Addressing depression and anxiety in dementia: Targeting ruminative processing via music and attentional bias modification.

PHD

Biomedical Engineering

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March 2024

Declaration:

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

Anne-Marie Greenaway
March 2024

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May the music play on forever.

Abstract

Persons with dementia (PwD) with comorbid depression or anxiety face increased risk of cognitive decline, hospitalisation, and institutionalisation. Music-based interventions, e.g., music listening, are used in dementia-care to alleviate depression and anxiety due to a lack of side-effects. Although music can affect two key processes in the development and maintenance of depression and anxiety, attentional biases (AB) (the tendency to attend to, or avoid, certain types of information) and rumination (repetitive, self-focused thoughts), these processes are overlooked within music research/interventions involving PwD. Moreover, an intervention used to alter AB and rumination levels, attentional bias modification (ABM), was yet to be explored with PwD. Hence, this thesis explored for PwD the reliability of rumination scales, and the relationship between depression, anxiety, rumination, and AB as steps toward identifying potential treatment targets to improve outcomes. The feasibility of conducting remotely-delivered AB measures using webcam-based eye-tracking (WBET) within music and ABM research/interventions involving PwD was examined, alongside the reliability of WBET measures of AB. A lab-based gaze-contingent musical ABM (GCM-ABM) paradigm was developed for use with PwD and was piloted with students.

The Cognitive Emotional Regulation Questionnaire, Ruminative Thought Style Questionnaire, and Ruminative Response Scale demonstrated adequate to good reliability for PwD. The positive relationship between depression, anxiety, and rumination demonstrated for PwD aligned with literature. These findings, alongside the variance in depression and anxiety accounted for by rumination suggests that rumination is a viable intervention target. Clinically-relevant reductions in depression, anxiety, and rumination were indeed found post music with ABM and GCM-ABM interventions. Single and multi-session WBET measures of AB were feasible with PwD, with single-session measures demonstrating literature-based gaze-location failure rates and lab-based eye tracker reliability levels.

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List of abbreviations

AB	Attentional biases
ABM	Attentional bias modification
ACC	Anterior cingulate cortex
AD	Alzheimer's disease
CBT	Cognitive behavioural therapy
CERQ	Cognitive Emotion Regulation Questionnaire
dACC	Dorsal anterior cingulate cortex
DBS	Deep brain stimulation
DMN	Default mode network
dMPFC	Dorsal medial prefrontal cortex
EEG	Electroencephalogram
fMRI	Functional magnetic resonance imaging
GAD-7	Generalized Anxiety Disorder Scale 7
GCM-ABM	Gaze-contingent musical attention bias modification
HC	Cognitively healthy/healthy controls
MCI	Mild cognitive impairment
MDD	Major depressive disorder
NST	Neurostimulation techniques

PANAS	Positive Affect Negative Affect Scales
PCC	Posterior cingulate cortex
PHQ-9	Patient Health Questionnaire 9
PlwD	People living with dementia
P/pwAD	People/persons/participants with Alzheimer's disease
PwCI	People/persons/participants with cognitive impairment
PwD	People with dementia
rACC	Rostral anterior cingulate cortex
RRS	Ruminative Response Scale
rTMS	Repetitive transcranial magnetic stimulation
RTSQ	Ruminative Thought Style Questionnaire
sgPFC	Subgenual prefrontal cortex
SN	Salience network
TICS	Telephone Interview for Cognitive Status
MPFC	Medial prefrontal cortex
WBET	Webcam-based eye tracking

Chapter 1

Introduction

1.1 Dementia

Dementia is an umbrella term for a group of symptoms which affect cognitive ability and behaviour to the extent that the performance of everyday activities is significantly impacted (Alzheimer's Association, 2022; Brancatisano et al., 2020). Dementia symptoms, e.g., memory and visual spatial impairment, are caused by different neurological diseases such as Alzheimer's disease (AD), cerebrovascular disease, and Lewy body disease (Alzheimer's Association, 2022). AD is the most common variant of dementia in older persons and accounts for approximately 60%-80% of dementia cases, followed by other types of dementia such as vascular dementia (5%-10%) and dementia with Lewy bodies (5%) (Alzheimer's Association, 2023). It is estimated that there will be over 2 million persons with dementia (PwD) living in the United Kingdom by 2051 and dementia-care costs have been forecasted to reach £80.1 billion by 2040 (Wittenberg et al., 2019, 2020). There is currently no cure for the diseases that cause dementia. Recent progress has been made in clinical trials of AD modifying medication (e.g., Donanemab) which may delay cognitive and functional decline in persons with mild-to-moderate AD (Rashad et al., 2023; Salloway et al., 2023). However, disease modifying medications are not yet approved for use in the United Kingdom and may show most efficacy earlier in the disease progression (Rashad et al., 2023). Therefore, it is important to target any factors which can increase cognitive and functional decline in dementia, e.g., neuropsychiatric symptoms of dementia (NPS). Most PwD (≥90%) will experience at least one NPS, e.g., depression, during disease progression, the consequences (see section 1.1.1) of which also contribute to the increasing socioeconomic impact of dementia care (Pless et al., 2023; Staedtler & Nunez, 2015; Wimo et al., 2017).

1.1.1 Neuropsychiatric symptoms in dementia

The umbrella term of NPS (also referred to as behavioural and psychological symptoms in dementia) include agitation, anxiety, depression, apathy, delusions, hallucinations, elation, disinhibition, irritation, and aberrant motor behaviours. Some NPS may be more common in different types of dementia, at different stages of the diseases. For example, visual hallucinations are more common in dementia with Lewy bodies and are present in the early stages of the disease whereas this symptom appears at later stages of the disease in AD (Phan et al., 2019). On average, depression, anxiety, and apathy are the most frequently occurring NPS, and are highly prevalent across the mild (38%-54%), moderate (41%-59%), and severe (37%-43%) stages of dementia (Leung et al., 2021). However, prevalence figures in individual studies vary depending on whether there is a focus on clinically significant or sub-syndromal symptoms, the instrument used for diagnosis or screening (clinical diagnosis versus self- or proxy-report), and the population that was sampled (e.g., residential care-home versus community-based PwD) (Olin et al., 2002).

Although all NPS, when severe, are associated with poor outcomes and thus should be treated (Phan et al., 2019), depression and anxiety were the focus of this thesis. PwD with comorbid depression or anxiety have greater difficulty performing activities of daily living (e.g., self-care), and a higher risk of hospitalisation and re-admission, residential care-home admissions, and mortality than persons without cognitive impairment or dementia (Breitve et al., 2016; Davydow et al., 2014; Okura et al., 2010; Pickens et al., 2017). Although it should be noted that specific research to assess whether a reduction in depression or anxiety for PwD is associated with delayed hospitalisation or residential care admission has not been conducted (Livingston et al., 2020; Phan et al., 2019).

1.1.2 Depression

The relationship between depression and dementia is complex. There is evidence suggesting that depression is a prodromal symptom, a risk factor, both a prodromal symptom and risk factor, or neither, of dementia (Becker et al., 2009; J. Da Silva et al., 2013; Diniz et al., 2013; Jorm, 2000; Li et al., 2011). Recent research suggests that if depression was eliminated in older adulthood, the incidence of dementia could be reduced by 4% (Livingston et al., 2020). The prevalence of depression is higher for PwD (30%-42%) than for older persons without dementia (28%) (Hu et al., 2022), with approximately 25% of PwD having major depression as compared to 1%-5% for older persons without dementia (Fiske et al., 2009; Mayer et al., 2006; Sibley et al., 2021). Persons with depression can experience, for example, persistent sadness, feelings of hopelessness and guilt, a loss of interest, difficulty concentrating and sleeping, and fatigue (Fiske et al., 2009). Depression in dementia could be a psychological response to the diagnosis, a result of brain atrophy, disrupted signalling and changes in neurotransmitter levels, or the sharing of common pathological pathways between depression and dementia (Caraci et al., 2010; Holston, 2014; Kepe et al., 2006; Pless et al., 2023). While the root cause of depression in dementia is difficult to identify, its consequences, such as an increased risk of further cognitive decline at a faster rate and reduced functional capability compared to PwD without depression and persons without dementia, highlight the importance of diagnosis and treatment where possible (see section 1.1.6 for types of treatment) (Gonzalez-Salvador et al., 1999; Lyketsos et al., 1997; Spalletta et al., 2012; Starkstein & Mizrahi, 2006). However, depression (and anxiety) in dementia is difficult to diagnose, and these difficulties are briefly discussed in Chapter 3 and 4 (4.3).

Depression in later life is associated with increased disability and healthcare use even at subthreshold levels, and persons with cognitive impairment (PwCI) or PwD and comorbid depression are particularly at risk of poor outcomes and may benefit from targeted depression interventions (Davydow et al., 2014; Meeks et al., 2011). Effective treatment of depression in dementia could have a positive impact on not only the individual but also on their caregiver(s). The majority (70%–80%) of PwD are community-dwelling with informal caregivers (Livingston et al., 2014). Depression in dementia is the most frequently cited NPS associated with caregiver depression, and second most frequently cited NPS associated with caregiver burden, with the caveat that depression is one of the most frequently examined NPS (Ornstein & Gaugler, 2012). Depression in family caregivers can increase when the PwD has depression, and in turn, the poor psychological health amongst family caregivers adversely affects the care recipient's outcomes (Banerjee et al., 2011; Longacre et al., 2014).

