaging have examined facial emotion processing and associated neural activity in people with depression. From this review the authors described diverse findings

with some evidence of increased frontal activity in processing of mood congruent (negative) facial expressions (Anand et al., 2005; Keedwell et al., 2005; Lawrence et al., 2004; Rosenblau et al., 2012). Other studies however, found decreased frontal activity in those with depression compared with controls (Fu et al., 2004; Siegle, Ghinassi, et al., 2007; Siegle, Thompson, et al., 2007).

In limbic areas, processing of negative stimuli has been found to involve increased activity in a number of studies of individuals with depression, compared with controls (Anand et al., 2005; Siegle et al., 2002; Siegle, Thompson, et al., 2007). In contrast, other studies have found no differences in limbic activation (Lee et al., 2008; Scheuerecker et al., 2010).

A meta-analysis of neuroimaging studies which examined emotion processing in depressed participants compared with healthy controls, found differential patterns of activation for negative and positive emotions. In depressed participants, increased activation was found in the amygdala, striatum, parahippocampal, cerebellar, fusiform, and anterior cingulate cortex for negative stimuli, and hypoactivation for positive stimuli (Groenewold et al., 2013).

4.2 EMOTION PROCESSING IN YOUNGER PEOPLE WITH BIPOLAR DISORDERS

It has been suggested that emotion based cognitive changes in BD are more subtle than non-emotional cognitive deficits. Van Rheenen et al. (2014) showed that for every 1 SD decline in non-emotional cognition, there was an estimated 0.3-0.5 SD decline in emotional cognition. While this seems like a straightforward comparison, it is important to note that while this outcome might be linked to smaller emotional cognitive deficits in BD, it is also possible that this result may be due to difficulties in measuring emotion based cognitive changes (i.e., little consistency in tasks used and outcomes recorded), in comparison with non-emotion-based changes.

Samamé (2013) showed emotion-based cognitive deficits in active mood state and during euthymia, indicating trait-related changes. These changes have been shown across domains of facial expression recognition (Van Rheenen & Rossell, 2014), reward processing and decision making (Alloy et al., 2016; Nusslock & Alloy, 2017), and emotional regulation (Kjærstad et al., 2016; Van Rheenen et al., 2015). Some studies, however, have shown no changes in emotion processing in BD compared with healthy control participants, although it is noted that these studies are small (Caletti et al., 2013; Robinson et al., 2015).

Miskowiak et al. (2019) conducted a comprehensive systematic review of emotional cognition in BD. While there was marked inconsistency in study findings, some patterns were evident, particularly in FER studies, as reviewed below.

In examining FER, twenty-two studies in remitted patients were included in the systematic review. Lower accuracy and/or slower reaction times across emotions were found in seven studies. A further eight studies found selective deficits for individual emotions, and five studies showed no difference in performance compared with healthy control participants (Miskowiak et al., 2019). Two of the studies in the analysis showed better performance for disgust (Harmer et al., 2002) and fear (Lembke & Ketter, 2002) compared with the other basic emotions. Some evidence of misinterpretation of facial expressions in remitted patients was also found, however there was no consistency as to what expressions were misinterpreted as. In symptomatic BD, again results were inconsistent, with two studies showing no performance deficits in the depressed state (Getz et al., 2003; Robinson et al., 2015), and increased recognition of disgust in another (Schaefer et al., 2010). In patients in a manic episode, results were more clear, with five studies showing impairments in FER generally (Miskowiak et al., 2019). A portion of studies in this area have used mixed patient samples where participants were either remitted or in a depressed or manic state. General FER impairments were found in eight studies; however, four studies found no FER deficits compared with healthy control participants.

Studies using implicit emotion processing tasks, such as the emotional Stroop (eStroop) were also considered in the systematic review (Miskowiak et al., 2019). In studies with remitted patients, broad interference was found in six studies for emotional stimuli, regardless of valence and in one study only for positive stimuli. Conversely, three studies found no interference of emotional stimuli in remitted samples. In symptomatic populations, one small study found no effect on emotion regulation compared with healthy control participants. However, two studies in manic patients found broad attentional interference across all emotional stimuli. General interference of emotional stimuli was also found in four studies of patients in a depressive episode, with two more studies finding interference for negative stimuli only.

4.3 EMOTION PROCESSING IN YOUNGER PEOPLE WITH ANXIETY DISORDERS

In younger adults with anxiety disorders, there appears to be the tendency for a bias towards threat-related stimuli, which is hypothesised to maintain a heightened sense of anxiety

(Armstrong & Olatunji, 2012). In FER tasks, for example, evidence suggests that individuals with social anxiety are not significantly different from healthy control participants in identifying facial expressions (Philippot & Douilliez, 2005; Stevens et al., 2008) but show a tendency to misidentify neutral facial expressions as angry (Bell et al., 2011). Attentional bias towards threat-related stimuli has been reported in GAD when using a dot probe task (Bradley et al., 1999). There is also evidence of increased response latencies to both anxiety-related words and generally negative words when using eStroop tasks across anxiety disorders, suggesting an attentional bias towards threat-related stimuli (Joyal et al., 2019). In younger adults, changes in emotion processing similar to those in other anxiety disorders have also been seen in PTSD. For example, a meta-analysis of eStroop performance in PTSD (Cisler et al., 2011) found that individuals with PTSD, compared with healthy control participants, showed impairments in the eStroop task when processing trauma-related or generally threatening, but not positive information.

4.4 SUMMARY OF EMOTION PROCESSING IN YOUNGER ADULTS WITH MOOD AND ANXIETY DISORDERS

Overall, findings from the facial emotion processing literature in younger adults with mood or anxiety disorders indicate that:

- Individuals with depression are less accurate at identifying negative emotions than healthy control participants, although the specific emotions this has been shown for varies across studies.
- In individuals with depression, ambiguous, neutral, and emotional faces are more likely to be misinterpreted as a negative emotion, as opposed to a positive emotion.
- People with depression are likely to have an attentional bias towards negative and away from positive stimuli compared with healthy individuals.
- In BD, generalised deficits in FER in active mood state and remitted patients are seen across studies.
- In anxiety disorders, there is some evidence of bias towards threat-related stimuli compared with healthy individuals.

Chapter 5 - Emotion Processing and Non-Emotional Cognition in Older Adults and Aging

5.1 THE PARADOX OF AGING

Despite the knowledge that as people age their social networks grow smaller, older people have been found to have lower rates of mental health disorders and better emotional wellbeing than both younger and middle-aged people (Charles, 2010). The assumed drivers of happiness (social networks, physical health, mental sharpness etc.) all decrease with age and yet older people report higher levels of happiness (Carstensen, 2006). Researchers have developed theories about emotional aging to account for this paradox. Of particular importance to this current body of work is how these theories relate to the area of emotion processing and regulation in aging. Three of the most prominent theories examining this will be detailed in this chapter. First, however, current literature on emotional processing in old age and aging will be reviewed.

5.2 STUDIES OF EMOTION PROCESSING IN AGING

There is a large literature base showing a bias for negative or threat related material in younger people. This bias has been shown in infants where they orient more to threat-related than happy stimuli (Leppänen et al., 2007) and children are more likely to identify and remember threatening over non-threatening stimuli (Baltazar et al., 2012; Kinzler & Shutts, 2008; LoBue, 2009). Attentional preference for negative information has also been demonstrated in young adults (Baumeister et al., 2001; Rozin & Royzman, 2001). This negativity bias has been so consistently found across younger age groups that it may be regarded as an underlying principle of human behaviour, one which is thought to have an evolutionary advantage (Baumeister et al., 2001; Carstensen, 2006; Vaish et al., 2008).

While previous research had shown that older adults had a preference for emotional material over other sources of information (Fung & Carstensen, 2003), it was not until an experiment by Charles et al. (2003) that a preference for recalling positive images over negative was shown in older adults compared with younger participants. Since Charles et al's., study, this effect, termed the "positivity bias", has been demonstrated in multiple other emotion processing paradigms including those examining autobiographical memory (Cuddy et al.,

2017; Kennedy et al., 2004), working memory (Mikels et al., 2005), attention to emotional faces (Mather & Carstensen, 2003), and recall of facial expressions (Sava et al., 2017). This positivity bias in older adults (Carstensen & DeLiema, 2018) has been shown across multiple experimental paradigms and synthesised in meta-analysis (Hayes et al., 2020; Ruffman et al., 2008).

5.3 THEORIES OF EMOTION PROCESSING IN AGING

Three of the prominent theories of emotion processing in aging are discussed below; Socioemotional Selectivity Theory (SST), Dynamic Integration Theory (DIT), and the Aging Brain Model (ABM). The first two theories are lifespan developmental models of emotion processing. To ensure relevance to this particular piece of work, these models are discussed in relation to their theories of middle to late life aging specifically, rather than detailing the theories across the whole lifespan.

5.3.1 Socioemotional Selectivity Theory

Socioemotional Selectivity Theory attempts to explain the motivations behind social human behaviour (i.e., goal selection) as a function of time, and more specifically, time to end of life (Carstensen et al., 1999). The theory is based on the idea posited by Bandura (1991) that humans are goal directed and their behaviours and choices reflect these goals. As part of this, people are likely to hold multiple, often conflicting, goals at the same time. In order to take action, goals must be given priority for selection. A factor influencing this selection is the person's perception of time as either expansive or limited.

Carstensen et al. (1999) broadly classify these goals into two categories: acquisition of knowledge and regulation of emotion. They posit that the priority between these goals shifts as the perception of time shifts (Carstensen, 2006). When time seems expansive and unconstrained, such as when we are younger, our priority is on gathering knowledge and experiencing novelty. However, when time is experienced as finite, such as when we are older, goals likely shift to shorter term outcomes, such as the regulation of emotion states in order to enhance wellbeing. Kellough and Knight (2012) used an emotion perception task in which younger adults were prompted to see time as limited and older adults to see time as expansive, and each group were compared with control samples from their age groups. They found that a reduction in perception of positive affect in expressions was seen in older adults who were induced into the expanded time perspective, compared with control participants. Further, a study considering this using a paradigm which participants time horizons are

manipulated by using a writing task in which life expectancy is indicated to be either short (6 months) or long (12 years) showed that when older adults are encouraged to think of their future as not constrained, the positivity bias is weakened (Barber et al., 2016). Conversely, when younger adults are encouraged to focus on seeing time as limited, a positivity bias is found (Barber et al., 2016).

The outcomes of the studies support the ideas put forward in the SST that perception of time and the subsequent effect on the goals that drive behaviour may be responsible for the positivity bias seen in older adults. Further to this, in order to implement goal directed emotion regulation, sufficient cognitive capacity must be available and studies have shown that the positivity bias is often not seen when older adults have limited cognitive resources available for emotion regulation (Mather & Knight, 2005; Petrican et al., 2008). For example, Sakaki et al. (2019) explored the relationship between the positivity bias and cognitive control by examining memory for emotional stimuli and included a Stroop task to test cognitive control. They found that the positivity effect was stronger for older old adults than younger old adults. Within the group of older old adults, they also found that a stronger positivity effect was found in those with better Stroop performance. Overall, this suggests a role for cognitive control in goal-based emotion regulation mechanisms.

5.3.2 Dynamic Integration Theory

Dynamic Integration Theory considers the pattern of gains and losses of affective cognitive functioning across the lifespan and attempts to explain these changes. DIT suggests that there are two modes of processing affective information – affect optimisation and affect complexity (Labouvie-Vief, 2003, 2005; Labouvie-Vief & González, 2004). Affect optimisation involves focusing on maximising positive affect and minimising negative during emotion processing and affect complexity involves focus on emotional awareness and tolerating negative emotional experiences in search of personal growth (Labouvie-Vief et al., 2007). The theory suggests that these two modes work together dynamically where if one reduces then the other will likely compensate and vice versa. However, this system may reduce in flexibility and result in a bias towards one of the modes. Alongside maladaptive regulation styles as a factor which may relate to inflexibility, the theory suggests that a bias could occur through normal age-related changes in executive and cognitive functioning seen in later life.

Consequently, DIT postulates that processing negative affect is more cognitively demanding (Pratto and John, 1991) and proposes that as we age, diminishing cognitive capacity (reduced capacity for processing) makes it more difficult to accept and integrate negative feelings.

Therefore, older adults disconnect from negative feelings, resulting in the positivity bias (Labouvie-Vief et al., 2007).

Further extrapolation of this theory suggests that the positivity bias would be seen most significantly in those with poor or impaired cognitive function. However, evidence seems to suggest that the opposite finding is true; that older people with the greatest levels of executive control show the strongest evidence of the positivity bias (Mather & Knight, 2005; Petrican et al., 2008). For example, a study involving an emotional delayed-recall task showed that a positivity bias was present in healthy older adults, but not in participants with Alzheimer's disease (Kalenzaga et al., 2016). Furthermore, in situations of high cognitive load, this theory would predict that the positivity bias would not be as significant. Noh and Isaacowitz (2015) used an eye-gaze paradigm to test the positivity effect under different levels of cognitive load. They found that when under high cognitive load, manipulated by visual and auditory noise, older adults no longer showed a gaze preference for positive material (e.g., reduced positivity bias) compared with low cognitive load conditions. Other studies have also shown that increased cognitive load seems to reduce the positivity effect, supporting the DIT (Knight et al., 2007; Kryla-Lighthall & Mather, 2009; Mather & Knight, 2005; Nashiro et al., 2012).

5.3.3 The Aging Brain Model

The Aging Brain Model suggests that age-related changes in the structure and neural networks of the brain, particularly in adrenergic and amygdala function, may be the mechanism behind differences in the processing of negative stimuli (Cacioppo et al., 2011). Studies have shown differences in brain activation associated with emotion processing as aging occurs, indirectly suggesting a change in processing capacity in emotion processing areas. For example, older adults show reduced limbic and greater cortical activation (e.g., insula, frontal cortex) during processing of emotional faces (Fischer et al., 2005; Gunning-Dixon et al., 2003). Some of these changes have been shown to correlate with the positivity bias. Sakaki et al. (2013) found increased negative coupling between the medial pre-frontal cortex (MPFC) and amygdala, and enhanced MPFC activity when learning emotional faces. This increase in MPFC activity may indicate an attempt to overcome an age-related decline in capacity of MPFC processing areas. In general, a reduction in activity of pre-frontal cortical processing areas, with concomitant increased limbic activation (amygdala, basal ganglia) has also been shown in studies of depression both in young and older participants during emotion processing (Siegle, Thompson, et al., 2007), in particular in response to sad faces (Surguladze et al., 2005).

Because the ABM proposes degeneration of the amygdala as a mechanism explaining the positivity bias, exploring change in other measurable processes which rely on the amygdala is another way to consider the legitimacy of this theory. A function well known to rely on the amygdala is fear conditioning (Delgado et al., 2006). Some research has shown that this fear conditioning is preserved in aging (LaBar et al., 2004; Lee et al., 2018). Sakaki et al. (2019) examined fear conditioning and the positivity bias in the same study to determine if the positivity effect was associated with weaker fear conditioned responses, as this model would suggest. They found that while older adults were able to acquire a fear response, the magnitude of this was not correlated with a positivity effect in memory for emotional material. Thus, this finding does not support amygdala degeneration as a mechanism underlying the positivity bias.

5.4 NON-EMOTIONAL COGNITION IN AGING

As with other aspects of cognitive function discussed in this thesis, data regarding non-emotional cognitive aging are far from consistent. Methodological issues are the most likely cause of this, with most studies in aging, like the studies to be presented in Chapters Eight and Nine, using a cross-sectional design. Cross-sectional designs have potential confounds due to cohort differences such as environment, culture, education, and medical status (Hertzog, 1996). Longitudinal designs remove the effects of cohort differences; however, they bring other limitations of design including attrition bias, and effects of repeated testing. Alongside these methodological issues is the problem of the normality of participants, with some likely appearing to be healthy and intact, but having early or subtle brain disease (De Santi et al., 2008). As such, it is important to consider the research in terms of patterns of outcomes, rather than from single results. A brief review of changes in non-emotional cognition with aging will be presented below, ordered within cognitive domains.

5.4.1 Processing Speed/Psychomotor Function/Attention

Psychomotor function or processing speed is considered a significant factor in many of the age-related changes seen across cognitive tasks, more specifically that many tasks of complex functions are timed which may have a confounding effect (Lezak et al., 2012). For example, a large study by Salthouse (2010) found a linear decline in processing speed of -0.02 SD per year from the age of 20 years. Further to this, other cross-sectional studies have also found age related impairment to a level of 1-1.5 SD occurring for psychomotor speed (Bates & Wolbers, 2014; Schaie, 2005; Van Hooren et al., 2007). This difference is seen for processing

speed using tasks such as Digit Symbol Coding task. A 13 year follow up of older adults using a simple reaction time task showed no changes with age (Deary et al., 2009) and this outcome was reflected in a study by Harrington et al. (2017). This may suggest that age-related processing speed decline becomes more apparent when performing more complex processing tasks. Consistent with this finding for processing speed, studies examining attention have found that the complexity of the task is a significant factor in performance with age (Lezak et al., 2012). For example, span tasks such as digit span are relatively unaffected, even at 80 years of age (Ryan et al., 1996). In tasks of divided attention, such as choice reaction time tests, or colour discrimination tasks, participants make more mistakes or respond more slowly as age increases (Hartley, 2001).

5.4.2 Verbal Functioning

In general, verbal abilities are often suggested to be resistant to the effects of aging, with vocabulary and verbal reasoning changing little as age increases, and some studies suggesting a slight improvement might be present, with general information and vocabulary increasing until past age 60 (Salthouse, 2009b; Schum & Sivan, 1997). Verbal fluency is an area of particular interest in aging research and a category fluency task is included in the study in Chapter Eight. Studies of fluency tasks have reported results showing both significant (Huff, 1990; Hultsch et al., 1992) and little or no decline in performance (Parkin & Java, 1999; Salthouse et al., 1996). Overall, effects of age have been frequently reported, often from age 55, with total number of words produced reducing as age increases (Crossley et al., 1997; Gladsjo et al., 1999; Harrison et al., 2000; Stolwyk et al., 2015; Tombaugh et al., 1999; Troyer, 2000). However, a study by Tombaugh et al. (1999) found a larger effect of age on category fluency (animals) than on letter fluency, and this effect was then supported by findings in a longitudinal study by Clark et al. (2009). This may suggest that category fluency declines faster than letter fluency, accounting for some of the discrepancy in studies examining overall verbal fluency.

5.4.3 Memory

While immediate memory shows little decline with age on simple tasks, such as digit span forwards, when the task then involves manipulation of the stimulus, such as in digit span backwards, a reduction in performance with increasing age is found (Bopp & Verhaeghen, 2005). This is supported by a study by Hess (2005), which found that as the complexity of the task or processing demands increase, there is an increase in the negative effects on memory.

Some studies have shown large changes in memory for visuospatial material (Howieson et al., 1993; Koss et al., 1991) although, this was contradicted in a learning paradigm by Janowsky et al. (1996). This likely suggests that the deficit in these tasks occurs in the learning of the material, but once learned, retention over time is relatively good (Haaland et al., 2003; Trahan, 1992; Youngjohn & Crook, 1993). Studies examining recognition memory show that there is little difference in retention with age, even at long term follow up (75 days) (Fjell et al., 2005; Whiting IV & Smith, 1997).

A large population study conducted by Murre et al. (2013), showed that memory changed differently across the lifespan, depending on the type of material presented. They found that for visuospatial memory, decline in performance was identified to begin at 18 years old. In comparison to verbal memory changes, visuospatial memory was found to decline at twice the rate. The outcome of visual memory declining faster than verbal has also been found in other studies (Bopp & Verhaeghen, 2007; Logie & Maylor, 2009; Turcotte et al., 2005; van den Daele et al., 2018). Overall, the study by Murre et al. (2013), indicated a steady decrease in memory performance after the age of 25.

5.4.4 Executive Function

The nature of executive functions is still under debate, with some researchers suggesting there exists a single unifying function underlying organisation of goal directed behaviour (de Frias et al., 2006) and others, a collection of functions which work together to perform more complex tasks (Salthouse et al., 2003). Research has however, allowed for the pattern of executive function over the lifespan to be described. In many studies, executive function performance has been found to have an inverted u-shaped curve with improvements occurring in childhood/adolescence, stable function in adulthood, and then a decline seen with aging. In a study by (Cepeda et al., 2001), examining task switching across the life span, a u-shaped pattern emerged. This was also seen in a study using a stop signal task (Bedard et al., 2002) and in a sorting task (Zelazo et al., 2004). A cross-sectional study by Ferguson et al. (2021) found continued improvement in working memory capacity across adolescence and into young adulthood, followed by declines in both working memory and inhibitory control, beginning from as early as 30–40 years old and continuing into older age. While there is little consensus on when performance peaks, it has been suggested that this likely occurs either in late adolescence or in a person’s 20’s (Friedman et al., 2016; Zelazo et al., 2014).

5.5 KEY POINTS

- A “positivity bias” is found in studies in normal aging, however, findings are inconsistent and overall patterns of change in emotion processing with age are still unclear.

- Three main theories attempt to explain the positivity bias in aging but currently no one theory can explain the results across studies.

- Age related decline in processing speed and attention is consistently found in tasks which involve complexity (e.g., digit symbol coding, choice reaction time).

- Memory ability varies across the lifespan, with visual memory skills likely declining quicker than those for verbal memory.

- Executive functioning may have an inverted u-shaped performance curve across the lifespan, with peak ability likely in a person’s 20s and then declining from this point.

Chapter 6 - Systematic Review of Emotion Processing in Older Adults with Depression and Anxiety

The previous sections have examined emotion processing in younger adults with mood disorders or anxiety, and in healthy older adults. This chapter will systematically review studies investigating emotion processing in older adults with depression and anxiety. The current chapter draws on theories of emotion processing in aging as explored in Chapter Five and considers these in the context of theories of cognitive change in mood and anxiety disorders. The systematic review within this chapter has been published previously (Gray et al., 2021).

6.1 AIM OF THE SYSTEMATIC REVIEW

This systematic review will synthesise findings from studies examining emotion processing in older adults with mood and anxiety disorders. Findings may clarify the differential impact of depression and anxiety disorders, cognitive decline, and the positivity bias in older adults on emotion processing.

Specific questions relating to this review are:

- In older adults with depression and anxiety disorders (including PTSD), does the positivity bias in old age mitigate the emotion processing abnormalities that might be expected given the evidence of negativity bias in younger people with depression or anxiety disorders?
- Are changes in emotion processing circuitry in older adults with depression and anxiety disorders similar to those seen in younger people with depression or anxiety?
- Are behavioural and brain changes different in people with late onset compared with early onset depression, and what is the relationship between these changes and age-related cognitive decline?

6.2 METHODS OF SYSTEMATIC REVIEW

6.2.1 Protocol and Registration

Details of the protocol for this systematic review were registered on PROSPERO on 28 April 2020 and can be accessed via PROSPERO ID: CRD42020124980

6.2.2 Search Strategy

Up to December 2019, a systematic review of electronic databases was carried out for relevant papers using Pub Med and Web of Science. In the initial search, the search terms used were “depression”, “anxiety”, “PTSD”, “bipolar”, “emotion processing”, “older persons” and “elderly” in different permutations. Reference lists of all relevant papers were then checked to ensure inclusion of all pertinent articles. Citations of relevant articles were then followed using Web of Science to allow for capture of any missed articles.

During write up of this thesis the above searches were redone to capture any additional articles up until May 2023. Three studies in MDD and one in GAD were found. Two of the MDD studies were excluded (1 x MMSE <25, 1 x emotion processing specific data not available). Leaving only one new study in MDD (Baruch et al., 2021) and one in GAD (Cabrera et al., 2020). These new studies have been added to the tables and discussion where appropriate.

6.2.3 Inclusion Criteria

Peer-reviewed articles involving assessment using an emotion-based processing task and comparison of a clinical sample with a healthy control sample were included in the review. Studies examining all psychiatric disorders were to be considered, however, studies were only found for depression, anxiety, and PTSD populations. Sample participants were to be aged over 60 years and samples were to be categorised as “older adult” or similar.

6.2.4 Exclusion Criteria

Reasons for exclusion were: (i) comorbid major medical or neurological disorder in either group in the study, (ii) studies involving participants with mild or greater levels of cognitive impairment (MMSE < 25 or equivalent). All studies were limited to English-language publications.

6.2.5 Full Study Review

This review was undertaken using recommended PRISMA guidelines and using the PRISMA statement to guide the search, screening, and extraction process (Moher et al., 2009). Articles

were screened by the PhD candidate, who independently reviewed the titles and abstracts of studies, to accept or reject for full text review. The PhD candidate then examined the full texts of the studies that had passed initial screening, to determine if they still met inclusion criteria. If inclusion of a paper was unclear, three reviewers (PhD candidate, KD, and RP) discussed this in order to achieve a consensus. For each study, the following data was extracted: (1) characteristics of the sample, including sample size, average age, and baseline depression/anxiety severity, (2) study design, (3) cognitive tests used during assessment, and (4) study outcomes.

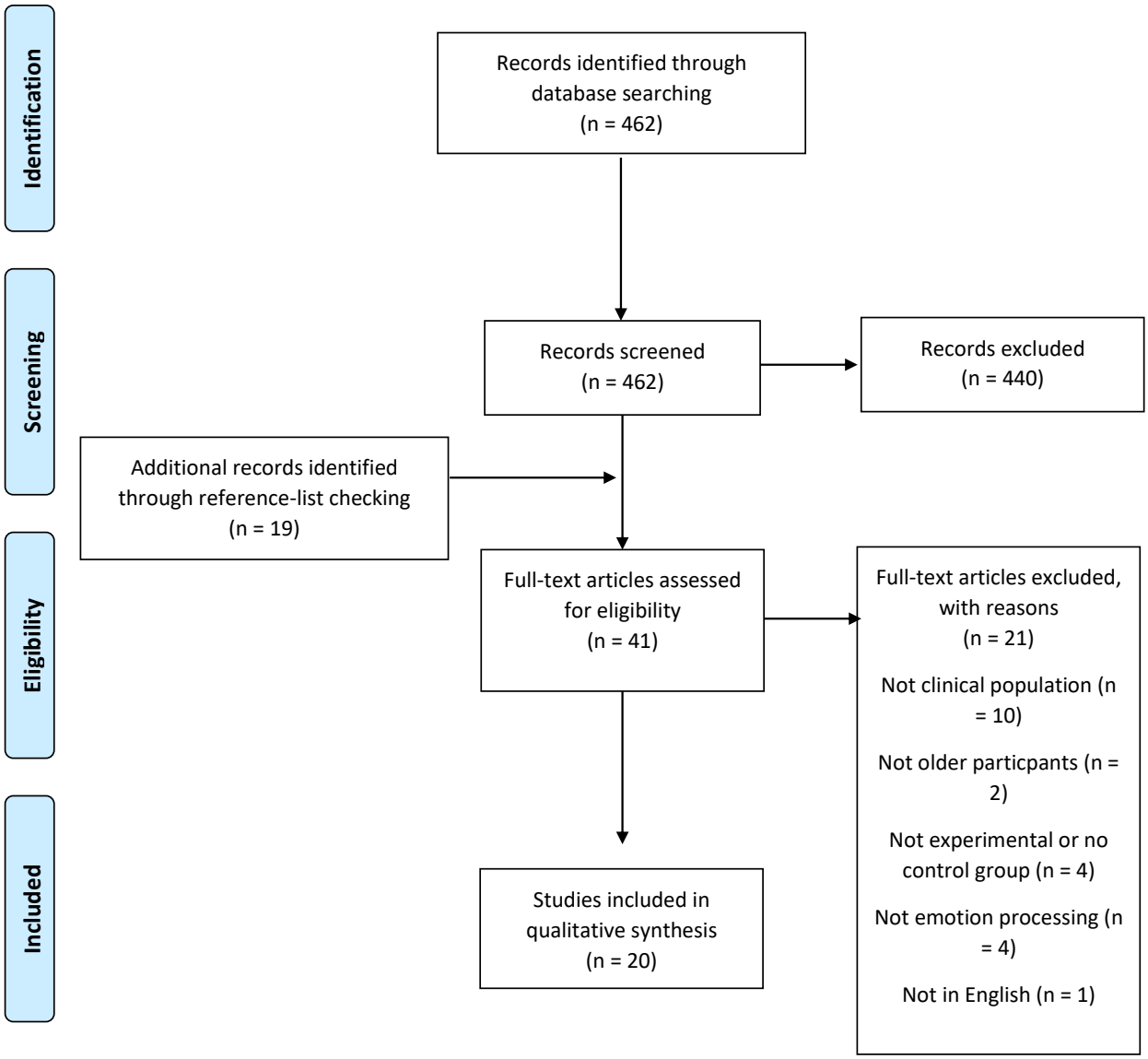

Figure 3 PRISMA diagram of studies retrieved for the review

6.3 RESULTS OF THE SYSTEMATIC REVIEW

The initial search for this review found 462 articles. After a title and abstract review, 440 of these were excluded. The full text of the remaining 22 studies were obtained and reviewed. Nineteen additional papers were found through examination of the reference sections of the full text studies. Of these 41 studies, 21 were then excluded due to not being clinical or experimental studies, not recruiting older participants or measuring emotion processing, or not being in English. The remaining 20 papers were included in the review. All studies included clinically diagnosed populations, unless otherwise stated. In this area of research, there is little consistency regarding terminology. Late Life Depression (LLD), depression, and late or early onset depression are all used with varying intended meaning; as such terminology that was used by the original authors in each paper has been deferred to.

6.3.1 Depression

Table 2 displays characteristics and main findings of studies examining behavioural data of samples with depression.

Table 2 *Selected Demographic Characteristics of Included Studies Examining Behavioural Data of Samples with Depression*

Author	**Arm**	**N**	**Gender**	**Age (SD)**	**Task**	**Outcomes**
Dudley et al. (Dudley et al., 2002)	LLD	12	9F	74.4 (7)	Emotional Stroop (interference)	LLD participants had longer response times across blocks than control participants. Older LLD participants showed a specific increase in response time to negative words.
	Control	12	9F	72.9 (8)		No difference in response time across any word valence.
Broomfield et al. (Broomfield et al., 2007)	LLD	16	9F	73 (6.23)	Emotional Stroop (interference)	Older LLD patients had slower reaction times across all trial types compared with controls. Older LLD patients had significantly slower reaction times to negative words relative to neutral when compared with controls.
	Control	19	9F	72.05 (5.56)		No change in reaction time for any valence of words.

Author	Arm	N	Gender	Age (SD)	Task	Outcomes
Huang et al. (Huang et al., 2019)	LLD	55	38F	66.36 (5.42)	Emotional Stroop (interference)	Both positive and negative words were associated with longer latencies in both groups. There was, however, no group by emotion interaction on any of the measures.
	Control	40	25F	68.10 (5.30)		Control participants were more accurate and had shorter response latencies.
Mah and Pollock (Mah & Pollock, 2010)	LLD	11	7F	73 (8.4)	Emotion Regulation Task (interference)	Overall response latencies did not differ between LLD and control groups.
	Control	11	8F	75 (6.9)		Response latencies for all emotions were significantly longer compared with response to neutral stimuli.
Zhou et al. (Zhou et al., 2018)	LLD	14	9F	66.36 (5.20)	Primed Face Emotion Recognition Task (interference)	Reaction times for happy and sad primes were significantly longer than for ambiguous primes for all participants.

Author	Arm	N	Gender	Age (SD)	Task	Outcomes
	Control	14	9F	65.64 (3.93)		
Zhou et al. (Zhou et al., 2018) Event-related potential	LLD	14	9F	66.36 (5.20)	Primed Face Emotion Recognition Task (interference)	LLD participants had smaller event-related potential amplitudes overall, compared with controls for all priming stimuli, irrespective of valence. No differences were seen in event-related potential amplitudes between the different prime valences.
	Control	14	9F	65.64 (3.93)		No differences were found between happy and ambiguous primes, but there were significant differences between happy (larger) versus sad and ambiguous (larger) versus sad primes within the control group.
Mah and Pollock (Mah	LLD	11	7F		Emotion Perception	LLD participants were significantly more likely to misidentify a neutral face compared with control participants.

Author	Arm	N	Gender	Age (SD)	Task	Outcomes
& Pollock, 2010)					Task (recognition)	
	Control	11	9F			
Savaskan et al. (Savaskan et al., 2008)	LLD	18	14F	76.2 (1.8)	Face Portrait Recognition Test (recognition)	LLD participants recalled fewer faces overall compared with controls. This lower recall was especially pronounced for recall of happy faces. There were no differences in recall for LLD participants between happy and angry faces. Treatment with Escitalopram did not improve memory recognition for happy faces but did improve memory for faces with an angry expression.
	Control	22	16F	76.9 (1.8)		Participants in the control group had better memory for happy over angry faces.
Brassen et al. (Brassen et al., 2008)	LLD	13	13F	66.4 (6.1)	Verbal Emotion Recognition	No differences in correct responding, reaction time, or misattribution of emotions were seen

Author	Arm	N	Gender	Age (SD)	Task	Outcomes
					Task (memory and recognition)	between the LLD and control groups at baseline or follow-up.
	Control	13	13F	65.6 (6.1)		
Callahan et al. (Callahan et al., 2016)	LLD	19	15F	72.4 (9.0)	Memory for Emotionally Valenced Words (memory)	At delayed recall, LLD participants recalled significantly fewer words compared to control participants. At immediate recall, LLD participants recalled more negative than neutral words. At delayed recall, LLD participants recalled more positive and negative words than neutral words.
	Control	28	21F	72.1 (8.1)		No differences were seen in immediate word recall between LLD and control participants. At both immediate and delayed recall, control participants recalled more positive and negative words than neutral words.
	Suicidal/LLD	24	38% Men	68.2 (8.7)	Reading the Mind in the	LLD suicide attempters had significantly poorer emotion recognition compared with controls.

Author	Arm	N	Gender	Age (SD)	Task	Outcomes
Szanto et al. (Szanto et al., 2012)					Eyes Task (social cognition)	This difference was not maintained when global cognition was accounted for.
	Non-suicidal LLD	38	34% men	70.2 (7.7)		LLD participants who had not attempted suicide had an emotion recognition ability which fell between the control and suicide attempters groups, but such differences were not statistically significant.
	Control	28	61% men	69.6 (6.3)		
Baruch et al (Baruch et al., 2021)*	LLD	19	10F	70 (8.17)	Facial Emotion Recognition Task (recognition)	No significant difference between groups for accuracy or misclassification. Significant group by valence interaction for reaction time. LLD were significantly slower than controls for surprise.
	Control	19	10F	71 (7.95)		
Baruch et al (Baruch et al., 2021)*	LLD	19	10F	70 (8.17)	Emotion Categorisation Task with	No significant group differences for accuracy or reaction time.

Author	Arm	N	Gender	Age (SD)	Task	Outcomes
					Recall (recognition and memory)	LLD participants recalled significantly less words than the control group, but there was no effect of valence.
	Control	19	10F	71 (7.95)		
Baruch et al (Baruch et al., 2021)*	LLD	19	10F	70 (8.17)	Dot Probe Task (interference)	All participants showed a general bias away from emotional faces. No differences were found between groups.
	Control	19	10F	71 (7.95)		

LLD = Late Life Depression. * Denotes study found in updated search

6.3.1.1 Emotion Interference

The emotion processing tasks discussed in this section involve inhibition of emotional information in order to carry out a cognitive task. This is most commonly the eStroop paradigm. A pilot study by Dudley et al. (2002) (12 depressed, 12 healthy control), showed an interaction between group and word valence which was explained by a greater interference (longer time to colour name) of depression-related words in the depressed group, with an effect size difference compared with healthy control participants of 0.9 (Cohen's *d*). Broomfield et al. (2007) (16 depressed, 19 healthy control) also showed a group by valence interaction in depressed participants compared with healthy control participants, with depressed participants being slower to respond to negative words compared with neutral words. The group by valence interaction persisted when anxiety was controlled for. Callahan and Hudon (2014) found those with LLD (n = 10) were generally slower than healthy control participants (n = 15), but with no difference seen across valences. No group by valence analysis was reported. Finally, in 55 people with LLD and 40 healthy control participants, healthy participants were more accurate and had shorter latencies (Huang et al., 2019). There was no effect of emotion on accuracy, but there was on latency, with both positive and negative words associated with longer latencies. There was, however, no group by emotion interaction on any of the measures. Apart from the study of Dudley, no estimates of effect size difference between depressed and healthy control participants were reported (Dudley et al., 2002).

Mah and Pollock (2010) used a facial emotion-based paradigm to measure emotion inhibition in 11 depressed and 11 healthy control participants. In this paradigm, participants were presented with faces displaying different emotions (happy, sad, fearful, and neutral) and were asked to answer questions about a non-affective aspect of the face (inhibition). There was a significant group by valence interaction whereby overall latencies were similar in both groups but were significantly longer for all emotion-laden stimuli (not only negative emotions) compared with neutral stimuli in the control group. This did not vary by emotion in the depressed group.

Zhou et al. (2018) studied Event Related Potentials (ERP) in response to emotional faces, in 14 older adults with depressive symptoms (but specifically not meeting criteria for a DSM-IV diagnosis of depression) and 14 healthy control participants. The study was included in the review, after discussion, since the patient group had significant depressive symptoms despite no formal diagnosis (Centre for Epidemiologic Studies Depression Scale mean group score =

20.21±5.65). Participants were presented with an emotional prime (facial expressions – happy, sad, ambiguous) then asked to identify the emotion of the target which followed. Older adults with depressive symptoms had smaller overall ERP amplitudes compared with healthy control participants, regardless of valence of the priming stimulus. Older adults with depressive symptoms showed no differences in amplitude between the different prime valences. In control participants, there were no differences found between happy and ambiguous primes, but there were significant differences between happy and sad (larger ERP), and between ambiguous and sad (larger ERP) primes. However, it was notable that the group by prime interaction was not statistically significant ($p = 0.07$) making further analyses and conclusions very tentative. Behavioural data showed no differences between groups.

6.3.1.2 Emotion Recognition and Memory

Most commonly used for examining emotion processing is an FER task (Harmer et al., 2003), in which participants are presented with various facial expressions – usually happy, sad, angry, disgusted, fearful, surprised, and neutral – and asked to identify the emotion portrayed. Mah and Pollock (2010) used a FER task in which participants were presented with happy, sad, fearful, or neutral faces. Whilst overall accuracy was similar between depressed ($n = 11$) and control ($n = 11$) groups, there was a significantly increased probability of depressed participants incorrectly identifying neutral faces.

Savaskan et al. (2008) used a memory for faces paradigm that included both happy and angry faces. At baseline, depressed participants ($n = 18$) recalled fewer faces overall compared with healthy control participants ($n = 22$). There was no group by valence interaction, although the authors suggested that compared with healthy control participants, depressed participants showed lower ability to recognise previously viewed happy facial expressions after a delay. Following four weeks of treatment, the depressed group showed a significant reduction in depressive symptoms and a significant improvement in general cognitive function. Further, their memory for angry faces significantly improved from baseline, while no effect was seen for happy faces.

Two studies examined emotion recognition and memory for emotional material using verbal stimuli. Brassen et al. (2008) used an emotion recognition task with positive, neutral, and negative words to examine neural responses in 13 antidepressant-naive female participants with LLD versus 13 healthy control participants. Participants were shown a positive, negative, or neutral adjective which was then replaced by a response screen where they indicated the valence of the word. No significant differences in response correctness,

response time, or misattributions of emotion were found at either time-point between the two groups.

Callahan et al. (2016) examined recall of neutral, positive, and negative words from a list including 12 of each. At immediate recall, healthy control participants (*n* = 28) displayed better recall of positive and negative words compared with neutral words, while depressed participants (*n* = 19) recalled more negative than neutral words. However, performance of the two groups was not directly compared. At delayed recall, both groups generally showed better recall of emotional compared with neutral words. During recognition, all participants were more likely to report false recognition for emotional than neutral words. Once again, there was no group comparison.

Baruch et al. (2021) using a FER task found no differences between depressed (*n* = 19) and healthy control participants (*n* = 19) for accuracy or misidentification of faces. They did find a significant difference between groups for reaction time to surprised faces, with depressed participants being slower. In addition, the authors conducted an emotion categorisation task with a recall component. They found no difference between groups on accuracy or reaction time for categorisation, however, depressed participants were able to remember fewer words at recall.

6.3.1.3 Social Cognition

The RMET (Baron-Cohen et al., 2001) requires individuals to identify complex or social emotions from images portraying only the eyes of the face. Szanto et al. (2012) examined the RMET in depressed older adults who had (*n* = 24) or had not (*n* = 38) attempted suicide. A control group was also examined (*n* = 28). Individuals who had attempted suicide performed significantly worse than healthy control participants. The performance of depressed participants who had not attempted suicide fell between control participants and those who had attempted suicide but was not significantly different from either. Further analysis showed that when global cognitive function was accounted for (Mattis Dementia Rating Scale (Mattis, 1988)), the significant difference found for individuals who had attempted suicide was not maintained, suggesting that the group's reduced ability to recognise social emotions may have been attributable to global cognitive impairment, rather than a specific impairment in social cognition.

6.3.1.4 Functional Magnetic Resonance Imaging Studies

Table 3 displays characteristics and main findings of studies examining neuroimaging data of samples with depression.