1.1.3 Anxiety

While research regarding the role of anxiety in dementia is relatively lacking compared to other NPS, there is evidence suggesting that anxiety, like depression, could be a prodromal symptom, risk factor of cognitive impairment and dementia, associated with brain atrophy, and (AD-)specific biomarkers (e.g., tau–amyloid beta) (Gulpers et al., 2016; Kuring et al., 2020; Mendez, 2021). The prevalence of anxiety disorders for PwD is much higher (28%-63%) than for older persons without dementia (1%-15%) (Bryant et al., 2008; Goodarzi et al., 2019; World Health Organization, 2015). As generalised anxiety disorder (GAD) is the most common anxiety disorder in older persons, with prevalence rates of 2%-7% for persons without dementia and up to 75% for PwD (Bryant et al., 2008; Seignourel et al., 2008), GAD was measured within this thesis. Persons with GAD experience excessive and difficult to control anxiety and worry, and several other symptoms such as irritability or feeling on edge, having difficulty concentrating and sleeping, fatigue, and physical tension which can overlap with symptoms of dementia in the absence of anxiety (Bryant et al., 2008; Seignourel et al., 2008). Anxiety in dementia, like depression in dementia, is associated with poorer cognitive performance and quality of life, but also disturbed sleep and more problem behaviours (Seignourel et al., 2008; Tales & Basoudan, 2016). Depression and anxiety often co-occur in dementia (Ryu et al., 2005) and is discussed next.

1.1.4 Comorbid depression and anxiety

It is estimated that 36% of older persons with depression have comorbid anxiety, and 13% of older persons with anxiety have comorbid depression (World Health Organization, 2015), although estimates can vary widely (e.g., 57% and 28%, respectively [Almeida et al., 2012]) (Almeida et al., 2012; Braam et al., 2014; Curran et al., 2020; Sibley et al., 2021). Nonetheless, comorbid depression and anxiety, particularly at disorder level, is associated with disability (e.g., frailty) levels above that of depression or anxiety alone, no depression or anxiety, and is more persistent (Almeida et al., 2012; Braam et al., 2014; Zhao et al., 2020). Moreover, fewer (older) persons with comorbid depression and anxiety recover compared to those with depression or anxiety alone (Almeida et al., 2012; Van Balkom et al., 2008).

Comorbid depression and anxiety in dementia has prevalence rates of 26%-75% and is associated with more severe cognitive impairment compared to depression or anxiety alone, and no depression or anxiety (Ryu et al., 2005; Seignourel et al., 2008; Sibley et al., 2021; Starkstein et al., 2007). Remission may take longer for PwD with comorbid depression and anxiety, and there is an increased risk of early relapse and reoccurrence (Neville & Teri, 2011). While guidelines to address comorbid depression and anxiety for PwD are lacking, treatment may be more urgent and depression and anxiety symptoms should be treated simultaneously (Neville & Teri, 2011; Sibley et al., 2021). Given the high rate of comorbidity and the exaggerated negative consequences of comorbidity, the intervention paradigms discussed in Chapters 2 (2.2), 4, and 5 were relevant for persons with depression and/or anxiety. The interventions also targeted rumination (discussed next and in Chapters 2 [2.1 and 2.2] and 3 in more detail), which is (1) an underlying process in both depression and anxiety, and (2) may account for the close relationship between depression and anxiety.

1.1.5 Rumination, depression, and anxiety

The type of rumination a person engages in has been shown to affect their mood, risk of depression and anxiety, probability of experiencing future depressive and anxious episodes, and mediates the association between concurrent and prospective depression and anxiety symptoms (Brinker & Dozois, 2009; McLaughlin & Nolen-Hoeksema, 2011; Nolen-Hoeksema et al., 2008; Roberts et al., 1998). Rumination has been sub-divided into a maladaptive and more adaptive coping mechanisms, and it is the maladaptive styles that are associated with depression and anxiety (Joormann et al., 2006; McLaughlin & Nolen-Hoeksema, 2011; Schoofs et al., 2010). Maladaptive styles include, amongst other, brooding (a ruminative response to depression), counter-factual thinking (a ruminative thought style) and rumination as an emotional coping strategy (Aldao et al., 2010; Michl et al., 2013; Tanner et al., 2013).

Each style/type of rumination is associated with a separate scale or subscales (see Smith & Alloy, [2009] for an in-depth review) and they all reliably index different constructs within rumination (Mandell et al., 2014). However, most of the research relating to rumination has focussed on depression, and the rumination as a response to depression scales are the most widely used rumination scales, even when the research focus is anxiety (Ball & Brewin, 2012; Olatunji et al., 2013). None of the scales assessing rumination had been used with or validated for PwD at the start of this thesis. Rumination has since been examined in one study (Keune et al., 2023) involving PwD. However, only one type of rumination (i.e., as a response to depression) was assessed, and as such, information regarding the other types of rumination used in dementia was still lacking. Moreover, test-retest reliability was not examined in the study, nor were the relationships between rumination and anxiety explored. Rumination was also understudied within interventions for or that affect depression and anxiety in dementia.

1.1.6 Recommended treatment for persons with dementia

Depression and anxiety in dementia are still inadequately treated (Banerjee et al., 2011). The National Institute for Health and Care Excellence (NICE) dementia guidelines (NICE, 2018) sets forth different recommendations for the treatment of depression and anxiety in dementia based on the stage of dementia and the severity of symptoms.

1.1.6.1 Psychological therapy

NICE dementia guidelines (NICE, 2018), recommends that psychological therapy should be considered for PwD in the mild to moderate stage with mild to moderate depression and/or anxiety. In reality, there are long waiting lists for psychological therapy in the UK (Punton et al., 2022), which is an important consideration given the increased cognitive decline for PwD associated with the presence of depression and anxiety symptoms. Psychological therapies, such as cognitive behavioural therapy, have been successful in reducing depression and anxiety for some PwD (Bell et al., 2022; Cheston & Ivanecka, 2017; García-Alberca, 2017; Regan & Varanelli, 2013). Still, psychological therapy is used less by PwD, and clinically relevant change and recovery is less likely for PwD compared to older persons without dementia (Bell et al., 2022). Unfortunately, PWD are also more likely to deteriorate compared to older persons without dementia (Bell et al., 2022), and talking-based interventions may not be suitable for PwD with communication difficulties. Although rumination has become a target in psychological therapy due to its association with relapse rates (Hvenegaard et al., 2015), information regarding the effect of psychological interventions on rumination levels for PwD is lacking.

1.1.6.2 Pharmacological treatment

NICE also states that antidepressants should not be offered routinely to PwD in the mild to moderate stage with mild to moderate depression and/or anxiety but their use could be considered for cases of severe, pre-existing, mental-health conditions (NICE, 2018). However, anti-depressant treatment of depression is three times more prevalent for PwD (Laitinen et al., 2015) although research suggests they are only marginally effective when compared to placebo (Banerjee et al., 2011). Selective serotonin reuptake inhibitor antidepressants, for example Sertraline, are the most prescribed antidepressants in dementia (Banerjee et al., 2013). Their advocacy seems to relate to the lower level of side effects associated with their use compared to other anti-depressants and that they have beneficial effects for some people (A. Cipriani et al., 2018; G. Cipriani et al., 2015). Nonetheless, the use of anti-depressants is associated with side-effects such as impaired vision, delirium, an increased risk of falls, and fractures with increasing dose and age (G. Cipriani et al., 2015; Eom et al., 2012; van Poelgeest et al., 2021; Vestergaard et al., 2013). Evidenced-based treatment strategies for anxiety in dementia are lacking (Kwak et al., 2017). Current pharmacological treatment of anxiety in dementia also includes the use of anti-psychotic, and benzodiazepines (Dimitriou et al., 2020). However, these medications have questionable efficacy, can exacerbate cognitive impairment and NPS, they can be inappropriately prescribed, and used for excessive durations without review (Van Der Spek et al., 2018).

Current recommended interventions aimed at ameliorating cognitive symptoms can also affect emotional and behavioural symptoms in dementia (Pless et al., 2023). For mild to moderate AD, treatment includes donepezil, galantamine and rivastigmine which are acetylcholinesterase (AChE) inhibitors, and Memantine is typically prescribed for severe

AD or as an alternative treatment for those with moderate AD when the inhibitors are not tolerated (NICE, 2018). Some improvement in mood and behavioural symptoms (e.g., depression, hallucinations, and delusions) have been observed (Almkvist et al., 2004; Brousseau et al., 2007; Phan et al., 2019; Rozzini et al., 2007). However, cognitive medication is not available to all individuals with dementia (e.g., persons with cerebrovascular dementia), may cause side-effects (e.g., gastrointestinal symptoms, and dizziness), and increase cognitive decline and mortality (Pless et al., 2023).

Consequently, the use of nonpharmacological interventions to manage NPS has increased as adverse effects are rarely experienced (Staedtler & Nunez, 2015). Still, there has been conflicting or little supporting evidence for some interventions.

1.1.7 Nonpharmacological interventions in dementia

There are a large number of nonpharmacological interventions which can be subsumed under several categories: (1) sensory stimulation (e.g., sensory gardens, aromatherapy, massage/touch and light therapy, (2) cognitive or emotionally-oriented (e.g., cognitive stimulation therapy [CST], music and/or dance therapy, and reminiscence therapy [RT]), (3) behaviour management techniques (e.g., CBT), and (4) other interventions (e.g., exercise, animal-assisted therapy, and environment-based) (see Abraha et al. [2017] for an extensive review of the literature). RT, CST, and cognitive rehabilitation (CR) are focussed on here as (1) NICE recommends that these interventions could be considered (RT and CR) or should be offered (CST) for PwD to promote well-being, with well-being being significantly correlated with depression and anxiety, and (2) RT and CST are widely used in dementia (NICE, 2018; Segerstrom et al., 2010; Woods et al., 2005, 2018). Musical intervention literature is also reviewed as music is widely adopted as a treatment for NPS in dementia (Leggieri et al., 2019).

1.1.7.1 Reminiscence therapy

RT has gained popularity as an intervention in dementia care and involves the discussion of events and experiences from the past using prompts such as photographs and objects (Woods et al., 2005, 2018). There are mixed findings regarding the effect of RT on depression with significant reductions, no improvement, and unclear effects in terms of the clinical importance of the changes being reported (Charlesworth et al., 2016; Haight et al., 2006; Saragih et al., 2022; Woods et al., 2018). There is less evidence supporting its effectiveness in reducing anxiety, and the benefits of RT are more evident in residential care-home settings compared to community-based settings, although more studies are conducted in the former setting (Saragih et al., 2022; Syed Elias et al., 2015; Woods et al., 2018). The differences in findings could also relate to the components used in the RT. For example, memory trigger components are associated with inconsistent findings regarding mood improvement, whereas life-stages is associated with more consistent findings (Macleod et al., 2021). Importantly, engaging in reminiscence with a ruminative tendency can lead to increased depression and the interaction between reminiscence and rumination can predict depression for older persons (Brinker, 2013). Therefore, the tendency for rumination could contribute to null findings in terms of the effect of RT on mood, and should be assessed, where possible.

1.1.7.2 Cognitive stimulation therapy

CST involves a range of activities (e.g., word games, music, and discussions with different themes) to stimulate thinking, concentration, and memory, and CST sessions are typically delivered in a group setting (Aguirre et al., 2013; Woods et al., 2012). Cochrane systematic reviews state that CST may slightly improve depression and anxiety, but not always (Woods et al., 2012, 2023). In contrast, other systematic review and meta-analyses state that there is moderate to strong evidence for the positive effect of CST on depression and anxiety (Chen, 2022; Fukushima et al., 2016). Mixed findings could be related to floor effects given that the participants within CST studies are not recruited based on their mood status. Futures studies could attempt to elucidate the participant characteristics which are associated with reductions in depression and anxiety.

1.1.7.3 Cognitive rehabilitation

CR involves setting goals (e.g., remembering to take medication) and implementing strategies (e.g., using assistive technology and/or a Dosette box) to achieve those goals (J. Y. C. Chan et al., 2020). A recent Cochrane systematic review (Kudlicka et al., 2023) suggests that there are negligible effects of CR on depression and anxiety in dementia. However, this review contained few studies.

1.1.7.4 Music interventions

Musical interventions (e.g., music listening, singing, and playing instruments, with and without a music therapist) are increasingly used in neurological and psychiatric rehabilitation and can have beneficial effects in the treatment of depression and anxiety (M. F. Chan et al., 2011, 2012; Dorris et al., 2021; Särkämö, 2018; Sihvonen et al., 2017;

Simmons-Stern et al., 2010; van der Steen et al., 2018; Vasionyte & Madison, 2013; Wan & Schlaug, 2010). The therapeutic effects of music on depression and anxiety may stem from the modulation of the stress response (e.g., modulating cortisol levels), emotion regulation, and inducing positive affect (Chanda & Levitin, 2013; Evers & Suhr, 2000; Menon & Levitin, 2005; Schäfer et al., 2013; Thoma et al., 2013). Music can also modulate the production of dopamine, serotonin, and brain neurotrophic factors which are depleted in depression and anxiety, and music can be accessed by PwD across the stages of dementia (Bathina & Das, 2015; Evers & Suhr, 2000; Menon & Levitin, 2005; Morgese & Trabace, 2019; Vasionyte & Madison, 2013; Xing et al., 2016; Zarrindast & Khakpai, 2015).

However, inconclusive findings have also been reported, with some literature, for example, reporting positive and little effects of music on anxiety (Abraha et al., 2017; Petrovsky et al., 2015; Ting et al., 2023; van der Steen et al., 2018). Inconsistent findings may result from the components of the music interventions (e.g., music listening versus active music making, music therapist-led versus non-therapist-led, and personalised versus non-personalised music), the frequency of sessions, length of the intervention, and the severity and type of dementia that may be present (Abraha et al., 2017; Leggieri et al., 2019; Tsoi et al., 2018). While individualised music-listening interventions are suggested to provide the best outcomes for PwD (Leggieri et al., 2019; Tsoi et al., 2018), not all PwD have positive responses to music, even when the music is self-selected. PwD may express increased sadness via facial expressions and increase in depression and anxiety symptoms (Garrido et al., 2018; Park et al., 2019). Moreover, depressed individuals may ruminate to (sad) music, yet rumination assessment has been under explored in music interventions for PwD (Garrido et al., 2020). Further community-based music intervention studies are required as most music interventions involve PwD living in residential care-homes, and studies should include PwD in the earlier stages of dementia (Möhler et al., 2020; Petrovsky et al., 2015). Hence, the music-based elements discussed in Chapter 6 in this thesis focussed on community-based PwD with cognitive impairment levels that were indicative of mild dementia.

1.1.8 The use of technologies

Technology can be used to provide care for PwD and support well-being (Moyle, 2019). Some of the literature regarding the use of technology to treat depression and anxiety is reviewed here, and further in Chapter 4 (4.1).

1.1.8.1 Robots

The most common type of healthcare robots (e.g., robotic pets) are used to aid social interaction (Hsieh et al., 2023). It is possible that interactions with robots may impact depression and anxiety via the modulation of stress as demonstrated by improved biophysiological indicators of stress (e.g., pulse rate and electrodermal activity) (Iqbal et al., 2021; Petersen et al., 2017). Reductions in depression, anxiety, and behaviour medication dosage have been reported for PwD living in residential care-homes following interactions with robotic pets (Petersen et al., 2017). However, conflicting evidence of the benefits of social robots on depression and anxiety has been presented in recent systematic reviews and meta-analyses (Hsieh et al., 2023; Pu et al., 2019; Rashid et al., 2023). Still, differences in findings may be due to differences in sample characteristics (e.g., the stage of dementia) (Pu et al., 2019), and the included study's characteristics (e.g., the frequency of sessions) (Hsieh et al., 2023). Nonetheless, social robots are expensive and may be inaccessible to some individuals/establishments, they can be confusing and challenging for some PwD, and technical issues may cause negative affect (Koh et al., 2021).

1.1.8.2 Neurostimulation techniques

Neurostimulation techniques (NST) involve invasive (e.g., deep brain stimulation [DBS]) and non-invasive (e.g., electroconvulsive therapy, and repetitive transcranial magnetic stimulation) brain stimulation. The exact mode of action of NST is unclear but is suggested that the stimulation of target areas of the brain has downstream activation effects and indirectly modulates the production of neurotransmitters (e.g., dopamine, serotonin, and brain neurotrophic factors) (Lv et al., 2018; Xing et al., 2016). There has been increased investigation of the brain networks to target in depression treatment, and the networks which have yielded an anti-depressant response includes the dorsolateral prefrontal cortex (DLPFC), subcallosal cingulate region, nucleus accumbens, and medial forebrain bundle (Mayberg et al., 2016).

Deep brain stimulation (DBS) involves the surgical implantation of an electrode into a target area of the brain and the electrode releases a pulse of a certain magnitude and rate. DBS has been used for treatment resistant depression and has produced significant and long-lasting improvements (e.g., up to 6 years in responders) (Ryder & Holtzheimer, 2016). The focus of DBS research in dementia is related to cognitive ability (e.g., memory) in AD and Parkinson's disease dementia (Lv et al., 2018). However, as demonstrated by DBS for persons with Parkinson's disease (no dementia), depression and anxiety can be positively and negatively affected by DBS (Zhang et al., 2022). This could be associated with the individual's response to the target treatment (i.e., motor ability) outcome (e.g., no, little, or a large improvement), or via the stimulation of the target and/or non-target brain areas which are functionally involved in emotional processing (Accolla & Pollo, 2019).

PwD with severe or treatment resistant depression have been treated with electroconvulsive treatment, and PwD with varying severity of mood symptoms have been treated with repetitive transcranial magnetic stimulation, and transcranial direct current stimulation (R. J. Anderson et al., 2012; Di et al., 2021; Elder & Taylor, 2014; Liu et al., 2014; Morrin et al., 2018; Rao & Lyketsos, 2000; Takahashi et al., 2009; Wu et al., 2015). Although these NST have yielded reductions in depression and anxiety, their side effects may include delirium, confusion, and anxiety for some PwD (R. J. Anderson et al., 2012; Di et al., 2021; Elder & Taylor, 2014; Liu et al., 2014; Morrin et al., 2018; Rao & Lyketsos, 2000; Takahashi et al., 2009). Additionally, NST techniques are only feasible in a select number of patients and effectiveness may be limited to patients with less advanced brain atrophy and cognitive decline (Baldermann et al., 2017).

1.1.9 Modifiable factors of depression and anxiety in dementia

The information regarding depression and anxiety treatment discussed in this thesis thus far relates to treating depression and anxiety symptoms within the individual. However, other potentially modifiable factors are associated with depression and anxiety in dementia amongst community-dwelling individuals such as pain, their environment, social isolation, quality of life, and to some extent, caregiver burden and communication (Botto et al., 2022; Kolanowski et al., 2017; Magierski et al., 2020). Stressors and cumulative stressful life events (e.g., a change in sleep patterns, financial status, or living arrangements) are also associated with depression and anxiety in older persons (Dautovich et al., 2014; Fiske et al., 2009; Tibubos et al., 2021; Yu & Liu, 2021). It is possible that these modifiable factors may impact the effect of any given intervention. For example, isolation can negatively mediate stress management interventions (Peters et al., 2023). Still, individual psychological factors are the predominant drivers of intervention effects (Peters et al., 2023).