Table 3 *Selected Demographic Characteristics of Included Studies Examining Neuroimaging Data of Samples with Depression*

Author	**Arm**	**N**	**Gender**	**Age (SD)**	**Task**	**Outcomes**
Aizenstein et al. (Aizenstein et al., 2011)	LLD	33	21F	67.7 (5.2)	Faces and Shapes Task (recognition)	Greater limbic activation for LLD versus control participants during affective processing
	Controls	27	19F	71.6 (7.5)		
Huang et al. (Huang et al., 2019)	LLD	55	38F	66.36 (5.42)	Emotional Stroop (interference)	LLD participants showed reduced activation in middle frontal gyrus and left dorsolateral prefrontal cortex and increased activation in anterior cingulate cortex compared with controls. This was mediated by cognitive reserve such that greater cognitive reserve correlated with greater middle frontal gyrus activation.
	Control	40	25F	68.10 (5.30)		
Brassen et al. (Brassen et al., 2008)	LLD	13	13F	66.4 (6.1)	Verbal Emotion Recognition Task (memory and recognition)	LLD participants showed an attenuated neural response in the ventromedial prefrontal cortex in response to negative stimuli when compared with positive stimuli. At 7-month follow-up, when participants symptoms had significantly improved, this

Author	Arm	N	Gender	Age (SD)	Task	Outcomes
						attenuated response was found to have normalised.
	Control	13	13F	65.6 (6.1)		
Briceño et al. (Briceño et al., 2015)	LLD	26	12F	Not provided	Emotion Recognition Task (recognition)	In older participants, women with LLD showed hypoactivation in emotion processing circuits, particularly the right prefrontal cortex, when compared with healthy controls. In contrast, older men with LLD showed hyperactivation in these areas when compared with the control group.
	Control	25	12F	Not provided		
Vanyukov et al. (Vanyukov et al., 2015)	LLD and Suicide	18	6F	67.44 (7.0)	Face Matching Task (recognition)	LLD and suicide attempts did not predict a different response to angry faces than healthy controls.
	LLD	13	9F	68.15 (6.1)		
	Control	18	11F	70.05 (7.7)		

LLD = Late Life Depression.

Aizenstein et al. (2011) used a facial expression affective-reactivity task. Depressed participants (*n* = 33) showed greater subgenual cingulate activity during affective processing compared with healthy control participants (*n* = 27), with a significant correlation between white matter hyperintensity and activity. Huang et al. (2019) (55 LLD, 40 control) showed reduced activation in the middle frontal gyrus and left dorsolateral prefrontal cortex and increased activation in the anterior cingulate cortex in LLD compared with healthy control participants in a study examining activation during an eStroop task. This was mediated by cognitive reserve, such that greater cognitive reserve correlated with greater middle frontal gyrus activation in the LLD group. Brassen et al. (2008) reported that in comparison with control participants (*n* = 13), female patients with LLD (*n* = 13) showed attenuated neural response in the ventromedial prefrontal cortex in response to negative compared with positive words. When correlated with depression severity (Geriatric Depression Scale) in the depressed group, reduced activation in the medial orbito-frontal cortex was correlated with higher depression scores. Increased activation in the superior medial frontal cortex, for positive compared with negative words, was also correlated with higher depression scores. At 7-month follow-up, when patients' symptoms had significantly improved, this attenuated response was found to have normalised.

Briceño et al. (2015) examined the effects of age and gender on neural circuits in a FER paradigm which involved four emotions (happiness, sadness, fear, anger). The study included participants in younger and older age groups, as well as depressed and non-depressed participants (older depressed participants, n = 26; older controls, n = 25). When depressed and non-depressed groups were not separated by age and gender, no overall effects were detected between groups. However, when separated by age and gender, older females with depression showed hypoactivation in emotion processing circuits, particularly the right prefrontal cortex, when compared with older control participants. In contrast, older males with depression showed hyperactivation in these areas when compared with the control group.

Vanyukov et al. (2015) used the faces and shapes task (Hariri et al., 2002), in which participants were required to match a target face to one of two presented faces. Authors used faces showing anger and fear during the face trials. In neutral trials, shapes were used as non-affective controls. The study examined patients with depression (*n* = 13), patients with depression who had attempted suicide (*n* = 18), and control participants (*n* = 18). There was no difference in response to angry faces in either depressed group compared with the control group. Responses to fear-related stimuli were not discussed.

6.3.2 Anxiety Disorders

Table 4 presents characteristics and key findings from reviewed studies examining samples with anxiety disorders.

Table 4 *Selected Demographic Characteristics of Included Studies Examining Anxiety and Post-Traumatic Stress Disorder*

Author	**Arm**	**N**	**Gender**	**Age (SD)**	**Task**	**Outcomes**
Price et al. (Price et al., 2012) Behavioural	High (Late life GAD)	20	16F	67.2 (6.2)	Emotional Stroop (interference)	Reaction time for threat-related words was slower than for neutral words. Reaction time for positive words was faster than for neutral words.
	Mid	19	12F	68.5 (6.4)		Low and medium worry groups had faster reaction times for threat words compared with neutral words, and slower reaction times for positive words compared with neutral words.
	Low	21	15F	68.3 (5.6)		
Mohlman et al. (Mohlman et al., 2013) Behavioural	GAD	34	68%F	66.67 (4.56)	Dot Probe Task (interference)	A bias away from positive information in positive-neutral pairs was seen across all participants.
	Control	28	71%F	67.37 (5.53)		No significant differences in reaction time overall or between word types was found between the two groups.

Author	Arm	N	Gender	Age (SD)	Task	Outcomes
Cabrera et al (Cabrera et al., 2020)*	GAD	32	25F	72.93 (7.21)	Dot Probe Task (interference)	GAD participants paid more attention to negative information and avoided positive information.
Behavioural	Control	28	18F	68.71 (5.24)		Control participants paid more attention to positive and avoided negative information. No differences were found between groups for reaction time.
Price et al. (Price et al., 2011)	GAD	16	11F	63.1 (3.1)	Emotional Stroop (interference)	Slower reaction times and decreased prefrontal cortex activation when identifying negative versus neutral words, compared with controls.
	Control	12	8F	67.2 (7.6)		
Wu et al. (Wu et al., 2019)	GAD	16	9F	67.38 (5.78)	Faces and Shapes Task (recognition)	No significant differences between the GAD and control groups in either connectivity in the amygdala or bed nucleus of the stria terminalis.
	Control	20	10F	67.8 (7.88)		
Karim et al. (Karim et al., 2016)	GAD	17	10F	64 (6)	Faces and Shapes Task (recognition)	No significant differences were found in brain activation between GAD and control groups.
	Control	20	10F	67.5 (8.5)		

Author	Arm	N	Gender	Age (SD)	Task	Outcomes
Wittekind et al. (Wittekind et al., 2015)	PTSD	22	20F	72.73 (2.27)	Spatial Cueing Paradigm (interference)	No attentional bias for trauma-related stimuli in the PTSD group.
	No PTSD	26	17F	73.00 (2.00)		
	Control	22	15F	73.73 (2.98)		
Wittekind et al. (Wittekind et al., 2017)	PTSD	20	18F	72.75 (2.31)	Emotional Stroop (interference)	The PTSD group had longer response latencies to trauma- and depression-related words compared with healthy controls.
	No PTSD	26	17F	73.00 (2.00)		
	Control	21	15F	73.86 (2.99)		Within group slowing for trauma compared with neutral words found in all groups in the study.

GAD = Generalised Anxiety Disorder. **PTSD** = Post Traumatic Stress Disorder; *Study added after new search

Price et al. (2012) divided 60 community recruited adults into high, medium, and low trait anxiety based on responses to the Penn State Worry Questionnaire. Ninety percent of participants in the high worry group (n = 20) scored at or above 50 on the Penn State Worry Questionnaire, which has been noted as a cut-off for late life GAD (Webb et al., 2008). The remaining participants (n = 40) formed comparison groups. An eStroop task containing positive, threat-related, and neutral words was used. In the high worry group, response time for threat-related words was longer than neutral words (Cohen's d = 0.76). The high worry group also showed faster reaction times for positive words than neutral. The low and medium worry groups showed the opposite pattern - faster response time for threat-related words compared with neutral, and slower response time for positive words compared with neutral. Between group comparisons of estimated marginal means showed a difference between the high worry and the low worry group with bias towards threat related words being greater (Cohen's d = 0.67).

Mohlman et al. (2013) used a dot probe task which included depression, threat, positive, and neutrally-valenced words to examine attentional biases. There were no significant between-group differences in reaction time overall or between word types in GAD (n = 34) versus healthy control participants (n = 28). Using differences between probe-target congruent word pairs and incongruent pairs, bias scores were calculated. No significant differences in bias scores between GAD and control groups was found. A bias away from positive information in positive-neutral pairs was seen across all participants in the study. No significant change in performance following treatment (Cognitive Behavioural Therapy vs waitlist) was found.

Cabrera et al. (2020) also used a dot probe task, which consisted of negative, positive, and neutral faces as stimuli. No significant differences were seen for reaction time between the healthy control group (n = 28) and the GAD group (n = 32). A bias towards negative information and away from positive information was seen in the GAD group, and conversely, a bias towards positive and away from negative information was found in the control group.

6.3.2.1 Functional Magnetic Resonance Imaging Studies

Price et al. (2011) examined fMRI responses to performance on an eStroop task in older adults with late life GAD. Participants with GAD (n = 16) had slower reaction times when responding to negative versus neutral words, compared with control participants (n = 12) (Cohen's d = 0.85), and also showed less activation in the prefrontal cortex in response to

negative compared with neutral words. An increase in activation was seen in the GAD group in the left amygdala, compared with the control group.

Two studies (Karim et al., 2016; Wu et al., 2019) examined functional connectivity associated with emotional reactivity in late life GAD compared with healthy control participants. Neither study found any significant differences between the GAD and control groups using a faces and shapes task. Both studies examined the data using the factor of worry, as measured by the Penn State Worry Questionnaire. Wu et al. (2019) found that there was a significant interaction between group and "worry" on connectivity between the left amygdala and left orbitofrontal cortex, medial prefrontal cortex and both anterior cingulate cortices and on connectivity between the bed nucleus of the stria terminalis and the left orbitofrontal cortex. When worry was examined across groups, there was a U-shaped curve, whereby connectivity between limbic and cortical areas was optimal at medium levels of "worry". The effect sizes of these curves varied from $r^2 = 0.21$ to $r^2 = 0.25$. Karim et al. (2016) found that across the groups, increased global anxiety, measured by the Hamilton Anxiety and Depression Scale, was associated with greater activation in the parahippocampal area and precuneus. In contrast, worry as measured by the Penn State Worry Questionnaire was associated with decreased precuneus and prefrontal activation. Complex mediation analyses broadly suggested that the mediation between increased white matter hyperintensity burden and anxiety symptoms are mediated by increased activation of limbic and paralimbic structures and decreased activation of regulatory regions, for example the ventromedial prefrontal cortex.

6.3.2.2 Post Traumatic Stress Disorder

One study, published as two papers, examined emotion processing in older populations with PTSD. Wittekind et al. (2015) used a spatial cueing task involving priming with an emotional facial stimulus (anxiety, depression, trauma, and neutral), then a spatial (left or right) decision, in response to a non-affective target (26 PTSD, 22 healthy control). Authors found no attentional biases within the PTSD group for trauma-related stimuli. Post hoc redistribution of participants into those who met criteria for depression or not, however, showed participants in the depressed sample had slower reaction times to depressive stimuli (Cohen's $d = 1.5$).

The same participants also completed an eStroop task (Wittekind et al., 2017) using words related to depression, trauma, anxiety, or neutral words. Participants with PTSD showed longer response latencies to trauma- and depression-related words compared with healthy

control participants, but no differences in latency for neutral and anxious words. Slowing for trauma compared with neutral words was found across all groups in this study.

6.4 FINDINGS OF THE SYSTEMATIC REVIEW

The main findings of the systematic review were as follows.

- At a behavioural level, evidence regarding differences in emotion processing between older adults with depression and healthy control participants is inconsistent. This is the case for interference of emotional material in cognitive processes (eStroop), memory for emotional compared with other material, and the explicit process of recognition of emotional facial expressions.
- There are few studies in older adults with anxiety disorders. Studies suggest interference with processing from threat-related words in anxiety disorders and from trauma-related words in PTSD, but there are no replication studies.
- Studies show differences in activation in emotional processing circuitry in older adults with depression, with the general pattern of increased limbic but reduced prefrontal activity as in younger depressed participants.

The systematic review more specifically examined three main questions as outlined below.

6.4.1 How does the positivity bias seen in older persons interact with biases towards negative or threat-related emotional material in depression or anxiety?

There are no consistent findings regarding any of the aspects of emotion processing studied. This was the case both for implicit processes, for example the eStroop, and for explicit processes such as emotion recognition. Not all these phenomena have been consistently replicated in younger people with depression either. For example, results on the eStroop have not been found to be consistent (Epp et al., 2012). The phenomenon seen most consistently in younger depression is the misinterpretation of neutral faces (Bourke et al., 2010; Harmer et al., 2018). In older adults with depression, this was only examined in three studies and was not seen consistently.

The lack of consistent evidence of a bias towards negative emotional stimuli in older adults with depression may reflect a situation in which, on average, negative biases are less in late life depression than in younger depression. It could be hypothesised that this relates to the positivity bias associated with aging, which counteracts the biases seen in depression.

However, the inconsistencies in the data are more likely to be related to the small numbers of studies and limited power of most studies. Further issues with the data are that there are no studies directly comparing emotion processing between younger and older patients with depression. Similarly, no comparisons across the life span have been conducted in anxiety disorders. The interaction of age with depression or anxiety cannot therefore be fully evaluated. Finally, studies generally did not examine possible complicating factors such as concomitant cognitive impairment, age of onset and the effects of medication.

6.4.2 Are changes in emotion processing circuitry similar to those seen in younger people with depression or anxiety?

In younger people with depression, studies have generally shown a reduction in activity of dorsal-cognitive structures combined with increased activity of ventral-affective structures during emotion processing (Roiser et al., 2012). The studies in older adults with depression are broadly in line with this pattern, with the largest studies showing increased activation of limbic structures or decreased activation of prefrontal structures in late life depression compared with control participants, in line with a general pattern of reduced top down processing (Aizenstein et al., 2011; Brassen et al., 2008; Huang et al., 2019).

Of interest, there was also evidence of an interaction between depression and both white matter lesions (Aizenstein et al., 2011) and cognitive reserve (Huang et al., 2019) in determining patterns of activation during emotional processing. White matter changes were associated with an exaggeration of the increase in subgenual cingulate activation seen during emotion processing in older adults with depression (Aizenstein et al., 2011). In the study of Huang et al. (2019), severity of depression was associated with reduced medial frontal activation during emotion processing but this was attenuated by having greater cognitive reserve (measured using years of education and verbal fluency). Both findings suggest a situation in which if processing capacity is reduced for a variety of possible reasons, this may impair efficient emotion processing, resulting in processing being driven to a greater extent by limbic structures.

6.4.3 Are behavioural and brain changes different in people with late onset compared with early onset depression and what is the relationship between these changes and age-related cognitive decline?

Of note, this review excluded studies in which participants had MMSE <25. The rationale was that while the interaction between mood and anxiety, cognitive ability, and the relationship of

these to emotion processing and positivity bias was of interest, it was important for the research question that the review did not extend into mild cognitive impairment and dementia. Four studies examined the relationship between emotional processing and other aspects of cognitive functioning. Callahan et al. (2016) examined the influence of depression on emotion processing in mild cognitive impairment, based on the suggestion that mild cognitive impairment and depression is a combination particularly likely to progress to dementia and therefore constitutes a prognostically important subtype of mild cognitive impairment (Apostolova & Cummings, 2008; Rosenberg et al., 2013). Consistent with the hypothesis that negative information requires greater capacity to process, Callahan et al. (2016) showed that for patients with mild cognitive impairment, immediate recall was better for positive words than negative words, but this was not the case for patients with mild cognitive impairment with depression, depression alone, or healthy control participants. A caveat to this conclusion is the lack of an analysis of group by valence interaction. Furthermore, a similar effect was not seen in a separate examination of effects on an eStroop test (Callahan & Hudon, 2014). Although Huang et al. (2019) did not find the hypothesised eStroop effect in older adults with depression, there was more preserved middle frontal gyrus activity during eStroop performance in people with greater cognitive reserve. This suggests that cognitive reserve (measured using a combination of years of education and an executive task) mediates a more top-down emotional regulation, i.e., preserved processing capacity in those with greater cognitive reserve. Szanto et al. (2012) examined social cognition in older adults with depression. Those who attempted suicide had lower scores than control participants but interestingly this did not survive co-varying for general cognitive function, suggesting that the two functions are related at least in depression.

6.4.4 Specific issues in late life anxiety disorders

Six studies examining emotion processing in older adults with anxiety disorders were identified. Those using an eStroop task both showed increased latency for negatively valenced words (Price et al., 2011; Price et al., 2012). In one of the studies which examined brain activation (Price et al., 2011), the hypothesised difference from healthy control participants was seen, with an increase in activation of part of the amygdala, accompanied by a decrease in activation of the dorsal lateral prefrontal cortex in older GAD patients. Two further studies showed no difference between patients with GAD and healthy control participants in brain activation and connectivity (Karim et al., 2016; Wu et al., 2019). However, in one study there was a complex relationship between worry and connectivity, suggesting that connectivity

between limbic and cortical areas was maximal at an intermediate level of worry (Wu et al., 2019). In the other study, anxiety was associated with greater activation in parahippocampal areas and the precuneus (Karim et al., 2016). In general this is in keeping with attenuation of activity in and connectivity with processing areas seen in younger patients (Goossen et al., 2019).

Data regarding interference by trauma-related words in eStroop tasks has been consistently demonstrated in younger adults with PTSD (Cisler et al., 2011). Both in older adults with anxiety and PTSD, most studies examining simple attention bias towards negative stimuli have not shown a difference from control participants (Mohlman et al., 2013; Wittekind et al., 2015). One more recent study has shown a differential effect of attention away and towards emotional material between GAD and control participants (Cabrera et al., 2020). However, these results have not been replicated. Overall, studies may suggest that the basic focus of attention is not altered but that negative emotional stimuli do however interfere with processing.

6.4.5 Limitations and recommendations for future research

This systematic review has limitations, both directly related to the methodology and to the content of the studies reviewed. Related directly to the review, it considered English language papers only. While this is standard practice for an English language-based review, it may mean that some relevant studies have been missed. Second, meta-analysis has not been possible given the heterogeneity of paradigms investigated in the studies examined, and in the variety of ways the data has been analysed and presented.

Limitations of the data which can be translated into recommendations for the field are as follows:

- While studies are in “older adults”, the majority have mean ages from 65 to 75 years with the lower age cut off being 60 in most. This may mean that effects of age which might have been seen for example in 70–80-year-olds, are washed out by there being relatively less effect in the lower age range. This could of course be overcome by studies being adequately powered to examine the effects of age in a linear fashion, possibly even over a larger age range so that the effects of age and its interaction with depression or anxiety could be examined. This better reflects the fact that risk factors and neurobiology likely change in a linear fashion across the lifespan (Schaakxs et al., 2017).

- Most studies did not analyse the effects of having early onset compared with late onset depression. Once again, the issue is mainly one of power. With sufficiently larger studies this factor should be examined.
- Thirdly, a variety of paradigms have been used to study emotion processing even within similar processes. This makes it generally difficult to pool or synthesise results from different studies. Consensus on the most useful and clinically relevant paradigms would aid progress in the field.
- Studies have rarely attempted to determine the extent to which decline in non-emotional cognitive processes, such as executive function, may be affecting emotional processing directly. Future studies should consider undertaking testing of non-emotional memory and executive function and examining the relationship between this and emotion processing.
- Critically, studies have tended to be very small. Future studies should be adequately powered to show differences at least as small as 0.5 standard deviations between groups. They should also, ideally, be large enough to consider the possible effects of varying medication, late compared with early onset, and age as a longitudinal factor on emotion processing.
- In reporting results, most studies use analysis of variance but do not report estimated marginal means and standard deviations making it impossible to calculate the magnitude of differences between groups. These should be reported, or effect sizes calculated.

6.5 CONCLUSIONS OF THE SYSTEMATIC REVIEW

The ability to correctly process and interpret emotions is an important part of social interactions, something that becomes especially important as we age. The Cognitive Neuropsychological Hypothesis of Depression also suggests that these interactions are an important part of the aetiology of depression and may provide a target for treatment. Indeed, packages of emotion recognition training are being developed to address this issue (e.g. (Penton-Voak et al., 2021)).

The review has highlighted the fact that there are relatively few large studies of emotion processing in older adults with depression and anxiety disorders. We have provided recommendations for future research.

Given the lack of studies that examine emotion processing in depression or anxiety across the lifecycle, it is not possible to determine the interaction of abnormalities in these conditions with the aging positivity bias. In general, there have been findings of a bias towards negative stimuli, and concomitant alteration of brain activity to a pattern of greater limbic and reduced prefrontal cortex activation in younger people with depression and anxiety. Similar patterns have been shown in studies in older persons, although not consistently in some aspects of emotion processing.

In the chapters that follow, two different analyses will attempt to address some of the current gaps in the literature. Chapters Seven and Eight will present a cross-sectional analysis of emotion processing in healthy adults from the early through to later stages of aging. This study has been designed to use paradigms of emotion processing that are commonly used in this field to enable future comparisons with other data sets. Chapter Nine presents pooled data of emotion processing outcomes, including an examination of the interaction between age and non-emotional and emotion-based processing. This is a particularly important relationship due to previously described changes in non-emotional cognition in both mood disorders and aging.

6.6 KEY POINTS

- Behaviourally, evidence regarding differences in emotion processing between older adults with depression and healthy control participants is inconsistent. This is the case for interference of emotional material in cognitive processes (eStroop), memory for emotional compared with other material, and the explicit process of recognition of emotional facial expressions.
- Studies show differences in activation in emotional processing circuitry in older adults with depression, with the general pattern of increased limbic but reduced prefrontal activity as in younger depressed participants.
- There are few studies in older adults with anxiety. Studies suggest interference with processing from threat-related words in anxiety and from trauma-related words in PTSD, but there are no replication studies.
- A lack of studies and poor consistency within those that are available mean that there is little ability to have a general idea of what is occurring in regard to depression and anxiety in older age.

- Adding to this difficulty is the lack of differentiation between late life depression and those with early onset. This is also the case for anxiety.

Chapter 7 - Methods and Materials

This chapter will describe the methods used for a cross sectional study, results of which will be reported in Chapter Eight. The materials used and rationale for selection of these will also be described.

7.1 STUDY DESIGN

This study was approved by the University of Otago Human Ethics Committee (Health) (see Appendix A/B). Participants were given an information sheet prior to study participation (see Appendix C/D). Written informed consent was then obtained (see Appendix E/F).

This study was a cross-sectional study of people aged above 45 years. Participants all underwent the same assessment battery which included measures of mood, cognitive functioning, and emotion processing.

7.2 PARTICIPANTS

The sample consisted of participants meeting the following criteria:

- 45 years of age or older
- No history of, or current, major psychiatric conditions (e.g., DSM-5 Axis I disorders)
- No current serious alcohol and/or substance dependence
- No significant chronic medical illness or neurological disorders that may affect cognitive testing (e.g., cancer, Multiple Sclerosis, epilepsy)
- No history of significant brain injury (e.g., moderate/severe traumatic brain injury, stroke, anoxic injury)
- No use of medications that may cause cognitive changes (e.g., beta blockers)
- If visual or hearing impairment was present - corrective devices were used during the testing
- Montreal Cognitive Assessment score of 24 or above (as detailed below in Section 7.3.2)

7.2.1 Recruitment Procedure

Participants were recruited through advertisement. Advertising materials were shared using various methods including posters in public areas (e.g., libraries, cafes), social media (e.g., Facebook, emails to organisations and clubs), and word of mouth. Participants contacted the PhD candidate directly to discuss the study further and complete preliminary screening based on inclusion and exclusion criteria. When participants attended the testing session, they were given the information sheet (see Appendix C/D) and opportunity was given for questions and clarifications. Written informed consent was then obtained using the consent form (see Appendix E/F). Participants then underwent the testing battery.

7.2.2 COVID-19 Adaptations and Implications

From early 2020, the COVID-19 pandemic impacted healthcare and alongside this, health research worldwide. As was seen in many nations, changes and restrictions on business, travel, and social events were implemented and enforced in New Zealand. Restrictions of most significance to this study were mask mandates and nationwide lockdowns.

During the recruitment period for this study, two nationwide lockdowns occurred. During these periods individuals were required to stay at home unless they were deemed an essential worker (i.e., providing fundamental services such as food or healthcare) or were procuring necessities. After these initial lockdown periods, a step down of restrictions occurred over time, although people were still encouraged to stay at home as much as possible and mask mandates were still in place.

Due to these restrictions, face-to-face research activities were unable to be conducted for a significant period of time. Due to the sample consisting of older adults, extra caution was taken, and recruitment and testing was not restarted for a period, even when restrictions allowed for this. Due to the pen-and-paper and computerised nature of most of the tasks in this study, telehealth-based testing was not deemed a feasible alternative, and as such, recruitment needed to be placed on hold. It was noted that even when recruitment was restarted, there was a reluctance within society to go into communal spaces and this may have stopped potential participants, particularly older adults, from deciding to participate in the study. As such, recruitment for the study took significantly longer than was anticipated and this delay in conjunction with time restrictions of a PhD thesis has meant that some data gathered, and tasks completed during the testing, were unable to be presented in this thesis.

When face-to-face testing was able to be restarted after periods of restriction, some indoor mask wearing mandates were still in place. Due to this, for participants whose testing fell during these mandates, surgical masks were worn by both. Care was taken to ensure that this did not cause hearing difficulties for participants and that extra breaks were offered if participants seemed uncomfortable. Due to slow recruitment rates, this only affected a handful of participants, and once mask wearing became voluntary it was up to the participant whether they wished to wear a mask themselves and if they wished for the tester to wear one. Most participants chose for neither party to wear a mask during the testing.

7.2.3 Cultural Considerations for Māori

Māori are the tangata whenua (people of the land; indigenous people) of Aotearoa New Zealand. During the development of this study, Māori consultation was undertaken during the ethics application stage to ensure that culturally respectful and responsive research was being conducted and the principles of Te Tiriti o Waitangi were being adhered to. During recruitment, advertisements were placed in public locations and on social media and extra attention was given to placing these in areas where Māori might be more or equally likely to come across these (e.g., the Māori studies department of a university, supermarkets, public facilities). Unfortunately, due to the recruitment difficulties and restrictions, particularly the implications of COVID-19, relationships with the Māori community were not able to be properly developed, and as such, recruitment of Māori participants fell well short of what was aimed for. This is recognised as a significant limitation of this study. Less than 1% of study participants identified themselves as Māori, well below the current New Zealand population proportion of 16.5% (Stats NZ, 2018).

7.3 SCREENING INSTRUMENTS AND CLINICAL RATING SCALES

7.3.1 Administration of Measures

Testing for all participants involved in the study was completed by the PhD candidate. Prior to starting recruitment, the PhD candidate was trained in administering the testing battery by an experienced research nurse who had been involved in previous studies using these tasks. Additionally, during candidature the PhD candidate undertook formal training on the Montreal Cognitive Assessment as required by its creators. The PhD candidate was also completing clinical psychology training over this time period and as such is familiar with general guidelines and procedures for administering neuropsychological tests.

7.3.2 Montreal Cognitive Assessment: Version 7.1

The Montreal Cognitive Assessment (MoCA (Nasreddine et al., 2005)) was used to screen for mild cognitive impairment. This was included in the study due to the age range of the participants and the impact that cognitive decline may have on the subsequent cognitive based tasks.

The MoCA consists of 12 items examining seven cognitive domains: executive functioning; visuospatial abilities; language; attention, concentration and working memory; abstract reasoning; memory, as well as testing orientation to place and time. The MoCA is interviewer-administered using paper and pencil. Written instructions for version 7.1 were provided by MoCA Cognition with the test itself. These contained exact phrasing and allowable responses by the interviewer which were adhered to by the PhD candidate. During the PhD tenure, certification to use the MoCA became mandatory, and this training was completed by the candidate. Version 7.1 was continued to be used, as opposed to the newer version, to ensure consistency across the participants (see Appendix G).

In a systematic review by Abd Razak et al. (2019), the validity of screening tools for MCI and dementia was examined. The review found that the MoCA appeared to be a better screening tool for detecting MCI in primary care settings than others (e.g., Addenbrooke's Cognitive Examination III, Brief Cognitive Assessment Tool), with a high sensitivity of 83-97% and a specificity of 60-86%. A previous review also found the same result with 89% sensitivity and 75% specificity for the MoCA (Tsoi et al., 2015). Sensitivity is recommended as the gold-standard for a screening tool's validity over specificity at the first stage of testing (Abd Razak et al., 2019).

Psychometrically, the validation study by Nasreddine et al. (2005), which used the MoCA on three groups of people (healthy, MCI, AD), showed good internal consistency with a Cronbach alpha of 0.83. They also found that all items were able to discriminate between at least two of the groups, with most discriminating between all three groups in a step-down trend.

The 12 items of the screen add up to 30 points in total. A correction point is added to the scores of individuals with 12 or less years of education as the original validation study found that education affects overall performance (Nasreddine et al., 2005). This original study also showed no effect of age in healthy adults. Subsequent research has suggested that adjustments to the final total may need to be more nuanced, considering both age and education level

(Bruijnen et al., 2020), however, we have adhered to the current guidelines for use in regard to the total score.

While no changes were made to the calculation of final total scores, the cut-off used was lowered. This was undertaken as the original study was to include older people currently in a depressive episode. As is well known, MDD can cause significant cognitive deficits and it was felt that without loosening the MoCA criteria we would be significantly restricted in finding participants to include (Douglas et al., 2018). As the study and recruitment had already begun when the focus of this study changed, the cut-off was unable to be modified at this point. Supporting this, Malek-Ahmadi et al. (2015) examined what may be more appropriate cut-off points for older adults, taking into account both age and education as previous studies had highlighted that the currently recommended cut-off may be too stringent (Damian et al., 2011; Luis et al., 2009; Rossetti et al., 2011). Damian et al. (2011) found that a cut-off of 24 was optimal for reducing type I and II errors while maintaining high specificity and sensitivity in populations with possible prior cognitive decline, such as older populations, and Luis et al. (2009) suggested that 23 was most useful. Malek-Ahmadi et al. (2015) provided normative data for age and education cut-offs which ranged from 23-28. To this end, a cut-off of 24 was decided upon for this study.

7.3.3 Mini International Neuropsychiatric Interview: Version 5.0.0

The Mini International Neuropsychiatric Interview (MINI (Sheehan et al., 1998)) is a short (15 minutes) structured interview of psychiatric disorders based on the Diagnostic and Statistical Manual of Mental Disorders: 4th Edition (DSM-IV; (American Psychiatric Association, 1994)). The MINI has been found to reliably and validly obtain symptom criteria used in making DSM diagnoses (Sheehan et al., 1998). In the current study, the MINI was used as a screening tool to ensure participants had not experienced current or past clinical level psychiatric disorders including major depression (with or without melancholic features), dysthymia, suicidality, mania, panic disorder, agoraphobia, social phobia, obsessive-compulsive disorder, post-traumatic stress disorder, generalised anxiety disorder, alcohol abuse or dependence, anorexia nervosa, or bulimia nervosa. Initially, participants are asked yes/no questions about these psychiatric disorders. If any of the questions are answered as "yes" then a more detailed interview is conducted to see if a diagnosis needs to be considered (see Appendix H). The version used in the current study does not screen for personality disorder, and this was not assessed for in this study.

7.3.4 Quick Inventory of Depressive Symptomatology - Clinician Rated

The Quick Inventory of Depressive Symptomatology - Clinician-Rated (QIDS-C (Rush et al., 2003)) was used to assess for the presence of depressive symptoms. The QIDS-C was selected as it is a brief scale which provides an equal weighting to each symptom item and gives clearly stated anchors to items, making estimates of frequency and severity more consistent between participants. The assessment timeframe of seven days prior to the interview is also useful to assess current functioning, important in cognitive testing.

The QIDS was derived from the longer 30-item Inventory of Depressive Symptomatology (Rush et al., 2000; Rush et al., 2003). The scoring system for the QIDS-C transforms responses to 16 separate items into the nine DSM-IV symptom criterion domains used to characterise a major depressive episode. Four items are apportioned to sleep disturbance (early, middle, and late insomnia and hypersomnia), two items to psychomotor agitation and retardation, four items to appetite and weight disturbance, and one item for the following six domains: depressed mood, decreased interest, decreased energy, worthlessness and guilt, concentration and decision making, and suicidal ideation. Each item is rated from 0 to 3 and for symptom domains with more than one item, the highest score obtained on the relevant item for each domain was used. The total score is obtained by adding the scores of each of the nine symptom domains of the DSM-IV criteria, with higher scores indicating more symptoms reported (Rush et al., 2003; see Appendix I).

The QIDS-C has shown strong concurrent validity with established depression rating scales with robust correlations between QIDS-C and the Inventory of Depressive Symptomatology (IDS-C30) for outpatients with MDD (r = 0.82) and BD (r = 0.81) (Rush, Carmody, et al., 2006). The QIDS-C has also been found to be correlate strongly with the Hamilton Depression Rating Scale (r = .61 to .83) (Rush, Bernstein, et al., 2006) and evaluation of QIDS-C in comparison with the MADRS and the QIDS-SR revealed nearly equal Cronbach α reliability (r= 0.85-0.89) (n = 229) (Doraiswamy et al., 2010). High internal consistency (r = 0.85) has also been demonstrated for QIDS-C (Trivedi et al., 2004). A more recent meta-analysis of the psychometric properties of the QIDS (Reilly et al., 2015), analysing 37 studies, showed Cronbach's α of 0.65- 0.87 for the QIDS-C. They concluded that the QIDS-C is a scale with acceptable internal consistency.

The QIDS has been used in inpatient and outpatient psychiatric clinics, primary care settings, and a variety of research settings. In older persons, it has been used in depression samples and as a screening tool to distinguish between those with and without depression (Doraiswamy et

al., 2010). Doraiswamy et al. (2010) showed the QIDS-C was as good as or slightly better than the MADRS for detecting and screening for depression in older persons. While the Geriatric Depression Scale is likely the most widely used scale in the elderly, this study also includes people from a younger age group and it was necessary to have a scale applicable to both groups, and as such, the QIDS-C was chosen.

7.3.5 National Adult Reading Test

The National Adult Reading Test (NART) was used to estimate verbal IQ for all participants (Nelson & Willison, 1991). It is noted that using a test such as the NART as a measure of IQ maybe overly simplistic, as it does not consider other predictors of IQ such as demographic variables like education level and socioeconomic status. However, for the purposes of this study, the NART was only used as a rudimentary measure to check homogeneity between groups and as such, its accuracy as a level of general cognitive function is not as pertinent to this study.

The NART requires participants to read aloud a list of 50 English words, printed in order of increasing difficulty. This test is considered to be a reliable measure of verbal IQ in clinical settings (Strauss et al., 2006). This test is particularly useful in research which is focused on aging as word reading is a skill which has shown to be able to be preserved even in the presence of neurological and psychiatric disorders (Crawford et al., 2001). This task incorporates words that are phonetically irregular (e.g., ‘naïve’ and ‘gaol’) as well as words that are generally unfamiliar (e.g., ‘demesne’ and ‘campanile’). Including words that are unfamiliar means an individual’s prior word knowledge is tested, rather than solely relying on phonetic decoding ability (Nelson & Willison, 1991).

Participants were asked to read each of the words on the list aloud and the number of errors made were recorded. The predicted Weschler Adult Intelligence Scale- Revised Verbal IQ score is then obtained from the NART manual conversion table, using the total number of errors (see Appendix J) (Nelson & Willison, 1991). In this study, United Kingdom norms were used, as there was limited availability of New Zealand norms during study development. The number of mispronounced words was determined using the pronunciation guide for Australia and New Zealand, developed by Macquarie University of Australia.

7.3.6 Demographic Questionnaire

A demographic questionnaire was developed to obtain general information from all participants (see Appendix K). This was verbally administered by the PhD candidate. The

questionnaire covered demographic details including age, gender, ethnicity, English as first language, handedness, and confidence with computer use. Additionally, medical information covering current medical illness, current medication, visual and hearing impairment, history of head injury and/or neurological disease, and history of seizures was screened. Frequency of cigarette smoking, use of caffeinated beverages, and alcohol use was also collected (for a rationale for these items, see Section 7.4.3). Demographic factors including gender, handedness, and medications taken by participants will be presented and discussed in Chapter Nine.

7.4 COGNITIVE ASSESSMENT

7.4.1 Controlling for Factors That May Affect Cognitive Function

When undertaking cognitive studies, many factors need to be considered. Intelligence level, psychoactive substance use, and state anxiety can all influence cognitive functioning. These factors were considered in the current study by 1) measuring estimated premorbid verbal IQ, 2) noting substance consumption and timing for all participants, particularly considering any deviation from usual consumption, 3) measuring state anxiety for all participants at the end of the testing. A brief description of how these factors were measured is described in the following sections.

7.4.2 State Anxiety

The Spielberger State Trait Anxiety Inventory (STAI) State Questionnaire was administered to all participants at the end of the testing session (see Appendix L). This was done to consider if the testing process itself induced anxiety which may have influenced the emotion-based tasks in particular.

The STAI was designed as a brief self-report scale of both state and trait anxiety. The State section of the measure consists of twenty questions asking a person to "indicate how you **feel** right now, that is, **at this moment**". Response options given can be seen in Figure 4. To reduce the effects of acquiescence, the subscale itself was constructed to have 10 items for which high ratings indicate high anxiety and 10 items where high ratings indicate low anxiety (Spielberger, 1983).

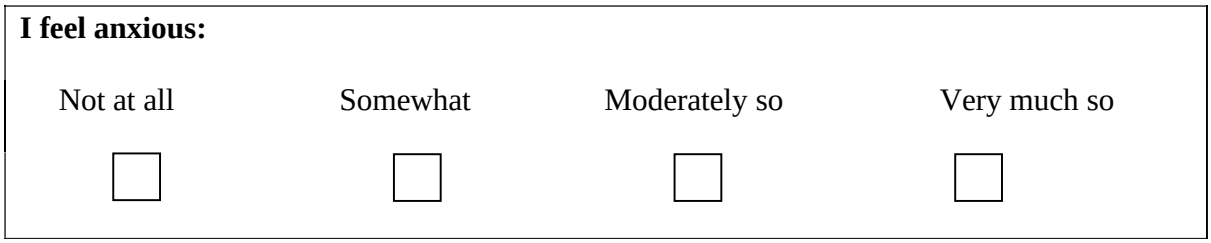

Figure 4 Sample of response options for the STAI state (Spielberger, 1983)

The STAI was chosen for this study as it has robust psychometric properties which have been shown across different population groups. The STAI has been shown to discriminate between healthy controls and those with anxiety disorders (Curtiss & Klemanski, 2015; Mohlman et al., 2004) which is useful alongside other mental health screening questionnaires to ensure the participants in this study are not affected by clinical level disorders. The STAI has also been shown as valid in detecting mental disorder in older adult patients, making it appropriate for use in this study (Kvaal et al., 2005). Overall, the STAI has been shown to have good validity (Kabacoff et al., 1997) and reliability (Barnes et al., 2002).

7.4.3 Psychoactive substances

Psychoactive substances, such as alcohol and nicotine, have been shown to affect cognitive functioning. Evidence suggests alcohol slows down the central nervous system which may impact on tasks assessing psychomotor speed (Lyvers & Maltzman, 1991; Weissenborn & Duka, 2003). Conversely, nicotine and caffeine consumption, may improve performance on cognitive tasks, especially those involving attention and working memory (Kumari et al., 2003). As part of the demographic questionnaire (see Appendix K), participants were asked about their consumption of alcohol, caffeine, and nicotine. If participants identified drinking alcohol in the past 12 hours or consuming significantly greater than their usual intake of caffeine or nicotine they were to be excluded from testing at that time. No participants had to be excluded due to this criterion.

7.4.4 Visual and Hearing Acuity

Prior to attending the testing session, all participants were reminded to bring any visual or hearing corrective devices with them to the session. As part of the demographic questionnaire (see Appendix K), participants were asked about their visual and hearing acuity, and it was ensured that corrective devices were used if needed to ensure performance was not impacted.

7.4.5 Cognitive Task Selection

The cognitive tasks in this study were selected with two aims in mind. The first was to have a range of cognitive tests assessing areas affected by aging (e.g., executive functioning, processing speed) and which involve processes which may contribute to completion of the below emotion processing tasks (e.g., attention, processing speed). The remaining tasks were a selection of paradigms that sought to measure emotion processing in various modalities (e.g., visual and verbal). Within these tasks, some that have shown differences across aging were chosen (e.g., FER), while other novel paradigms were also used (eStroop).

7.4.6 Order of Administration of Cognitive Tests

The test battery was administered to all participants in the same order (see Table 5). While doing this brings into play possible systematic biases, counterbalancing of tasks was not possible due to some tasks having a delay component, meaning only certain tasks were able to be administered during the delay period to minimise interference with the task involving the delay. In this battery, the verbal fluency, category fluency and category switching tasks were administered during the GMLT delay as these would not interfere with the visual nature of that task. Visual emotion processing tasks were also not presented sequentially to minimise overlapping of any information.