Not all individuals who experience stressful life events, for example, will experience depression and anxiety, rather, psychological vulnerability factors such as rumination and the tendency to attend to negative information, i.e., negative attentional biases (NAB), can mediate the relationship between stressful life events, depression, and anxiety (L. R. Anderson et al., 2022; LeMoult & Gotlib, 2018; Michl et al., 2013). Modifying attentional biases (AB) can be associated with a reduced stress response following a stressor in younger adults, and reductions in the risk factors of depression reoccurrence (e.g., depression symptoms during depression remission) in younger and older persons (Browning et al., 2012; Jonassen et al., 2019; LeMoult & Gotlib, 2018). Attentional bias modification (ABM) interventions, discussed in Chapters 2 (2.2 to 2.2.2.1) in more detail, could be a front-line intervention or used in conjunction with other approaches (Blackwell et al., 2017). Person-centred dementia-care approaches are designed to look at range of factors or unmet needs that may contribute to NPS in dementia (Kim & Park, 2017; Schölzel-Dorenbos et al., 2010). Given the multiple potentially modifiable factors involved in depression and anxiety for PwD noted earlier, ABM could possibly be used as part of a person-centred approach, should it be found to reduce depression and anxiety in dementia. However, the relationship between AB and mood has been understudied in older persons (Demeyer & De Raedt, 2013), and effect of ABM on depression and anxiety for PwD was yet to be examined.

1.1.10 Summary

Depression and anxiety are prevalent in PwD, is associated with increased cognitive decline, poor quality of life and outcomes, and is difficult to treat. The recommended treatments for depression and anxiety can be underutilised by PwD (i.e., psychological therapy) or over utilised (i.e., pharmacological treatment) by professionals, and their efficacy is reduced in dementia. The majority of the interventions for PwD with depression and/or anxiety described in this thesis can have adverse effects (e.g., confusion, and falls), and all of the interventions used in dementia-care, including those with few side-effects (e.g., music, reminiscence, and cognitive stimulation therapy), rarely examine the key cognitive processes, i.e., rumination and AB, involved in depression and anxiety. Consequently, there is still a need for safe, and efficacious treatment options for depression and anxiety in dementia, and for an examination of the effect of such treatments on rumination and AB in dementia.

While rumination as a response to depression has just recently been examined in one study involving PwD, test-retest reliability, other types of rumination, and the relationships between rumination, anxiety, and AB were yet to be explored. And, although ruminative processing and AB have become targets for depression and anxiety interventions in cognitively healthy individuals, research regarding the effect of an intervention on rumination and/or AB in dementia was lacking. Hence, the following research questions addressed the aformentioned knowledge gaps.

1.2 Research questions

The first research question in this thesis pertained to whether existing rumination measures were reliable measures of rumination for PwD. Exploring the reliability of several rumination measures allowed for an appropriate outcome measurement tool for both depression and anxiety to be selected for the interventional study described in Chapter 5. These findings extended upon the sparse research regarding rumination as a response to depression for PwD and offer new insight into other constructs of rumination for PwD.

The second research question pertained to the level of the rumination present in PwD, and the third, to whether the literature-based relationship between rumination and depression, anxiety, and AB, established within studies involving (younger) persons without dementia, were demonstrated by data collected from PwD. As discussed in Chapters 2 (2.1.3) and 3, deficits in attentional control in AD could possibly be associated with a cognitive vulnerability to rumination given that a lack of attentional control puts individuals at risk of rumination. Given the roles of rumination and AB in depression and anxiety risk, maintenance, and relapse, understanding the contribution of rumination in depression and anxiety in dementia could possibly identify target/s for depression and anxiety treatment.

Lastly, the fourth research question pertained to the feasibility of conducting remotely-delivered AB measures using WBET within music and ABM research/interventions for community-based persons with and without dementia, given the lack of research in this area.

1.3 Aims

The overarching aims of this thesis was to design a technology-based music-mediated intervention for depression and anxiety in AD, to explore the potential of rumination as a target for the intervention, and the use of ABM with PwAD. To this end, additional aims were generated to:

1. Identify a reliable rumination measurement tool for use with PwAD
2. Determine the level of rumination in AD, and the relationship between rumination, depression, anxiety, and AB in AD

3. Explore the technologies used spontaneously in dementia
4. Explore remotely-delivered music research with WBET involving older persons with and without AD
5. Explore the feasibility of remotely-delivered multi-session ABM with WBET involving persons with and without AD
6. Develop a music-based ABM intervention, and
7. Explore the feasibility of the music-based ABM intervention with younger persons prior to future testing with older persons with and without AD

1.4 Thesis structure

The structure of the remaining sections of this thesis is as follows. Chapter 2 reviews the literature related to (1) rumination and AB (theories, and models), (2) rumination and AD (potential brain connectivity indicators, association with AD risk, and relationship with depression in AD), and (3) ABM, rumination, and AD (the premise of ABM and the mechanism of AB change, the effect of ABM on rumination and mood, and the relevance of ABM for PwAD). Music-based ABM is also discussed. Literature is also reviewed within Chapters 3, 4, 5, and 6.

Chapters 3, 4, 5, and 6 of this thesis are a collection of manuscripts written according to the structure and format requirements of the peer-reviewed journal where the manuscripts were submitted, or published. Chapter 3 investigated and confirmed the test-retest reliability of three rumination scales which measured rumination as an emotion regulation style, thinking style, and as a response to depression, comparing findings for older persons with and without dementia. The relationships between these types of rumination and depression, anxiety, and AB were examined, and rumination was determined a potential intervention target for PwD. These findings could prove useful to future research/interventions involving PwD which, as discussed earlier in this chapter, should examine rumination in this population. Webcam-based eye tracking measures of AB were touched upon in this chapter but are discussed in more detail in Chapter 4.

Chapter 4 contains four manuscripts, the first of which reviewed literature related to the use of technologies for mental-health interventions for older persons and identified the most frequently owned and used technologies by PwD compared to older persons without dementia, and most frequently conducted tasks on these technologies. This chapter provided much needed data surrounding spontaneous technologies use, and data from PwD in the United Kingdom. The second and third manuscripts provided preliminary data from the exploration and confirmation of the feasibility of webcam-based eye tracking (WBET) with PwD, and the reliability of AB measures using WBET, respectively. The fourth manuscript explored the feasbility and impact of multi-session ABM using webcam-based eye tracking for older persons with and without AD. Clinically relevant changes in depression and anxiety were yielded.

Chapter 5 explored and provided preliminary data on the effect of music on the AB of older person with and without AD, comparing and identifying differences in the relative time spent on different emotional faces and the top-half and bottom-half of these faces during viewing in silence and in background music. Rumination levels were explored in terms of AB differences in the silence versus background music condition for high and low ruminators, and the potential link discussed.

Chapter 6 explored the effect of a technology-based music-mediated intervention, created as part of this thesis, on younger adults' momentary mood and AB after a single session of the intervention, and momentary mood, depression, anxiety, rumination and AB after multiple sessions of the intervention. Clinically relevant changes in depression, anxiety, and rumination in relation to the multi-sessioned intervention were yielded.

Finally, Chapter 7 and 8 discusses the novel findings of this thesis, the impact of this body of works, followed by future research directions. Figure 1 below illustrates how each of the aims of this thesis aligns with a relevant chapter/s.

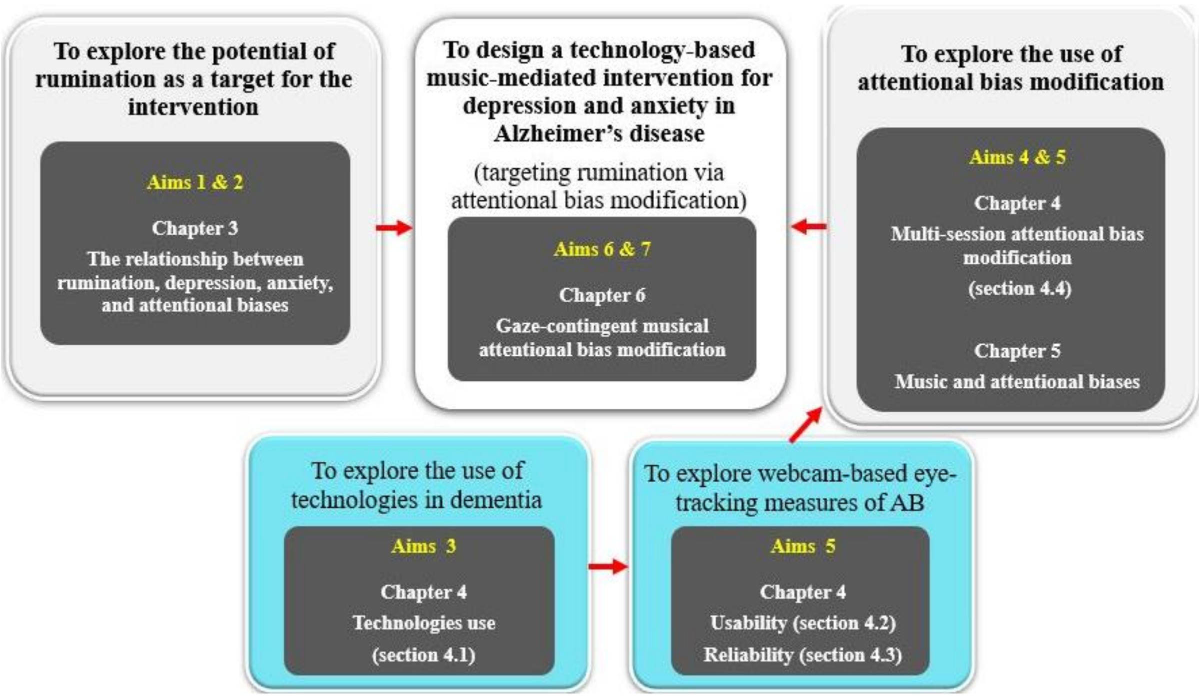

Figure 1 Thesis aims aligned to relevant chapters (top-line boxes = overarching thesis aims)

Chapter 2

Literature review

2.1 Rumination and attentional biases

Depression and anxiety disorders are characterised by biased information processing of negative and threat-related information, respectively, in memory, attention, and interpretation (Clark & Beck, 2010; De Raedt & Koster, 2010). These biases stem from representations of the self and the environment (schemata) that are developed from genetic factors and negative events occuring in early childhood (Clark & Beck, 2010) (see Figure 2). Rumination, a cognitive vulnerability of depression and anxiety, arises once these schemata are triggered and is associated with the aforementioned processing biases (Gotlib & Joormann, 2010; Krahé et al., 2019).

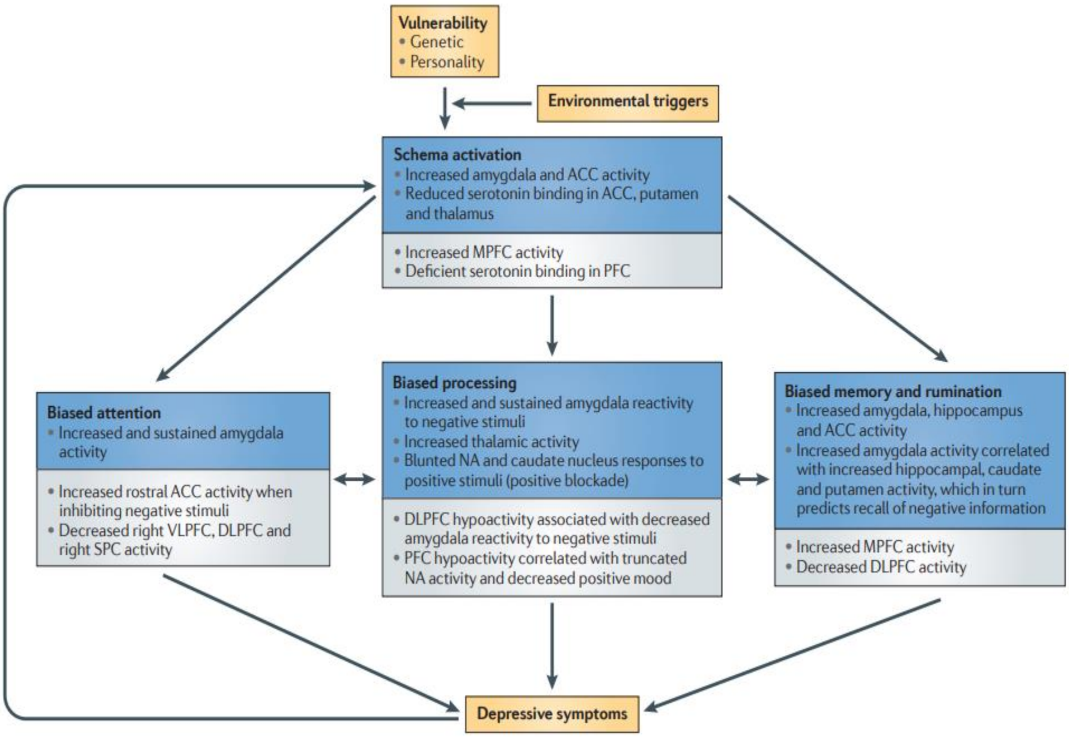

Figure 2 Illustration summarising the integrated cognitive neurobiological model of depression. Reprinted by permission from Springer Nature Customer Service Centre GmbH: Springer Nature, Nature Reviews Neuroscience, Neural mechanisms of the cognitive model of depression, S.G. Disner, C.G. Beevers, E.A.P Haigh, and A.T Beck, COPYRIGHT, (2011).

2.1.1 Rumination theories, models, and measures

Ruminative processing involves different constructs, such as the trigger/focus, purpose, valence, and timeframe of the ruminations, and the various theories of rumination differ regarding the construct on which the theory is based. For example, the rumination on sadness model (Conway et al., 2000) relates to repetitive thinking about the distress and circumstances of current sadness whereas the stress-reactive rumination model (Alloy et al., 2000) relates to negative self-referential thinking associated with stressful events (see Smith & Alloy, [2009] for an in-depth review). Although these theoretical conceptualisations differ in terms of the focus of the ruminations, both types of rumination predict depression, and other types of rumination, e.g., post-event rumination, have been associated with anxiety (Kashdan & Roberts, 2007; Peled & Moretti, 2010; Rachman et al., 2000; Robinson & Alloy, 2003). The response styles theory (Nolen-Hoeksema et al., 2008) and the goal progress model of rumination (Martin & Tesser, 1996) are discussed here as the rumination scales that were used within this thesis are based on these conceptualisations.

2.1.1.1 Response styles theory

The response styles theory (Nolen-Hoeksema & Morrow, 1991) posits that depressive rumination is a stable, trait-like response style to a depressed mood whereby individuals have repetitive thoughts and feelings about the causes, consequences, and symptoms of a depressed or dysphoric mood (Nolen-Hoeksema & Morrow, 1993). These thoughts and feelings can be negative/maladaptive (depressive or broody) or relatively positive/adaptive (reflective) in nature and orientated in the past and/or present (Alderman et al., 2015). Reflective rumination can be associated with higher levels of concurrent depression but is relatively more adaptive than brooding rumination as it is associated with less depression over time (Treynor et al., 2003). There is considerable evidence which suggests that a ruminative disposition, particularly to engage in ruminative brooding, plays a critical role in the onset and maintenance of depression and anxiety, and mediates the link between stressful life events and depression and anxiety (Aldao et al., 2010; McLaughlin & Nolen-Hoeksema, 2011; Michl et al., 2013; Moberly & Watkins, 2008; Nolen-Hoeksema et al., 1993, 2008; Ruscio et al., 2015) (see Kasch et al. (2001) and Lara et al. (2000) for conflicting stability and predictive ability findings). Rumination increases and prolongs distress by exacerbating the impact of a depressed mood on thinking, impairs effective problem solving, and interferes with the actions required to reach goals (instrumental behaviour) (Nolen-Hoeksema et al., 2008). There is experimental support for the causal role of rumination in depression and anxiety vulnerability whereby a negative mood can increase following rumination induction (McLaughlin et al., 2007; Morrow & Nolen-Hoeksema, 1990; Nolen-Hoeksema & Morrow, 1993) but not always (Wisco & Nolen-Hoeksema, 2009).

The response styles theory's conceptualisation of rumination underscores two of the scales that were used within this thesis, the Ruminative Responses Scale (RRS) (Nolen-Hoeksema, 1991) and Cognitive Emotion Regulation Questionnaire (CERQ) (Garnefski et al., 2001). The RRS contains three subscales, depression-related, brooding, and reflective rumination items. The RRS has been criticised due to the overlap between the depression-related items and depression screen items (Treynor et al., 2003; Whitmer & Gotlib, 2012). While a shorter form exists which contains only brooding and reflective rumination items (Treynor et al., 2003), the 22-item scale was used in this thesis for comparative purposes with existing literature and analysis was conducted on the totalled full-scale score alongside the brooding and reflective rumination subscale scores (see Chapter 3 [3.1.1]) for further discussion). It has recently been found that brooding and reflective rumination have positive correlations (r = .60 and .56, respectively) with depression for PwD (Keune et al., 2023). However, the reliability of the measure was not examined, nor the relationship between anxiety and rumination.

The CERQ examines rumination as an emotion regulation style and assesses the individual's thoughts surrounding the feelings about negative or unpleasant events (Garnefski et al., 2001). A ruminative emotion regulation style is more strongly and consistently correlated with symptoms of depression and/or anxiety in older persons than other maladaptive styles such as avoidance and suppression (Nowlan et al., 2016; Ramirez-Ruiz et al., 2019). Still, more research relating to older persons is required, and PwD or PwCI should be included, where possible, as PwD or PwCI can be excluded from studies examining the CERQ, or cognitive status may not be reported (Carvajal et al., 2022; Garnefski & Kraaij, 2006; Rossi et al., 2023). However, examining the relationship between rumination and anxiety with scales that focus on a depressed mood could obscure the relationship between rumination and anxiety, and does not enable an assessment of an individual's general tendency to engage in ruminative thinking (Brinker & Dozois, 2009). As such, rumination as a thinking style was assessed in this thesis by the Ruminative Thought Style Questionnaire (RTSQ) (Brinker & Dozois, 2009) which is based on a broader conceptualisation of rumination by Martin & Tesser (1996).