Table 5 *Order of Test Administration in the Cognitive Testing Battery*

Order	**Cognitive Test**	**Cognitive Domain**
1	Reading the Mind in the Eyes	Complex emotion recognition
2	Groton Maze Timed Chase Test	Psychomotor speed
3	Groton Maze Learning Test, immediate recall	Visuospatial learning and memory
4	Category Fluency	Verbal fluency
5	Category Switching	Verbal fluency and executive functioning
6	Groton Maze Learning Test, delayed recall	Visuospatial learning and memory
7	Digit Symbol Substitution Test	Psychomotor speed
8	Test of Facial Expression Recognition	Facial emotion processing
9	Emotional Stroop Test	Verbal emotion processing

7.4.7 Cognitive Testing Software

A variety of administration methods were used during the testing battery. Many of the tasks were paper-and-pencil tasks and these were administered using standardised instructions (Lezak et al., 2004). Computerised tasks were administered in line with the guidelines from the programmes used (Cogstate and E-Prime) as well as the instructions attached to the individual tasks. Computerised tasks were presented on a Dell Latitude E5570 laptop computer.

7.4.7.1 Cogstate

Cogstate Research™ is a digital cognitive testing system which can be customised and has been used in across a variety of different clinical populations. Cogstate version 5.13.1 was used to administer the Timed Chase Test and GMLT. A USB computer mouse was used by participants for responding. The Cogstate program automatically captures the task data and after testing the data was uploaded to the online data storage tool DataPoint.

7.4.7.2 E-Prime

E-Prime is software that enables customised computerised experiments and is commonly used in behavioural research (Schneider et al., 2002). In this study, the FER task and eStroop tasks were created using the E-prime software. This software package then allowed the tasks to be run and the data saved into useable files.

7.5 DESCRIPTION OF TASKS IN THE COGNITIVE TESTING BATTERY

7.5.1 Verbal Fluency

Verbal fluency is a commonly used measure of both executive functioning and verbal ability. The tasks require both executive skills such as inhibition (i.e. of words already used) and verbal skills like word finding (Sauzéon et al., 2011; Shao et al., 2014). Category fluency was chosen for this study as it is a commonly used task in research and clinical practice and the expected profile of changes with age is well-known. Using tasks where age-related changes are known is useful in determining what impact these areas of cognitive functioning might have on emotion processing.

There is evidence that demographic variables including, age, education, and sex influence category fluency performance (Strauss et al., 2006). Effects of age have been frequently reported, often from age 55, with total number of words produced reducing as age increases (Crossley et al., 1997; Gladsjo et al., 1999; Harrison et al., 2000; Stolwyk et al., 2015; Tombaugh et al., 1999; Troyer, 2000).

The task itself asks participants to name as many different examples as they can think of in a particular category (animals) within 90 seconds. The task is then repeated using a second category (boy's names). The responses are noted down in order by the examiner and the task is also audio recorded to ensure accuracy (see Appendix M). The recordings are deleted once the task has been marked. The primary outcome measure for the task is total words generated across both tasks. Secondary outcomes of words per category were also recorded.

7.5.2 Category Switching

Category Switching builds on the retrieval of semantically linked words from the category fluency task by adding the additional demands of switching and mental flexibility (Delis et al., 2001). This task also places more demand on working memory and inhibition than Category Fluency (Iudicello et al., 2008; McDowd et al., 2011).

The task itself asks participants to name as many different examples as they can think of in two different categories (fruit and furniture) within 90 seconds. They are required to alternate between saying one example from one category and then an example from the other category. The responses are noted down in order by the examiner and the task is also audio recorded to ensure accuracy (see Appendix N). The recordings are deleted once the task has been marked. The primary outcome measure for the task is total number of correct switches between categories. Secondary outcome of words per category were also recorded.

7.5.3 Visuospatial Learning and Memory

7.5.3.1 Groton Maze Learning Test

The computerised GMLT was used in this study to assess visuospatial learning and memory, alongside processing speed. The GMLT has been used in assessing visuospatial processing speed for many years and is a valid measure of this construct (Pietrzak et al., 2007). Of extra benefit to the study is that this task only takes five to ten minutes to administer (Faletti et al., 2006). The GMLT has demonstrated reliability and validity in assessing cognitive functioning across a variety of disorders (Cairney et al., 2007; Collie et al., 2003; Darby et al., 2002; Mollica et al., 2004). In a small study of older adults compared with younger participants convergent validity of the GMLT was substantiated when compared to two other tasks assessing visuospatial processing speed (Pietrzak et al., 2007).

The GMLT, as presented using Cogstate software, consists of a 10 by 10 grid of square tiles (see Figure 5). Under these tiles, a 28-step pathway from the start tile in the top left corner to the end in the bottom right is hidden. Participants are advised to find the hidden pathway, one

tile at a time. Four rules were enforced while trying to find this pathway: participants must move one tile at a time, i.e., no skipping tiles, participants are not allowed to move diagonally, participants must not move backwards along the pathway, and participants must not tap twice on the same tile. Feedback regarding accuracy of each move was given as the participant progressed through the pathway. Three practise trials, using a smaller 5 by 5 grid were given initially to ensure the participant understood the rules of the task. The main task then involved five successive trials, using the same pathway. After the five learning trials, participants were directed to complete two non-visual, unrelated tasks during a ten-minute delay (category fluency and category switching). After the delay period, participants were then asked to find the pathway they had been learning prior one more time. For each trial, the number of errors made, as well as the total number of moves, are automatically recorded.

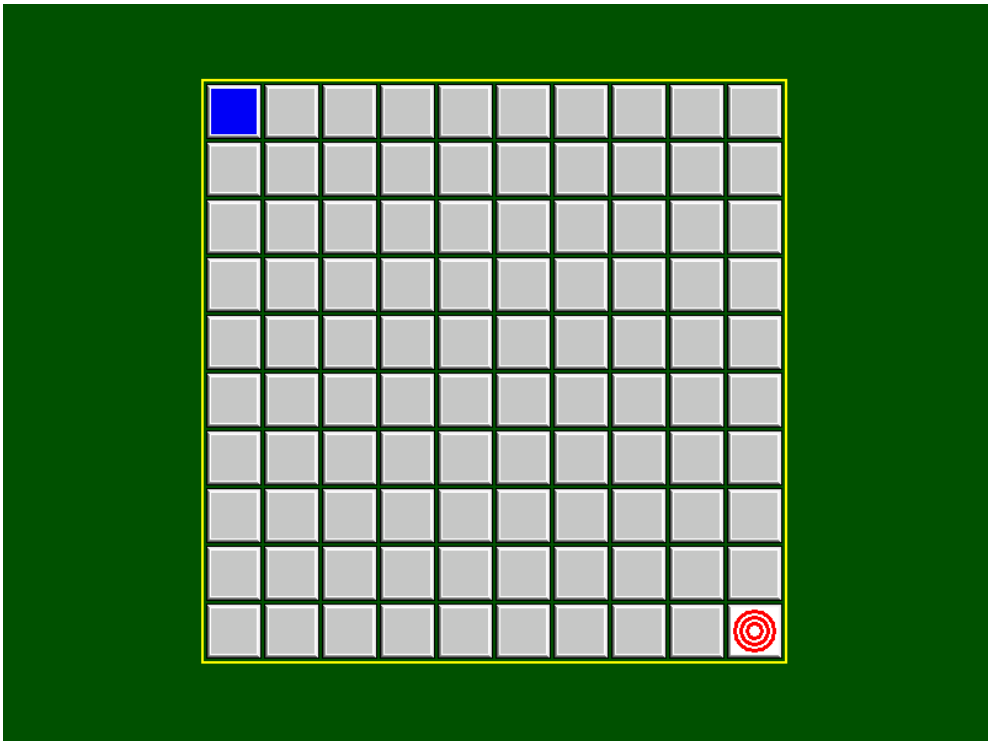

Figure 5 The Groton Maze Learning Test (CogState, 2006).

7.5.4 Processing Speed

7.5.4.1 Digit Symbol Substitution Test

The Digit Symbol Substitution Test (DSST) is predominantly a measure of psychomotor speed, and includes processes of visual scanning, motor persistence, response speed, and visuo-motor coordination (Schear & Sato, 1989). The DSST has been shown to be relatively unaffected by intelligence, education, or learning. (Erber et al., 1981; Hoyer et al., 2004). Age

effects in this task are well-identified, some appearing as early as the 30s (Wechsler, 1997). Raw scores drop significantly after the age of 60 (Ivnik et al., 1992).

In this task, participants are given a table which contains numbers from one to nine, and matching symbols below these numbers. They are then asked to draw the symbols that match each number in the blank square below it on a separate answer sheet (see Appendix O). They are given a practise trial where they practise drawing all the symbols. After this, they are presented with a sheet consisting of 100 boxes and asked to fill in as many boxes as they can in 90 seconds. They are asked to fill in the boxes from left to right, without skipping any. The primary outcome measure for this task is number of correct symbols drawn within 90 seconds.

7.5.4.2 Timed Chase Test

The Timed Chase Test (CogState) was included to measure visuomotor processing speed and as a control task for the motor speed aspect of the GMLT. This task used the same 10 by 10 grid of tiles as presented in the GMLT. Participants were instructed to follow a coloured moving tile, as quickly and accurately as they could, by clicking on the coloured tiles one after another. An untimed practise session was given to allow participants to become familiar with the task. After the practise trial, the main trial was presented, and participants followed the coloured tile for 30 seconds. The main outcome recorded was the number of correct moves per second in the main trial.

7.6 EMOTION PROCESSING TASKS

As emotion processing is the core feature of this study, four tasks measuring different aspects of emotion processing were selected to be included in the battery. Emotional cognition involves a range of functions including "perceiving, interpreting, managing, and generating responses to socially relevant stimuli, such as intentions and behaviour of others" (Green et al., 2012). Current research into aging shows a positivity bias in older adults (Mather & Carstensen, 2003). The aim of this study was to comprehensively examine emotion processing across different age ranges (particularly older individuals) and explore how 'cold' cognitive processes might affect this.

7.6.1 Reading the Mind in the Eyes

The RMET (Baron-Cohen et al., 2001; Baron-Cohen et al., 1997) was initially designed to assess emotion processing in individuals with autism spectrum disorders. This study has used the revised version of this task (Baron-Cohen et al., 2001). The RMET has previously been

used to measure emotion processing in psychiatric samples including patients with anorexia (Harrison et al., 2010), schizophrenia (Kettle et al., 2008), borderline personality disorder (Schilling et al., 2012), and in healthy samples (Sapienza et al., 2009; Voracek & Dressler, 2006).

Psychometrically the properties of the RMET have not been well investigated. Studies by the original authors provide scant data in this area and little follow up has been done on the original version of the task. A study using the Spanish version found acceptable test-retest reliability (Fernández-Abascal et al., 2013), and an Italian study (Vellante et al., 2013) showed a reliability value of 0.83 and an internal consistency (Cronbach' α) of 0.60. Another study in a Turkish population showed a reliability value of $p = 0.81$ (Yildrim et al., 2011). Local studies were not identified for this task. While psychometric properties of this task are inconsistent, the ease of use and simple method of completion made this task attractive for use in an older population.

The RMET consists of 36 images of the eye region of Caucasian individuals, and an additional practise item is used at the beginning (Baron-Cohen et al., 2001). The task requires participants to choose one of four adjectives (e.g., "jealous", "panicked", "arrogant", "hateful") which best describes what the person in the picture may be thinking or feeling (see Figure 6). There was no time limit given to complete the task, however, participants were encouraged to answer as quickly and accurately as they could. The participant score on this task was the total number of correctly identified items (see Appendix P).

Figure 6 Example from Reading the Mind in the Eyes Task (Baron-Cohen et al., 2001)

7.6.2 Test of Facial Emotion Expression Recognition

To examine facial emotion recognition in these groups, the FER Task developed by Harmer and colleagues at Oxford University was selected (Harmer et al., 2003). As noted in Chapter Five, there is growing evidence showing changes in facial emotion recognition across the lifespan. Including the FER Task allows for this to be examined not just in older people or in younger people, but in a sample which spans a wide age range, to more accurately determine when changes might be starting to occur.

This FER Task in this study used five of the six basic facial emotions, as described by Ekman (Ekman & Friesen, 1976); anger, disgust, happiness, sadness, fear, as well as neutral expressions. The pictures presented to the participants came from the Pictures of Affect Series (Ekman & Friesen, 1976). Each picture is morphed between the original (full emotion) and neutral by taking a variable percentage of the shape and texture differences between the two standard images 0% (neutral) and 100% (full emotion) in 10% steps (Bhagwagar et al., 2004; Young et al., 1997). In the current study, expressions depicting surprise (19) were not included and the number of neutral expressions presented was increased from 30 to 49. Furthermore, expression intensities from 50% of each emotion (halfway between the full emotion and neutral) to 100% of each emotion were included only (see Figure 7).

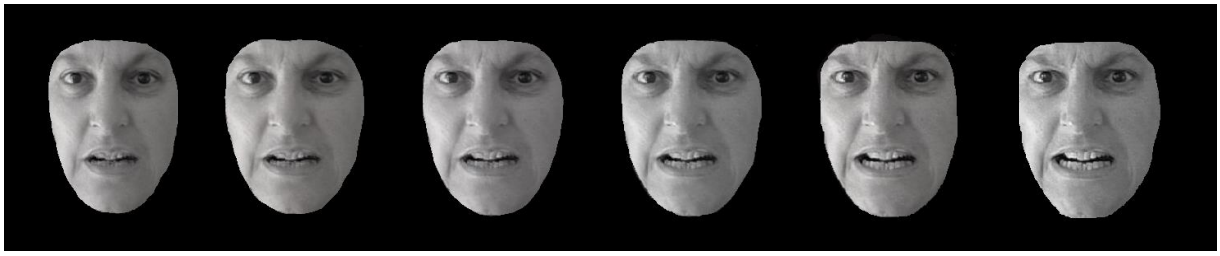

Figure 7 Example from Facial Emotion Recognition task

This task involved participants being presented with successive faces displaying one of the five basic emotions or a neutral expression on a computer screen. Each face was presented for 800ms and then followed immediately by a blank screen. Participants were instructed to press one of six labelled buttons on the response pad (NEUTRAL, ANGRY, HAPPY, SAD, FEAR and DISGUST) as quickly and as accurately as possible after the face was presented. A total of 144 pictures were presented (49 neutral, and 19 each of angry, happy, sad, fear, and disgust). The accuracy and reaction time for each picture was generated and recorded using E-Prime software. This task took approximately 10 minutes for participants to complete.

7.6.3 Emotional Stroop Test

To examine emotion processing and emotional interference effects, an emotional Stroop (eStroop) task was produced. The task was adapted from that used by McKenna and Sharma (McKenna & Sharma, 1995). E-prime software was used to develop the task. The words used are presented in Table 6. Research on the eStroop task in older populations has been presented in Chapter Five. This task was included in the battery to expand the emotion processing tasks to include non-facial stimuli.

Table 6 *Stimuli Words Used in the Emotional Stroop Task*

Negative Words	**Positive Words**	**Neutral Words**
HURT	GLAD	GATE
FEAR	HOPE	NOTE
CRASH	TREAT	CLOCK
GRIEF	BLISS	THUMB
DEATH	PEACE	FIELD
DOOM	FAIR	SEND
GLOOM	SUNNY	PULSE
WORRY	SMILE	PILOT
DANGER	BRIGHT	FOURTH
INJURY	CARING	BARREL
HATE	CALM	WIRE
SHOCK	CHARM	CABIN
ENEMY	HAPPY	COVER
AFRAID	VIRTUE	AUTUMN
MISERY	ADMIRE	ANCHOR
EVIL	NICE	FOOT
KILL	WARM	SHOP
GUILT	PRIZE	NAVEL

Negative Words	Positive Words	Neutral Words
TRAGIC	POLITE	SENIOR
LINK	HEAVEN	EXCEED
FIRE	LOVE	SOON
RAGE	ROSY	LINK
PANIC	LAUGH	PLATE
SORROW	SUPERB	DIVIDE
FATAL	JOYOUS	WILLOW

Participants were shown the instructions for the task on the computer screen (see Figure 8 for an example). Three presentation blocks were used in the task. Trial one was a non-letter condition which used letter (X) sequences the same length as the emotional words. This was used both as a practise trial and as a basic response time task. Participants were asked to respond using the laptop keyboard on which stickers with the correct colours were placed on the appropriate keys. The corresponding letters were left visible. The target word remained on the screen until a response was given. A delay of 500 milliseconds was in place once the response was given to enable time for the participant to reset for the next stimuli. In the main task the negative, neutral, and positive words were randomly presented one at a time using the different colours. Lastly, a trial presenting 25 colour incongruent words was used, representative of the original Stroop effect. The accuracy in naming the colours across the trials as well as the reaction times in the different trials were measured.

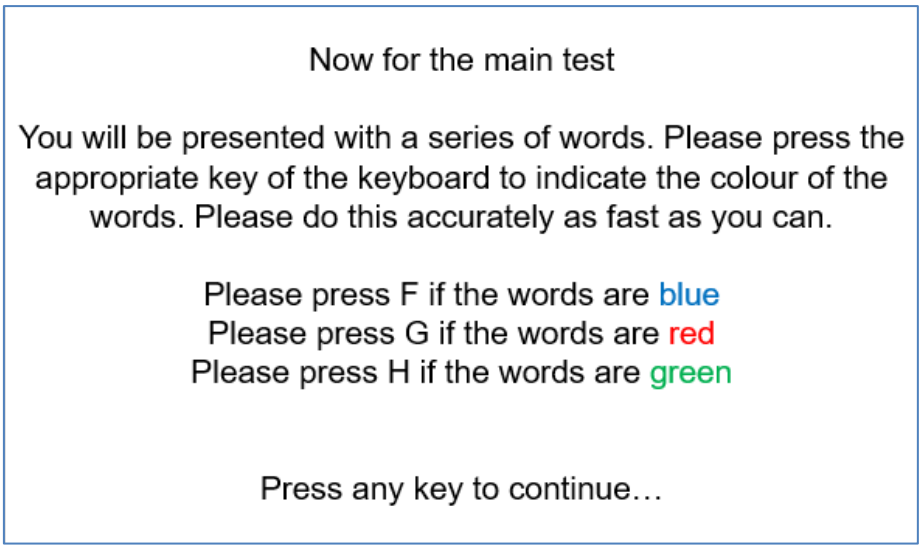

Figure 8 Instruction screen for emotional stroop task

7.7 DATA MANAGEMENT

7.7.1 Assumption of Normality

To confirm the assumption in parametric analysis that continuous variables are normally distributed, all such variables were plotted on a normal residual plot. All variables were found to be normally distributed.

7.7.2 Power Calculation

During the initial study design, statistical power calculations were undertaken to ensure that enough participants were recruited to enable the study to be able to detect differences between the groups, if they were present. In order to detect a difference of 0.5 of a standard deviation, or an effect size of 0.5, 64 participants in each group would give sufficient power (80 percent at α=0.05, two-tailed). Once the study was completed, it was decided to split the sample into four groups for the analysis.

7.7.3 Computer Software

Statistical Packages for the Social Sciences (SPSS), Version 28 for Windows was used for all statistical analyses and data storage (SPSS, 2021).

7.8 STATISTICAL METHODS

General statistical methods are described below. Methods specific to outcome measures are described in Chapter Nine. Statistical methods for the data analysis in Chapter Eight is presented in that chapter.

7.8.1 Approach to Analyses

Due to the number of outcome measures, multiple statistical comparisons were conducted which increased the risk of a Type I error. The risk of Type I error was addressed by 1) using an *a priori* analysis plan for each task to reduce the number of comparisons done, 2) including non-significant results alongside significant in the results for clarity, 3) interpreting results based upon patterns of outcomes rather than single values of significance, 4) clearly stating that further research would be needed to confirm any outcomes. To indicate statistical significance, a two-tailed alpha significance level <.05 was used.

7.8.2 Statistical Tests

7.8.2.1 Descriptive Data

One-way ANOVA and Pearson's Chi-square tests were used to analyse descriptive data. Means and standard deviations are presented for continuous data, and number of cases and percentages for categorical data.

7.8.2.2 Cognitive Tests

Differences on cognitive measures between age groups were analysed using univariate or repeated measures ANOVA. Age group was used as a between-participants factor for univariate tests. For repeated measures ANOVA, trial number (GMLT) or stimuli valence (FER, eStroop) were within-participants factors.

Correlations were conducted to determine associations between age group, non-emotional cognition, and emotional cognition using two-tailed Pearson's correlations.

7.8.2.2.1 Performance Index

A Performance Index (PI) was calculated using FER outcomes. As is also described in Chapter Nine, the PI was calculated as follows. FER accuracy and reaction time items were z-transformed. Z-scores outside a range of ± 2.5SD were excluded from further analysis as these outlying scores likely represent an impairment with that task which cannot be accounted for due to normal variation, such as a misunderstanding of instruction or individual cognitive impairment. The z-score for reaction time was then subtracted from that for accuracy with a higher score reflecting a combination of more rapid and accurate performance and a lower score reflecting more slower and incorrect responses.

Chapter 8 - The Effects of Age on Emotion Processing in a Healthy Sample of Older People

8.1 INTRODUCTION AND AIMS

Chapters Two through Six have presented the background for undertaking the current study. They have discussed the literature with regard to emotion processing in aging, and emotion processing in mental health conditions. Chapter Seven presented the methodology for the study presented in this chapter, which was designed to explore emotion processing (both facial and verbal) in a sample of healthy people aged over 45 years.

The chapter will first present the demographic data of the sample. Cognitive data will then be presented, categorised by cognitive domain.

The aims of this chapter are as follows:

- To examine how aspects of emotion processing change with age.
- To examine the effects of age on non-emotional cognitive functioning and how this relates to emotion processing.

8.2 DEMOGRAPHIC DATA

Descriptive statistics were calculated for each group. Differences between these groups were then examined using one-way ANOVA or Pearson's Chi-square test. Descriptive statistics for each group are presented in Table 7.

Table 7 *Means (SD) or Percentages for Demographic Characteristics in Age Groups*

Age Group	**N**	**Age (years) Mean (SD)**	**Gender Female (%)**	**NART score Mean (SD)**	**QIDS score Mean (SD)**	**STAI score Mean (SD)**	**Handedness Right (%)**
45 - 54	40	49.0 (3.7)	36 (90)	107.4 (7.6)	3.8 (2.6)	29.2 (5.1)	37 (92.5)
55 - 64	32	60.0 (2.9)	26 (81.3)	109.7 (7.7)	3.8 (2.3)	28.9 (9.1)	29 (90.6)
65 - 74	39	70.1 (2.8)	23 (59)	110.9 (7.3)	3.2 (1.7)	29.3 (5.9)	34 (87.2)
75+	26	78.6 (2.4)	15 (57.7)	110.0 (9.8)	3.7 (2.1)	30.6 (9.7)	25 (96.2)

NART = National Adult Reading Test; **QIDS** = Quick Inventory of Depressive Symptoms; **STAI** = State Trait Anxiety Inventory.

As seen in Table 8, no between-group differences were seen for NART, STAI, or QIDS scores. It was thus decided not to include these variables as covariates in the primary analyses. Gender was significantly different between groups, with the younger groups having significantly more females than the older groups. This may have been due to the nature of the recruitment, with men aged 45-65 more likely to be in full-time employment than women. In 2018, the New Zealand Census reported that in people aged 45-65, 78% of men were employed, compared with 56% of women (Stats NZ, 2018).

Table 8 *Between-Group Differences for Possible Covariates*

	STAI	**QIDS**	**NART**	**Gender**
Between Groups	$F(3, 132) = 0.29$, $p = .83$	$F(3, 128) = 0.61$, $p = .61$	$F(3, 133) = 1.32$, $p = .27$	$\boldsymbol{X^2}$ **(3,** $\boldsymbol{N}$ **= 137) = 13.95,** $\boldsymbol{p}$ **= .003**

Note: Significant outcomes in bold ($\boldsymbol{p} \leq .05$). **STAI** = State Trait Anxiety Inventory**; QIDS** = Quick Inventory of Depressive Symptoms; **NART** = National Adult Reading Test.

Table 9 presents data on the general medications taken in each age group. As described in Chapter Seven, care was taken to exclude participants taking medications well known to affect cognitive functioning (e.g., beta blockers), however, it is possible that other classes of medication may have small cognitive effects, and as such, medications are noted.

Table 9 *General Medications Taken Across Age Groups*

Medication Type	**45-54** **N = 40**	**55-64** **N = 32**	**65-74** **N = 39**	**75+** **N = 26**
	N (%)	**N (%)**	**N (%)**	**N (%)**
Non-steroidal Anti-inflammatories	-	3 (9.3)	1 (2.6)	5 (19.2)
Statins	-	3 (9.3)	9 (23.1)	6 (23.1)
Proton Pump Inhibitors	4 (10)	4 (12.5)	6 (15.4)	1 (3.9)
Birth Control	2 (5)	-	-	-
Hormone Replacement Therapy	1 (2.5)	1 (3.1)	-	-
Anti Hypertensives	1(2.5)	4 (12.5)	9 (23.1)	10 (38.5)
Oral Hypoglycaemics	-	1 (3.1)	2 (5.1)	4 (15.4)
Pradaxa	-	-	-	4 (15.4)
Other (e.g., Antihistamines, Antibiotics, Asthma Medication, Allopurinol)	9 (22.5)	4 (12.5)	9 (23.1)	6 (23.1)

8.3 COGNITIVE VARIABLES

The primary analyses looked at associations between cognitive functioning and age. Analyses are presented based on cognitive domain. These comparisons were calculated using univariate or repeated measures ANOVA. In these calculations, Age Group (45-54, 55-64, 65-75, and 75+ years) and Gender were entered as between-participant factors. For repeated measures ANOVA, different trials (e.g., trial in the GMLT) or types of stimuli (e.g., emotional valence in the FER Task) were within-participant factors.

8.4 VISUOSPATIAL LEARNING AND MEMORY

8.4.1 Groton Maze Learning Test

Repeated measures ANOVA was conducted on total errors on the learning trials of the GMLT, with Age Group and Gender as between-participant factors and Trial as a within-participants factor. There was a significant main effect of Trial, $F(5, 625) = 182.95$, $p < .001$, indicating a differential effect of trial overall. There was no Age Group by Trial interaction, $F(15, 625) = 1.1$, $p = .36$, indicating that there was no differential effect of Age Group between trials (see Figure 9).

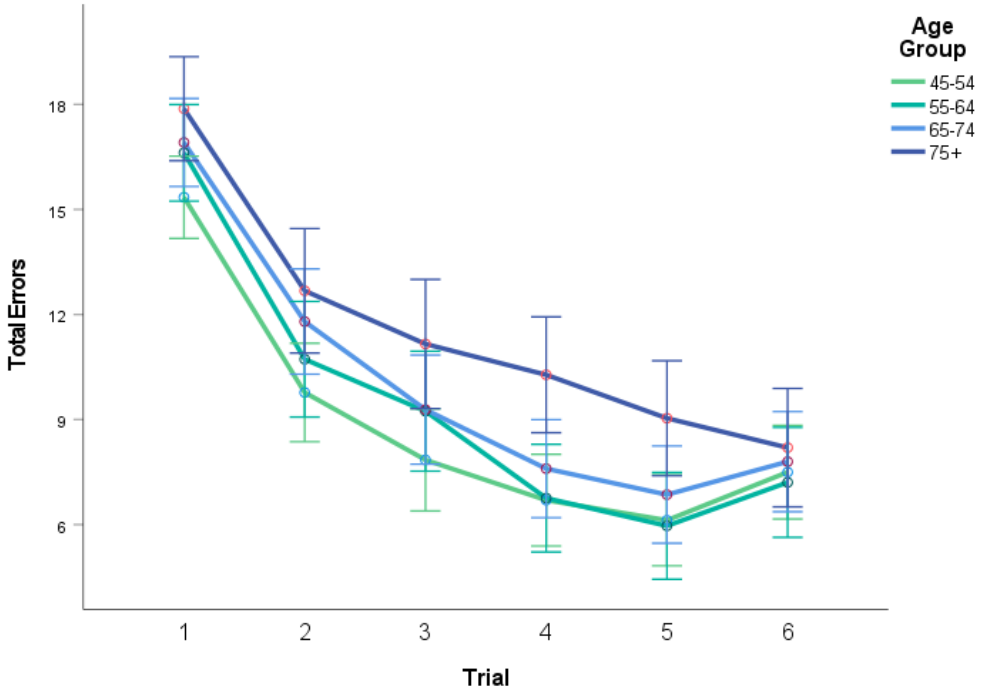

Figure 9 Mean (± s.e.m.) total number of errors on the Groton Maze Learning Test over the five learning trials and delay trial for all age groups.

Univariate ANOVA was conducted comparing the Age Groups on total number of errors for trials 1-5 of the GMLT, including Gender as a between-participants factor. A significant effect of Age Group was found, $F(3, 128) = 7.56$, $p < .001$ (see Figure 10), indicating that the total number of errors made during the learning trials in this task increases with Age Group, suggesting that visuospatial learning in this task becomes more difficult (i.e., less accurate) as people get older. A significant effect of Gender was found, $F(1, 128) = 12.61$, $p < .001$, showing that females made significantly more total errors on this task than men.

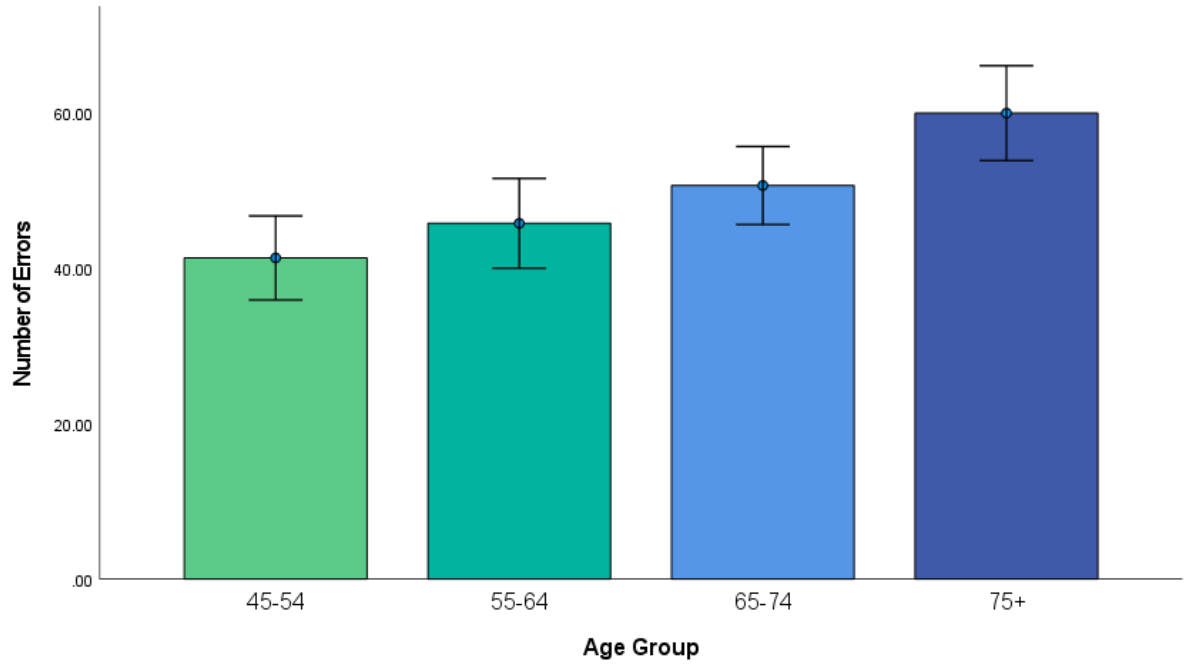

Figure 10 Mean (± s.e.m.) total number of errors for trials 1-5 combined on the Groton Maze Learning Test for all age groups.

8.4.2 Groton Maze Learning Test Delay Trial: Visuospatial Memory

A sixth trial of the GMLT was conducted 10 minutes after the learning trials. Univariate ANOVA was conducted comparing the Age Groups on total number of errors on the delay trial, including Gender as a between-participants factor. No significant effect of Age Group was found, $F(3, 124) = 0.97$, $p = .40$, showing that the number of errors made in this delayed recall task did not differ between Age Groups. This can be seen in Figure 11. A significant effect of Gender was found, $F(1, 124) = 9.24$, $p = .003$, reflecting that, similar to in the learning trials, females made more errors on this delay trial than males.

Delayed memory was further explored by adjusting for the number of errors made on the final learning trial, which was calculated by subtracting the total number of errors on the delay trial from number of errors on the final learning trial. This created an index of how much information was forgotten at recall. A univariate ANOVA was conducted with Age Group as a between-participants factor. No significant effect of Age Group was found, $F(3, 125) = 1.53$, $p = .21$, confirming no difference with age for visuospatial memory, irrespective of how much learning had occurred previously.

Overall, the GMLT findings suggest that visuospatial learning reduces with age, but visuospatial memory is less affected by age.

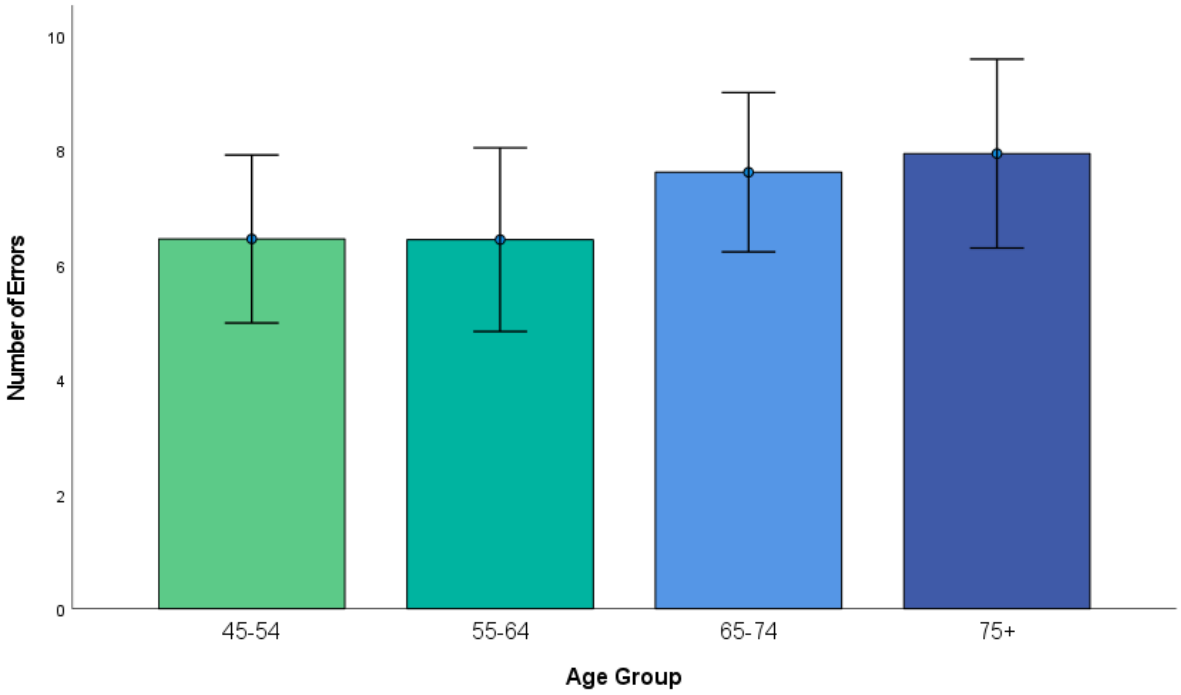

Figure 11 Mean total errors (s.d.) for the Groton Maze Learning Test- Delay trial

8.5 VERBAL FLUENCY AND SWITCHING

8.5.1 Category Fluency

Univariate ANOVA was conducted comparing the Age Groups on total number of words produced across both trials, animals and boys names, including Gender as a between-participants factor. No significant effect of Age Group was found, $F(3, 132) = 2.66$, $p = .051$. This effect can be seen in Figure 12 and indicates no change in the ability to produce words from different categories in a limited time frame as age increases. A significant effect of Gender was found, $F(1, 132) = 4.95$, $p = .028$, indicating that females produced significantly more words in the limited time period than males

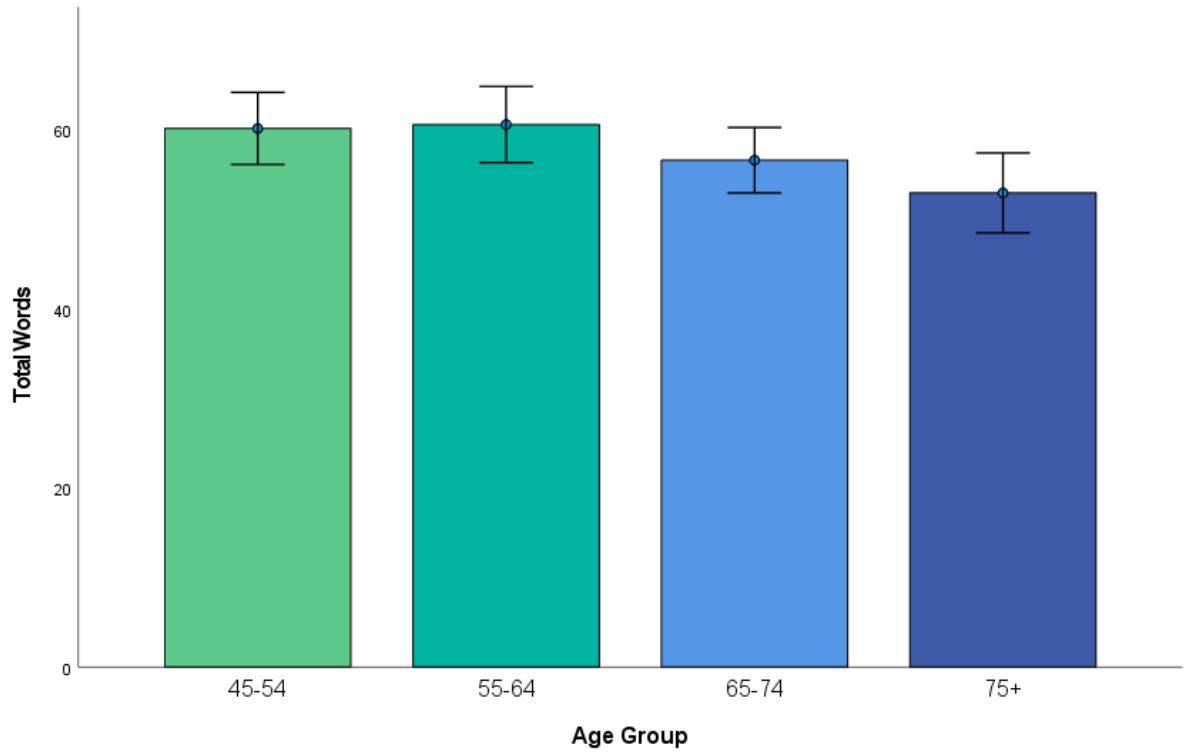

Figure 12 Mean (± s.e.m.) number of words generated on the Category Fluency task for all age groups.

8.5.2 Category Switching

Univariate ANOVA was conducted comparing the Age Groups on total number of correct switches between the categories of fruit and furniture, including Gender as a between-participants factor. A significant effect of Age Group was found, $F(3, 131) = 2.78$, $p = .044$, indicating a decrease in the number of switches between two categories able to be made in a limited time period with age. This effect can be seen in Figure 13. A significant effect of Gender was also found, $F(1, 131) = 5.33$, $p = .022$, reflecting that females made significantly more correct switches than males on this task.

Overall, these two verbal fluency tasks indicate that while there is little change in the number of words able to be produced in a limited time frame with age, when asked to do a more complex verbal fluency task involving mental flexibility (switching between two categories), older people have more difficulty.

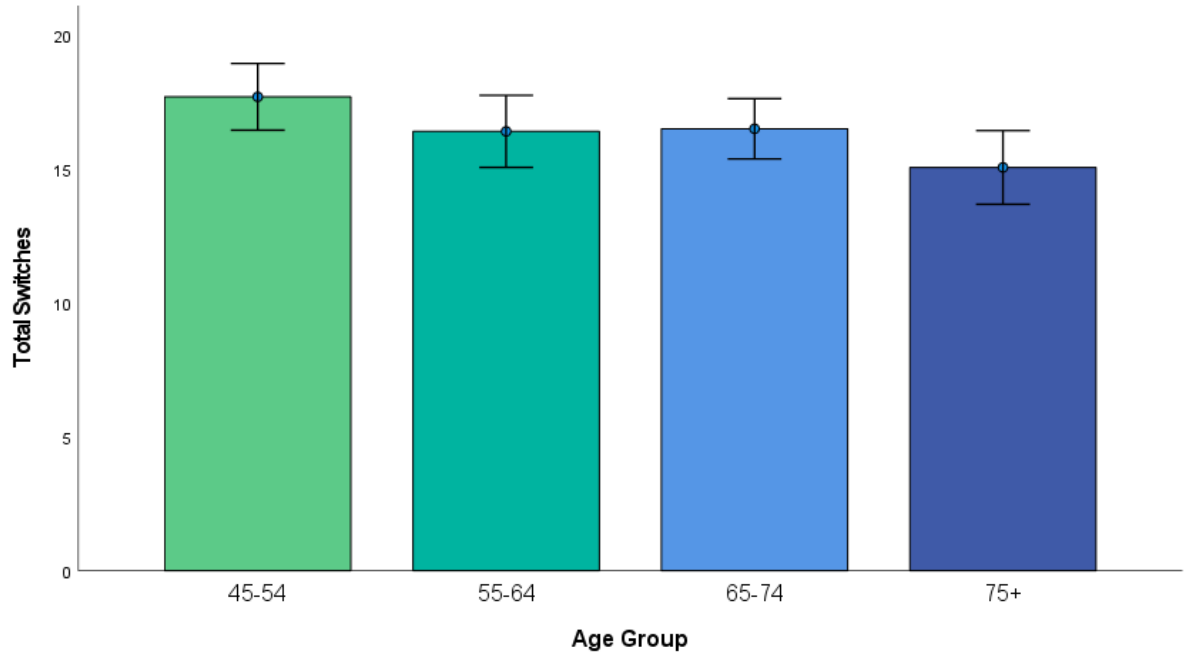

Figure 13 Mean (± s.e.m.) number correct switches on the Category Switching task for all age groups.

8.6 MOTOR SPEED AND VISUAL SCANNING

8.6.1 Digit Symbol Substitution Task

Univariate ANOVA was conducted comparing Age Groups on total number of correct symbols generated, including Gender as a between-participants factor. A significant effect of Age Group was found, $F(3, 129) = 19.40$, $p < .001$. This effect can be seen in Figure 14 which shows that as age increases, people are slower in this task. A significant effect of Gender was also found, $F(1, 129) = 4.26$, $p = .041$, indicating that females made more correct symbol substitutions than males on this task.

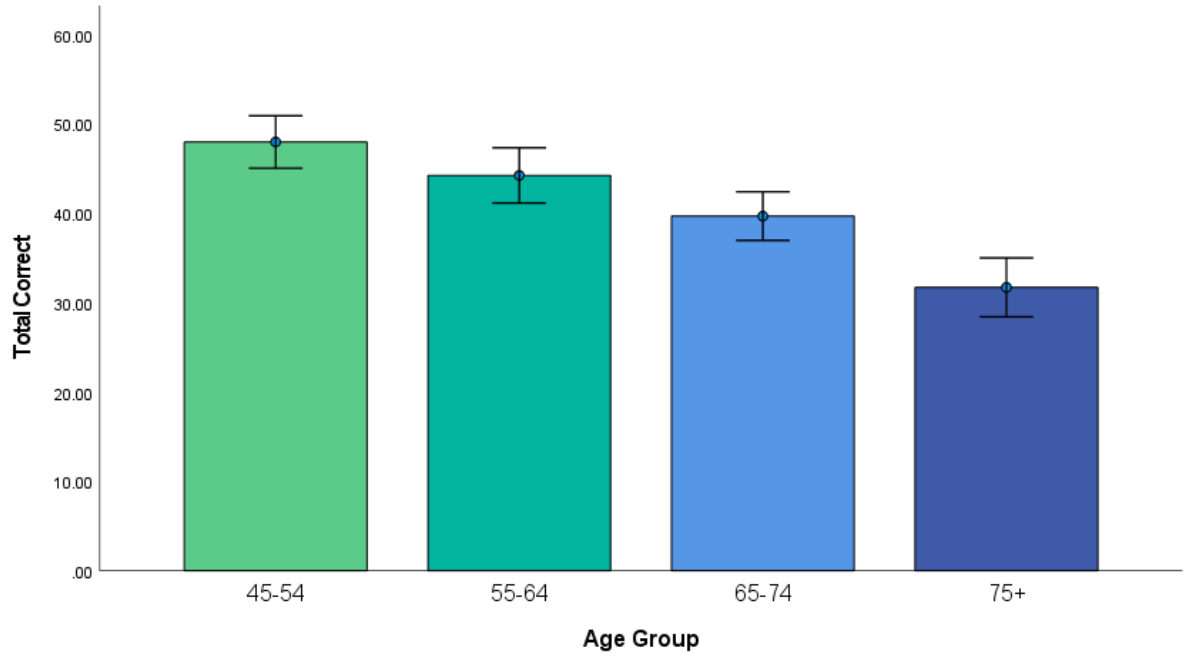

Figure 14 Mean (± s.e.m.) number of correct substitutions on the Digit Symbol Substitution Task for all age groups.

8.6.2 Timed Chase Test

The Timed Chase Test was performed as a precursor to the GMLT. Participants were required to chase a target around a grid of squares for 30 seconds. Univariate ANOVA was conducted comparing the Age Groups on total number of correct moves, including Gender as a between-subjects factor. A significant effect of Age Group was found, $F(3, 128) = 26.03$, $p < .001$, indicating that older participants were slower to follow the target in the time period. This effect can be seen in Figure 15. No significant effect of Gender was found, $F(1, 128) = 1.37$, $p = .25$.

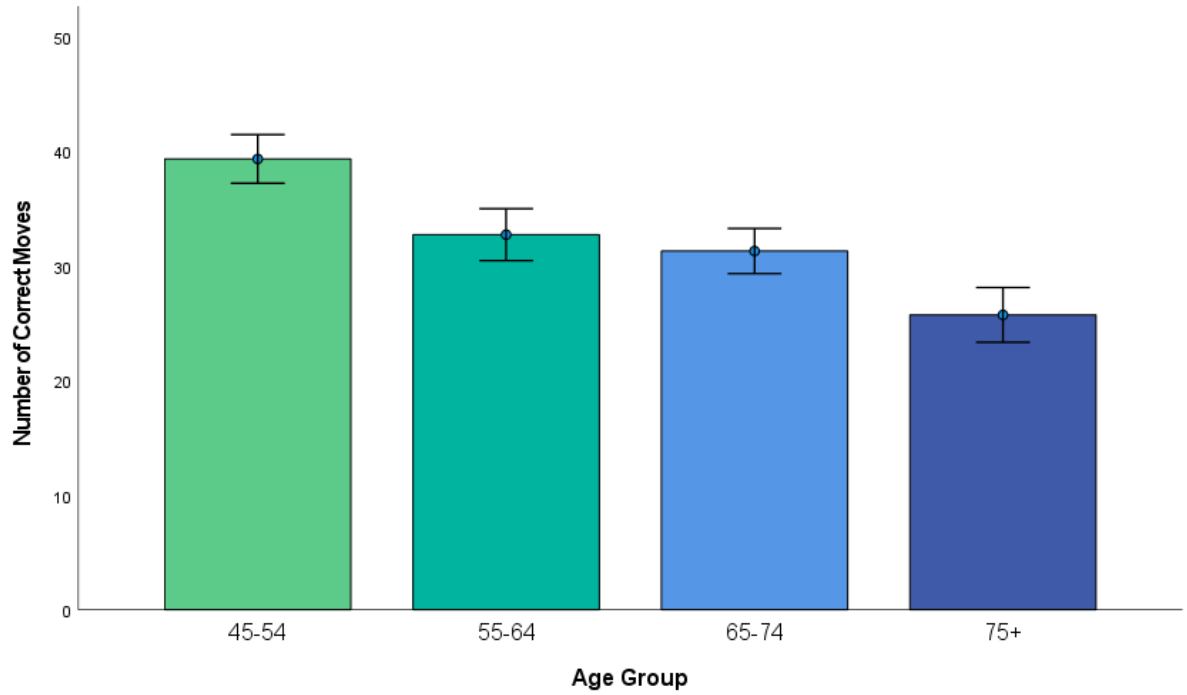

Figure 15 Mean (± s.e.m.) number of correct moves made in the Timed Chase Test for all age groups.

8.7 EMOTION PROCESSING

The RMET was examined using univariate ANCOVA to compare total number of stimuli correct between Age Groups, including Gender as a factor. For the remaining emotion processing tasks (FER and eStroop task) a repeated measures ANOVA was conducted to determine if an Age Group by Emotion interaction was present, and if so, individual univariate ANOVAs were done to elucidate further the nature of this effect. For the FER Task, outcomes examined were Accuracy (percentage correct), Reaction Time, a Performance Index (created using the procedure discussed in Chapter Seven), and Misidentification of neutral stimuli. For the eStroop Task, the outcome used was a change in reaction time variable, calculated by taking the time difference between the straight psychomotor speed portion of the task and each valenced trial, producing a value which could be attributed to the valence itself.

8.7.1 Reading the Mind in the Eyes Task

Univariate ANOVA was conducted comparing the Age Groups on total number of stimuli correct, including Gender as a between-subjects factor. No significant effect of Age Group, $F(3, 131) = 1.64$, $p = .18$, or Gender, $F(1, 131) = 1.38$, $p = .24$, was found. This can be seen in Figure 16.

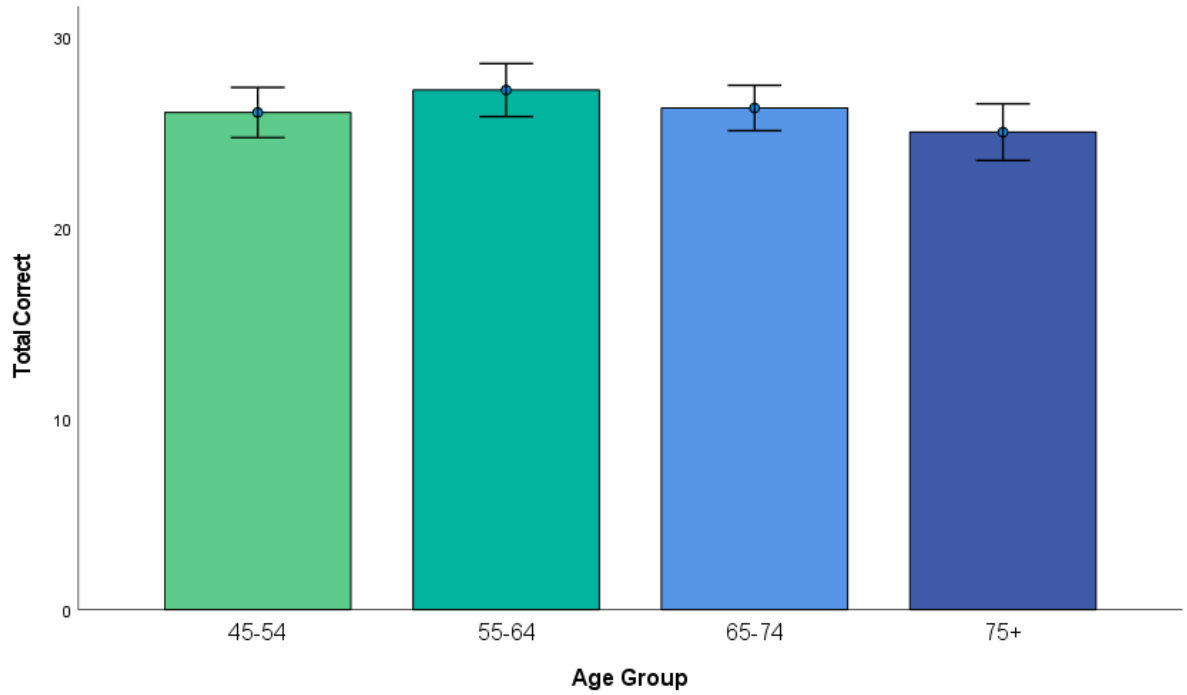

Figure 16 Mean (± s.e.m.) total number of correct emotions identified in the Reading the Mind in the Eyes Task.

8.7.2 Facial Emotion Recognition Task

Data for this task are presented per outcome measure. This was considered the most parsimonious method for examining what is happening per task component, and to allow consideration of an overall PI.

8.7.2.1 Accuracy

The total percentage correct for each emotion as an overall sample (Figure 17) and per Age Group (Figure 18) are presented below. These figures are presented to examine possible ceiling or floor effects, so these can be incorporated into interpretation of the more detailed analyses to follow.

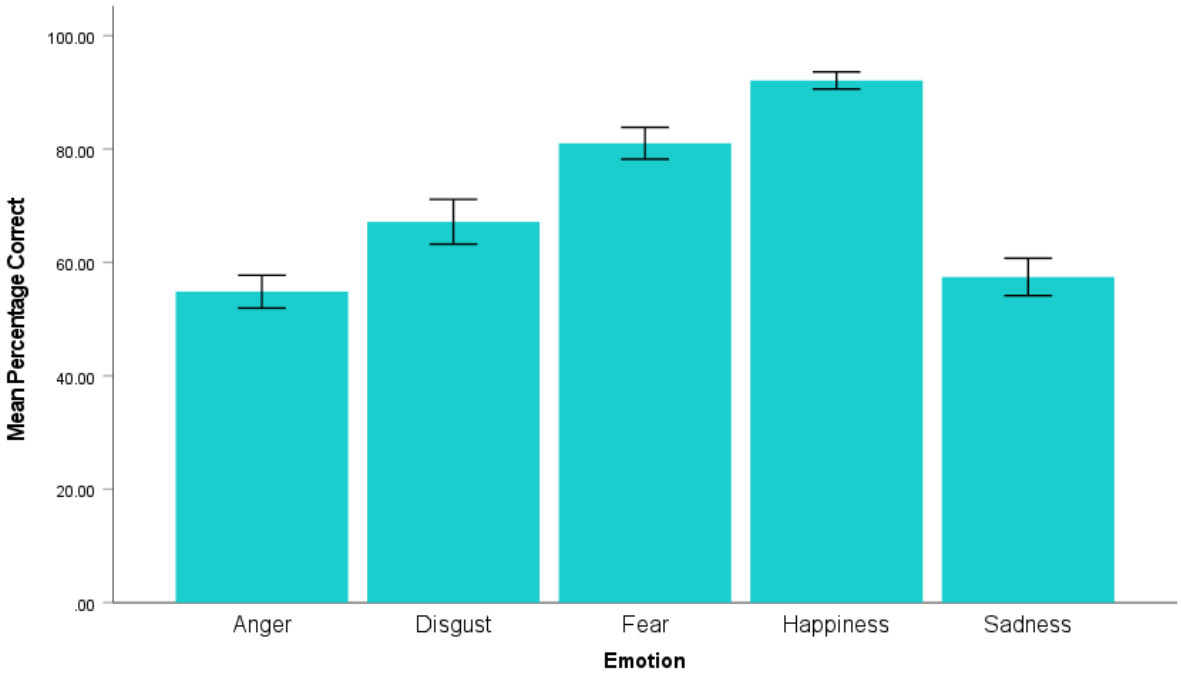

Figure 17 Mean (± s.e.m.) percentage of faces correctly identified by emotion in the Facial Emotion Recognition Task.

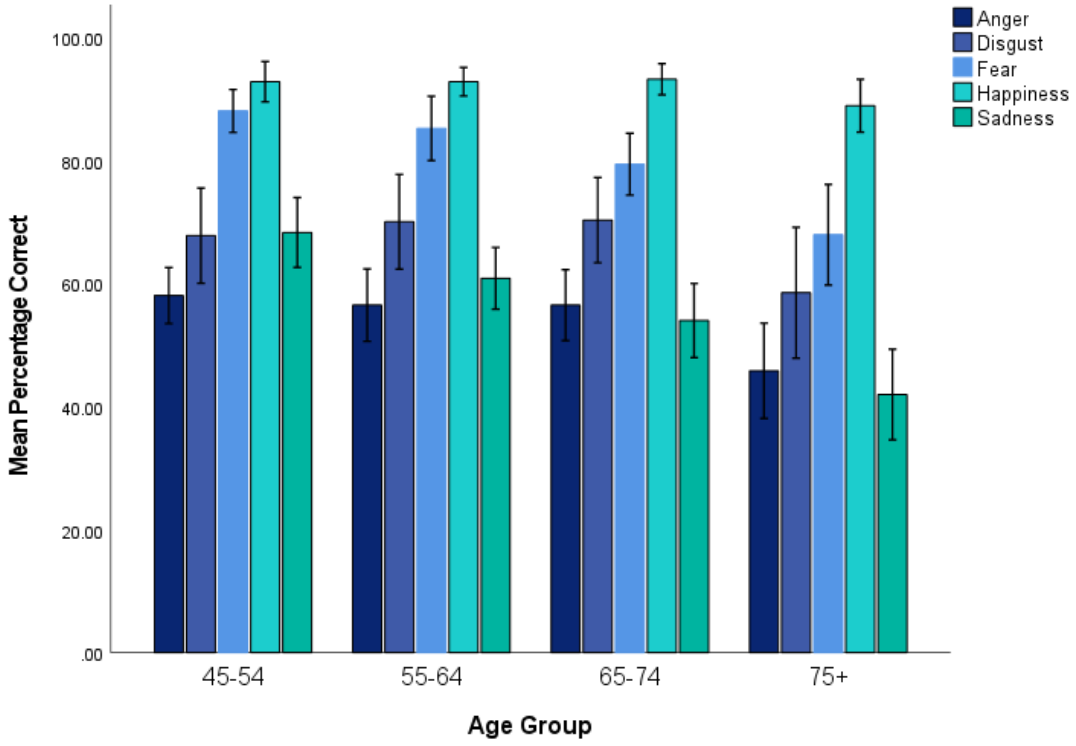

Figure 18 Mean (± s.e.m.) percentage of faces correctly identified by emotion per age group in the Facial Emotion Recognition Task.

Repeated measures ANOVA was performed to examine the effects of age on overall accuracy of recognition of emotions and whether age had differential effects on processing of different emotions (Age Group by Emotion interaction). A significant interaction between Age Group and Emotion was found, $F(12, 524) = 2.47$, $p = .004$, indicating that age has a different effect on accuracy of processing each emotion.

As can be seen in Figure 18 (see also Figures 19-20), there was a significant decrease in accuracy as age increases for fear and sadness. As can be seen in Figures 21-23, no difference with Age Group was seen for happiness, disgust, and anger. Gender differences were seen for anger, disgust, and sadness, with women being more accurate.

Table 10 *Univariate ANOVA of Accuracy by Age Group and by Gender for Each Individual Emotion*

Accuracy (%)	**Age Group**	**Gender**
Anger	$F(3, 130) = 2.60$, $p = .06$	$\mathbf{F(1, 130) = 4.06, p = .05}$
Disgust	$F(3, 130) = 1.50$, $p = .22$	$\mathbf{F(1, 130) = 5.17, p = .03}$
Fear	$\mathbf{F(3,1\ 30) = 8.24, p < .001}$	$F(1, 130) = 2.90$, $p = .09$
Sadness	$\mathbf{F(3, 130) = 10.20, p < .001}$	$\mathbf{F(1, 130) = 4.29, p = .04}$
Happiness	$F(3, 130) = 1.29$, $p = .28$	$F(1, 130) = 1.63$, $p = .20$

Note: Significant results in bold ($\mathbf{p} \leq .05$)

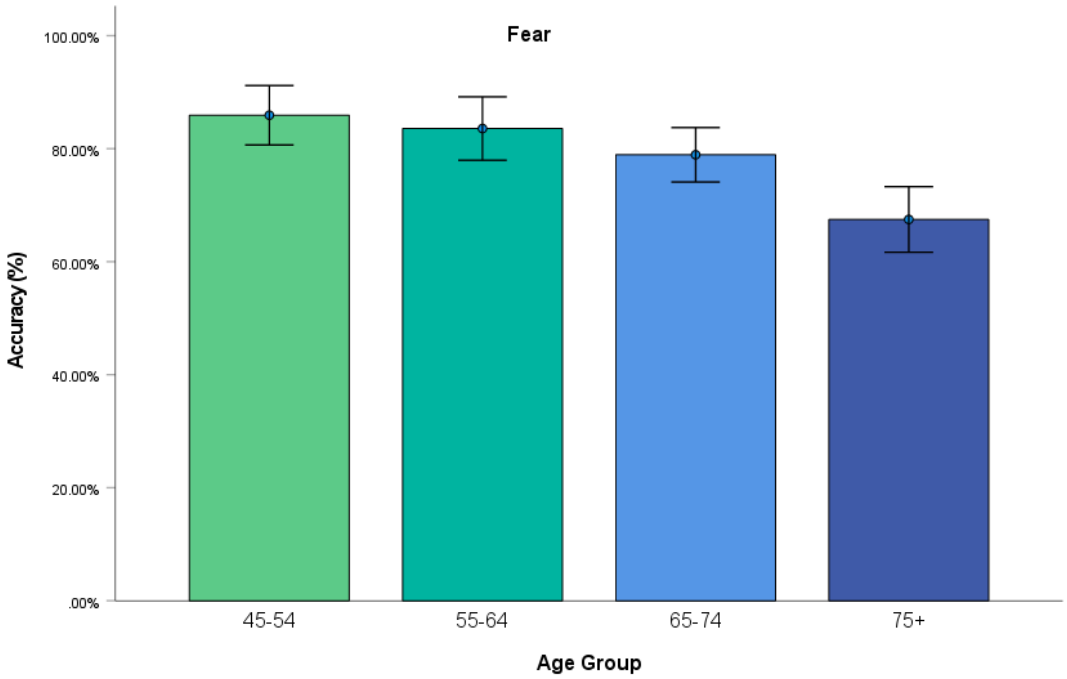

Figure 19 Mean (± s.e.m.) recognition accuracy for fearful faces, on the Facial Expression Recognition Task in all age groups

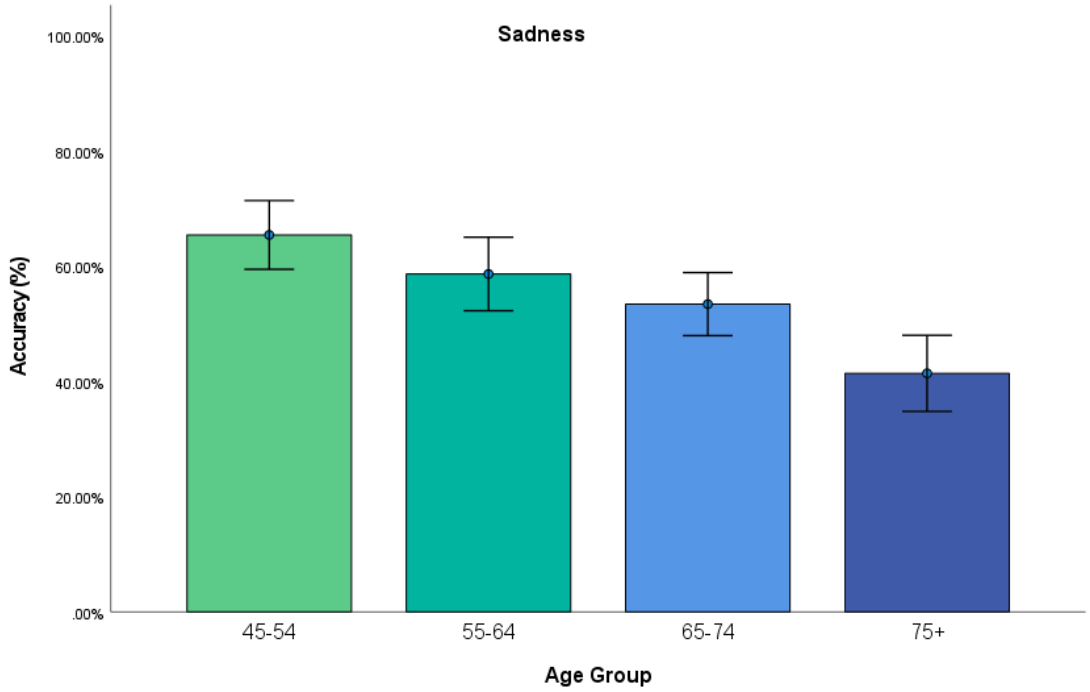

Figure 20 Mean (± s.e.m.) recognition accuracy for sad faces, on the Facial Expression Recognition Task in all age groups

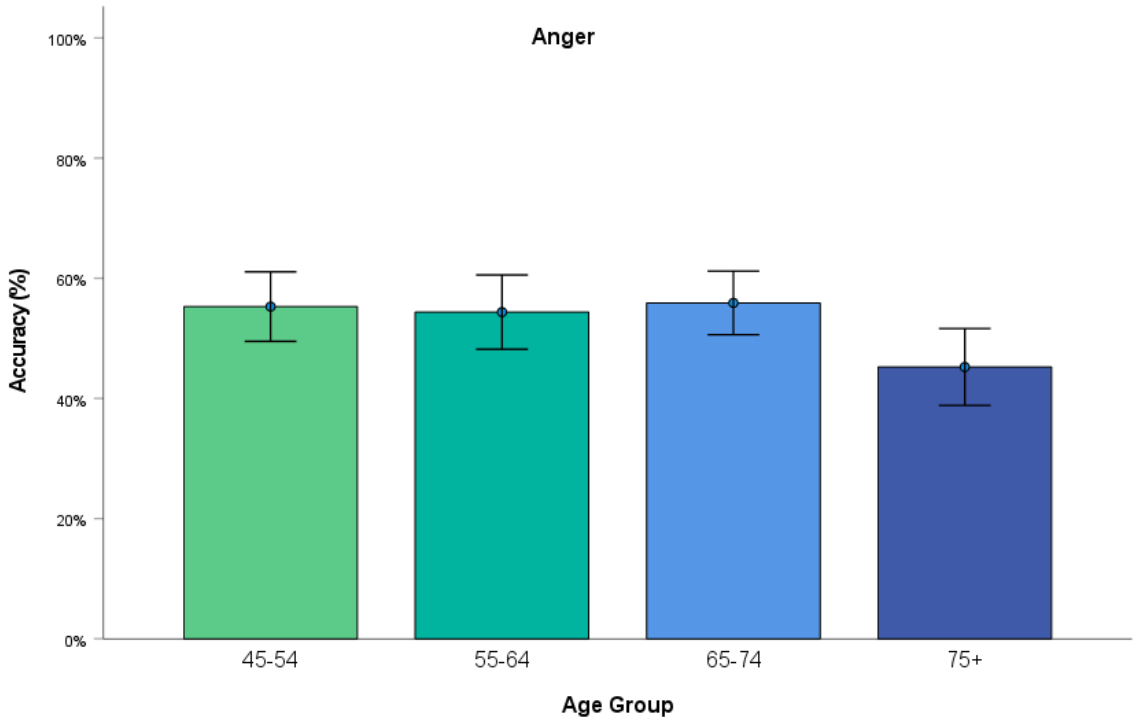

Figure 21 Mean (± s.e.m.) recognition accuracy for angry faces, on the Facial Expression Recognition Task in all age groups

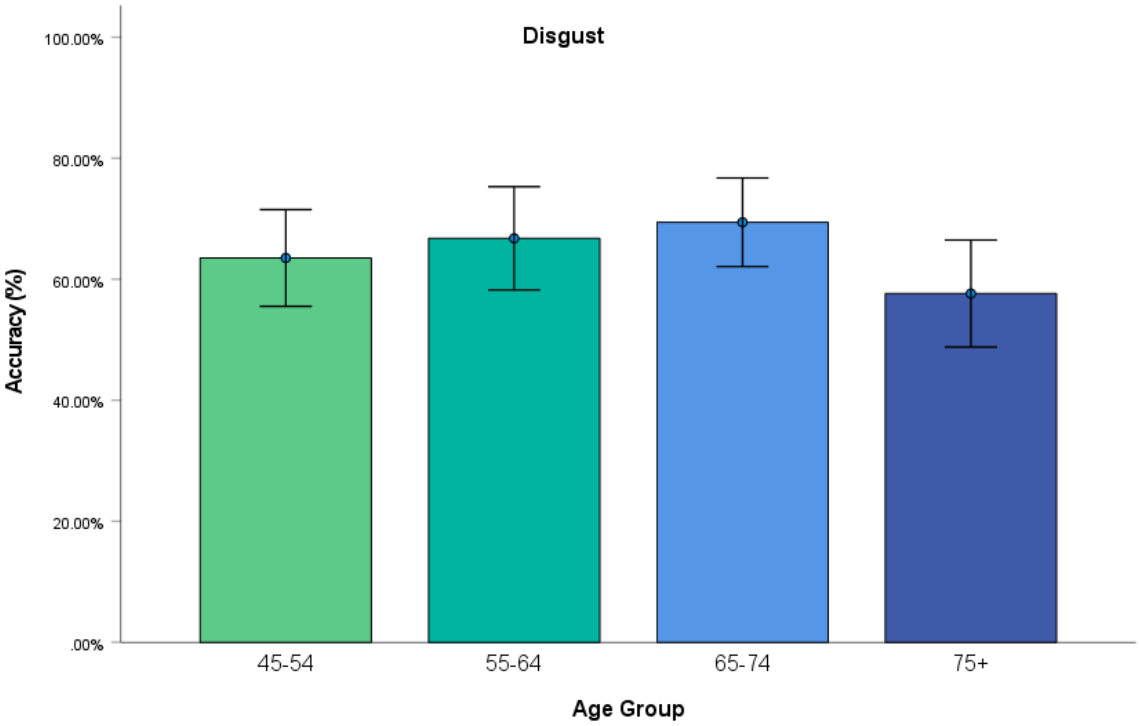

Figure 22 Mean (± s.e.m.) recognition accuracy for disgusted faces, on the Facial Expression Recognition Task in all age groups

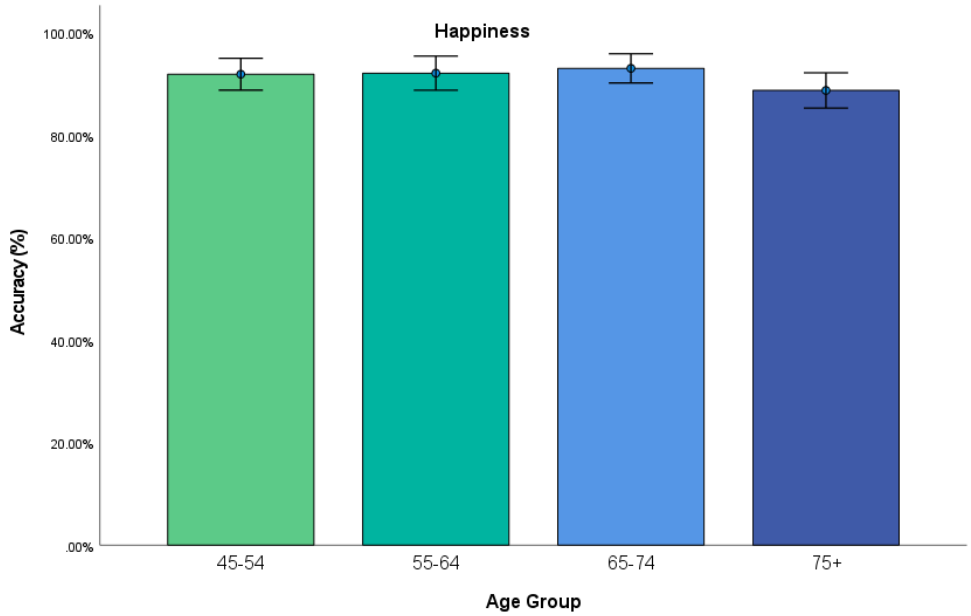

Figure 23 Mean (± s.e.m.) recognition accuracy for happy faces, on the Facial Expression Recognition Task in all age groups

8.7.2.2 Reaction Time

Repeated measures ANOVA was performed to examine the effects of Age Group on overall reaction time and whether Age Group had differential effects on processing of different Emotions (Age Group by Emotion interaction). A significant Age Group by Emotion interaction result was seen for Reaction Time, $F(12, 524) = 2.53$, $p=.003$, indicating that age has a different effect on reaction time for each emotion.

As can be seen in both Table 11 and Figures 24-28, significant differences were found between Age Groups for reaction time, with reaction time significantly increasing with age. No differences in Gender were present for reaction time.

Table 11 *Univariate ANOVA of Reaction Time by Age Group and by Gender for Each Individual Emotion*

Reaction Time (ms)	**Age Group**	**Gender**
Anger	***F*(3, 130) = 9.86, *p* < .001**	$F(1, 130) = 0.09$, $p = .76$
Disgust	***F*(3, 130)= 6.63, *p* < .001**	$F(1, 130) = 0.49$, $p = .48$
Fear	***F*(3, 130) = 14.11, *p* < .001**	$F(1, 130) = 0.91$, $p = .34$
Sadness	***F*(3, 130) = 14.22, *p* < .001**	$F(1, 130) = 0.002$, $p = .97$
Happiness	***F*(3, 130) = 4.85, *p* = .003**	$F(1, 130) = 0.08$, $p = .77$

Note: Significant results in bold ($p \leq .05$)

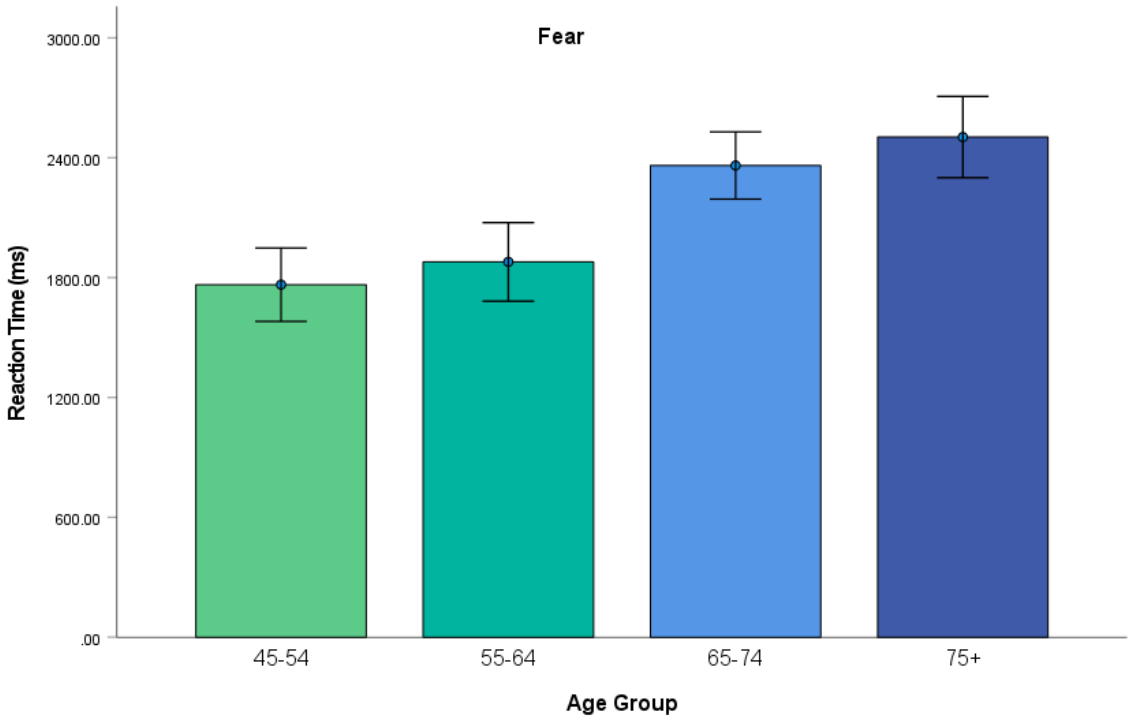

Figure 24 Mean (± s.e.m.) reaction time for fearful faces, on the Facial Expression Recognition Task in all age groups

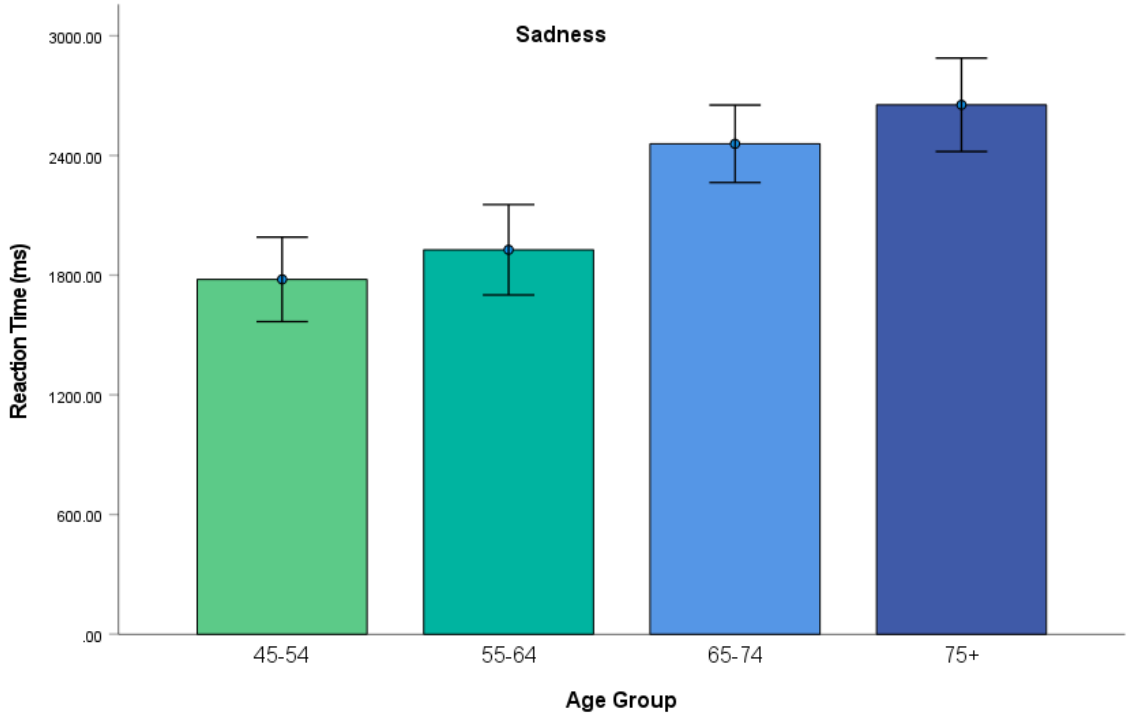

Figure 25 Mean (± s.e.m.) reaction time for sad faces, on the Facial Expression Recognition Task in all age groups

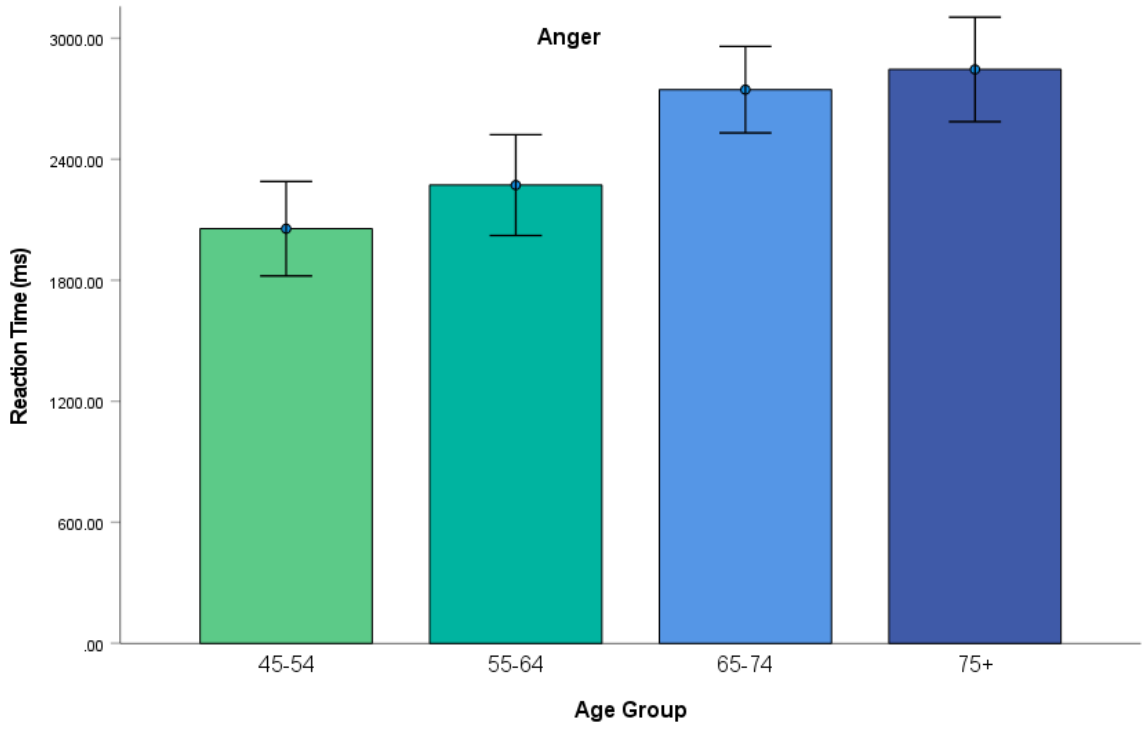

Figure 26 Mean (± s.e.m.) reaction time for angry faces, on the Facial Expression Recognition Task in all age groups

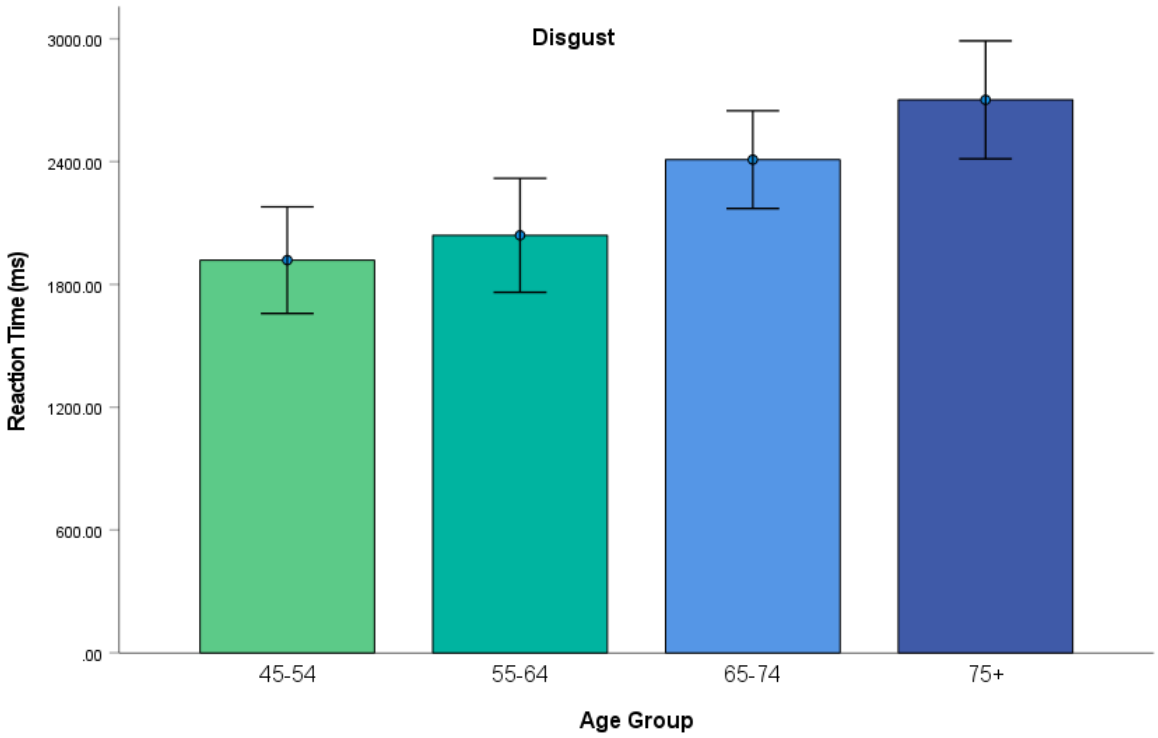

Figure 27 Mean (± s.e.m.) reaction time for disgusted faces, on the Facial Expression Recognition Task in all age groups

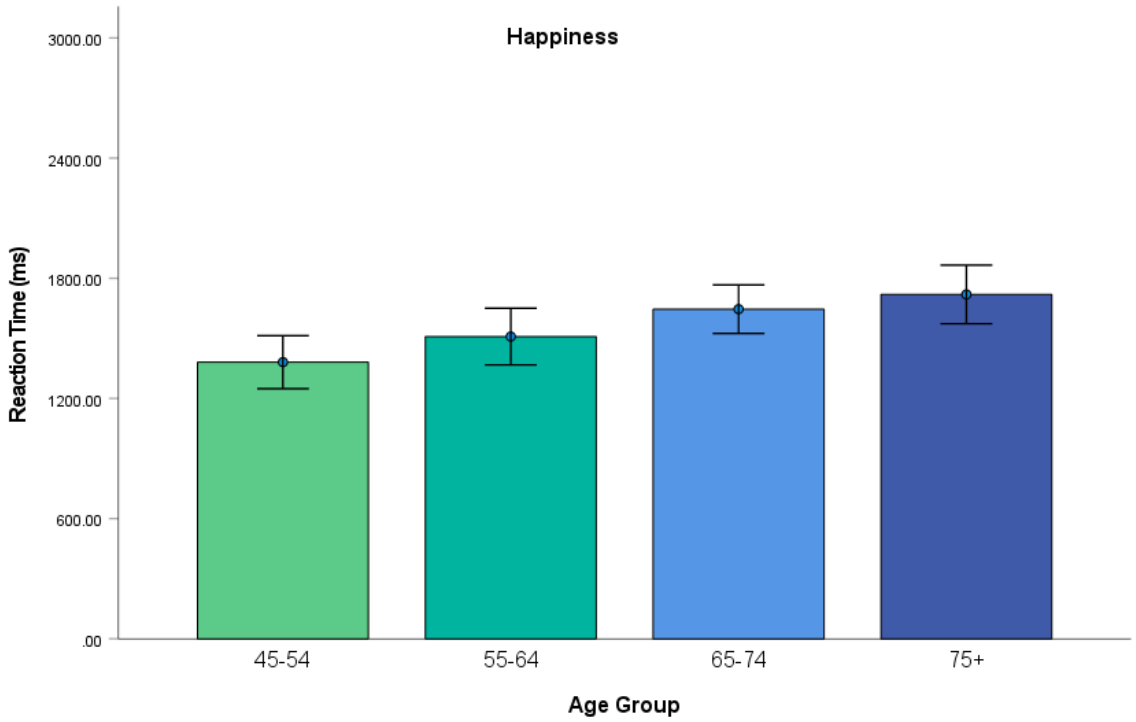

Figure 28 Mean (± s.e.m.) reaction time for happy faces, on the Facial Expression Recognition Task in all age groups

8.7.2.3 Performance Index

Repeated measures ANOVA was performed to examine the effects of Age Group on overall PI and whether Age Group had differential effects on efficiency of different Emotions (Age Group by Emotion interaction). A significant interaction between Age Group and Emotion result was seen for PI, $F(12, 460) = 2.31$, $p = .007$, indicating that age has a different effect on PI for each emotion.