2.1.1.2 The goal progress model

The goal progress model (Martin & Tesser, 1996) posits that rumination arises as a response to a failure to progress satisfactorily towards a goal rather than a specific trigger/focus (e.g., depressed mood, or sadness) (Smith & Alloy, 2009). The ruminations can be negative (e.g., worry) or positive (e.g., reminiscing) in nature, and have different temporal orientations (past, present, or future). Individuals who experience threats to goal attainment, particularly important goals, ruminate more than those who do not, and rumination will persist until there is satisfactory progress, the goal is achieved, or there is no further pursuit of the goal (Martin & Tesser, 1996; McIntosh et al., 1995). There is evidence which supports and contradicts this perspective as rumination can be evident without current or perceived failure (Jones et al., 2013; Martin & Tesser, 2006; Smith & Alloy, 2009). Within this model, negative affect arises indirectly, and as an appraisal-based response to the goal failures.

Based on this conceptualisation, the RTSQ examines a general tendency to ruminate without a specific focus. It encompasses repetitive, recurrent, uncontrollable, and intrusive thoughts with different valences (positive, negative, and neutral) which are past, present, and future-oriented (Brinker & Dozois, 2009). This is important as anxiety is thought to surround future-related thoughts (McLaughlin, Borkovec, & Sibrava, 2007; Watkins, Moulds, & Mackintosh, 2005). Moreover, more repetitive thought in general, irrespective of valence or purpose, has been linked to poor psychological health in older persons (Segerstrom et al., 2010). Rumination as a thinking style, as assessed by the RTSQ, has a positive relationship with depression for older persons, and can predict future depressed mood (Brinker, 2013). However, cognitive status was either not assessed or not reported. While there is substantial evidence to suggests that engaging in ruminative brooding plays a critical role in depression and anxiety, and a ruminative emotion regulation style correlates more strongly and consistently with depression and anxiety in older persons, rumination as a thinking style assessed by the RTSQ has not been as robustly explored. While there are inconsistencies regarding the underlying factor structure, the RTSQ total score (as used in this thesis) is most associated with global rumination and is reliable to use (Brinker & Dozois, 2009; Kovacs et al., 2021; Mihić et al., 2019). This scale was selected here to contrast the depression focussed nature of the RRS. Still, more research relating to older persons is required, and PwD or PwCI should be included.

In sum, there is some evidence of relationship between depression, anxiety, and rumination as response to depression for older persons, but evidence is sparse regarding PwD. This is surprising given that attentional control impairments occur in dementia (see Chapter 3 for further discussion) and attentional control impairments contribute to rumination as outlined in the impaired disengagement hypothesis of rumination (Koster et al., 2011), and when comparing the proposed neural correlates of rumination and the neural function described in AD (Agosta et al., 2012; Celone et al., 2006; Marchetti et al., 2012; Zhu et al., 2017). Each of these points will be discussed in the following sections of this thesis.

2.1.1.3 Impaired attentional disengagement, biases, and rumination

According to the impaired disengagement hypothesis of rumination (Koster et al., 2011), a reduced ability to disengage attention, i.e., a lack of attentional control, from negative information is the key element that places individuals at risk for heightened levels of maladaptive rumination, i.e., brooding. Individuals with attentional control impairment will demonstrate an AB to negative information as they cannot disengage their attention from the negative information. Authors broadly define attentional control as the ability to selectively attend to task-relevant information and inhibit task-irrelevant information. Various studies support each of these proposals. Inhibition and attentional switching deficits have related to trait and state ruminative processing, respectively (Whitmer & Gotlib, 2012). Inhibitory deficits are related to brooding in particular, and this type of rumination is associated with valence specific inhibitory deficits (de Lissnyder et al., 2010; Joormann, 2006; Whitmer & Banich, 2007). A difficulty disengaging from and inhibiting negative material has been demonstrated in depression and these difficulties have significantly correlated with rumination (Kircanski et al., 2012). Findings confirm an AB towards negative information and attentional disengagement impairments in trait ruminators (Cooney et al., 2010; Donaldson et al., 2007; Grafton et al., 2016; Southworth et al., 2017). Further, rumination and AB are thought to have a bi-directional relationship in that NAB may lead to rumination, which in turn, increases NAB (LeMoult & Gotlib, 2018).

Research findings regarding AB in anxiety is mixed, suggesting enhanced attentional engagement but not impaired disengagement, both enhanced engagement and impaired disengagement, and enhanced engagement followed by avoidance of negative information are involved (Blicher et al., 2020; Grafton & Macleod, 2016; Rudaizky et al., 2014). Additionally, timing matters in terms of the emotional processing stages being addressed (early versus late) and stimuli presentation duration within AB measure paradigms (short versus long) as to whether NAB may be demonstrated. For example, NAB in the later stages of information processing may be demonstrated by persons with depression (stimuli durations >1000 ms), and persons with anxiety can demonstrate an initial bias towards negative stimuli (early stage, short stimuli duration <500 ms) and then avoidance of negative stimuli (longer stimuli durations) (Armstrong & Olatunji, 2012; Donaldson et al., 2007; Grafton et al., 2016; Mogg & Bradley, 2005). Threat avoidance, expressed by looking longer at non-threat stimuli, is an emotional regulation strategy (Lisk et al., 2020). Additionally, persons with anxiety may not show an initial bias towards threat but then maintain their gaze on it once it is attended to (Liang et al., 2017). Still, rumination may be related to attentional disengagement rather than engagement bias in anxiety, with attentional disengagement mediating between rumination and state anxiety (Vălenaş et al., 2017).

The presence of comorbid depression and anxiety further complicates matters. Mood-congruent AB are thought to operate in depression and anxiety, with persons with depression maintaining their gaze on dysphoric stimuli (e.g., sad faces) more than positive stimuli, and persons with anxiety maintaining or avoiding threat-related stimuli (e.g., angry, or disgusted faces) (Armstrong & Olatunji, 2012; Suslow et al., 2020). In the few studies examining comorbidity in younger persons, findings are mixed showing that clinically comorbid individuals may, or may not, demonstrate depression-related biases (i.e., AB to sad faces), may demonstrate anxiety-related biases (e.g., AB towards and away from angry faces) (Hankin et al., 2010; Kishimoto et al., 2021; LeMoult & Joormann, 2012), or show a bias towards or away from happy faces depending on their clinical history (i.e., current versus lifetime symptoms, respectively) (Hankin et al., 2010).

2.1.2 Attentional and memory biases in Alzheimer’s disease

Non-depressed PwAD can display NAB and have difficulty disengaging their gaze from negative stimuli compared to neutral stimuli (Bourgin et al., 2020; LaBar et al., 2000) (see Chapters 3 [3.1.3], 4 [4.3], and 5 for further discussion). These findings were viewed as the preserved effect of emotional stimuli to modulate attention in AD, yet anxiety and rumination were not assessed in either study, and as such, anxiety and/or rumination cannot be ruled out as influencing factor(s). Conflicting findings have also presented as to whether or not early engagement with negative stimuli is preserved in AD (Bourgin et al., 2018; LaBar et al., 2000). It is possible that the differences in findings could relate to study tasks, with early attentional orienting being evidenced under naturalistic viewing but not via prosaccade testing whereby the participant is instructed to look at a target as quickly as possible.

Most of the research regarding biases in dementia come from studies related to memory biases. As noted earlier in section 2.1.1, depression and anxiety are also characterised by biased information processing in memory. Inhibitory control deficits are suggested to lead to a reduced ability to prevent negative information from entering working memory and to disengage from this information (Joormann, 2010). Elaborated processing is facilitated by the inability to update working memory, contributing to rumination and negative biases in long-term memory (LeMoult & Gotlib, 2018). Negative, positive, and an absence of memory biases have been demonstrated in AD, and positive biases are mostly reported in studies whereby PwAD with depression or NPS are excluded, or depression is controlled for (if assessed) (Belleville et al., 2007; Boller et al., 2002; De Vita et al., 2023; Maria & Juan, 2017; Werheid et al., 2011).

In a recent systematic review and meta-analysis study (De Vita et al., 2023) examining memory biases in AD, only one out of 41 studies reported anxiety scores, and none assessed rumination. Most of the studies examining emotional processing in PwAD use emotional labelling, discrimination, recall, or recognition tasks. Anxiety may be associated with biases in (free) recall rather than recognition memory, and with tasks involving attentional encoding of the information, and as such, may contribute to some of the different findings in the literature (Herrera et al., 2017; Mitte, 2008). The types of tasks used in emotional processing studies place constraints on information processing which can also affect findings (da Silva et al., 2021; Reed et al., 2014). The unconstrained and natural viewing of the emotional stimuli in the studies described within this thesis, potentially allowed for the participant's own emotional goals, attention and/or resources allocation to be exhibited (Reed et al., 2014), thus providing a clearer picture of biases in AD.

2.1.3 Rumination and Alzheimer's disease

Although rumination in dementia was understudied at the inception of the studies within this thesis, there was available literature regarding the altered electroencephalogram (EEG) oscillatory patterns exhibited by persons with major depressive disorder (MDD) and PwAD (Babiloni et al., 2016; Fingelkurts & Fingelkurts, 2014). Thus, the literature regarding the neural correlates of rumination in cognitively healthy and depressed populations were compared against EEG findings in AD to identify patterns of processing that may be indicative of rumination.