Figures 29-33 and Table 12 show the significant change in PI across Age Groups. Increasing age was associated with a decrease in PI. As seen in Table 12, Gender differences were found in the PI for disgust, sadness, and happiness. Women were found to be more efficient than men for these emotions.

Table 12 *Univariate ANOVA of Performance Index by Age Group and by Gender for Each Individual Emotion*

Performance Index	Group	Gender
Anger	***F*(3, 127) = 7.58, *p* = .001**	*F*(1, 127) = 1.05, *p* = .31
Disgust	***F*(3, 124) = 6.28, *p* = .001**	***F*(1, 124) = 8.22, *p* = .005**
Fear	***F*(3, 122) = 16.40, *p* = .001**	*F*(1, 122) = 0.77, *p* = .38
Sadness	***F*(3, 126) = 30.24, *p* = .001**	***F*(1, 126) = 3.45, *p* = .07**
Happiness	***F*(3, 126) = 5.56, *p* = .001**	***F*(1, 126) = 4.12, *p* = .05**

Note: Significant results in bold (***p*** ≤ .05)

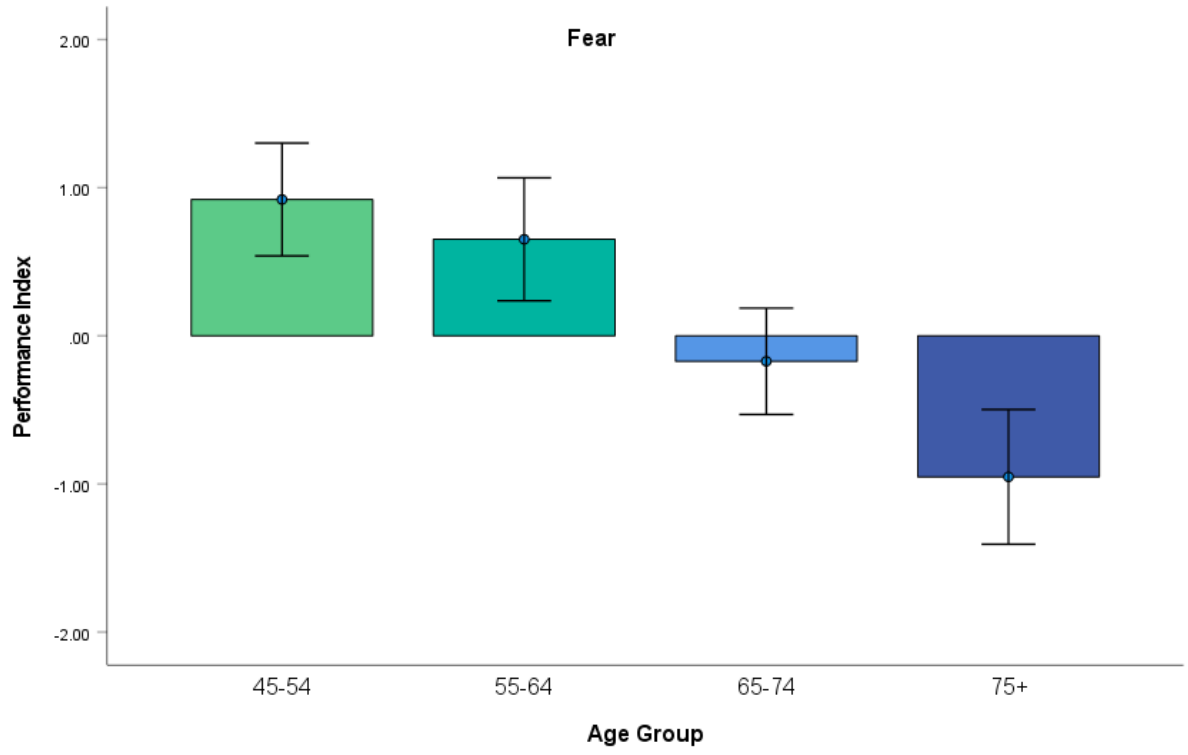

Figure 29 Mean (± s.e.m.) performance index for fearful faces, on the Facial Expression Recognition Task in all age groups

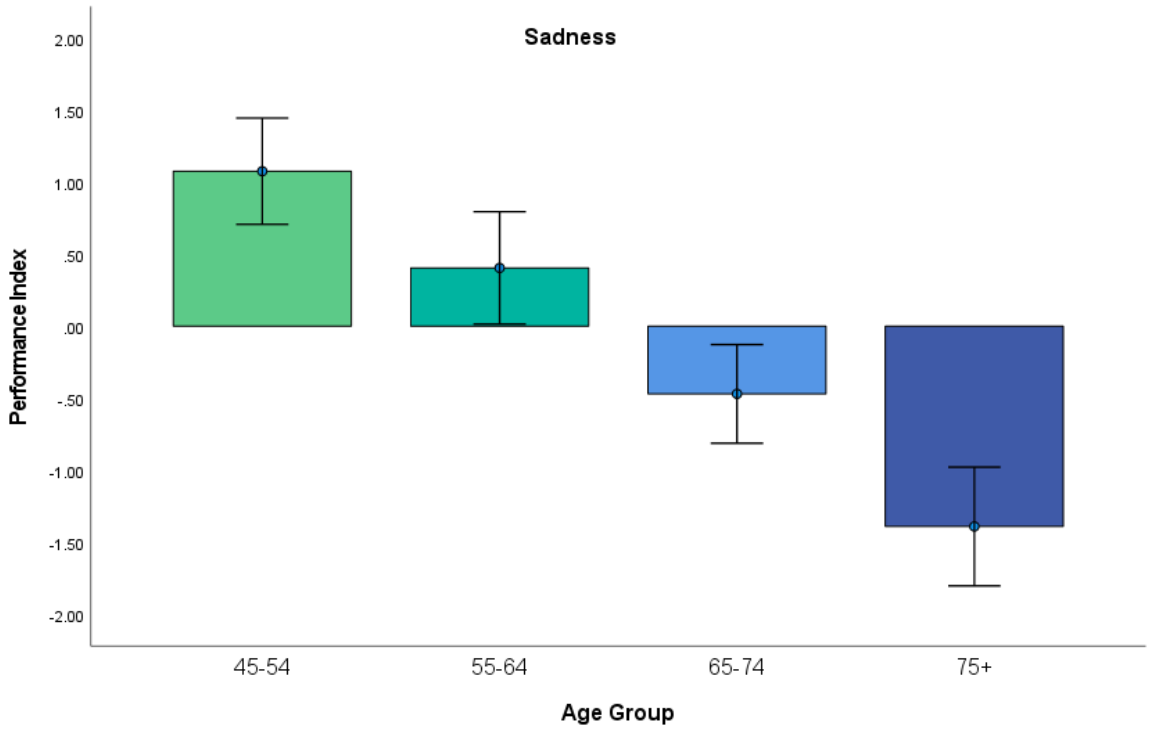

Figure 30 Mean (± s.e.m.) performance index for sad faces, on the Facial Expression Recognition Task in all age groups

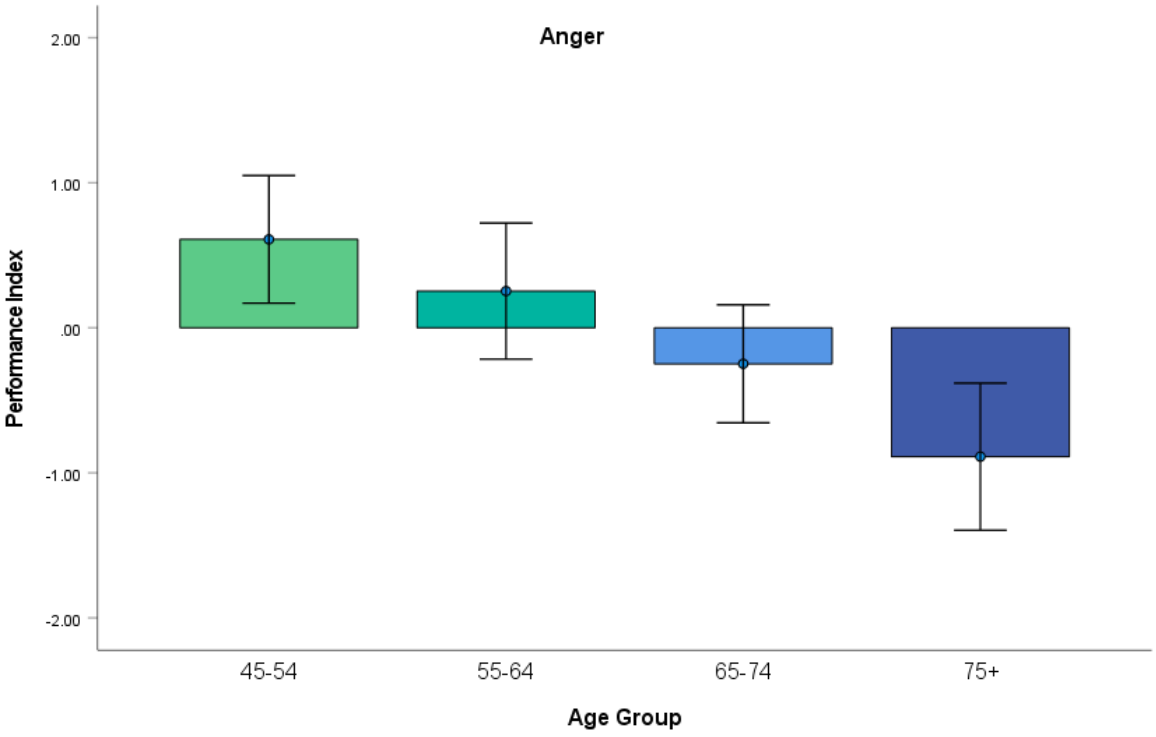

Figure 31 Mean (± s.e.m.) performance index for angry faces, on the Facial Expression Recognition Task in all age groups

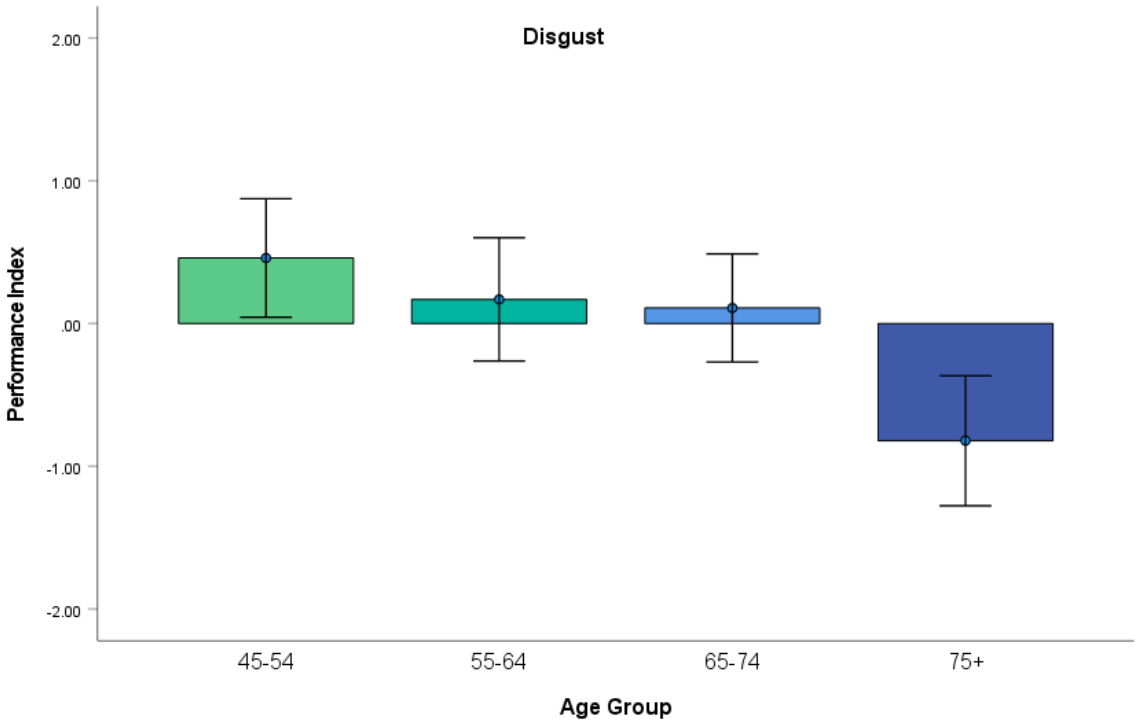

Figure 32 Mean (± s.e.m.) performance index for disgusted faces, on the Facial Expression Recognition Task in all age groups

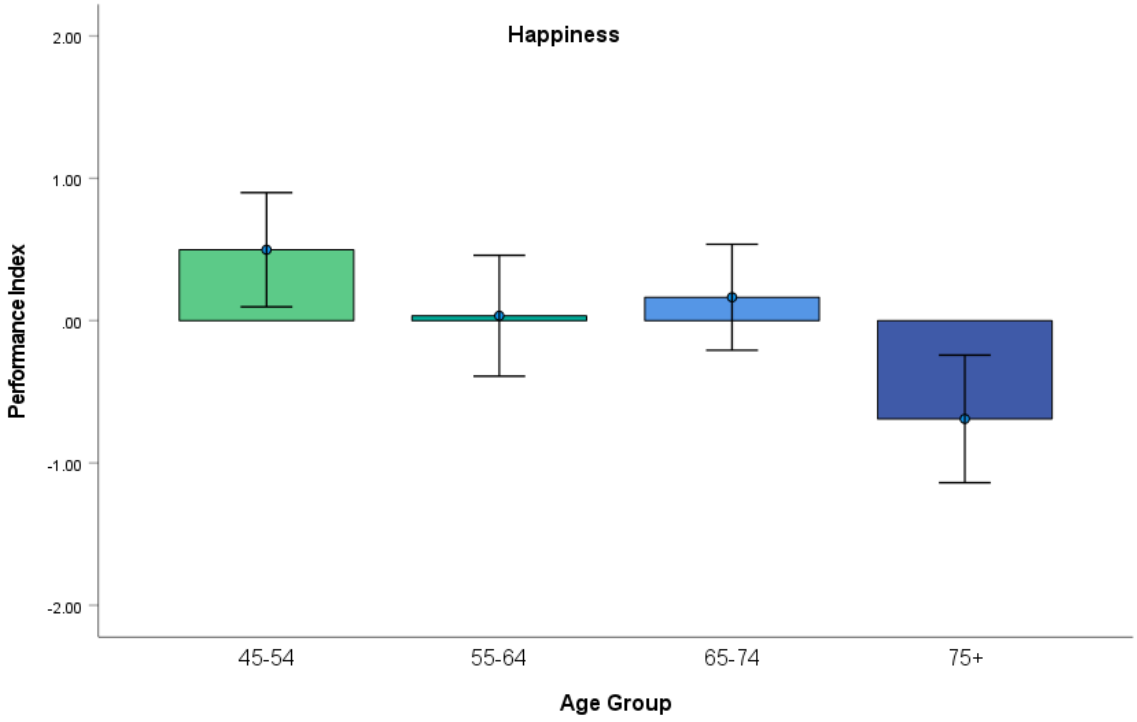

Figure 33 Mean (± s.e.m.) performance index for happy faces, on the Facial Expression Recognition Task in all age groups

8.7.3 Neutral Misidentification

As mentioned previously, evidence of emotional processing bias has been found by examining how neutral faces are categorised when they are misidentified as emotional faces. The FER Task used in this study had a sufficient number of neutral faces present in the task (49) to allow for analysis of this process. For this analysis, the misidentified faces were categorised in two ways, those that had been misidentified to happiness (i.e., positive valence) and those that had been misidentified to either sadness, anger, or fear (i.e., negative valence).

No significant difference was seen in the percentage of neutral faces misidentified as happiness between Age Groups, $F(3, 130) = 0.65$, $p = .59$ (see Figure 35). A significant difference was seen in the percentage of neutral faces misidentified as a negative valence (sadness, anger, or fear) across Age Groups, $F(3, 130) = 3.24$, $p = .02$. As seen in Figure 34, findings showed that as age increased, participants were less likely to misclassify neutral faces as sadness, fear, or anger.

No significant effects of Gender were found in these analyses for either misinterpretation to positive, $F(1, 130) = 0.001$, $p = .98$ or negative facial expressions, $F(1, 130) = 0.13$, $p = .73$.

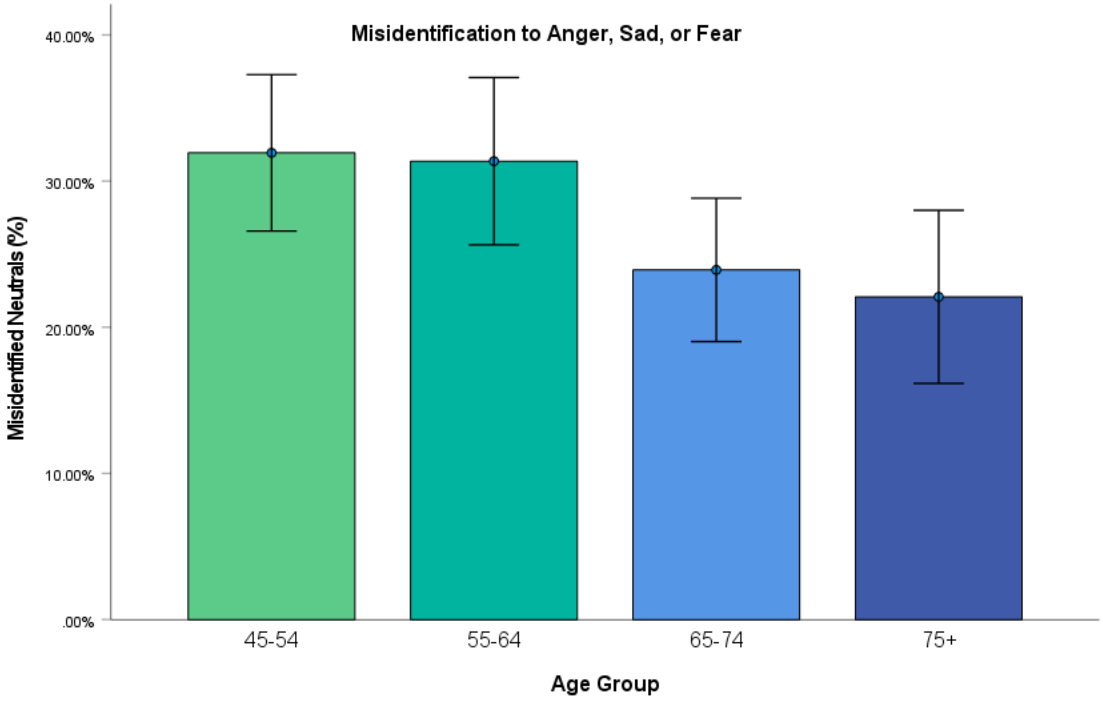

Figure 34 Percentage (± s.e.m.) of misinterpreted neutral faces misinterpreted as anger, sadness, and fear on the Facial Expression Recognition Task in all age groups.

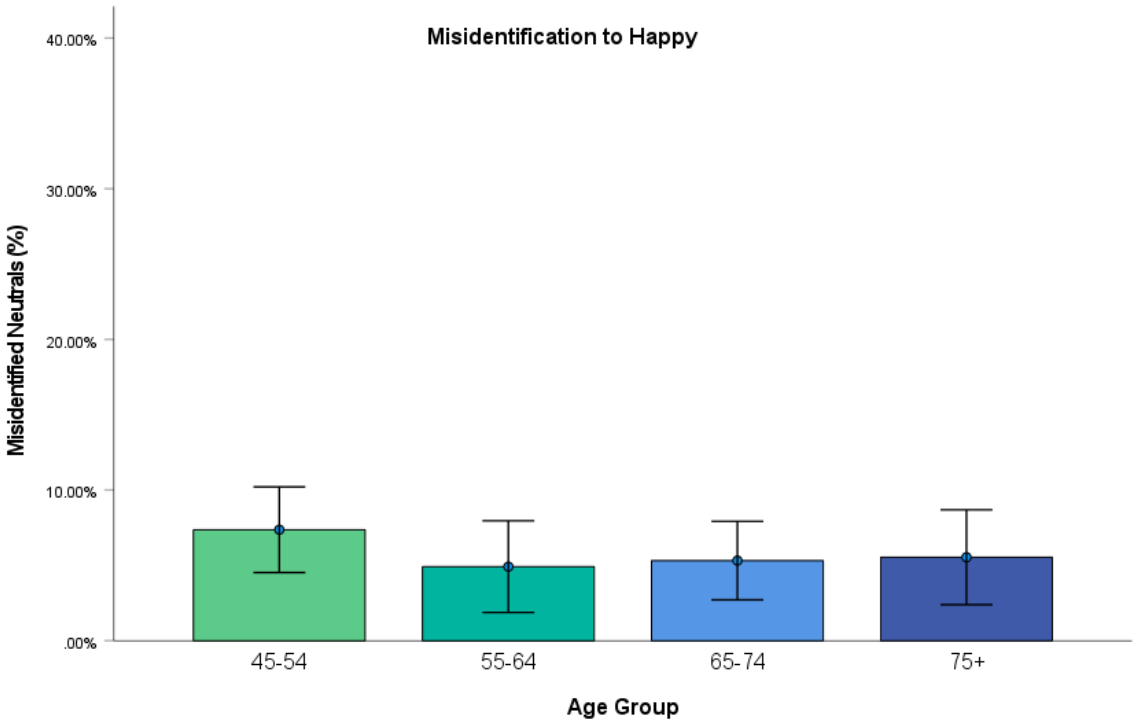

Figure 35 Percentage (± s.e.m.) of misinterpreted neutral faces misinterpreted as happiness on the Facial Expression Recognition Task in all age groups.

8.7.4 Correlations Between Non-emotional and Emotional Cognitive Tasks

Partial correlations between Emotion Accuracy and Age, controlling for different cognitive variables (Category Fluency, Category Switching, DSST, GMLT- Total Errors, GMLT-Delay Errors*)*, were conducted. Significant correlations between age and accuracy of recognition were found for the Emotions of fear and sadness when controlling for all cognitive domains. For the Emotion of anger, significant correlations were found when controlling for category fluency, category switching, and GMLT delay errors (see Table 13). There were no correlations between age and accuracy for happiness when any cognitive variables were controlled for.

Table 13 *Partial Correlations Between Emotion and Continuous Age, Controlling for Non-Emotional Task Performance (Category Fluency, Category Switching, Digit Symbol Substitution Task, Groton Maze Learning Test- Total Errors, Groton Maze Learning Test – Delay Errors)*

Emotion	**Category Fluency**	**Category Switching**	**Digit Symbol**	**GMLT Total Errors**	**GMLT Delay Errors**
	r (p)	***r (p)***	***r (p)***	***r (p)***	***r (p)***
Anger	**-0.21 (.01)**	**-0.20 (.02)**	-0.11 (.21)	-0.16 (.06)	**-0.20 (.03)**
Fear	**-0.35 (<.001)**	**-0.35 (<.001)**	**-0.29 (<.001)**	**-0.37 (<.001)**	**-0.39 (<.001)**
Happiness	-0.09 (.30)	-0.10 (.27)	0.05 (.60)	-0.07 (.41)	-0.11 (.23)
Sadness	**-0.42 (<.001)**	**-0.46 (<.001)**	**-0.37 (<.001)**	**-0.42 (<.001)**	**-0.47 (<.001)**

Note: Significant results in bold (***p*** ≤ .05). **GMLT** = Groton Maze Learning Test.
r = Pearson's correlation

To explore associations between emotional and non-emotional cognition, partial correlations between emotional (Accuracy) and non-emotional Cognitive variables (Category Fluency, Category Switching, DSST, GMLT- Total Errors, GMLT- Delay Errors*)*, controlling for Age, were conducted. Only two significant correlations were found: between happiness and DSST, a measure of processing speed and between sadness and Category Fluency.

Table *14 Partial Correlations Between Emotion Non-Emotional Task Performance (Category Fluency, Category Switching, Digit Symbol Substitution, GMLT Total Errors, GMLT Delay Errors), Controlling for Continuous Age*

Emotion	**Category Fluency**	**Category Switching**	**Digit Symbol**	**GMLT Total Errors**	**GMLT Delay Errors**
	r (p)	***r (p)***	***r (p)***	***r (p)***	***r (p)***
Anger	0.04 (.69)	0.07 (.45)	0.1 (.27)	-0.11 (.24)	-0.15 (.10)
Fear	0.15 (.08)	0.13 (.14)	0.03 (.73)	-0.004 (.97)	0.01 (.89)
Happiness	0.05 (.55)	0.02 (.83)	**0.22 (.015)**	-0.07 (.14)	-0.01 (.92)
Sadness	**0.33 (<.001)**	0.01 (.86)	0.005 (.96)	-0.08 (.40)	-0.07 (.46)

Note: Significant results in bold (***p*** ≤ .05). **GMLT** = Groton Maze Learning Test.
r = Pearson's correlation

8.7.5 Emotional Stroop

As described in Chapter Seven, the eStroop has words of three valences (positive, negative, and neutral), alongside a traditional Stroop effect (colour-word inhibition) section. Scores used in the analysis were created by subtracting the average reaction time for the valence condition from the average reaction time for a simple reaction time measure. Negative scores were possible if the participant was faster for the valence than for the simple measure. This was done for each participant for all four sections of the task.

A significant effect of Age Group was found for negative words, $F(3, 128) = 3.18$, $p = .03$. No significant effect of Age Group was seen for positive words, $F(3, 128) = 2.38$, $p = .07$, or neutral words, $F(3, 128) = 2.53$, $p = .06$. This indicates that reaction time increased significantly with age for words with a negative valence. This can also be seen in Figures 36-38.

A significant effect of Gender was found for positive words, indicating that women were faster at responding to positive words than men, $F(3, 128) = 3.94$, $p = .049$. No significant effect of Gender was seen for neutral or negative words, respectively, $F(3, 128) = 1.83$, $p = .18$; $F(3, 128) = 1.75$ $p = .19$.

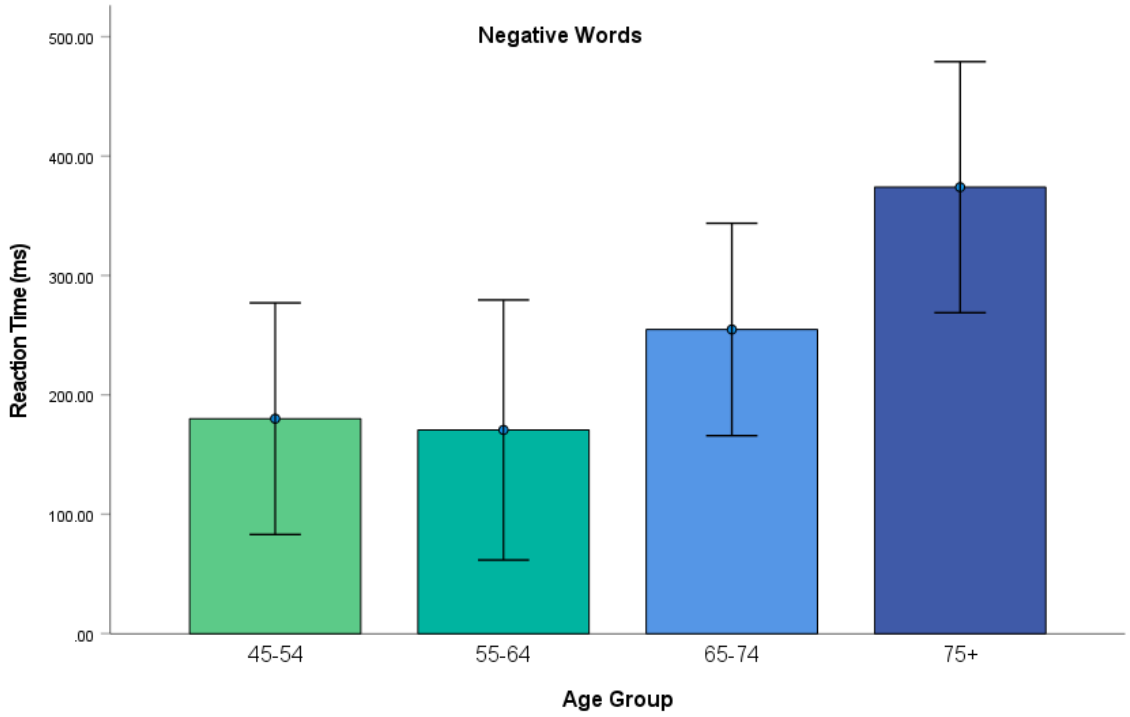

Figure 36 Mean (± s.e.m.) reaction time on the Emotional Stroop Task for negative words in all age groups.

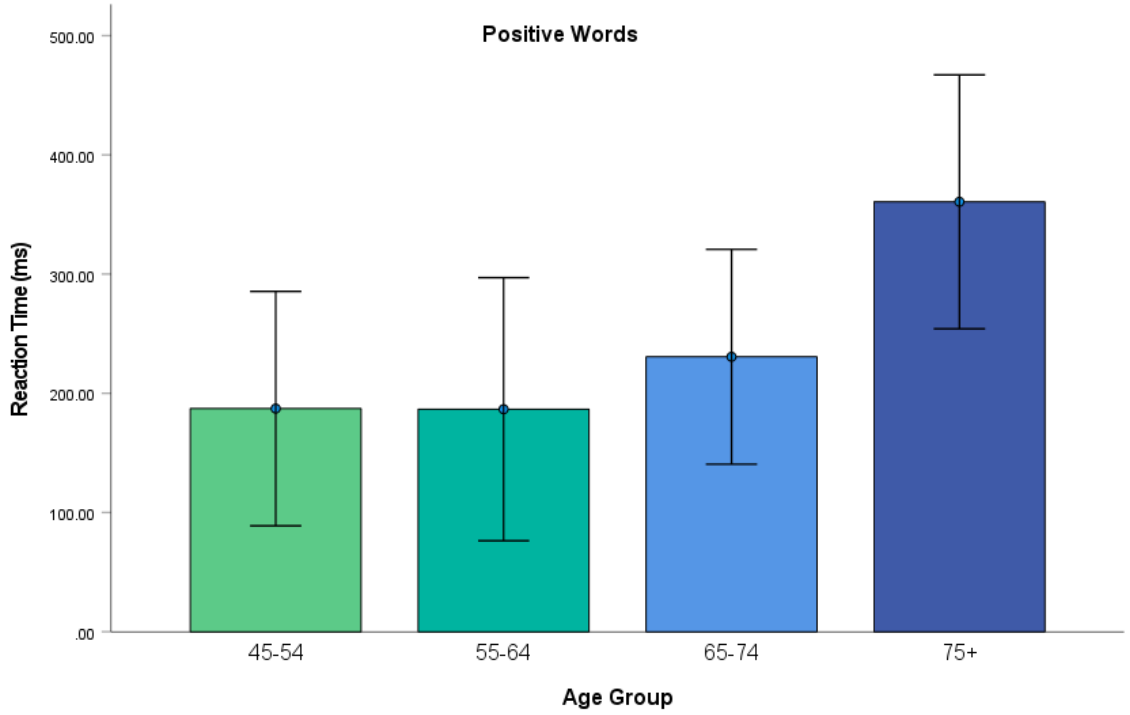

Figure 37 Mean (± s.e.m.) reaction time on the Emotional Stroop Task for positive words in all age groups.

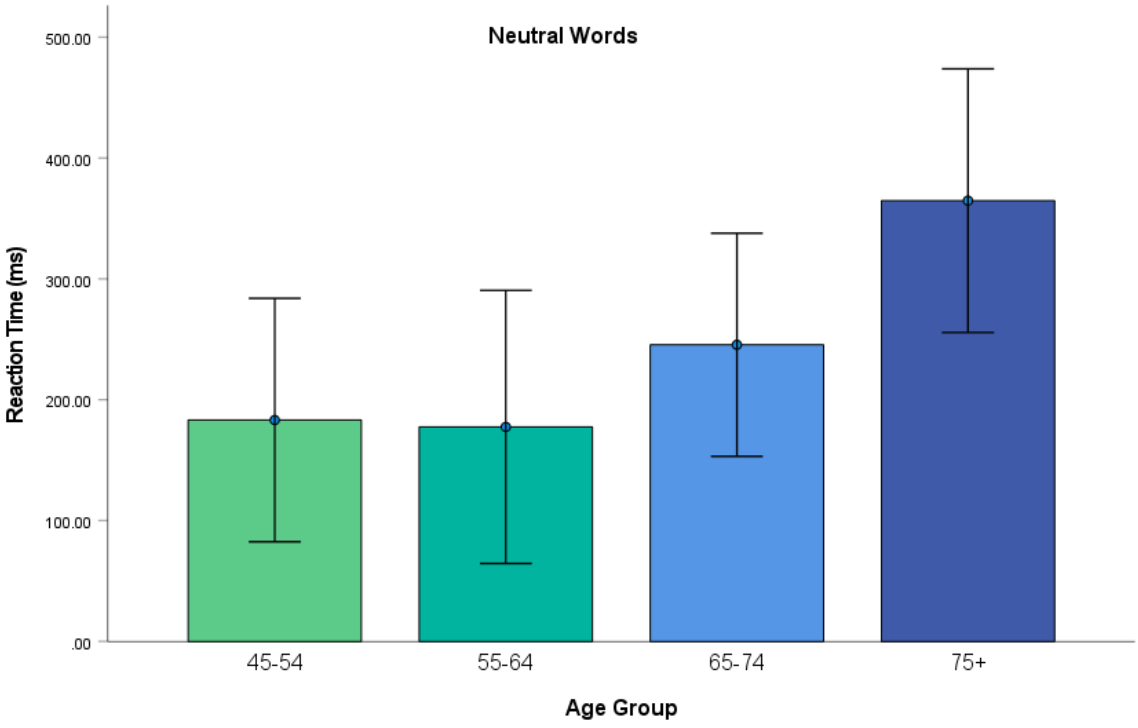

Figure 38 Mean (± s.e.m.) reaction time on the Emotional Stroop Task for neutral words in all age groups.

8.7.5.1 Stroop Effect

On the traditional Stroop effect measure, where participants were asked to name the ink colour of printed words which were incongruent with the word meaning, no significant difference was found for Age Group, $F(3, 128) = 0.39$, $p = .76$, or Gender, $F(3, 128) = 0.96$, $p = .33$. This suggests that for these participants, inhibition did not differ with age.

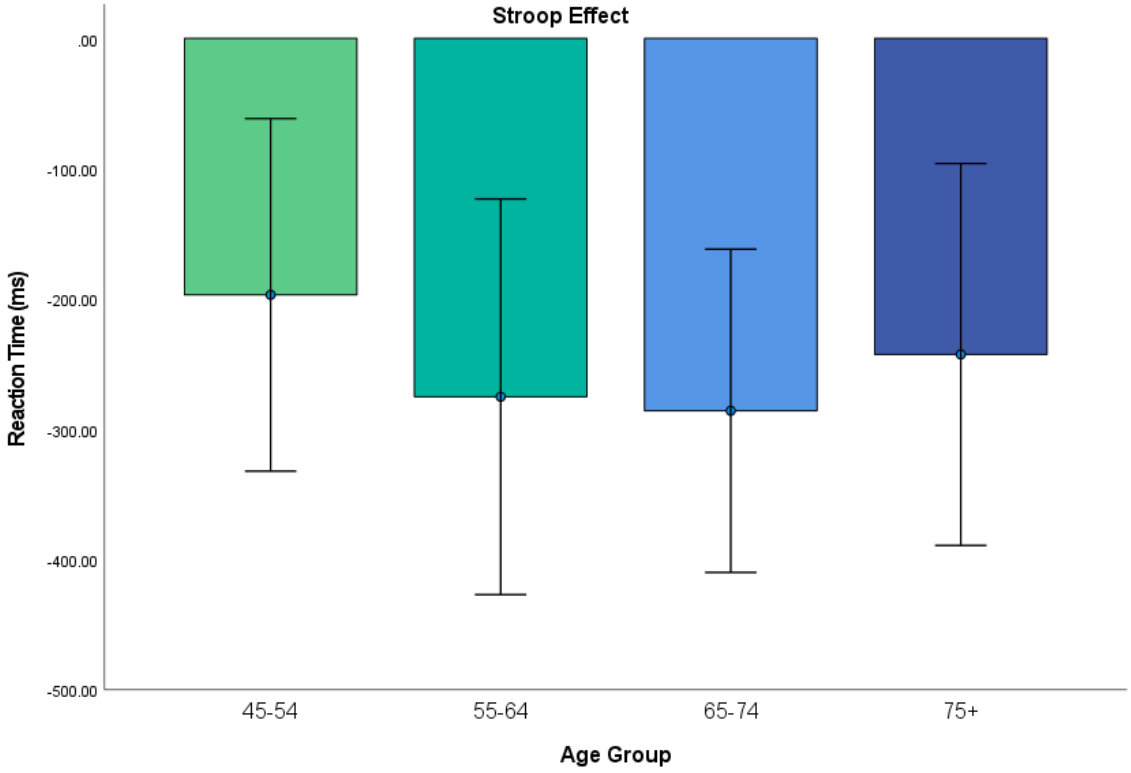

Figure 39 Mean (± s.e.m.) reaction time on the Emotional Stroop Task for the traditional Stroop Task in all age groups.

8.8 SUMMARY OF RESULTS

The primary aim of this study was to examine the relationship between age and emotional cognition in a sample of healthy participants over the age of 45 years. The secondary aim was to conduct exploratory analysis of correlations between non-emotional cognition, emotional cognition, and age. A summary of the results are as follows:

1. For non-emotional cognition, a decrease in performance was found with age in visuospatial learning and category switching. Slowed processing speed was also found in this sample as age increases. No changes with age were found for visuospatial memory or verbal fluency.

2. A decrease in identification accuracy with increasing age was found in FER for the emotions of fear and sadness. No change was found for disgust, anger, or happiness. Slower reaction times were seen with increasing age across emotions. The PI indicated that as age increased, participants were less able to efficiently manage the competing demands of accuracy and time (i.e., the instruction to respond as quickly as possible). No effects of age were seen on the RMET.

3. Participants were less likely to misidentify neutral faces as negative (i.e., sadness, anger, or fear) as age increased.

4. Significant correlations were consistently found between accuracy for recognition of the emotions of fear/sadness and age, when controlling for various domains of non-emotional cognition. Significant correlations between accuracy of recognition of the emotion of anger and age were found when controlling for verbal fluency, executive functioning, and visual memory.

5. Correlations between emotional and non-emotional cognition, controlling for age, were found between happiness and the DSST, a measure of processing speed, and between anger and a Category Fluency task.

6. As age increased, participants showed increased interference effects for negative words (i.e., longer latency for responding to negative words) on the eStroop Task.

8.9 DISCUSSION

8.9.1 Non-emotional Cognition

8.9.1.1 Visuospatial Learning and Memory

For visuospatial learning and memory, the results suggest that the ability to learn the location of a hidden visual path reduces with age, however, when asked to recall that same path later, age did not appear to have an effect. A consistent decline in new learning ability alongside ability to retrieve and recall recently learned information has been found with age (Lezak et al., 2004; Murman, 2015), which is in line with the result found in this study. In the current study, when previous learning ability was taken into account, no differences were seen with age for delayed recall. This is consistent with previous research suggesting that in learning and memory tasks, the difference seen with age most likely occurs in the learning phase, but once learned, retention and recall is relatively good (Haaland et al., 2003; Janowsky et al., 1996).

8.9.1.2 Verbal Fluency

Verbal fluency and switching tasks revealed no significant change in the total number of words able to be produced in a limited time frame with age. This finding is inconsistent with the literature in this area. Past research suggests that while many aspects of language ability remain stable, or even improve with age (Hayden & Welsh-Bohmer, 2012; Park & Reuter-Lorenz, 2009; Salthouse, 2009a; Singh-Manoux et al., 2012), verbal fluency, particularly for categorical word generation, declines (Murman, 2015; Salthouse, 2010; Singh-Manoux et al., 2012). It is noted, however, that although the findings for verbal fluency did not quite reach significance (p = .051), Figure 12 suggests a decrease in verbal fluency performance with increasing age, particularly in the two older age groups (65-74, and 75+). Therefore, it may be that inconsistency between the current study's findings and previous literature is the result of a lack of power in the current study.

For the switching component of the verbal fluency task (e.g., total correct switches), older participants performed more poorly. The switching task, while including a verbal fluency component, is best categorised as a measure of executive function/mental flexibility. Previous research looking into mental flexibility with aging is mixed. Some studies suggest there is a decline with age (Henry & Phillips, 2006; Wecker et al., 2005), while others do not (Salthouse et al., 2000; Stolwyk et al., 2015; Wecker et al., 2000). This inconsistency within the literature is likely due to differences across study characteristics and designs, and as such, makes comparisons with the current study difficult.

8.9.1.3 Processing Speed

Overall, both tasks examining processing speed showed significant slowing with age. This result is expected as motor slowing has been consistently found in the literature on aging. Multiple studies have found that processing speed starts to decline from the age of 30 years and continues as people get older (Salthouse, 2010; Salthouse et al., 1995). One large study showed a linear decline in processing speed per year of -0.02 standard deviations (Salthouse, 2010). Decline in processing speed is a significant contributor to cognitive changes reported in older adults, as many cognitive tasks involve an aspect of this function (Harada et al., 2013; Hayden & Welsh-Bohmer, 2012). As such, it is important to acknowledge this when interpreting cognitive task results in this age group. Alongside the tasks specifically targeting processing speed in the current study, other tasks in which this slowing should be considered include the verbal fluency and switching tasks, and FER task as these tasks include a timed component. For the FER task an index has been created to examine the effects of accuracy versus speed which may give insight into how processing speed changes with age affect other aspects of task performance.

8.9.2 Emotion Processing

8.9.2.1 Reading the Mind in the Eyes Task

No significant differences were found on the RMET with age or gender. In contrast to the current study, previous research using the RMET in aging has found that younger adults perform better than older adults on this task in general (Bailey & Henry, 2008; Bailey et al., 2008; El Haj et al., 2016; Pardini & Nichelli, 2009; Phillips et al., 2002; Slessor et al., 2007). Some studies, however, have not shown this difference (Castelli et al., 2010; Li et al., 2013). A meta-analysis by Henry et al. (2013) showed inconsistency in the literature regarding aging and Theory of Mind (ToM), with the authors suggesting that methodological issues related to task (e.g., methods of stimulus presentation or type of stimuli used) may be behind this. For the RMET specifically, however, Henry et al. (2013) found older adults were significantly worse than younger adults with a moderate effect size (r = -0.43).

8.9.2.2 Facial Emotion Recognition

8.9.2.2.1 Accuracy

There was an overall reduction of accuracy with age on the FER Task. Additionally, there was a differential effect of age on different emotions (Age by Emotion interaction). Examining individual emotions, a reduction in accuracy for identification of fearful and sad faces was

found as age increased in this sample. It is also noted that for angry faces, the result was at trend level (p = .06).

Ruffman et al.'s 2008 meta-analysis found that older adults were less accurate at identifying anger, sadness, and fear. The meta-analysis also found older adults to be less accurate at identifying happiness and surprise, albeit with smaller magnitude. A meta-analysis by Goncalves et al. (2018) examined emotion identification in younger and older adults in 24 studies published after 2008 (N = 1033 older adults, N = 1135 younger adults). The authors found an overall effect of lowered accuracy with age across emotions. More specifically, per emotion, Goncalves et al. found significant reductions in accuracy with age for anger, sadness, fear, surprise, and happiness, and no differences in accuracy of identification of disgust. As with Ruffman et al. (2008), effect sizes of significant differences varied between emotions, with large effect sizes for anger and fear, moderate effects for sadness and surprise, and small effects for happiness (Goncalves et al., 2018). An updated meta-analysis by Hayes et al. (2020), using various FER paradigms, found older adults to be significantly less accurate than younger adults across all emotions, excluding disgust. The size of the effect did differ between the emotions themselves, however, with sadness having a large effect, and fear and anger a moderate effect. A small effect was found for happiness in the Hayes et al. meta-analysis.

The results found in the current study are consistent with the overall findings of the previous meta-analyses with regard to sadness and fear. It is suggested that a result approaching significance for angry faces is in line with the previous work also. The sample size in this study may be a factor in this outcome not reaching significance. No differences were found for happiness in this study. It is noted that accuracy for happiness was very high overall, and as such, this lack of difference may in fact be due to a ceiling effect. Alongside this, happiness was the only positive emotion used in the task and again this aspect of task design might be implicated in the results found. No significant difference seen for disgust is consistent with the meta-analyses by Hayes et al. and Goncalves et al. As noted by Hayes et al., further analysis of their non-significant result showed that papers in their analysis had inconsistent results and this likely resulted in no overall effect when results were pooled.

It is important to note that in the current study, differences between emotions were able to be examined due to including an Emotion by Age interaction. The meta-analyses referenced above were only able to examine changes of each individual emotion and not differences between them. Including this interaction term has allowed this study not only to identify

changes for each emotion with age. but also to determine whether these differences were specific to the emotions themselves, therefore giving insight into the differential effect of different facial expressions.

The result of a decrease in accuracy for sadness and fear may suggest an attentional bias away from negative information, reflecting a positivity bias present with increased age. A positivity bias may then indicate that older people are subconsciously not attending to negative stimuli, possibly in order to maintain an overall sense of wellbeing, and as such are less accurate at identifying negative emotions. It is important to note, however, the higher accuracy rate for happiness suggesting that it was easier to identify, which may confound the results found.

The stimuli used in the FER Task itself is an important methodological issue to consider. Stimuli which use high intensity of expression can be vulnerable to ceiling effects, which limits the sensitivity of the task to detect group differences. Research has suggested that in tasks using exaggerated expressions, both younger and older adults have been found to have accuracy levels of over 95% for one or more of the emotions used in the task. In this study, the accuracy rate for happiness was 92% which is also high and may reflect ceiling effects. This issue has been noted in previous studies also, with happiness generally easier to recognise (Campbell et al., 2017; Ebner et al., 2011; Halberstadt et al., 2011).

In some research, including the current study, altered or morphed photographs, displaying reduced intensities of emotion, have been used to attempt to mitigate this ceiling effect (Young et al., 2002). It is, however, noted that there is some suggestion that using these morphed or somewhat more ambiguous images may in fact place a higher load on general cognition, consequently disadvantaging older participants due to models of suggested general cognitive decline with age (Hayes et al., 2020).

Alongside image intensity, whether images are presented in black and white or colour has also been implicated as a factor which may differ with age. Older adults may be more familiar with black and white images than their younger counterparts, also as colour vision declines with age (Owsley, 2011), older adults may be more practised at decoding images with lesser amounts of colour.

8.9.2.2.2 Reaction Time

Reaction time increased with age across all emotions, likely reflecting a generalised motor slowing. This result is what would be expected based upon previous research and is also what was found during the motor processing tasks conducted in the current study. It is suggested

that this is likely why meta-analyses in FER in older adults tend to only report outcomes related to accuracy or misidentification and do not include latency outcomes (Goncalves et al., 2018; Hayes et al., 2020; Ruffman et al., 2008). The reaction time result has been reported in this thesis, both to ensure all aspects have been considered and so that both outcomes that make up the PI are reported in their original form.

8.9.2.2.3 Performance Index

In the current study, the PI reduced for participants across all emotions as age increased. This suggests that as age increases, participants were less able to manage the competing efficiency demands of both speed and accuracy. It is, however, possible that any differential effect of age across emotions may be obscured by the strong effect of age on processing speed, which was seen consistently across emotions.

8.9.2.2.4 Neutral Misidentification

As age increased, participants in the current study were less likely to misidentify neutral faces as anger, fear, or sadness. This pattern of misidentification suggests an attentional bias away from negative faces is present with older age. An attentional bias away from negative information is one of the proposed mechanisms of the positivity bias (Charles et al., 2003; Mather & Carstensen, 2003). This bias is the opposite of the negativity bias, which is seen in younger adults with depression, where they are more likely to misidentify neutral faces as negative (Douglas & Porter, 2010).

8.9.2.2.5 Relationship between non-emotional and emotional cognition

Correlations between accuracy in recognising facial emotions and age, controlling for non-emotional cognition, showed a negative correlation between recognition of the emotions of fear and sadness with age even when corrected for non-emotional cognitive variables. A negative correlation between anger and age, when controlling for verbal fluency, visual memory, and executive function was also found, but there was no correlation when measures of processing speed/attention/visuospatial working memory were controlled for. Overall, the data suggests that the decline seen in accuracy of these emotions as age increases is not driven by cognitive changes in the areas of processing speed, visuospatial learning and memory, verbal fluency, or executive function. This then implies that a change other than cognitive ability is indicated in these differences, suggesting that the changes with age may be driven more by processes independent of a general decline in brain or cognitive function. This finding is then more in line with the mechanisms suggested by Socioemotional Selectivity Theory (SST) as a model for the changes in emotion processing with age.

Correlations between emotional and non-emotional cognition, controlling for age, only showed significant correlations between happiness and DSST, a measure of processing speed, and between sadness and a measure of verbal fluency. The result for happiness is unexpected. It would otherwise be expected that any correlation for the processing speed variable would be seen for the more difficult emotions to identify, not happiness as is seen here. This is based on the suggestion that the processing of negative emotions involves greater cognitive load. Overall, these results are only two correlations among the many conducted, and as such, may be due to chance rather than a true statistical difference.

8.9.2.3 Emotional Interference

Significantly slowed reaction time for negative words during the eStroop was observed with increasing age. Findings from the few previous studies using the eStroop paradigm have been inconsistent. Wurm et al. (2004) used a mixed block paradigm with positive, negative, and neutral stimuli. They found an emotional interference effect for older adults for high arousal emotional words (e.g., nightmare, rage, thrill), with no difference found between negative and positive words, compared with younger adults. Ashley and Swick (2009), also using mixed blocks of negative and neutral words, showed that while emotional interference was not observed in older adults, young adults responded more slowly to negative than neutral words. Jain and Labouvie-Vief (2010), using mixed blocks, found an emotional interference effect was present but no positivity effect was found in stimulus processing. When the words were presented in blocks of only negative or neutral words, an emotional interference effect was found in both groups. LaMonica et al. (2010), using blocked stimuli, reported that less interference for emotional than neutral stimuli was found in older adults compared with younger adults. It has been suggested that when using mixed block presentations there may be an “emotional lingering effect” persisting past the presentation of the emotional stimuli, seen as a slowing (or interference) on the words presented after the emotional word, making the emotional interference (eStroop) effect more difficult to detect (Holle et al., 1997; McKenna & Sharma, 2004; Richards et al., 1992). This may explain some of the variation in outcomes of previous studies as these vary between mixed and pure block presentations.

The results found in the current study are therefore moderately in line with previous research, in that an interference effect was found for negative words. This study found no effect of age on processing of positive words, which deviates from previous research which has shown little difference in interference effects of positive and negative emotional words in older adults. An interference effect shown for negative words however does indicate that emotional

content has some effect with age, and it is possible that further effects are not shown in this study due to the use of a mixed block design.

8.10 STRENGTHS

The current study provides a more detailed analysis of age and emotion compared with previous studies. The following strengths are noted:

- Previous studies have often examined the positivity effect for individual emotions but have not examined whether there is a differential effect of aging on different emotions. This study examined this using a repeated measures ANOVA and was able to demonstrate an interaction between Age and Emotion. This confirms a differential effect of age on different emotions.
- The main emotion processing task used in the study (FER Task) included 49 neutral faces so that the effects of age on misidentification of neutral faces could be explored. This is important as misidentification can provide valuable information about attentional biases, as indicated by the finding that the misidentification of neutral stimuli is the most consistent evidence of attentional biases in mood disorders (Bourke et al., 2010).
- The study included a short non-emotional cognitive battery to determine whether non-emotional cognitive functioning could account for changes in emotion processing seen with age.

8.11 LIMITATIONS

Limitations of this study are noted below, particularly with respect to design of tasks used, sample size, and gender differences within the sample.

- As mentioned above, the stimuli used is an important factor in the ability to interpret results. Images in the FER Task used were presented in black and white, which may give advantage to older adults who may be more used to viewing low colour images. Alongside this, using emotional faces between 50 and 100% intensity, particularly for happy faces, may have given rise to a ceiling effect for this emotion.
- The groups in this study differed significantly with respect to the ratio of male and female participants in each group. Having even numbers of male and female participants in each group would have been beneficial to the study as previous

research suggests that not only are there differences between genders with respect to cognitive functioning, but there are differential aging effects between males and females. In the current study, limitations due to the restricted timeframe of a doctoral thesis and further reduced availability for sample recruitment due to the COVID-19 pandemic meant that attempting to have age groups with matching gender distribution was not feasible. This gender difference was particularly apparent in the two younger age groups. Additional barriers to recruitment in this age range may have been the fact that men are more likely to be in full-time employment than women in this age bracket, meaning less time and availability to participate in such a study.

- The sample size of this study was limited. While 137 participants overall were included in the analyses for most tasks, a much larger number of participants would be needed for the outcomes to be considered robust. Difficulties with recruitment of older people in the context of the COVID-19 pandemic, alongside the limited timeframe of the doctoral thesis, meant that recruitment could not continue beyond 137 participants recruited.

8.12 FUTURE RESEARCH AND IMPLICATIONS

From the results obtained in this chapter, the following future directions are recommended:

- Studies should employ FER tasks with larger numbers of stimuli, and with more moderate emotional intensities, to reduce possible ceiling level effects. Additionally, the use of more neutral or ambiguous stimuli in FER tasks will enable detailed consideration of patterns of misidentification.
- Studies are recommended to use other emotion processing tasks, not just FER. Studies such as Baruch et al. (2021) provide a positive example of this, using FER, emotion categorisation, and a recall memory task to explore different aspects of emotion processing. Further, using a variety of stimuli types (i.e., verbal and auditory), or static and dynamic images, would again add depth to the analysis available. In addition to this, using ToM tasks which measure both affective and cognitive ToM are vital when examining that specific affective process.
- Studies examining the relationship between emotion processing and non-emotional cognition would benefit from using larger non-emotional cognitive batteries, particularly using multiple tasks in each cognitive domain. Alongside this, creating

a global cognition score, or at least domain level scores, would reduce the problem of multiple statistical testing.

- Returning to the initial aims of this thesis, this study could then be extended to older people with mood disorders and anxiety, also including larger numbers and more even gender ratios in the middle age groups to further elucidate when changes in emotional cognition become important to functional outcomes. In order to do this, adding functional measures to testing materials would be beneficial.
- Relationships between non-emotional and emotional cognition should be considered further in older samples with mood disorders and anxiety. The effects of these disorders on cognitive functioning with age is likely to then have effects on emotion processing capabilities in these groups, which may contribute to maintenance or recurrence of these disorders.

Chapter 9 - The Effect of Age on Emotion Processing in Mood Disorders and Healthy Participants

9.1 INTRODUCTION AND RATIONALE FOR ANALYSIS

As discussed in Chapter Four, research suggests that people with MDD perceive emotional stimuli as more negative and attend to and recall more negative information (Bourke et al., 2012; Disner et al., 2011; LeMoult & Gotlib, 2019). In BD, emotion processing findings are less consistent, however, some research has shown that individuals with BD are less accurate and slower at identifying facial expressions than healthy control participants, with this effect most often observed with negative emotions (Miskowiak et al., 2019; Van Rheenen & Rossell, 2013; Van Rheenen et al., 2017; Vederman et al., 2012). Further to this, Chapter Five discussed that in aging, a "positivity bias" in older adults has been found using multiple experimental paradigms (Carstensen & DeLiema, 2018). While older adults are worse overall at identifying facial expressions, the ability to recognise positive facial expressions (most often happiness, but also surprised expressions) seems to be least affected, showing either smaller deficits, similarity, or better performance than their younger counterparts (Ruffman et al., 2008). However, it is not clear how these results in aging intersect with the changes seen in mood disorders, as few studies have examined both age effects and mood disorders combined.

Using data from two previous studies examining FER in people with mood disorders, this chapter examines the effects of mood disorder diagnosis, age, and global cognitive function (and interactions between these factors) on aspects of FER. One study examined individuals in a MDE compared with matched healthy control participants (Bourke et al., 2012; Carter et al., 2013), and the other study examined individuals with BD, in a range of mood states (Inder et al., 2015). This analysis is currently submitted for review.

9.2 METHODS

9.2.1 Data Sets

Baseline data (single time-point) from two studies conducted at the Department of Psychological Medicine, University of Otago, Christchurch were used (Bourke et al., 2012; Carter et al., 2013; Inder et al., 2015).

9.2.1.1 Study 1

The first data set (Study 1) consisted of 98 people who were experiencing a MDE, either in the context of BD (*n* = 8; BD II only) or MDD (*n* = 90), and healthy control participants (*n* = 61), aged 18 to 65 years. Mean age was 38.2 years (patient = 38.5 years, healthy control = 37.7 years) (Bourke et al., 2012; Carter et al., 2013). The Structured Clinical Interview for DSM–IV Axis I Disorders – Research Version was used to confirm mood disorder diagnosis (First et al., 1998). Because one of the factors to be entered in the analysis was 'group' (healthy control vs mood disorder – combined MDD plus BD) in any mood state, the eight patients in this data set with bipolar depression were classified as being in the group with BD.

Exclusion criteria were schizophrenia, BD I, current serious alcohol or drug misuse or dependence, neurological illness (e.g., epilepsy) and pregnancy. Participants needed to be free of any centrally active drug, other than the occasional hypnotic, and the oral contraceptive pill, for a minimum of six weeks.

The healthy control group consisted of age and gender-matched psychologically healthy individuals without a personal history, or a history in a first-degree relative, of major mental illness.

9.2.1.2 Study 2

The second data set (Study 2) consisted of 100 people with a diagnosis of BD (I or II) aged between 16 and 36 years, with a mean age of 26.5 years (Inder et al., 2015). As in Study 1, the Structured Clinical Interview for DSM–IV Axis I Disorders – Research Version was used to confirm mood disorder diagnosis. Participants could be in any mood state at entry. Exclusion criteria were minimal, including only alcohol or drug dependence as a principal diagnosis (Inder et al., 2015).

9.2.2 Mood Measure

The Montgomery-Asberg Depression Rating Scale (MADRS) is administered by a clinician and measures depressive symptoms experienced in the previous week (Montgomery &

Asberg, 1979). The MADRS measures ten depressive symptoms on a scale of 0 (least severe) to 6 (most severe), with a total possible score of 60. Higher scores indicate more severe symptoms experienced and a score of 31 or above has been suggested as an indicator of severe depression (Müller et al., 2003). The ten symptoms measured are: apparent sadness, reported sadness, inner tension, reduced sleep, reduced appetite, concentration difficulties, lassitude, inability to feel, pessimistic thoughts, and suicidal thoughts. Sensitivity to change over treatment course is a core feature of the MADRS and this was shown in a study by Santen et al. (2009), which found that almost all the items of the MADRS demonstrated sensitivity to symptom response.

9.2.3 Cognitive Measures

The following tasks were administered in both studies and were included in the analysis.

9.2.3.1 The National Adult Reading Test (Nelson & Willison, 1991)

For more detail on the NART see Chapter Seven (section 7.3.5).

9.2.3.2 Facial Emotion Recognition Task

A computerised FER Task developed by Harmer et al. (2003), at Oxford University was used to examine emotion recognition. This FER task uses the six basic facial emotions as described by Ekman and Friesen (1976); anger, disgust, happiness, sadness, surprise, fear, as well as neutral expressions. Pictures presented to participants come from the Pictures of Affect Series (Ekman & Friesen, 1976), with each picture morphed between the original (full emotion) and neutral expression using a method described by Young et al. (1997). Pictures are black and white. Four examples of each of the six emotion categories (portrayed by male and female actors) at each level of intensity are presented (40 stimuli for each emotion). Each face is also presented in a neutral expression (24 stimuli), giving a total of 264 stimulus presentations.

The task is presented in three blocks (88 stimulus presentations per block), with an untimed rest period between each block to prevent fatigue. Each face is presented in random order for 500ms and is then immediately replaced with a blank screen. On identification of the emotional expression, participants need to press the corresponding labelled key on a response pad. Accuracy and mean reaction time (ms) data were collected.

9.2.4 Non-Emotional Cognitive Tasks

9.2.4.1 CANTAB tasks:

The Cambridge Neuropsychological Test Automated Battery (CANTAB®) was used for many of the cognitive tasks (Sahakian & Owen, 1992). The CANTAB is a battery of non-verbal computerised cognitive tests administered with the aid of a touch-sensitive screen for reaction timing. Selected from the suite of tests were the following:

9.2.4.1.1 Motor Screening

The motor screening test records mean reaction time to respond to 10 pink or green crosses on the screen. This task is used both as training for the CANTAB tests and to exclude motor or visual disorders. Outcome recorded was speed of response.

9.2.4.1.2 Spatial Recognition Memory

This task assesses the ability to remember the spatial location of visual stimuli (squares). Five squares are presented sequentially at different locations on the screen, then participants are presented with a pair of squares in counterbalanced order. They are instructed to identify which square is at a location where one was previously presented. Outcomes recorded were accuracy and speed.

9.2.4.1.3 Spatial Working Memory

Participants are asked to search through boxes on the screen to find which one hides a coloured token. In doing this, they are required to remember where the tokens were previously placed. This task begins with four trials of four boxes and progresses to four trials of six, then eight boxes. Repetitious search errors were reported and a performance index for search strategy was generated.

9.2.4.1.4 Spatial Span

Participants are required to remember, then replicate, the order of nine white squares on-screen that change colour one by one. Trials progress from two to nine squares and the task self-terminates after three successive trial failures (incorrect sequence) on a given number of squares. The longest span length correctly recalled was reported.

9.2.4.1.5 Psychometric Properties of CANTAB

De Luca et al. (2003) identified that the CANTAB has good ability to differentiate between normal adults and clinical populations including schizophrenia (Tyson et al., 2005), Alzheimer's disease (Saunders & Summers, 2010), and mild cognitive impairment (Klekociuk et al., 2014). Smith et al. (2013) conducted a study using 255 healthy control

participants. The authors showed moderate correlations between CANTAB tasks and non-computerised cognitive tasks measuring similar cognitive functions. This study also noted that the CANTAB provides a good assessment of general cognitive function, but caution must be used when interpreting specific domains due to concern about specificity of measurement. This caution was also suggested in a study of 500 healthy older control participants (Lenehan et al., 2016).

A validation study by Robbins et al. (1994) examined the CANTAB in a sample of almost 800 healthy controls, aged 55 to 80 years. This study and others showed that performance on the CANTAB declines with age, in a way that is consistent with what is expected in normal aging (De Luca et al., 2003; Robbins et al., 1994).

In studies of depression, selections of tasks from the CANTAB, rather than the entire battery are normally used, similar to what has been done in the current studies. In studies using the CANTAB in depression, deficits have been seen in problem solving, spatial recognition memory, attentional set shifting, and episodic memory (Beats et al., 1996; Elliott et al., 1997; Sweeney et al., 2000). A study by Egerhazi et al. (2013), using the CANTAB in participants in current mood episode and then in remission demonstrated that this battery can be sensitive to treatment related changes. A meta-analysis by Rock et al. (2014), of cognition measured using the CANTAB, in symptomatic and remitted states of depression, was also able to show changes in cognition across mood states.

9.2.4.2 Pen-and -Paper Tasks:

9.2.4.2.1 Rey Auditory-Verbal Learning Test (Rey, 1964)

This task involves repeated learning and recall trials of a 15-word list. In the described studies, words are pre-recorded and presented over computer speakers for consistency. Task administration involves auditory presentation of a list of 15 non-related words over five acquisition trials, followed by recall after each trial. A second distracter list of 15 different non-related words is then presented, and immediately after recall of this list, a sixth recall trial of the first list follows. After 20 minutes (during which other non-verbal tasks are completed), delayed recall of the first list is tested. Following the delayed recall of the first list, the recognition trial is completed. The recognition component of the Rey Auditory-Verbal Learning Test (RAVLT) is presented as a computerised task. Primary outcomes were total words recalled in the first five trials and total correct words recalled in a delayed recognition trial.

Word list learning is a particularly useful and sensitive verbal memory task as there is no influence of associative learning. The RAVLT has good test-retest reliability, with correlations of 0.61 to 0.86 for trials 1-5 and from 0.51 to 0.72 for delayed recall and recognition when using alternate forms at one month delay (Delaney et al., 1992).

With regard to age, a study by Vakil and Blachstein (1997) found reduced recall after the age of 60 years. This study found that trial 5, the distractor list recall, and the delayed recall trial were the most affected by age. In participants between 70 and 79 years old, significant changes are seen in task performance (Schmidt, 1996). Studies suggest that about 1.5 words are lost between the final learning trial and the immediate recall trial, although for people 65 years and over this gradually increases to 2 words, and then to 3 words after the age of 75 years (Sinnett & Holen, 1999).

The RAVLT has been used frequently in depressed populations to measure verbal learning and memory. A study by Thomas et al. (2009) was able to demonstrate differences between younger (< 60) and older (> 60) adults with depression. A study by Bourke et al. (2012) used the RAVLT to compare non-medicated depressed participants and healthy control participants. Schoenberg et al. (2006) in a large study, was able to show that the RAVLT has sufficient sensitivity to distinguish between healthy control participants, those with neurological disorders, and participants with psychiatric diagnoses.

9.2.4.2.2 Controlled Oral Word Association Test (Benton, 1983)

In the Controlled Oral Word Association Test (COWAT), participants are required to generate as many words as possible beginning with a particular letter over a one-minute period. Participants are instructed not to use proper nouns, place names, or the same word with a different ending (e.g., takes, taking). Three trials are completed using letters F, A, and S. Primary outcome was total number of correct words generated across the three trials.

A meta-analysis by Henry and Crawford (2005) examined verbal fluency in participants with depression and included studies using phonemic (i.e., COWAT) and semantic fluency tasks. That study found that fluency tasks were relatively sensitive to depression (r = 0.43 and 0.39 for semantic and phonemic fluency, respectively) compared to healthy controls. A review of longitudinal cognitive outcomes in depression found that in participants with depression there is a trend for deficits in verbal fluency to normalise with successful treatment (Douglas & Porter, 2009). Studies by Beblo et al. (1999) and Trichard et al. (1995) have separately demonstrated the sensitivity of verbal fluency to treatment response over other cognitive tasks.

9.2.4.2.3 Digit Span Forwards and Backwards (Wechsler, 1997)

The Digit Span task requires participants to repeat increasingly longer strings of numbers either forwards, as presented, or backwards, in the reverse order, after they are read aloud by the examiner (Lezak et al., 2012). Primary outcome was longest correct number of digits recalled by the participant in each condition. The Digit Span task is a measure of verbal working memory and attention (Lezak et al., 2012). It is purported that the forwards component measures attention and temporary storage ability, while the backwards component measures manipulation of information in this type of storage.

The Digit Span task has been shown to have a high test-retest reliability (r = 0.83) (Wechsler & De Lemos, 1981). Minimal aging effects are found in this task. For forward span, studies of participants over 65 show few changes (Craik, 1990; Jarvik, 1988), and even well-educated participants in the 84-100 year old range show few effects of age (Hickman et al., 2000; Howieson et al., 1993). The longest reverse span typically decreases about one digit during the seventh decade (Lezak et al., 2012). In depression, a meta-analysis by Bora et al. (2013) found significant working memory deficits in euthymic MDD, compared to healthy controls, of medium effect size (d= 0.39). A meta-analysis by Lee (2012) comparing cognitive function in first episode MDD compared to healthy controls showed significant impairment in the MDD sample on tasks of digit span backwards and spatial span (effect size = 0.36).

9.3 STATISTICAL ANALYSIS

Statistical analyses were conducted using IBM SPSS Statistics (Version 28). Demographic and clinical data were summarised using standard descriptive statistics. Comparison of demographic and clinical variables between healthy control participants, MDD patients, and BD patients used chi-square tests for categorial measures, and ANOVA for continuous measures, with Fisher's Protected Least Significant Difference and post-hoc chi-square tests for pairwise comparisons.

Three variables related to FER were examined: a) accuracy of emotion recognition, b) reaction time, and c) a Performance Index. The PI was calculated as follows. FER accuracy and reaction time items were *z*-transformed. *Z*-scores outside a range of ± 2.5SD were excluded from further analysis as these outlying scores likely represent an impairment with that task which cannot be accounted for due to normal variation, such as a misunderstanding of instruction or individual cognitive impairment. The *z*-score for reaction time was then

subtracted from that for accuracy, with a higher score reflecting a combination of more rapid and accurate performance and a lower score reflecting slower and more incorrect responses.

In examining the cognitive data, to rationalise the effects of co-linear variables, we completed a Principal Components Analysis (PCA) using Varimax rotation. Components that explained > 5% variability in the data were considered to be valid components of the data set. Standardised Component Scores were then used in the analysis. Variables that did not load on these components were analysed separately. Three factors emerged – a verbal memory factor incorporating RAVLT total words remembered from lists 1-5 and RAVLT delayed recall (termed Verbal Memory Component); a factor involving spatial working memory and incorporating CANTAB spatial working memory between errors and spatial span (termed Spatial Working Memory Component); and a digit span factor incorporating digit span forwards and digit span backwards (termed Verbal Working Memory Component). Verbal fluency and motor screening latency did not load on these factors and were thus examined and presented as separate variables.

Repeated measures ANOVA was used to examine the effects of emotion, age, and group (control vs mood disorder – combined MDD plus BD) and 'emotion by age' and 'emotion by group' interactions. Where there was a significant interaction, ANOVA was used to further examine the effects of age and group on separate emotions.

To examine the effect of participants being currently depressed, analyses were repeated as above however, patients who were currently experiencing a MDE, either unipolar or bipolar, were included in one group (MDE), and healthy control participants were in the other.

Finally, to examine the moderating effect of general cognitive function, partial correlations were calculated between FER variables and cognitive variables, controlling for age. The cognitive variables used were the factors from the PCA (Verbal Memory, Spatial Working Memory, Verbal Working Memory) and the variables that did not load on the PCA (verbal fluency, motor screening latency).

9.4 RESULTS

Descriptive statistics are shown in Table 15. There was a significant difference in age between groups, with the BD group being significantly younger than the MDD and healthy control groups. This was not unexpected and is attributable to differences in the samples recruited in each original study.

Table 15 *Demographic and Clinical Characteristics*

	Healthy Controls (N = 61)		**Major Depressive Disorder** (N = 90)		**Bipolar Disorder** (N = 108)	
	N (%)	M (SD)	N (%)	M (SD)	N (%)	M (SD)
Age	-	37.7 (12.7)*	-	38.6 (11.3)*	-	27.3 (7.0)*
MADRS	-	-	-	23.8 (6.7)	-	15.3 (10.7)
Gender (F)	41 (67)	-	61 (68)	-	79 (75)	-
Ethnicity (Pākehā)	50 (82)	-	70 (78)	-	90 (83)	-
Medication						
Lithium	-	-	-	-	29(27)	-
Other Mood Stabiliser	-	-	-	-	41 (38)	-
Antipsychotic	-	-	-	-	48 (44)	-
Antidepressant	-	-	-	-	55 (51)	-
Bipolar I Diagnosis	-	-	-	-	81 (75)	-

Note: * reflects significantly different at the .05 level. Note: Eight participants in Study 1 had a diagnosis of bipolar depression and are therefore included in the BD group.
F = Female, **MADRS** = Montgomery-Asberg Depression Rating Scale

9.4.1 Associations Between Age, Mood Disorder Diagnosis and Facial Emotion Recognition Variables

Repeated measures ANOVA showed a significant interaction between age and emotion for accuracy, $F(10, 1275) = 8.1$, $p < .001$, reaction time, $F(10, 1275) = 5.9$, $p < .001$, and PI, $F(10, 1275) = 9.8$, $p < .001$. There was no group by emotion interaction and no main effect of group (mood disorder vs healthy control) for accuracy, reaction time, or PI.

ANOVA results for individual emotions are presented in Table 16. Age showed multiple significant relationships for the three FER outcomes (see also Figures 40-42). A significant

group (mood disorder vs healthy control) by age interaction was found for both accuracy and PI for anger (see Figures 43-44). Adding the interaction ‘group by emotion’ did not affect the results for any other emotions.