2.1.3.1 Default mode network

Attentionally demanding cognitive tasks are associated with a pattern of brain activity within two anti-correlated networks, whereby one network shows task-related activations (task-positive network [TPN]) while the other network (default mode network [DMN]/task-negative network [TN]) activity attenuates (Fox et al., 2005; Gusnard & Raichle, 2001; Leech & Sharp, 2014). At rest, the DMN activity increases and the TPN activity attenuates (Hamilton et al., 2011). The DMN network consists of brain regions such as the medial prefrontal cortex (MPFC), the most rostral segment of the anterior cingulate cortex (rACC), precuneus, posterior cingulate cortex (PCC), and hippocampus (Buckner et al., 2008; Raichle, 2015). The TPN includes brain regions such as dorsolateral prefrontal cortex (DLPFC) and dorsal segment of the ACC (dACC).

The DMN is active during rest, and is thought to be involved in, for example, internal attention, self-related processing, and mind-wandering (Brewer et al., 2013). According to the DMN dysregulation framework by Marchetti et al. (2012), imbalanced activity between these anti-correlated networks, resulting in less TPN activity, is thought to be associated with impaired attentional control and rumination. Increasing levels of DMN dominance over TPN activity is associated with higher levels of brooding and lower levels of reflective rumination (Hamilton et al., 2011). Disrupted coupling between the TPN and DMN/TN could hamper the recruitment of cognitive control when negative information needs to be inhibited (Pizzagalli, 2011). AD is associated with increased DMN activity, reduced task-induced deactivation, and disrupted DMN connectivity, particularly decreased functional connectivity (a measure of the correlations in the activity between brain areas) between the posterior (precuneus and PCC) and anterior (MPFC and ACC) regions of the brain (Damoiseaux et al., 2012; Desgranges et al., 2011; Mohan et al., 2016; Pizzagalli, 2011; Zhou & Seeley, 2014).

2.1.3.2 Functional connectivity in depressive rumination versus Alzheimer's disease

The differences in functional connectivity between persons with MDD and healthy controls form the basis of the suggested neural mechanisms reflecting depressive rumination (Berman et al., 2014). Increased functional connectivity between the DMN and subgenual prefrontal cortex (sgPFC) in MDD has been suggested to reflect the neural underpinning of depressive rumination (Hamilton et al., 2015). Increased sgPFC activity is associated with a depressive state (Mayberg et al., 2005). Figure 3 illustrates normal (orange nodes and connections) and depressotypic (red nodes and connections) functional connectivity, and it is the abnormal degree of connectivity between the structures shown in depressotypic connectivity which culminates in a coupling of DMN and sgPFC-related processing that produces a ruminative state (Hamilton et al., 2015).

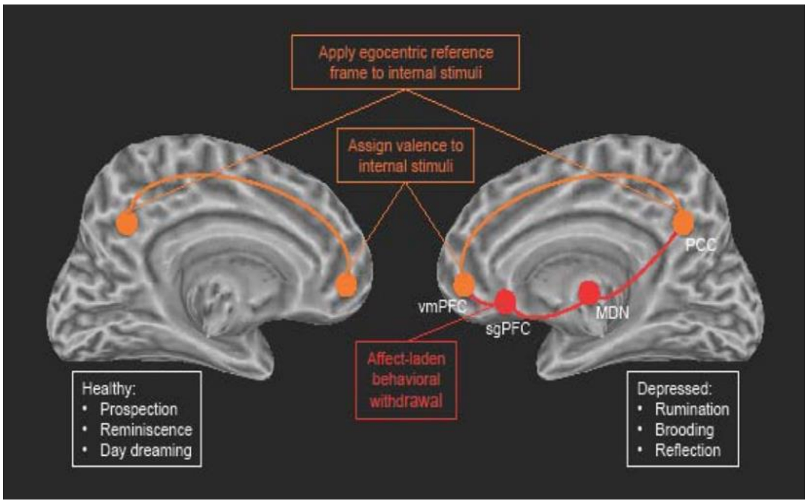

Figure 3 Illustration of the functional integration model of depressive rumination. Reprinted from Biological Psychiatry, 78 (4), Hamilton, Farmer, Fogelman, and Gotlib, Depressive Rumination, the Default-Mode Network, and the Dark Matter of Clinical Neuroscience, 224-230, Copyright (2015), with permission from Elsevier.

There is potential overlap when comparing findings regarding neural correlates of rumination in MDD and the findings related to functional connectivity in AD. A positive correlation between rumination scores and connectivity between the dorsal medial prefrontal cortex (dMPFC) and temporal pole has been found (Zhu et al., 2017). The dMPFC is involved in self-referential processes (Gusnard & Raichle, 2001). Compared to healthy controls (HC), PwAD have shown significantly increased connectivity in the dMPFC (Agosta et al., 2012). Similarly, increased connectivity in the ACC in PwAD relative to HC has also been found (Agosta et al., 2012). Areas within the ACC, particularly the rACC (Brodman area 24, 25 and 32) fall within the sgPFC (Furey et al., 2015). Bohr et al., (Bohr et al., 2013) speculate that observed increases in ACC functional connectivity in late life depression may be driven by subgenual cortex contributions. If so, it could be hypothesised that the increased ACC connectivity in AD could be linked with ruminative processing as connectivity in the sgPFC is modulated by maladaptive rumination (Zhu et al., 2017). The length of a depressive episode also correlates with resting state subgenual cingulate connectivity (Brodmann area 25 [Mayberg et al., 2005])

(Greicius et al., 2007). These results are in line with findings that rumination can increase the duration of depressive episodes (Nolen-Hoeksema et al., 2008).

It has, however, been suggested that increased functional connectivity in AD may be a result of compensatory mechanisms (Agosta et al., 2012; Celone et al., 2006). Still, a contributory or driving effect of rumination on functional connectivity and DMN activity in AD cannot be ruled out. For example, an increase in connectivity in specific networks, the salience network (SN), has been associated with some of the different NPS of AD such as agitation (Balthazar et al., 2014). Changes in functional connectivity is a result of underlying disease pathology, and recent research has linked repetitive negative thinking (RNT), a component of maladaptive ruminations, to underlying AD pathology.

2.1.3.3 Repetitive thinking and Alzheimer's disease risk

The formation of protein-based amyloid beta (Aβ) plagues and hyperphosphorylated tau tangles is a characteristic of AD pathology (Nordberg, 2015) and tends to initially occur in the temporal lobes and hippocampus (Rapp et al., 2008). Episodic memory networks are affected resulting in an inability to acquire and store new information (anterograde amnesia) (Weintraub et al., 2012) relating to the time, date, and details of events (Dickerson & Eichenbaum, 2010). Short-term (working) memory impairment is prominent during the earlier stage of the disease (Baddeley et al., 1991; Grossberg & Desai, 2003). The accumulation of Aβ in older persons without cognitive impairment is associated with an increased risk of progression to MCI and dementia, and more cognitive decline over time than those without Aβ accumulation (Moylan et al., 2013). Aβ accumulation is also associated increasing anxious-depressive symptoms over time, although the relationship may be weak or indirect (Donovan et al., 2018). Other findings suggests that RNT may underlie the comorbidity between protein deposits, cognitive impairment, and mood. Increased RNT has been associated with greater declines in memory, higher levels of protein deposits, and more depression and anxiety symptoms (Marchant et al., 2017, 2020). AD risks factors (memory decline, and protein deposits) were not directly associated with depression and anxiety symptoms, but RNT was associated with AD risk factors and depression and anxiety (Marchant et al., 2017, 2020).

In contrast, a study (Ravona-Springer et al., 2009) found repetitive thinking in mid-life to be associated with a lower incidence of dementia, stating this indicated that repetitive thinking in mid-life may be a protective factor. Although the authors assumed the context related to the repetitive thinking (i.e., work and family stress) would be associated with a negative cognitive style, the study generated measure of repetitive thinking did not allow for valence of the repetitive thinking, which can have different health outcomes, to be distinguished. The assessment question contained two parts, (1) the tendency to worry, and (2) to keep thinking about the issue. The respondent could focus on one, or both parts when generating their response. The response range only reflects how much the issue is thought about (from 'forget' to 'usually think repetitively'). Worry is considered a type of RNT which is associated with negative outcomes, whereas thinking about an issue repetitively could have a positive or negative basis and positive or negative outcomes (Lewis et al., 2019) (see Chapters 3 for further discussion). Brooding rumination in late life, but not reflective rumination, which is relatively more positive, is associated with accelerated brain aging (Karim et al., 2021).

All-in-all, different types of repetitive thinking may have different associations with dementia at different stages of life, and a clearer understanding may be provided by using validated scales.

2.1.3.4 Repetitive negative thinking in Alzheimer's disease

Research focussing on RNT has only recently begun to gain traction in the field of dementia (Karim et al., 2021). The limited amount of research in this area shows that PwD do engage in future-orientated repetitive thoughts (i.e., repeatedly thinking about the incidence of positive and negative future outcomes) that are pessimistic in nature (El Haj et al., 2021). Pessimistic future-orientated repetitive thoughts are associated with depression, anxiety, and rumination, induced rumination increases negative future thinking, and both pessimistic future-orientated repetitive thoughts and rumination are mediators between suicide attempts and future suicidal ideation in younger persons (Lavender & Watkins, 2004; Miranda et al., 2017; Miranda & Mennin, 2007). Suicidal ideation is highest for PwD (Lewy bodies = 20%, AD = 16%, vascular = 13%), particularly around the time of a dementia diagnosis, and is associated with depression (Naismith et al., 2022). Moreover, suicide attempts are also higher for around this period (Günak et al., 2021). Therefore, it is important to identify PwD who are ruminators and treat depression and rumination, if the mediatory relationship suicide attempts and future suicidal ideation in younger persons holds for PwD.