Table 16 *Effects of Age and Mood Disorder on Facial Emotion Recognition*

	Accuracy			Reaction Time			Performance Index		
	Group	Age		Group	Age		Group	Age	
	F (p)	***F (p)***	***B***	***F (p)***	***F (p)***	***B***	***F (p)***	***F (p)***	***B***
Anger	1.69 (.19)	**5.62 (.02)**	**-0.002**	0.35 (.70)	**4.11 (.04)**	**8.6**	1.52 (.22)	**8.68 (.004)**	**-0.03**
Disgust	0.34 (.71)	2.12 (.15)	-0.001	1.16 (.32)	**10.50 (.001)**	**12**	0.50 (.61)	**10.79 (.001)**	**-0.03**
Fear	0.99 (.38)	**4.42 (.04)**	**-0.002**	1.10 (.34)	**4.74 (.03)**	**7.9**	2.25 (.11)	**10.57 (.001)**	**-0.03**
Happiness	0.21 (.81)	**8.17 (.005)**	**0.002**	1.12 (.33)	2.36 (.13)	4.3	0.66 (.52)	0.75 (.39)	0.008
Sadness	0.72 (.49)	**26.9 (<.001)**	**-0.005**	1.38 (.26)	**26.61 (<.001)**	**17.4**	1.76 (.18)	**48.77 (<.001)**	**-0.06**
Surprise	0.31 (.73)	1.90 (.17)	-0.001	0.59 (.56)	**14.40 (<.001)**	**11.2**	1.01 (.37)	**15.31 (<.001**)	**-0.03**

Note: Significant outcomes in bold; **Group:** Control *n* = 61, Mood Disorder *n* = 198

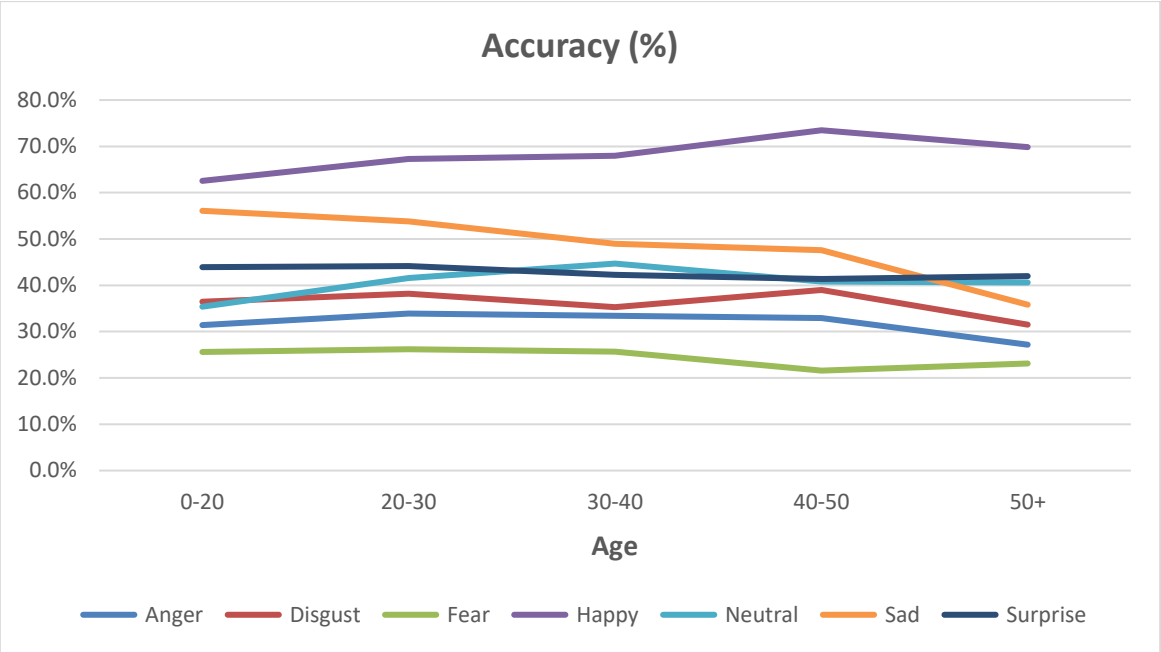

Figure 40 Accuracy for individual emotions with age

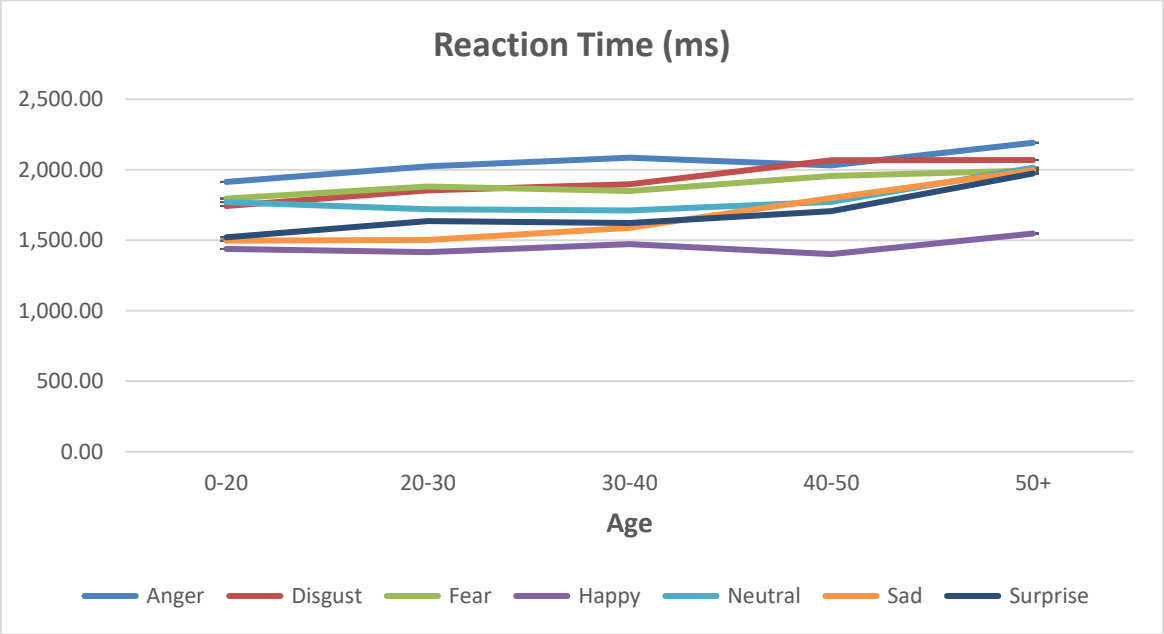

Figure 41 Reaction Time for individual emotions with age

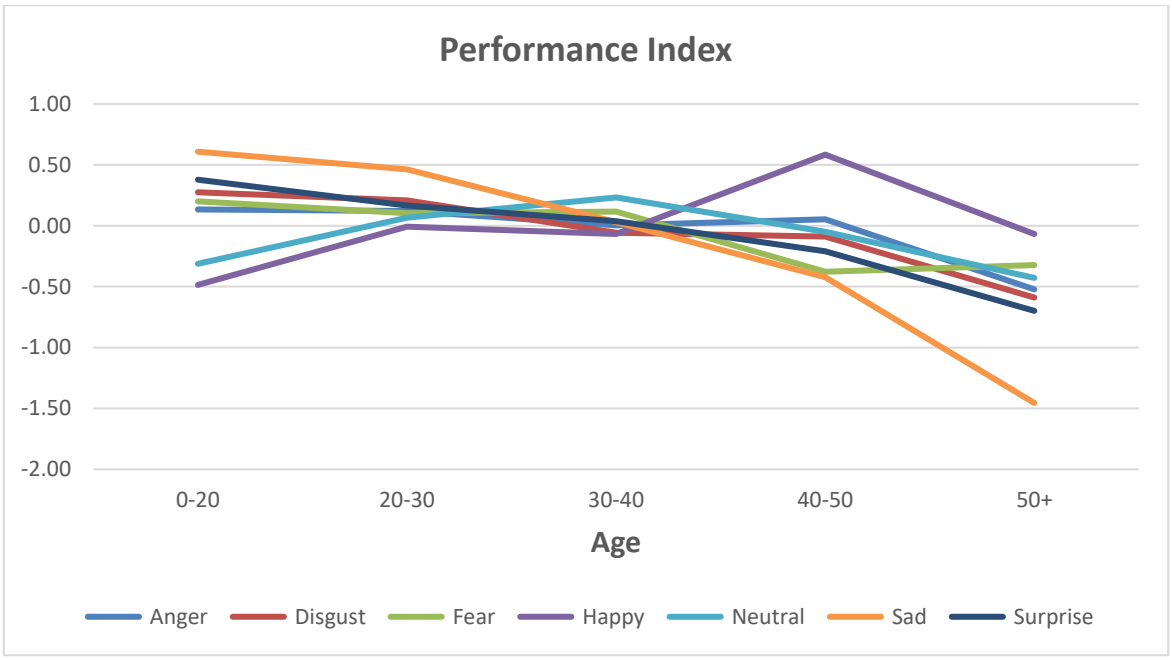

Figure 42 Performance Index for individual emotions with age

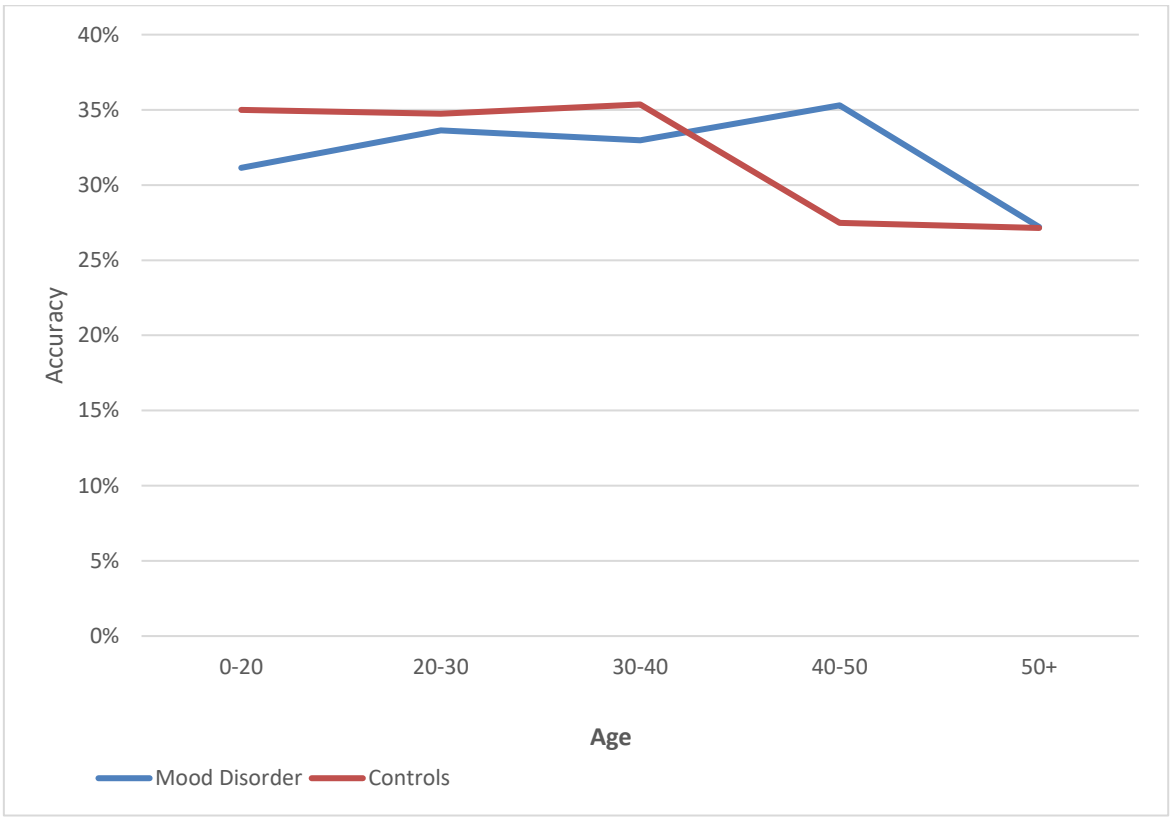

Figure 43 Accuracy for anger by group (healthy controls vs mood disorder) and age

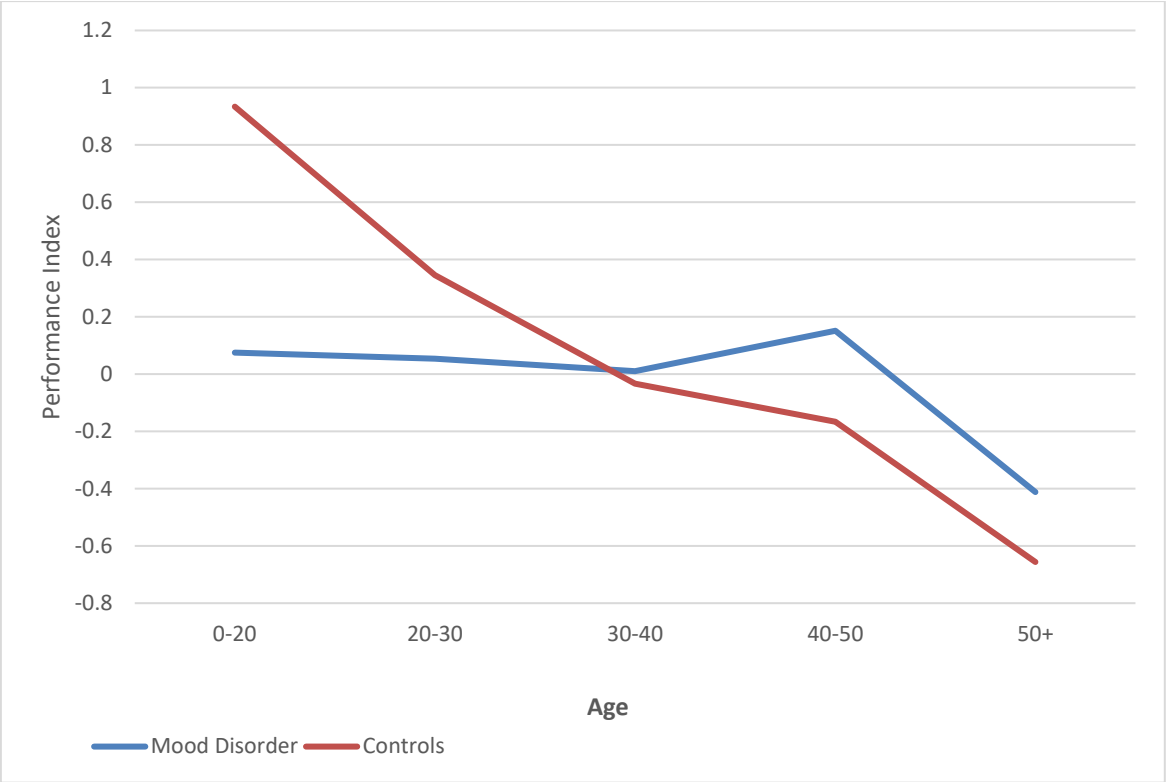

Figure 44 Performance Index for anger by group (healthy controls vs mood disorder) and age

9.4.2 Relationship Between Age, Current Depression and Facial Emotion Recognition Variables

Repeated measures ANOVA with current depression (MDE) as a factor (healthy controls, n = 61, MDE, n = 135) showed a significant interaction between age and emotion for accuracy, $F(5, 965) = 8.6$, $p < .001$, reaction time, $F(5, 965) = 6.5$, $p < .001$), and PI, $F(5, 965) = 9.7$, $p < .001$. There was no group by emotion interaction and no individual effect of group for accuracy, response time, or PI.

ANCOVA for individual emotions are presented in Table 17. Age showed multiple significant relationships for the three FER outcomes. Adding the interaction ‘group by emotion’ did not affect the results for any emotions.

Table 17 *Effects of Age and Current Depression on Facial Emotion Recognition*

	Accuracy			**Reaction Time**			**Performance Index**		
	Group	Age		Group	Age		Group	Age	
	F (p)	***F (p)***	***B***	***F (p)***	***F (p)***	***B***	***F (p)***	***F (p)***	***B***
Anger	0.260 (.61)	**5.30 (.02)**	**-0.002**	0.01 (.94)	**4.23 (.04)**	**8.52**	0.09 (.77)	**8.57 (.004)**	**-0.027**
Disgust	1.24 (.27)	1.17 (.28)	-0.001	0.10 (.75)	**8.16 (.005)**	**10.32**	0.36 (.55)	**7.60 (.006)**	**-0.024**
Fear	1.17 (.28)	**4.35 (.04)**	**-0.002**	0.001 (.97)	2.65 (.11)	5.95	0.63 (.43)	**7.42 (.007)**	**-0.022**
Happiness	0.12 (.73)	**6.64 (.01)**	**0.002**	0.05 (.83)	2.02 (.16)	4.12	0.005 (.94)	0.47 (.50)	0.007
Sadness	0.90 (.35)	**32.42 (<.001)**	**-0.005**	0.21 (.65)	**28.21 (<.001)**	**17.75**	0.90 (.35)	**55.69 (<.001)**	**-0.06**
Surprise	0.24 (.63)	0.79 (.38)	-0.001	0.01 (.92)	**13.49 (<.001)**	**11.02**	0.20 (.66)	**11.59 (.001)**	**-0.03**

Note: Significant outcomes in bold; **Group:** Control *n* = 61, Mood Depressed *n* = 135

9.4.3 Relationship Between Facial Emotion Recognition Variables and Non-Emotional Cognitive Variables

Table 18 presents the result of partial correlations (adjusted for age) between FER accuracy, reaction time, and PI, and non-emotional cognitive variables (three PCA Components and the individual cognitive variables of verbal fluency and motor screening). The influence of group was not examined given the lack of effects of group in the analysis of FER.

9.4.3.1 Accuracy

There was a significant positive partial correlation (adjusted for age) between disgust and both verbal fluency and the Verbal Working Memory Component. Sadness and surprise both showed positive partial correlations with the Verbal Memory Component. All correlations were positive, suggesting that better performance in these cognitive areas is related to better accuracy for those specific emotions.

9.4.3.2 Reaction Time

Reaction time to fear was not correlated with any of the non-emotional cognitive variables. Reaction time to anger showed a positive correlation with the Verbal Working Memory Component; that is, better verbal working memory performance was associated with slower reaction time for anger. Reaction time to sadness showed a positive partial correlation with the Spatial Working Memory Component, with better spatial working memory performance associated with increased reaction time to sadness. Reaction time to disgust, happiness, and surprise all showed negative partial correlations with verbal fluency, indicating that better verbal fluency was associated with faster reaction times for these emotions.

9.4.3.3 Performance Index

Anger and sadness did not corelate significantly with any of the non-emotional cognitive variables. Disgust, fear, happiness, and surprise all showed significant positive correlations with verbal fluency, while surprise was significantly positively correlated with the Verbal Memory Component.

Table 18 *Partial Correlations of Non-Emotional Cognitive Variables for Accuracy, Reaction Time, and Performance Index with Age Partialled Out.*

	Verbal Fluency	**Motor Screening**	**Verbal Memory Component**	**Spatial Working Memory Component**	**Verbal Working Memory Component**
Accuracy r(*p*)					
Anger	0.03 (.68)	-0.05 (.40)	0.04 (.49)	-0.11 (.08)	-0.05 (.40)
Disgust	**0.20 (.002)**	-0.05 (.45)	0.05 (.48)	-0.12 (.05)	**0.14 (.03)**
Fear	0.11 (.08)	0.05 (.47)	0.06 (.34)	-0.12 (.07)	0.10 (.11)
Happiness	0.06 (.35)	0.01 (.88)	0.01 (.84)	0.02 (.80)	0.02 (.71)
Sadness	0.10 (.58)	-0.10 (.10)	**0.13 (.05)**	-0.04 (.53)	0.03 (.65)
Surprise	0.03 (.62)	-0.01 (.91)	**0.13 (.03)**	-0.04 (.52)	0.09 (.17)
Reaction Time r(*p*)					
Anger	-0.07 (.24)	0.09 (.16)	0.01 (.93)	0.05 (.43)	**0.13 (.04)**
Disgust	**-0.14 (.02)**	0.04 (.48)	-0.02 (.75)	0.04 (.54)	0.07 (.27)
Fear	-0.10 (.18)	0.04 (.51)	-0.03 (.62)	0.04 (.53)	0.09 (.18)
Happiness	**-0.22 (.00)**	0.02 (.09)	-0.04 (.50)	0.12 (.06)	0.01 (.90)
Sadness	-0.08 (.19)	0.09 (.18)	-0.03 (.60)	**0.14 (.03)**	0.08 (.23)
Surprise	**-0.16 (.01)**	0.09 (.18)	-0.08 (.19)	0.08 (.21)	0.02 (.79)
Performance Index r(*p*)					
Anger	0.07 (.29)	-0.10 (.13)	0.03 (.69)	-0.11 (.09)	-0.12 (.05)
Disgust	**0.24 (.00)**	-0.06 (.32)	0.05 (.47)	-0.12 (.08)	0.05 (.45)
Fear	**0.16 (.011)**	0.00 (.97)	0.07 (.28)	-0.12 (.06)	0.01 (.85)
Happiness	**0.18 (.004)**	-0.07 (.31)	0.04 (.57)	-0.07 (.28)	0.01 (.88)
Sadness	0.08 (.21)	0.01 (.86)	0.11 (.09)	-0.12 (.06)	-0.03 (.60)
Surprise	**0.15 (.02)**	-0.07 (.27)	**0.17 (.009)**	-0.09 (.15)	0.05 (.39)

Note: Significant outcomes in bold; ***r*** = Pearson's correlation

9.5 DISCUSSION

9.5.1 Main Findings

This chapter examined the association between age, mood disorder diagnosis, and emotion processing. The main results were as follows:

- There was no effect of mood disorder on FER. This was the case whether healthy people were compared with people with mood disorder (MDD and BD combined) or healthy people were compared with people who were currently depressed (all MDE).
- There was an interaction between age and emotion on all three outcomes (accuracy, reaction time, PI). Further examination of this showed that increased age was significantly associated with reduced accuracy and/or PI, and increased latency, in processing emotions of anger, disgust, fear, sadness, and surprise. In no analysis was age associated with an improvement in PI on these emotions. However, increased accuracy in recognising happiness was seen with increased age, while there was no effect of age on reaction time or PI for happiness. As noted, these relationships were not modified by having a mood disorder or being currently depressed.
- To explore the relationship between emotion processing and non-emotional cognitive function, the age adjusted correlation between non-emotional cognitive function and FER performance was examined. The most consistent results were found for an association between verbal fluency and FER. A positive relationship was found between verbal fluency performance and accurate recognition of expressions of happiness, fear, surprise, and disgust. Conversely, a negative relationship was found between verbal fluency and speed of responding to expressions of disgust, happiness, and surprise.

9.5.2 Influence of Mood Disorder Diagnosis and Mood State

Having a mood disorder diagnosis did not have a significant effect on an individual's ability to process emotions when compared with people without such a diagnosis, and nor did being currently depressed (MDE). For individual emotions, results for the three facets of FER were generally consistent, with processing of happiness either improving or not changing significantly with increased age, while processing of other emotions declined with age. In all cases, apart from anger, mood disorder diagnosis did not modify the association between age

and FER performance. It could therefore be concluded that there is a “positivity bias” (regardless of mood disorder diagnosis) whereby processing of emotions other than happiness declines, while processing of happiness remains stable or improves with age. An analysis of the comparison between currently depressed (MDE) participants and healthy control participants, showing no difference in FER between groups, has been reported previously, but without considering the effects of age (Bourke et al., 2012). Data in the BD group have not been reported previously. However, one previous study analysing several FER tasks also found no overall performance difference from healthy controls in bipolar depression and euthymia (Robinson et al., 2015). The analysis in current depression (MDE) in the present study includes both the previously analysed group and a further 37 people with bipolar depression. The MDD group were only ‘moderately’ depressed, with a mean MADRS score of 24, which may have moderated against a significant group finding. It may also be the case that examining misidentification of neutral stimuli is a more sensitive measure than emotion identification, since previous research in mood disorders has shown most consistent results in misidentification of ambiguous faces as sad or attentional bias towards sad faces (Bourke et al., 2010). In the current analysis, misidentification was not examined, primarily because of the low numbers of neutral stimuli (only 24 neutral stimuli) which were presented in the paradigm employed.

These results conflict with the theory that in mood disorders, the opposite of the positivity bias (i.e., a bias towards negative emotional stimuli) would be seen, which increases or maintains a vulnerability to lowered mood (Disner et al., 2011; Miskowiak et al., 2019; Warren et al., 2015). Such findings have been seen in both euthymic and symptomatic mood disorder populations, but have not been completely consistent, in part due to the range of paradigms used to measure emotion processing. However, Miskowiak et al. (2019) conducted a comprehensive literature review of emotion processing which found that specifically for FER, deficits were seen in 77% of studies of remitted patients with BD (17/22) and in 71% of studies in symptomatic patients with BD (10/14).

There are further caveats to the data used in the current study. The BD group were relatively young, and conclusions cannot be drawn regarding effects of advanced aging. In addition, the BD group were in a variety of mood states and emotion processing may be different among manic, depressive, and euthymic mood states. Numbers of participants in each state in the BD group were too small to undertake sub-analysis, however, the influence of current depression

(MDE) has been examined in the combined group. The finding of an interaction between mood disorder and age for anger is an outlier in these results Figure 44.

9.5.3 Influence of Age

For identification of emotions other than happiness, increasing age was generally associated with reduced accuracy and PI, and longer reaction time. Increased accuracy of identifying happy faces was associated with increasing age, and no significant change was found with age in reaction time or PI. The PI was designed to examine overall performance, accounting for both speed and accuracy. Thus, in these data, older people are more accurate at recognising happy faces, but not quicker, and when these two variables are combined, "performance" is not improved. The current data suggest aspects of a positivity bias with increasing age. Results found are consistent with the findings of the Ruffman et al. (2008) meta-analysis for fear, where accuracy decreased with age. Regarding results related to happy faces, the Ruffman et al. meta-analysis did not find an increase in accuracy with increasing age, in fact, increasing age was associated with reduced accuracy, but less so for happy emotions. Of interest, the present study found a significant effect for surprise with age for accuracy, reaction time, and PI. Ruffman et al.'s meta-analysis did show a smaller decrease in accuracy for surprise, alongside what they found for happy. Similarly, Hayes et al. (2020), in their meta-analysis of task characteristics of 102 FER studies in young and older adults (n = 10526), showed that for reduced intensity photos only, surprise did show a reduction in accuracy with age. The image sets used in the two original studies described in this chapter included images that varied in intensity. A major difference between the current study and Ruffman et al.'s study is the mean age of participants. Ruffman et al. (2008) examined much older participants, with a mean age above 55 years. This is significantly older than the current sample, with a mean age of 25 years in the BD sample (maximum age 35) and a mean age of 38 years (maximum age 65) in the MDD and healthy samples.

Several previous studies have examined emotion recognition across the age range, which have been undertaken in healthy populations. In contrast, the current study examined the effects of age in populations with mood disorders in comparison to a relatively small healthy control group. Therefore, these analyses cannot be seen as directly comparable to previous studies examining the effects of age on emotion processing. Such studies have tended to suggest a U-shaped curve for overall emotion recognition performance, with ability peaking in middle-age and then declining (Horning et al., 2012; Olderbak et al., 2019). Olderbak et al. (2019) used an Identification of Emotion Expressions from Composite Faces Task and analysed

performance overall, rather than by specific emotion. They found peak performance at 30 years of age with performance declining thereafter. Using a dynamic image task, Horning et al. (2012) found that for fear, sadness, and happiness, there was a peak in performance at 45 years of age and decline in accuracy thereafter. In contrast, and keeping more in line with the current study's results and those of Ruffman et al.'s. West et al. (2012), also using a dynamic image task, found significant decline for fear, anger, and sadness, but no decline with age for happiness. In contrast to the current study, however, West et al. found no improvement in accuracy recognising expressions of happiness with age. West et al.'s study extended to a much greater age and the greatest declines were seen from the age of 60 years and onwards. Similarly, Kessels et al. (2014) found a linear decline with age using static images, that became significant in the 60s, particularly for anger, with relatively less decline for other emotions including happiness. Overall, the evidence is reasonably consistent that there is little decline in accuracy recognising happy expressions compared with negative emotions, while in the current study, in a group consisting mainly of relatively younger (young adult/middle age) people with mood disorders, age was associated with an increase in accuracy of recognising happy expressions. As noted, this is surprising given this current study's hypothesis of a negative bias in people with a mood disorder.

9.5.4 Relationship of Emotional Processing to Non-emotional Cognitive Function

The Dynamic Integration Theory suggests that negative emotions are more effortful to process, and therefore, reduced cognitive functioning in older people results in a tendency to attend less to negative information (Labouvie-Vief, 2003) . This theory suggests a relatively close relationship between emotional processing and non-emotional cognitive function. However, the current analyses found few outcomes of significance when examining the relationship between performance on FER ("hot" processing) and non-emotional cognitive function ("cold" processing). The emotion most clearly linked to non-emotional cognitive functions was disgust; with accuracy in recognising expressions of disgust correlating with performance on measures of verbal fluency (Controlled Oral Word Association Test) and Verbal Working Memory. Verbal fluency was the cognitive function most consistently linked to the processing of emotions, with a positive relationship with the PI, and negative relationships with reaction time, for disgust, fear, happiness, and surprise.

Generally, it is considered that crystalised knowledge such as word finding, procedural memory, or cultural knowledge are preserved in aging (Christensen, 2001). Verbal fluency, while requiring word finding, also involves executive functions to allow for specific letter- or

category-based retrieval (Whiteside et al., 2016). A meta-analysis by Rodríguez-Aranda and Martinussen (2006) indicated that verbal fluency is negatively affected by age. Specifically, this decline in verbal fluency changes most significantly after 60 years of age and continues thereafter. Associations found in the current analyses may suggest that some processes involved in emotion processing are linked to those used during verbal fluency tasks. It is of note, however, that most of the current sample reported here were much younger than 60 years.

In the current study, the age range of the sample was 16 - 65 years, so this does not provide evidence of decline in cognitive processes that occur beyond this age, which may be accelerated. At the younger age, results are also likely to be affected by brain maturation. De Luca et al. (2003) examined executive function changes over the lifespan, suggesting that improvement in executive functioning capabilities correlates with increased myelination and diffuse synaptogenesis of frontal regions, which continues well into the second decade of life. The peak of performance of some executive tasks such as organisation of goal-directed behaviour is seen between 20 and 29 years (De Luca et al., 2003), meaning that maturation of this skill is likely to still be occurring for participants in the current study. Conversely, De Luca et al. (2003) also found that for those skills that mature in early adulthood, decline is seen relatively early in the aging process, with some skills declining significantly in the 50-64 year age range.

9.5.5 Limitations

As an examination of the effects of age on emotional processing in mood disorders and healthy people, the current study has several limitations. First, as mentioned in previous sections, the age range means that in some participants, brain maturation was likely still occurring. This may have resulted in effects that are quite different to those of “aging”. Second, the age range did not extend into more advanced aging beyond the age of 65. Third, there was a small number of neutral faces in the FER paradigm, meaning misidentification of neutral faces was not able to be examined. This limitation is important, as misidentification shows the most consistent evidence of negative attentional biases in mood disorders (Bourke et al., 2010). When examining the hypothesis that declining executive function may impact on processing of negative emotions, the battery of cognitive tests was broad in nature, with relatively few tests in each domain. More detailed analysis using more cognitive tasks in each domain would be interesting, most especially in the verbal fluency, verbal memory, and

verbal working memory (digit span) domains, all of which showed preliminary results of significance.

9.5.6 Strengths

The current study represents an initial exploration of the effects of age on emotional processing in healthy participants and in people with mood disorders aged 16 to 65 years. It is the first direct examination of the effects of age in a large (n = 198) sample of individuals with mood disorders. Of note, is the use of a PI to explore the composite of speed and accuracy involved in the performance of the FER task.

9.6 CONCLUSION

The current study explored interactions between age and mood disorder diagnosis on emotion processing, while also considering the effect of non-emotional cognitive function. A degree of positivity bias was demonstrated with increasing age, across an age range of 16 – 65 years, in healthy participants and participants with mood disorders (MDD and BD). There was no group difference in emotional processing regardless of whether mood disorder diagnosis or current depression (MDE) was examined. The positivity bias is seen here by late middle age, and in people with mood disorders, which is surprising given that findings in mood disorder samples have generally shown the opposite. A clear future direction would be to examine the relationship between mood disorder, age, and emotional processing in older-age samples (over 65 years).

Chapter 10 - Summary and Conclusions

The aim of this thesis was to extend understanding of changes in emotion processing in mood disorders, aging, and the intersection of both. Additionally, of interest was the role of non-emotional cognitive functioning in these associations.

10.1 REVIEW OF AREAS OF INTEREST TO THE THESIS

A brief review of mood and anxiety disorders highlighted the importance of research examining these disorders (see Chapter Two). As indicated in Chapter Two, these disorders seem to exist on a spectrum of severity and at the more severe end of this spectrum, the course of these disorders is chronic and persistent (Steinert et al., 2014). Alongside this, premature mortality is a risk for those experiencing these conditions (Schaakxs et al., 2018), suggesting that understanding these disorders further is vital to improving the wellbeing of people who experience them.

Non-emotional cognitive processes are important when considering changes in emotion processing due to the suggestion that non-emotional processes may be involved in emotional regulation (for review of non-emotional cognition, see Chapter Three [mood disorders] and Chapter Five [aging]). For example, changes in executive functioning, such as inhibition or set shifting, may result in differences in the ability to regulate emotions in accordance with goal-directed processes, thus making regulation less efficient or inaccurate (Friedman & Miyake, 2017).

Evidence from meta-analyses in BD and MDD show the presence of difficulties with verbal and visual memory, attention, processing speed and executive function in people with these disorders, which persist into euthymia in a percentage of individuals (Douglas et al., 2018). There may be a cumulative effect of number of episodes on cognitive function, particularly demonstrated in the case of memory decline in MDD (Semkovska et al., 2019).

In aging, a decline in processing speed with age is seen consistently, when measured by tasks other than simple motor tasks. Simple attentional tasks show few changes with aging, but tasks involving divided or complex attention indicate a decline with age. Decreases in memory, particularly for visuospatial memory have been identified, however, there is some suggestion that for some aspects of memory the deficit is in learning the information, rather

than retention or retrieval. Vocabulary and verbal reasoning are not found to change significantly with age; however, fluency tasks do show a decline with age.

The facial emotion processing evidence in younger people indicates that individuals with depression show changes in emotion processing, although differential effects per emotion remain inconsistent (Bourke et al., 2010). Alongside this, compared with healthy control participants, those with depression are more likely to misinterpret neutral, ambiguous, and emotional faces as a negative emotion (Douglas & Porter, 2010; Stuhrmann et al., 2011). Further, an attentional bias towards negative and away from positive information is present in people with depression compared with healthy people (Joormann & Gotlib, 2007). In BD, generalised deficits in FER are seen in both mood episodes and in remission, however differential effects on individual emotions are again, not elucidated (Miskowiak et al., 2019). In anxiety disorders, there is some evidence of bias towards threat-related stimuli (Armstrong & Olatunji, 2012) (see Chapter Six for further review of emotion processing in mood disorders).

Significant research has explored changes in emotion processing in normal aging (see Chapter Five). This research, with respect to FER, has been summarised in a series of meta-analyses (Goncalves et al., 2018; Hayes et al., 2020; Ruffman et al., 2008). While an overall positivity bias has been found in many experimental paradigms, differential effects between emotions have not been consistent. The Ruffman et al. 2008 meta-analysis found that older adults were less accurate at identifying anger, sadness, and fear, and to a smaller degree, happiness (Ruffman et al., 2008). The Goncalves et al. 2018 analysis found significantly lower accuracy for older adults for the emotions of anger, sadness, fear, surprise, and happiness (Goncalves et al., 2018). Hayes et al. (2020) also found older adults to be less accurate in all emotions, including happiness, except for disgust. These meta-analyses suggest that the positivity bias may not be robust. While the difficulties with identifying negative emotions are larger in effect size than for positive emotions, an effect is still present for happiness.

Multiple theories attempt to explain the positivity bias in aging but currently no one theory can explain the results across studies (see Chapter Five). Dynamic Integration Theory suggests the importance of cognitive control or executive functioning in emotion processing. It suggests that negative information is more cognitively demanding to process. A decrease in cognitive control with age means that processing negative information becomes more difficult and as such, is not attended to, resulting in a bias for positive information. Exploring the association between non-emotional and emotion processing is particularly important in

examining the validity of this theory. Socioemotional Selectivity Theory, on the other hand, is a model of motivation and goal-directed behaviour which suggests as the time to the end of our life becomes shorter our goals shift. This shift is likely towards prioritising wellbeing and, as such, our motivation is to attend more to information which enhances wellbeing, namely positive information. Conversely, our attention also shifts away from negative information, which may decrease wellbeing.

A systematic review of emotion processing in older adults with mood and anxiety disorders (Chapter Six) showed that current evidence, particularly in depression, is inconsistent. However, some neuroimaging studies do show differences in activation in emotional processing circuitry in older adults with depression, with a general pattern of increased limbic but reduced prefrontal activity as in younger depressed participants. In anxiety, there is a paucity of studies, although from the few there are, there is a suggestion of interference with processing from threat-related words in anxiety and from trauma-related words in PTSD in older adults.

10.2 RESULTS OF CURRENT STUDIES

Chapter Eight presented the results of an original study conducted for this thesis. The study examined emotion processing and its association with age and non-emotional cognition.

Results from Chapter Eight indicated some evidence of a positivity bias with age in the sample, evidenced by reduced accuracy in identifying negative emotions (fear, sadness), and reduced negative misinterpretation of neutral expressions as age increased. Increasing age also reflected a reduced ability to efficiently manage the competing demands of accuracy and the instruction to respond as quickly as possible. Stronger interference effects from negative stimuli (eStroop) with aging aligns with the DIT, which proposes that negative information becomes more cognitively demanding to process. For non-emotional cognition, visuospatial learning, verbal switching, and processing speed were all found to be reduced as age increased.

Chapter Nine presented a pooled analysis from previously recruited participants with mood disorders and healthy control participants between the ages of 16 and 65 years. This analysis explored interactions between age and mood disorder on emotion processing, alongside consideration of the role of non-emotional cognition on these variables.

No group difference in emotion processing was found between healthy control participants and those with mood disorder, regardless of whether the participant was in a current MDE or

not. This lack of difference between mood disorder and healthy control groups was somewhat inconsistent with literature outlined in Chapter Four, which suggests that while differential effects between emotions are inconsistent, there is the general trend of a change in emotion processing overall in people with mood disorders. The most consistent change is a negativity bias in processing facial emotions in depression; a phenomenon which is suspected to increase or maintain a vulnerability to lowered mood. In BD, a comprehensive review by Miskowiak et al. (2019) found that FER deficits were seen in over 70% of studies regardless of mood state. In the Chapter Nine analysis, examination of misidentification of neutral emotions was not possible due to a low number of neutral stimuli in the paradigm.

Regarding changes in emotion processing with age, the analysis in Chapter Nine found the presence of a positivity bias by late middle age, including in those with mood disorders. This was shown by accuracy in processing happy faces either improving or not changing significantly as age increased, while accuracy in processing of other emotions declined with age. Apart from the emotion of anger, mood disorder did not modify the interaction between age and FER performance.

In examining the impact of non-emotional cognitive functioning on emotion processing, verbal fluency was found to have the most consistently significant association with emotion processing. A positive association between verbal fluency and PI, and a negative association between verbal fluency and reaction time, was found for disgust, fear, happiness, and surprise. These findings suggest that some of the processes used in verbal fluency tasks may also be involved in processing of emotion.

Overall, it is noted that evidence of a positivity bias with aging was found in both studies presented in this thesis. Considering this finding in the context of the explanatory models for the positivity bias mentioned in Chapter Five (DIT, SST, ABM), the following is noted. The ABM posits that age related changes in the brain are the driving mechanism for changes in emotion processing with aging. Accordingly, the changes seen in emotion processing should align with brain areas that are affected by aging, suggested to be in the limbic system, including the amygdala. As this study only focused on behavioural outcomes and did not have imaging or brain region activation data it is difficult to compare the results found to this theory. It could be suggested that a decline in amygdala processing could be seen in an overall decrease in ability to process social content. The RMET measures complex social emotions and asks the participant to infer the emotional state of the image. If there is a decrease in amygdala function with age, then it is likely there would be age related effects seen on this

task. In the current study, no differences with age were seen in accuracy across this task. Dynamic Integration Theory highlights the importance of non-emotional cognition as a factor contributing to changes in emotion processing with age. Across Chapters Eight and Nine, little evidence of a close relationship between non-emotional cognitive functioning and emotion processing was found. In Chapter Nine, the emotion that was most strongly linked to non-emotional cognitive functions was disgust, with accuracy correlated with performance on verbal fluency and verbal working memory tasks. In Chapter Eight, when controlling for non-emotional cognition, significant correlations were found between accuracy of recognition for fear/sadness/anger and age, suggesting that processes other than a decline in non-emotional cognitive function are important.

In turn, SST is a motivational model and highlights the importance of enhanced wellbeing as an increasing priority as age increases. In Chapter Eight, evidence of bias away from negative information with increased age (i.e., reduced accuracy for fear sadness, reduced negative misinterpretation) may suggest that a goal of enhancing wellbeing is being undertaken by less processing of negative information. The decline in accuracy of identifying negative emotions with age and increase in accuracy of happy faces with increased age found in Chapter Nine further supports the suggestion that prioritising wellbeing may be an underlying factor in processing behaviour with age. While these results add some evidence of a possible underlying change in processing mechanisms with age, it is difficult to link this further to the SST without including other measures. In particular, measures of wellbeing and of the goals being used, either explicitly or implicitly through an induction or manipulation type task.

10.3 FUTURE DIRECTIONS

As detailed in Chapters Eight and Nine, limitations of the presented analyses provide an indication for the future direction of research in this area. The FER task used in these studies, while being a task which is commonly used in clinical studies, has limitations which must be acknowledged. First, the ecological validity of the images used. Black and white, still and posed expression images are not particularly representative of everyday interactions that people may have. Tasks which use colour images, moving video, and genuine expressions are starting to be used in research in response to this criticism (see (Goncalves et al., 2018) for review). For this particular study, however, it was hoped that the data gathered would be able to be compared or pooled with FER data collected in other studies to further examine associations between emotion processing, aging and mood disorders. Second, the use of morphed images and the degrees of morphing used must be considered. Morphed images are

generally used to counter the ceiling effects sometimes seen in these types of tasks, particularly for positive emotions. Using morphing of faces in this manner has been done in previous studies and as such, using this paradigm in the current work further aligned the results obtained with the previous literature (Young et al., 2002). Future research including emotion processing tasks with more moderate emotion intensity levels to reduce possible ceiling effects, and inclusion of more neutral or ambiguous stimuli to allow for examination of misidentification, is recommended.

The emotion processing literature in older adults with mood disorders is still in the early stages and while using tasks which have more ecological validity will be important in future research, it was determined that for this work, use of tasks which have been more thoroughly studied at this point would provide the most useful data for analysis.

Inclusion of larger non-emotional cognitive batteries, including domain or global level indices created from multiple tasks per domain, would allow more detailed investigation of the processes being explored and also reduce statistical difficulties incurred when examining large numbers of individual variables.

As mentioned in Chapter One, the initial aims of this thesis were to explore emotion processing in older adults with mood disorders and the relationship with non-emotional cognition. Future studies could be conducted to examine this directly by recruiting a large sample of older adults with mood disorders. Even gender ratios and including participants from middle age would further add nuance to the outcomes explored.

10.4 TRANSLATION TO TREATMENT

It is suggested that the positivity bias itself has been developed as a protective factor in older people, likely to improve wellbeing and enhance survival desire (Carstensen, 2006). It is possible that this bias is only effective when older people are still socially active. For older people who end up isolated and removed from society in general, a reduction in positive stimuli may mean that the bias is not protective. Further, when mood is lowered to a level which is of clinical significance, this bias may be less apparent, and no longer a protective factor for wellbeing.

Of note, however, the analysis in Chapter Nine did not show a negativity bias in the mood disorder sample. In fact, a bias away from negative information was found with aging in this sample. This may be due to methodological issues, including the mixture of affective states (i.e., depression and euthymia), and the relatively young age of the sample overall. However,

if negativity bias is not present in older adults with mood disorders this has significant implications. That is, there may be other important mechanisms involved in mood disorder with aging. One possible explanation for this is that cognitive decline with aging opposes the effects of mood disorder. However, our data do not support this.

As mentioned much earlier in the thesis, the Cognitive Neuropsychological Hypothesis of depression attempts to explain emotion processing results seen in antidepressant action. In practice, this means that clinical studies use the results of emotion processing tasks to determine the effectiveness of antidepressant medications, including new medications that are being trialled. However, the effects of aging as discussed in this thesis are not simple or clear and this may suggest that data from pre-clinical studies of possible antidepressants in younger participants may not generalise to older populations.

The results from these studies are useful in helping to understand emotion processing in older people with mood disorders. The research in this area is still in its infancy and this study aimed to contribute more data to the field. The use of more established and less complex tasks is important when examining groups which are more likely to be impaired, as long batteries using multiple tasks are likely to be impacted by other changes, in areas such as cold cognition (i.e. attention) alongside other considerations such as fatigue.

It is hoped that as more data becomes available a clearer picture of what is occurring in this specific group will emerge and at that point, application of that knowledge will be able to inform treatments and interventions for patients directly.

10.5 CONCLUSION

This thesis set out with three main aims. First, to provide a background review of emotion processing in people with mood disorders and in healthy aging and to use systematic review methodology to synthesise the current literature in emotion processing in older adults with mood and anxiety disorders. Second, to examine emotion processing in aging and in mood disorders using two different methodologies and analyses. Finally, to highlight areas and directions for future explorations in aging and mental health.

From the first aim, the vital nature of understanding the place of emotion processing in mood disorders, particularly for people for whom these disorders have a chronic course, was emphasised. Alongside this, a brief discussion of the impact that non-emotional cognition, particularly in aging, may have on the processes was had. Findings from the second aim

provided some evidence of age-related changes in emotion processing and support further investigation in this area as a useful endeavour.

Finally, future directions for research in this area could focus on prioritising paradigms which have been shown to be more sensitive to detecting possible attentional changes, such as those which consider misidentification of neutral or ambiguous stimuli, or which use more realistic stimuli. Alongside these, larger studies including more participants both in middle age and older age who have mood disorders would further help to elucidate the changes occurring in emotion processing in mood disorders with advancing age. Identifying and understanding changes in emotion processing in mood disorders and in aging is important to allow development of interventions for mood disorders which take into account the interactions between aging and mood disorders in the crucial area of emotion processing.

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Appendices

Appendix A

Human Ethics Committee Approval Letter July 2016

H16/073

Academic Services
Manager, Academic Committees, Mr Gary Witte

Professor R Porter

27 July 2016

Department of Psychological Medicine (ChCh)
Terrace House, 4 Oxford Terrace
University of Otago, Christchurch
University of Otago Medical School

Dear Professor Porter,

I am again writing to you concerning your proposal entitled "**Emotional Processing in the Elderly Depressed**", Ethics Committee reference number **H16/073**.
Thank you to Vanessa Gray, student investigator on the above project, for her response of 22nd July 2016 to the issues raised by the Committee.
On the basis of this response, I am please to confirm that the proposal now has full ethical approval to proceed.
While responding to the issues raised by the Committee, it is noted that two further amendments are requested: i) to amend the follow up time from the baseline assessment to the second assessment from 12 weeks to 16 weeks and ii) to add the "Cognitive complaints in bipolar disorder rating assessment" scale.
The Committee approves the above amendments but recommends, however, that the title is removed from the questionnaire since most participants will not have bipolar disorder and, as such, may cause undue concern. The Committee also asks that the "NHS" field is removed as this is not applicable.
The standard conditions of approval for all human research projects reviewed and approved by the Committee are the following:
Conduct the research project strictly in accordance with the research proposal submitted and granted ethics approval, including any amendments required to be made to the proposal by the Human Research Ethics Committee.

Inform the Human Research Ethics Committee immediately of anything which may warrant review of ethics approval of the research project, including: serious or unexpected adverse effects on participants; unforeseen events that might affect continued ethical acceptability of the project; and a written report about these matters must be submitted to the Academic Committees Office by no later than the next working day after recognition of an adverse occurrence/event. Please note that in cases of adverse events an incident report should also be made to the Health and Safety Office:
http://www.otago.ac.nz/healthandsafety/i
ndex.html

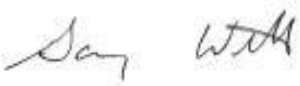
Advise the Committee in writing as soon as practicable if the research project is discontinued.

Make no change to the project as approved in its entirety by the Committee, including any wording in any document approved as part of the project, without prior written approval of the Committee for any change. If you are applying for an amendment to your approved research, please email your request to the Academic Committees Office:
gary.witte@otago.ac.nz

jo.farrondediaz@otago.ac.nz

Approval is for up to three years from the date of this letter. If this project has not been completed within three years from the date of this letter, re-approval or an extension of approval must be requested. If the nature, consent, location, procedures or personnel of your approved application change, please advise me in writing.
The Human Ethics Committee (Health) asks for a Final Report to be provided upon completion of the study. The Final Report template can be found on the Human Ethics Web Page http://www.otago.ac.nz/council/committees/committees/HumanEthicsCommittees.html

Yours sincerely,



Mr Gary Witte
Manager, Academic Committees
Tel: 479 8256
Email: gary.witte@otago.ac.nz

c.c. Professor R Porter Head Department of Psychological Medicine (ChCh)

Appendix B

Human Ethics Committee Study Re-approval 2019

H16/073

Academic Services
Manager, Academic Committees, Mr Gary Witte

Professor R Porter 25 June 2019

Department of Psychological Medicine (ChCh)
Terrace House, 4 Oxford Terrace
University of Otago, Christchurch
University of Otago Medical School

Dear Professor Porter,

I am again writing to you concerning your proposal entitled "**Emotional Processing in the Elderly Depressed**", Ethics Committee reference number **H16/073**.

Thank you to Vanessa Gray, PhD student investigator on the above project, for her email of 24th June 2019, with request for amendment attached.

The Committee accepts and approves the amended advertisement posters and grants re-approval of the study for a further 3 years from the date of this letter.

Your proposal continues to be fully approved by the Human Ethics Committee. If the nature, consent, location, procedures or personnel of your approved application change, please advise me in writing. I hope all goes well for you with your upcoming research.

Yours sincerely,

Mr Gary Witte
Manager, Academic Committees
Tel: 479 8256
Email: gary.witte@otago.ac.nz

c.c. Professor R Porter Head Department of Psychological Medicine (ChCh)

Appendix C

Information Sheet for Control Sample (45-65)

UNIVERSITY
of
OTAGO

Te Whare Wānanga o Otago

DEPARTMENT OF PSYCHOLOGICAL MEDICINE

Clinical Research Unit
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Emotion Processing in Older Persons

Information Sheet for Control Sample (45-65)

Introduction

You are being invited to take part in a research study. It is important for you to understand why the research is being done and what it will involve. Please take the time to read over this information sheet carefully and to ask us if there is anything that is not clear or if you would like more information. You are free to discuss this study with others to help you come to a decision. You are welcome to ask a support person to join you in asking further questions about the study.

What is the purpose of the study?

Changes in memory and thinking are common in aging. Research also suggests that aging may impact how people think about emotions. This study will measure emotion processing and memory in older persons. You have been asked to participate as we are recruiting a younger sample of healthy adults to explore what changes may occur due to aging, independent of depression.

What will I have to do if I take part?

First, you will have an interview with one of our research team to find out about your health and functioning. You will also be asked to complete questionnaires that assess mental health symptoms and general functioning, and to complete a cognitive assessment, which involves performing tests of memory and attention. The cognitive assessment will take about one and a half hours.

Who is running the study?

This research is being conducted by:

- Professor Richard Porter, Dr Katie Douglas, and Vanessa Gray from the Department of Psychological Medicine, University of Otago, Christchurch; Dr Dominic Lim from Older Persons Health, Burwood Hospital; and Associate Professor Adam Vogel from the University of Melbourne.

Do I have to take part?
It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are free to withdraw at any time without giving a reason.

What are the possible advantages of taking part?
The information we get from this study may help us to improve the treatment in the future for patients with depression.

What are the risks involved in taking part in the study?
We do not think it is likely that there will be any major risks in participation. Should any distress become apparent your GP will be contacted.

Will I receive compensation for time taken to be part of this study?
Participants will be compensated in the form of a $50 Westfield voucher.

Will my taking part in this study be kept confidential?
This study is conducted within the Department of Psychological Medicine (University of Otago, Christchurch).

All material that you provide us will be treated in the utmost confidence. We will hold research information about you on a computer in the Department of Psychological Medicine in Christchurch. The study has a security system which ensures that all information you provide is stored in anonymous form on computer files and that no data that can be linked to an individual can be accessed without knowledge of this security system. Only those directly involved in the study will have access to this information and we will ensure that confidentiality is kept. Your identity will not be revealed in any reports based on this study. Occasionally other researchers request data in order, for example, to add to data from other studies to gain better estimates of the effectiveness of treatments or to better understand factors influencing treatment outcomes. If data was provided to other researchers it would be anonymised (not able to be identified as yours) and we will ask you to consent to this specifically. One of the tasks will involve having your answers recorded using a sound recorder. These recordings will be sent to the University of Melbourne for analysis, however the content will not be listened to by any third party.

What will happen to the results of the research?
We plan to finish the study by the end of 2021 and to submit the results for publication in science journals. The results will also comprise part of the doctoral thesis of one of the researchers. The identity of the participants will not be made public in these works.

Where can I get information about the study?
Vanessa Gray may be contacted by telephone or email: Phone: 0274738587 Email: vanessa.gray@otago.ac.nz

*This study has been approved by the **University of Otago Human Ethics Committee (Health).***
If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 64-3-479 8256 or gary.witte@otago.ac.nz). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

Appendix D

Information Sheet for Control Sample (65+)

UNIVERSITY
of
OTAGO

Te Whare Wānanga o Otago

DEPARTMENT OF PSYCHOLOGICAL MEDICINE

Telephone: 0274738587
Email: vanessa.gray@otago.ac.nz

Clinical Research Unit
Terrace House
4 Oxford Tce
Christchurch

Emotion Processing in Older Persons

Information Sheet for Control Sample (65+)

Introduction

You are being invited to take part in a research study. It is important for you to understand why the research is being done and what it will involve. Please take the time to read over this information sheet carefully and to ask us if there is anything that is not clear or if you would like more information. You are free to discuss this study with others to help you come to a decision. You are welcome to ask a support person to join you in asking further questions about the study.

What is the purpose of the study?

Changes in memory and thinking are common in aging. Research also suggests that aging may impact how people think about emotions. This study will measure emotion processing and memory in older persons and in a younger sample of adults.

What will I have to do if I take part?

First, you will have an interview with one of our research team to find out about your health and functioning. You will also be asked to complete questionnaires that assess mental health symptoms and general functioning, and to complete a cognitive assessment, which involves performing tests of memory and attention. The cognitive assessment will take about two hours.

Who is running the study?

This research is being conducted by:

- Professor Richard Porter, Dr Katie Douglas, and Vanessa Gray from the Department of Psychological Medicine, University of Otago, Christchurch; Dr Dominic Lim from Older Persons Health, Burwood Hospital; and Associate Professor Adam Vogel from the University of Melbourne.

Do I have to take part?
It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are free to withdraw at any time without giving a reason.

What are the possible advantages of taking part?

The information we get from this study may help us to improve the treatment in the future for patients with depression.

What are the risks involved in taking part in the study?
We do not think it is likely that there will be any major risks in participation. Should any distress become apparent your GP will be contacted.

Will I receive compensation for time taken to be part of this study?
Participants will be compensated in the form of a $50 Westfield voucher.

Will my taking part in this study be kept confidential?
This study is conducted within the Department of Psychological Medicine (University of Otago, Christchurch).

All material that you provide us will be treated in the utmost confidence. We will hold research information about you on a computer in the Department of Psychological Medicine in Christchurch. The study has a security system which ensures that all information you provide is stored in anonymous form on computer files and that no data that can be linked to an individual can be accessed without knowledge of this security system. Only those directly involved in the study will have access to this information and we will ensure that confidentiality is kept. Your identity will not be revealed in any reports based on this study. Occasionally other researchers request data in order, for example, to add to data from other studies to gain better estimates of the effectiveness of treatments or to better understand factors influencing treatment outcomes. If data was provided to other researchers it would be anonymised (not able to be identified as yours) and we will ask you to consent to this specifically. One of the tasks will involve having your answers recorded using a sound recorder so we can look at how aspects of your voice change over the study. These recordings will be sent to the University of Melbourne for analysis, however the content will not be listened to by any third party.

What will happen to the results of the research?
We plan to finish the study by the end of 2021 and to submit the results for publication in science journals. The results will also comprise part of the doctoral thesis of one of the researchers. The identity of the participants will not be made public in these works.

Where can I get information about the study?
Vanessa Gray may be contacted by telephone or email: Phone: 0274738587 Email: vanessa.gray@otago.ac.nz

*This study has been approved by the **University of Otago Human Ethics Committee (Health).** If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 64-3-479 8256 or gary.witte@otago.ac.nz). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.*

Appendix E

Consent form for Control Sample (45-65)

UNIVERSITY
of
OTAGO

Te Whare Wānanga o Otago

DEPARTMENT OF PSYCHOLOGICAL MEDICINE

Telephone: 0274738587
Email: vanessa.gray@otago.ac.nz

Clinical Research Unit
Terrace House
4 Oxford Tce
Christchurch

Emotion Processing in Older Persons

Consent Form for Control Sample (45-65)

I have been invited to take part in a study investigating emotion processing and memory in older persons. This research is being led by Professor Richard Porter and Vanessa Gray at the Department of Psychological Medicine, University of Otago, Christchurch.

- I have read and understood the Information Sheet for 'Emotion Processing in Older Persons', dated 28 February 2020.
- I have had my questions about the study answered
- I know who to contact if I have any questions about the study

I understand that:

- My taking part in the study is voluntary (my choice).
- I may withdraw from the study at any time, and in the event that I withdraw from this study all data collected from me will be destroyed and will not be included in the study.
- I will complete questionnaires which will ask about mental health symptoms and general functioning.
- I will complete tests of memory, attention, organisation, and emotion processing.
- I will receive compensation of a $50 Westfield voucher.
- I understand how the data will be stored.

- I understand the results of the study will be published.
- I understand that every effort will be made to preserve my anonymity.
- That anonymised data may be shared with other research groups if requested
- I understand that this study has received ethical approval from *University of Otago Human Ethics Committee (Health).*

I consent to taking part in this study.	YES	NO
I consent to having a part of the sessions recorded and listened to by members of the research team and analysed overseas.	YES	NO
I understand I will receive a $50 Westfield voucher.	YES	NO
I consent to anonymised information I provide for this study being used in other related research.	YES	NO
I wish to receive a copy of the results of this study. I understand that there will be a significant delay between the information I provide and receiving the results. *If YES, please provide e-mail or mailing address: -* _____	YES	NO

I,		Hereby consent to take part in this study

(print full name)

Study Participant's Signature:	

(sign here)

Date:		Telephone:	

In my opinion, consent was freely given and the participant understands what is involved in this study.

Study Investigator's Name:	

(print full name)

Study Investigator's Signature:		Date:	

(sign here)

Appendix F

Consent form for Control Sample (65+)

UNIVERSITY
of
OTAGO

Te Whare Wānanga o Otago

DEPARTMENT OF PSYCHOLOGICAL MEDICINE

Telephone: 0274738587
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Clinical Research Unit
Terrace House
4 Oxford Tce
Christchurch

Emotion Processing in Older Persons

Consent Form for Control Sample (65+)

I have been invited to take part in a study investigating emotion processing and memory in older persons. This research is being led by Professor Richard Porter and Vanessa Gray at the Department of Psychological Medicine, University of Otago, Christchurch.

- I have read and understood the Information Sheet for 'Emotion Processing in Older Persons', dated 28 February 2020.
- I have had my questions about the study answered
- I know who to contact if I have any questions about the study

I understand that:

- My taking part in the study is voluntary (my choice).
- I may withdraw from the study at any time, and in the event that I withdraw from this study all data collected from me will be destroyed and will not be included in the study.
- I will complete questionnaires which will ask about mental health symptoms and general functioning.
- I will complete tests of memory, attention, organisation, and emotion processing.
- I will receive compensation of a $50 Westfield voucher for participating.
- I understand how the data will be stored.
- I understand the results of the study will be published.

- I understand that every effort will be made to preserve my anonymity.
- That anonymised data may be shared with other research groups if requested
- I understand that this study has received ethical approval from *University of Otago Human Ethics Committee (Health).*

I consent to taking part in this study.	YES	NO
I consent to having a part of the sessions recorded and listened to by members of the research team and analysed overseas.	YES	NO
I understand I will receive a $50 Westfield voucher	YES	NO
I consent to anonymised information I provide for this study being used in other related research.	YES	NO
I wish to receive a copy of the results of this study. I understand that there will be a significant delay between the information I provide and receiving the results. *If YES, please provide e-mail or mailing address: -* _____	YES	NO

I,		Hereby consent to take part in this study

(print full name)

Study Participant's Signature:	

(sign here)

Date:		Telephone:	

In my opinion, consent was freely given and the participant understands what is involved in this study.

Study Investigator's Name:	

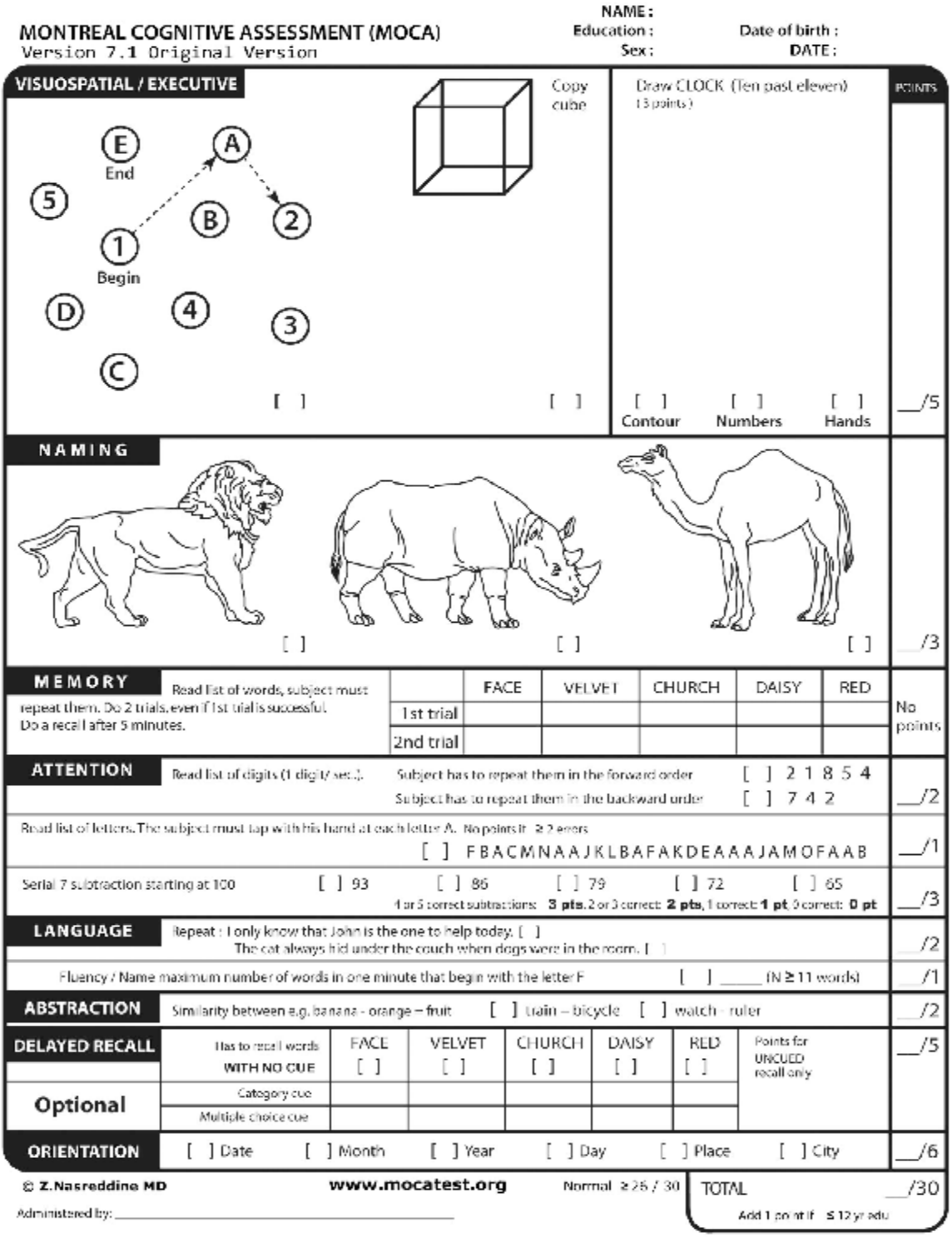
(print full name)

Study Investigator's Signature:		Date:	

(sign here)

Appendix G

Montreal Cognitive Assessment – Version 7.1



MONTREAL COGNITIVE ASSESSMENT (MOCA)
Version 7.1 Original Version

NAME :
Education : Date of birth :
Sex : DATE :

VISUOSPATIAL / EXECUTIVE — POINTS

Copy cube [ ] [ ]

Draw CLOCK (Ten past eleven) (3 points)
[ ] Contour [ ] Numbers [ ] Hands

__/5

NAMING

[ ] [ ] [ ]

__/3

MEMORY Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful. Do a recall after 5 minutes.

	FACE	VELVET	CHURCH	DAISY	RED
1st trial					
2nd trial					

No points

ATTENTION Read list of digits (1 digit/ sec.).
Subject has to repeat them in the forward order [ ] 2 1 8 5 4
Subject has to repeat them in the backward order [ ] 7 4 2

__/2

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors
[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B

__/1

Serial 7 subtraction starting at 100 [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt**

__/3

LANGUAGE Repeat : I only know that John is the one to help today. [ ]
The cat always hid under the couch when dogs were in the room. [ ]

__/2

Fluency / Name maximum number of words in one minute that begin with the letter F [ ] _____ (N ≥ 11 words)

__/1

ABSTRACTION Similarity between e.g. banana - orange = fruit [ ] train – bicycle [ ] watch – ruler

__/2

DELAYED RECALL

	Has to recall words WITH NO CUE	FACE [ ]	VELVET [ ]	CHURCH [ ]	DAISY [ ]	RED [ ]	Points for UNCUED recall only
Optional	Category cue						
	Multiple choice cue						

__/5

ORIENTATION [ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City

__/6

 www.mocatest.org Normal ≥ 26 / 30

TOTAL __/30

Add 1 point if ≤ 12 yr edu

Administered by: _____

Appendix H

Mini International Neuropsychiatric Interview: Version 5.0.0

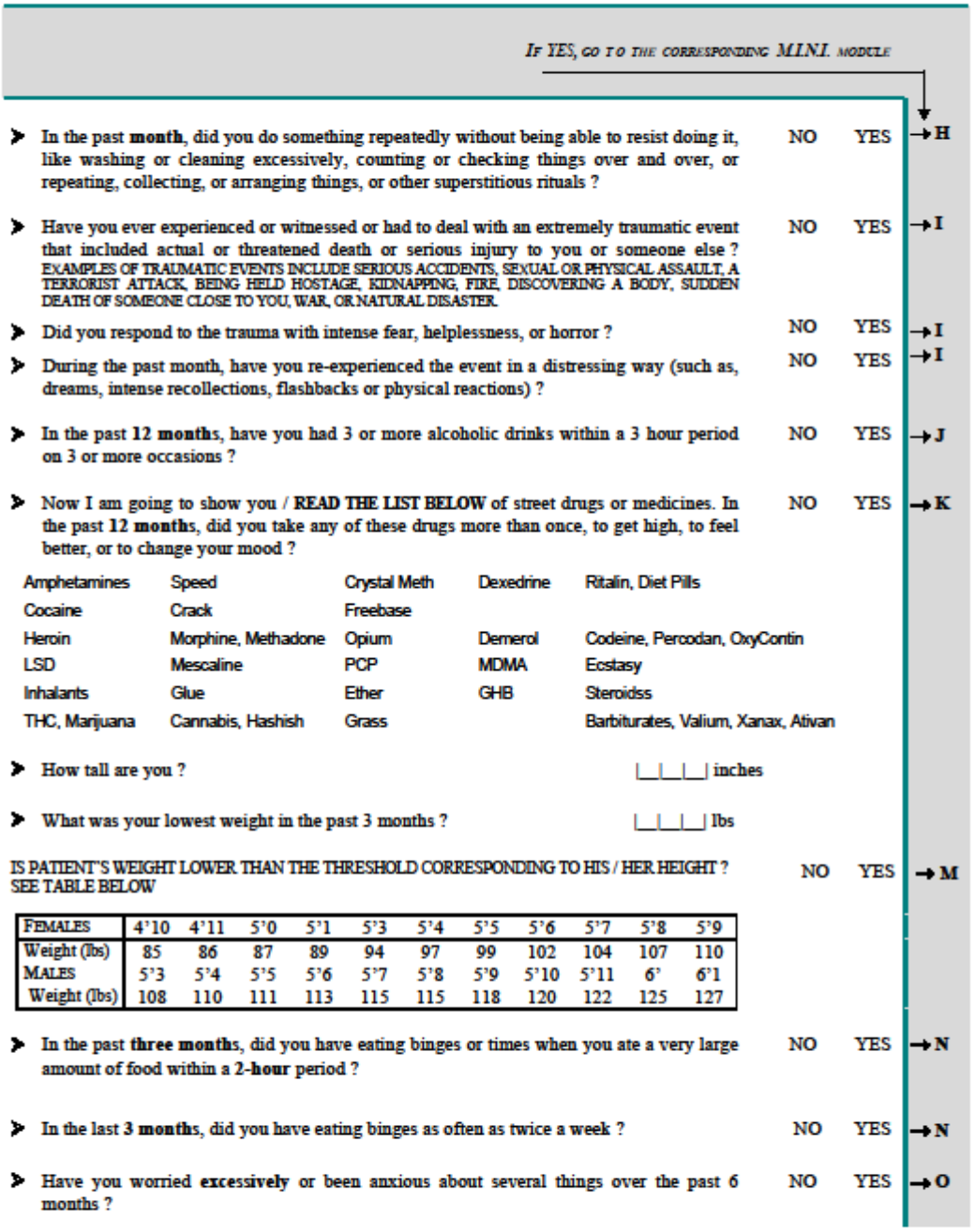
MINI SCREEN

PATIENT NAME : _____ *DATE OF BIRTH:* _____

DATE OF INTERVIEW: _____ *If YES, go to the corresponding M.I.N.I. module*

➢ Have you been **consistently** depressed or down, **most of the day, nearly every day**, for the past two weeks ?	NO	YES	→ A
➢ In the past two weeks, have you been much less interested in most things or much less able to enjoy the things you used to enjoy **most of the time** ?	NO	YES	→ A
➢ Have you felt sad, low or depressed **most of the time** for the last two years ?	NO	YES	→ B
➢ In the past month did you think that you would be better off dead or wish you were dead ?	NO	YES	→ C
➢ Have you **ever** had a period of time when you were feeling 'up' or 'high' or so full of energy or full of yourself that you got into trouble, or that other people thought you were not your usual self ? (Do not consider times when you were intoxicated on drugs or alcohol.)	NO	YES	→ D
➢ Have you **ever** been persistently irritable, for several days, so that you had arguments or verbal or physical fights, or shouted at people outside your family ? Have you or others noticed that you have been more irritable or over reacted, compared to other people, even in situations that you felt were justified ?	NO	YES	→ D
➢ Have you, on more than one occasion, had spells or attacks when you suddenly felt anxious, frightened, uncomfortable or uneasy, even in situations where most people would not feel that way ? Did the spells peak within 10 minutes ? CODE YES ONLY IF THE SPELLS PEAK WITHIN 10 MINUTES.	NO	YES	→ E
➢ Do you feel anxious or uneasy in places or situations where you might have a panic attack or panic-like symptoms, or where help might not be available or escape might be difficult : like being in a crowd, standing in a line (queue), when you are away from home or alone at home, or when crossing a bridge, traveling in a bus, train or car ?	NO	YES	→ F
➢ In the past **month** were you fearful or embarrassed being watched, being the focus of attention, or fearful of being humiliated ? This includes things like speaking in public, eating in public or with others, writing while someone watches, or being in social situations.	NO	YES	→ G
➢ In the past **month** have you been bothered by recurrent thoughts, impulses, or images that were unwanted, distasteful, inappropriate, intrusive, or distressing ? (e.g., the idea that you were dirty, contaminated **or** had germs, or fear of contaminating others, **or** fear of harming someone even though you didn't want to, **or** fearing you would act on some impulse, **or** fear or superstitions that you would be responsible for things going wrong, **or** obsessions with sexual thoughts, images or impulses, **or** hoarding, collecting, **or** religious obsessions.)	NO	YES	→ H

Turn Page



IF YES, GO TO THE CORRESPONDING M.I.N.I. MODULE

- In the past **month**, did you do something repeatedly without being able to resist doing it, like washing or cleaning excessively, counting or checking things over and over, or repeating, collecting, or arranging things, or other superstitious rituals ? — NO YES → H
- Have you ever experienced or witnessed or had to deal with an extremely traumatic event that included actual or threatened death or serious injury to you or someone else ? EXAMPLES OF TRAUMATIC EVENTS INCLUDE SERIOUS ACCIDENTS, SEXUAL OR PHYSICAL ASSAULT, A TERRORIST ATTACK, BEING HELD HOSTAGE, KIDNAPPING, FIRE, DISCOVERING A BODY, SUDDEN DEATH OF SOMEONE CLOSE TO YOU, WAR, OR NATURAL DISASTER. — NO YES → I
- Did you respond to the trauma with intense fear, helplessness, or horror ? — NO YES → I
- During the past month, have you re-experienced the event in a distressing way (such as, dreams, intense recollections, flashbacks or physical reactions) ? — NO YES → I
- In the past **12 months**, have you had 3 or more alcoholic drinks within a 3 hour period on 3 or more occasions ? — NO YES → J
- Now I am going to show you / **READ THE LIST BELOW** of street drugs or medicines. In the past **12 months**, did you take any of these drugs more than once, to get high, to feel better, or to change your mood ? — NO YES → K

Amphetamines	Speed	Crystal Meth	Dexedrine	Ritalin, Diet Pills
Cocaine	Crack	Freebase		
Heroin	Morphine, Methadone	Opium	Demerol	Codeine, Percodan, OxyContin
LSD	Mescaline	PCP	MDMA	Ecstasy
Inhalants	Glue	Ether	GHB	Steroidss
THC, Marijuana	Cannabis, Hashish	Grass		Barbiturates, Valium, Xanax, Ativan

- How tall are you ? |__|__|__| inches
- What was your lowest weight in the past 3 months ? |__|__|__| lbs

IS PATIENT'S WEIGHT LOWER THAN THE THRESHOLD CORRESPONDING TO HIS / HER HEIGHT ? SEE TABLE BELOW — NO YES → M

FEMALES	4'10	4'11	5'0	5'1	5'3	5'4	5'5	5'6	5'7	5'8	5'9
Weight (lbs)	85	86	87	89	94	97	99	102	104	107	110
MALES	5'3	5'4	5'5	5'6	5'7	5'8	5'9	5'10	5'11	6'	6'1
Weight (lbs)	108	110	111	113	115	115	118	120	122	125	127

- In the past **three months**, did you have eating binges or times when you ate a very large amount of food within a **2-hour** period ? — NO YES → N
- In the last **3 months**, did you have eating binges as often as twice a week ? — NO YES → N
- Have you worried **excessively** or been anxious about several things over the past 6 months ? — NO YES → O

Appendix I

Quick Inventory of Depressive Symptomatology (Clinician Rated)

QUICK INVENTORY OF DEPRESSIVE SYMPTOMATOLOGY (CLINICIAN-RATED)
(QIDS-C)

NAME _____ TODAY'S DATE: _____

Please circle one response to each item that best describes the patient for the last seven days.

1 Sleep Onset: Insomnia.

0 Never takes longer than 30 minutes to fall asleep.
1 Takes at least 30 minutes to fall asleep, less than half the time.
2 Takes at least 30 minutes to fall asleep, more than half the time.
3 Takes more than 60 minutes to fall asleep more than half the time.

2. Mid-Nocturnal Insomnia:

0 Does not wake up at night.
1 Restless, light sleep with few awakenings
2 Wakes up at least once at night, but goes back to sleep easily
3 Awakens more than once a night and stays awake for 20 minutes or more, more than half the time.

3. Early Morning Insomnia.

0 Less than half the time awakens no more than 30 minutes before necessary
1 More than half the time, awakens more than 30 minutes before need be
2 Awakens at least one hour before need be more than half the time
3 Awakens at least two hours before need be, more than half the time

4. Hypersomnia

0 Sleeps no longer than 7–8 hours/night, without naps
1 Sleeps no longer than 10 hours in a 24 hour period (include naps)
2 Sleeps no longer than 12 hours in a 24 hour period (include naps)
3 Sleeps longer than 12 hours in a 24 hour period (include naps).

Enter the highest score on any 1 of the 4 sleep items (1–4 above) _____

5. Mood (Sad):

0 Does not feel sad
1 Feels sad less than half the time
2 Feels sad more than half the time.
3 Feels intensely sad virtually all the time.

6 Appetite (Decreased):

0 No change from usual appetite
1 Eats somewhat less often and/or lesser amounts than usual.
2 Eats much less than usual and only with personal effort.
3 Eats rarely within a 24-hour period and only with extreme personal effort or with persuasion by others.

7. Appetite (Increased):

0 No change from usual appetite
1 More frequently feels a need to eat than usual
2 Regularly eats more often and/or greater amounts than usual.
3 Feels driven to overeat at and between meals.

8. Weight (Decrease) Within The Last Two Weeks:

0 Has experienced no weight change
1 Feels as if some slight weight loss occurred.
2 Has lost 2 pounds or more.
3 Has lost 5 pounds or more.

9 Weight (Increase) Within the Last Two Weeks.

0 Has experienced no weight change.
1 Feels as if some slight weight gain has occurred.
2 Has gained 2 pounds or more.
3 Has gained 5 pounds or more.

Enter the highest score on any 1 of the 4 appetite/weight change items (6–9 above) _____

10 Concentration/Decision Making:

0 No change in usual capacity to concentrate and decide.
1 Occasionally feels indecisive or notes that attention often wanders.
2 Most of the time struggles to focus attention or make decisions.
3 Cannot concentrate well enough to read or cannot make even minor decisions.

11. Outlook (Self):

0 Sees self as equally worthwhile and deserving as others.
1 Is more self-blaming than usual
2 Largely believes that he/she causes problems for others
3 Ruminates over major and minor defects in self.

12. Suicidal Ideation:

0 Does not think of suicide or death.
1 Feels life is empty or is not worthwhile
2 Thinks of suicide/death several times a week for several minutes.
3 Thinks of suicide/death several times a day in depth, or has made specific plans, or attempted suicide

13. Involvement:

0 No change from usual level of interest in other people and activities.
1 Notices a reduction in former interests/activities.
2 Feels only one or two former interests remain.
3 Has virtually no interest in formerly pursued activities.

14. Energy/Fatigability:

0 No change in usual level of energy
1 Tires more easily than usual
2 Makes significant personal effort to initiate or maintain usual daily activities.
3 Unable to carry out most of usual daily activities due to lack of energy

15. Psychomotor Slowing:

0 Normal speed of thinking, gesturing, and speaking.
1 Patient notes slowed thinking, and voice modulation is reduced
2 Takes several seconds to respond to most questions; reports slowed thinking.
3 Is largely unresponsive to most questions without strong encouragement.

16. Psychomotor Agitation:

0 No increased speed or disorganization in thinking or gesturing.
1 Fidgets, wrings hands and shifts positions often.
2 Describes impulse to move about and displays motor restlessness.
3 Unable to stay seated. Paces about with or without permission.

Enter the highest score on either of the 2 psychomotor items (15 or 16 above) ____

Total Score: _____ (Range 0 -27)

Appendix J

Recording Form for the National Adult Reading Test

ID No: | | | | Session: …… Date: | | | -- | | | -- | | |

Recording Form for the National Adult Reading Test (NART)

CHORD		**IDYLL**	
ACHE		**NAÏVE**	
DEPOT		**CATACOMB**	
AISLE		**GAOLED**	
BOUQUET		**THYME**	
PSALM		**HEIR**	
CAPON		**RADIX**	
DENY		**ASSIGNATE**	
NAUSEA		**HIATUS**	
DEBT		**SUBTLE**	
COURTEOUS		**PROCREATE**	
RAREFY		**GIST**	
EQUIVOCAL		**GOUGE**	
SUPERFLUOUS		**PUERPERAL**	
SIMILE		**AVER**	
BANAL		**GAUCHE**	
QUADRUPED		**TOPIARY**	
CELLIST		**LEVIATHAN**	
FAÇADE		**BEATIFY**	
ZEALOT		**PRELATE**	
DRACHM		**SIDEREAL**	
AEON		**DEMESNE**	
PLACEBO		**SYNCOPE**	
ABSTEMIOUS		**LABILE**	
DENTENTE		**CAMPANILE**	

Number correct: | | **Number of errors:** | | **Verbal IQ:** | |

NART Conversion Table

NART Errors	Predicted Verbal IQ
0	127
1	126
2	125
3	124
4	123
5	122
6	121
7	119
8	118
9	117
10	116
11	115
12	114
13	113
14	111
15	110
16	109
17	108
18	107
19	106
20	105
21	103
22	102
23	101
24	100
25	99

NART Errors	Predicted Verbal IQ
26	98
27	97
28	95
29	94
30	93
31	92
32	91
33	90
34	89
35	87
36	86
37	85
38	84
39	83
40	82
41	81
42	80
43	78
44	77
45	76
46	75
47	74
48	73
49	72
50	70

Appendix K

Pre-testing Demographic Questionnaire

Neuropsychological Testing – OPProcessing Study (Baseline)

ID: _____ **Date:** _____

DOB: _____

English as first language: Yes No

Previous computer usage: Yes No

Level of confidence with computer use: 1 (None) 2 3 4 5 (High)

Any current medical illness: Yes No Specify: _____

Any recent flu/colds: Yes No Specify: _____

Any current medication: Yes No Specify: _____

_____

Handedness: Left Right

Colour Blindness: Yes No Specify: _____ (which colours)

Visual acuity: Good (No visual aids) Glasses Contact Lenses Specify if any visual disturbances: _____

Hearing Impairment: Yes No Specify: _____

Hx of head injury: Yes No Specify: _____

Hx of neurological disease: Yes No Specify: _____

Hx of seizures: Yes No Specify: _____

No. caffeine drinks per day: Coffee ☐ Tea ☐ Other (Coke, V etc) ☐

No. caffeine drinks today: Coffee ☐ Tea ☐ Other (Coke, V etc) ☐

Cigarettes/tobacco: Yes No **No. per day: _____**

No. of years smoking: _____

How many today: _____ **Time of last cigarette: _____**

Have you had any alcohol in the past 24 hours: Yes No

If yes, how much? _____

Over how many hours? _____

Approximate time of last drink? _____

Ethnicity

Which ethnic group do you belong to? If you belong to multiple ethnic groups please tick appropriately (more than one box may be ticked):

[ ] New Zealand European
[ ] Māori
[ ] Samoan
[ ] Cook Island Māori
[ ] Tongan
[ ] Niuean
[ ] Chinese
[ ] Indian
[ ] Other (such as Dutch, Japanese, Tokelauan etc.) Please specify below:

_____

Time started: _____ Time finished: _____ Total time: _____

Tester: _____

Observations: _____

_____

_____

_____

Appendix L

Spielberger State Trait Anxiety Inventory (STAI) State

ID No: | | | | Session: ..... Date: | | -- | | | -- | | |

SSAI – State

Directions: A number of statements which people have used to describe themselves are given below. Read each statement and then place an **X** in the appropriate box to the right of the statement to indicate how you **feel** right now, that is, **at this moment**. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you presently feel.

	Not at all	Somewhat	Moderately so	Very much so
1. I feel calm	☐	☐	☐	☐
2. I feel secure	☐	☐	☐	☐
3. I am tense	☐	☐	☐	☐
4. I am regretful	☐	☐	☐	☐
5. I feel at ease	☐	☐	☐	☐
6. I feel upset	☐	☐	☐	☐
7. I am presently worrying over possible misfortunes	☐	☐	☐	☐
8. I feel rested	☐	☐	☐	☐
9. I feel anxious	☐	☐	☐	☐
10. I feel comfortable	☐	☐	☐	☐
11. I feel self-confident	☐	☐	☐	☐
12. I feel nervous	☐	☐	☐	☐
13. I am jittery	☐	☐	☐	☐
14. I feel "high strung"	☐	☐	☐	☐
15. I am relaxed	☐	☐	☐	☐
16. I feel content	☐	☐	☐	☐
17. I am worried	☐	☐	☐	☐
18. I feel over-excited and "rattled"	☐	☐	☐	☐
19. I feel joyful	☐	☐	☐	☐
20. I feel pleasant	☐	☐	☐	☐

Appendix M

Category Fluency Task Record Form

ID No: | | | | | | **BASELINE** Date: | | | -- | | | -- | | |

Category Fluency Word Recording Sheet

Allow **90 seconds** for each category. If the participant discontinues before the end of the 90 seconds, encourage them to try and think of more words. If there is a silence of **15** seconds, repeat the basic instructions and the category. Write down the words in the order in which they are produced. The score is the sum of all admissible words.

	Animals	Boys Names
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
Total:		

Grand total =

Appendix N

Category Switching Task Record Form

ID No: | | | | | | **BASELINE** Date: | | | -- | | | -- | | |

Category Switching Word Recording Sheet

Allow **90 seconds** for this task. If the participant discontinues before the end of the 90 seconds, encourage them to try and think of more words. If there is a silence of **15** seconds, repeat the basic instructions. Write down the words in the order in which they are produced (even if they are errors), like the example below:

EXAMPLE: Fruit / Furniture
Apple / Table
Banana / Chair

TEST: Fruit / Furniture

Number Correct Fruit = ____ Number Correct Switches = ____

Number Correct Furniture = ____

Appendix O

Digit Symbol Substitution Task Record Form

9	2	8	1	4	3	5	6	5	4

6	7	5	9	3	1	5	2	8	6

5	7	3	5	9	8	7	1	4	8

2	8	3	6	7	5	9	4	1	3

3	5	8	1	2	9	5	2	6	9

7	8	2	6	9	5	3	2	1	4

4	2	8	3	1	9	8	3	5	1

2	6	9	5	1	5	8	4	3	7

Total =	

Appendix P

Reading the Mind in the Eyes Task – Revised

Record Sheet

Date of Birth:..... Today's date:.....

Degree subject/occupation:.....

P				
	jealous	panicked	arrogant	hateful
1	playful	comforting	irritated	bored
2	terrified	upset	arrogant	annoyed
3	joking	flustered	desire	convinced
4	joking	insisting	amused	relaxed
5	irritated	sarcastic	worried	friendly
6	aghast	fantasizing	impatient	alarmed
7	apologetic	friendly	uneasy	dispirited
8	despondent	relieved	shy	excited
9	annoyed	hostile	horrified	preoccupied
10	cautious	insisting	bored	aghast
11	terrified	amused	regretful	flirtatious
12	indifferent	embarrassed	sceptical	dispirited
13	decisive	anticipating	threatening	shy
14	irritated	disappointed	depressed	accusing
15	contemplative	flustered	encouraging	amused
16	irritated	thoughtful	encouraging	sympathetic
17	doubtful	affectionate	playful	aghast
18	decisive	amused	aghast	bored
19	arrogant	grateful	sarcastic	tentative
20	dominant	friendly	guilty	horrified
21	embarrassed	fantasizing	confused	panicked
22	preoccupied	grateful	insisting	imploring
23	contented	apologetic	defiant	curious
24	pensive	irritated	excited	hostile
25	panicked	incredulous	despondent	interested
26	alarmed	shy	hostile	anxious
27	joking	cautious	arrogant	reassuring
28	interested	joking	affectionate	contented
29	impatient	aghast	irritated	reflective
30	grateful	flirtatious	hostile	disappointed
31	ashamed	confident	joking	dispirited
32	serious	ashamed	bewildered	alarmed
33	embarrassed	guilty	fantasizing	concerned
34	aghast	baffled	distrustful	terrified
35	puzzled	nervous	insisting	contemplative
36	ashamed	nervous	suspicious	indecisive