PwD also engage in reminiscence (i.e., recalling past memories either passively [involuntary recollection] or actively [deliberate recollection] [Brinker, 2013]). Reminiscence is considered to be a relatively more adaptive type of repetitive thinking, but it is the function of the reminiscence that determines its mal/adaptiveness. For example, reminiscence for boredom reduction and bitterness revival is negatively associated with well-being, and reminiscence can be associated with increased worry, rumination, depression, and anxiety (Brinker, 2013; Cully et al., 2001; Ricarte et al., 2020; Westerhof et al., 2010). In contrast, the interaction between rumination and other functions of the reminiscence (e.g., social interaction) may have a positive effect on depressive symptoms (Ricarte et al., 2020).

In a similar vein to this thesis to explore rumination as potential intervention target in dementia, a recent study (Keune et al., 2023) examined the relationship between rumination, depression, and mindfulness in AD. Findings showed that increased rumination was associated with increased depression and negatively correlated with mindfulness. However, anxiety was not examined.

2.1.4 Summary

When considering existing rumination literature, PwCI may be cognitively vulnerable to rumination. Yet, rumination is understudied in this population and PwD are encouraged to engage in other types of repetitive thinking (e.g., reminiscence), although there could be a negative interaction between them. When rumination is examined, the relationship with repetitive thoughts or rumination and depression and/or anxiety can be left unexplored. Given the findings regarding the negative relationship between RNT and plaque deposition, cognitive decline, and mood in older persons without dementia, RNT may have worse consequences for PwD. As such, it is important to (1) validate repetitive thinking or rumination scales to identify ruminative processing in dementia, (2) examine the relationship between rumination, depression, and anxiety simultaneously, and (3) investigate interventions which may alter repetitive thinking or ruminative thinking in dementia. If rumination arises from AB, then modifying AB could lead to a reduction in rumination.

2.2 Attentional bias modification and rumination

2.2.1 ABM task selection

ABM is designed to facilitate the attentional avoidance of one type of stimulus (i.e. dysphoric) in favour of another (i.e. positive), thereby improving inhibitory control (Clarke et al., 2014). Several tasks have been employed to modify AB such as the visual search task, spatial-cueing task, and the most commonly use, dot-probe task (MacLeod et al., 2002; MacLeod & Clarke, 2015; Waters et al., 2013).

2.2.1.1 Visual search task

The visual search task involves the location of a target stimulus (e.g., a happy face) from a matrix (e.g., 3 x 3 or 4 x 4) of distractor stimuli (i.e., one type e.g., sad faces, or multiple types, e.g., sad, angry, neutral, and disgust faces). This task involves the use of several cognitive control processes (e.g., goal-directed orienting and inhibitory control) which could improve the training effect (see Mogg & Bradley [2018] cognitive-motivational framework for detailed discussion of each of the processes) (Mogg et al., 2017). However, visual search accuracy can be impacted by the number of distractors for PwAD (Landy et al., 2015). The dot-probe task may be more appropriate as there is no interference from distractors during the presentation of the training stimuli (i.e., the dot).

2.2.1.2 Spatial-cueing task

The spatial-cueing task involves indicating the location of target (e.g., a star) which is presented in the same (congruent) or different (incongruent) location of a single facial image that had been presented and removed before the target (Bar-Haim et al., 2011). This task may reduce interference from competing stimuli (e.g., only presenting a single facial image at a time) (Lowther & Newman, 2014), which could, in theory be beneficial for PwAD. However, there is less research using this task, and ABM using the dot-probe may have a larger effect on depression and rumination reduction than ABM using spatial cue and visual search tasks (Clarke & Macleod, 2014; Lowther & Newman, 2014; Xia et al., 2023).

2.2.1.3 Dot-probe task

A modified version of the dot-probe task (MacLeod et al., 2002) typically involves an initial fixation stimulus being presented and removed, followed by two stimuli being presented simultaneously (one valanced and one neutral) briefly (e.g., 1000 ms). A probe will appear on either the left or right side of the screen, in the spatial location of one of the two stimuli previously presented. Participants are required to identify the probe, as quickly as possible, by button press. AB can be altered by manipulating the number of times the probe appears in the location of the desired valanced stimuli (Arditte & Joormann, 2014). The seminal studies were designed to test whether AB to threat could be encouraged (attend to threat condition), and altered (avoid-treat condition), and whether ABM had an effect on the response to induced stress (MacLeod et al., 2002). Following the successful modification of AB and reduction in stress response in the train positive condition participants, the therapeutic utility of ABM has been investigated. For example, Beevers et al. (2015) investigated the effect of ABM against placebo attention training. Compared to placebo, NAB reduced in the modification group and this significantly correlated with depressive symptom change. However, as discussed in Chapter 6, dot-probe ABM is not universally successful at reducing depression and anxiety.

2.2.1.4 Attentional bias modification, rumination, and mood

Few studies have investigated whether ABM training affects rumination (Daches & Mor, 2014). Causal data, via mediation analysis, supports targeting rumination via ABM to reduce mood symptoms. W. Yang et al. (2015) conducted a clinical randomized controlled trial that monitored the long-term effects of computerized ABM. Researchers found significant reductions in the symptoms of depression for up to 3 months with 53% of participants achieving clinically significant reductions in the treatment group. Half the participants remained asymptomatic at month 3. Anxiety and rumination were also significantly reduced up to 8 weeks. Researchers also performed pathway analysis and found that the change in rumination, not the change in AB, directly mediated the change in depressive symptoms. The change in AB directly mediated the reduction in rumination.

In contrast, others have yielded no change in AB, rumination and/or symptom change following ABM. Daches & Mor (2014) found no change in AB but a reduction in brooding following ABM, but not in depressive symptoms. The depressed participants did not show AB pre-training so an effect on AB would not necessarily have been observed. Baert et al. (2010) did not find training effects on AB nor rumination in those with mild depression, but depression symptomology reduced, and depressive state was significantly reduced. Bø et al. (2023) also failed to find training effects on AB, but a significant reduction in depression and anxiety was found in the ABM and control group. State rumination increased in the ABM training group and decreased in the control group post-intervention. It is possible that trait rumination was affected but this was not assessed. The participants also had a variety of anxiety disorders, as well as depression. As discussed in section 2.1.1.3, AB, particularly in anxiety, are complex. It has been suggested that conflicting findings in ABM research could result from a lack of NAB at baseline, unsuccessful AB change, symptom type (e.g., social anxiety versus GAD) and comorbidity of symptoms, and the level of baseline symptoms and rumination (Arditte &

Joormann, 2014; Clarke & Macleod, 2014). Arditte & Joormann (2014) examined whether rumination would moderate ABM training effects. They found that high ruminators trained to have a positive AB demonstrated a more pronounced positive bias after training whereas low ruminators did not differ to controls post-training.

Others have suggested that ABM paradigms may need to accommodate for other factors that are associated with depression and anxiety (e.g., interference, other biases, and motivation) (Koster & Bernstein, 2015; Mogg & Bradley, 2018). For example, section 2.1.1 notes that other biases, e.g., interpretation biases (the tendancy to interpret ambiguous information as negative), are also thought to be associated with depression and anxiety. Few studies have specifically focussed on the directional relationship between cognitive biases and rumination in depression (Everaert et al., 2017). An indirect effect of AB on depression via interpretation biases and brooding has been found, therefore, targeting AB may have the potential to have downstream effects on other biases, ruminative processing, and depression. Experimental support for targeting AB to effect other biases, interpretation biases in this instance, and reduce anxiety has been provided (Krejtz et al., 2018). Augmenting existing ABM protocols may be required to account for a variety of complexities and improve outcome effects (Koster & Bernstein, 2015) (see section 2.2.2 for further discussion).

2.2.1.5 Mechanism of attentional bias change

The lateral prefrontal cortex, particularly the DLPFC, is proposed as a region involved in attentional deployment (Ochsner et al., 2012) and through which a change in AB is facilitated (Clarke et al., 2014). During inhibitory control, the ACC is thought to regulate DLPFC control of the hippocampus (M. C. Anderson et al., 2016). Hypoactivation of the DLPFC has been found in high ruminators and this reduces its ability to modulate other structures (Ferdek et al., 2016) (see Figure 2 grey boxes for brain structure activation information). Higher levels of neural activity in the DLPFC and ACC are associated with successful inhibition and disengagement (Vanderhasselt et al., 2013, 2017). Anodal transcranial direct current stimulation of the DLPFC can reduce neural activity when inhibiting negative stimuli in high ruminators, supporting the DLPFC suggested causal role in ABM and that additional stimulation facilitates disengagement (Vanderhasselt et al., 2017). The cognitive costs associated with rumination can be reduced by stimulation as demonstrated by faster disengagement in high ruminators after stimulation (Vanderhasselt et al., 2017). However, as discussed in Chapter 1 (1.1.8.2), NST such as this may not be appropriate for everyone. Thus, this thesis explored music as a potential adjunct to ABM in Chapter 4 (4.4) and Chapter 5 partially due to the safe, neurostimulatory effects discussed next.

2.2.2 Music and attentional bias modification

Musically induced modulation of brain areas vital to emotional regulation (e.g. the prefrontal cortex and amygdala), particularly those implicated in ruminative processes, make musical interventions particularly relevant to the treatment of depression, anxiety, and rumination (Koelsch, 2015; Koster et al., 2011; Marchetti et al., 2012; Sambataro et al., 2014; Sridharan et al., 2008). In a similar vein to Vanderhasselt et al. (2017), musical stimulation could, in theory, be used to reduce the cognitive costs involved in ruminative processing. For example, the DLPFC is involved in handling spatially based information during auditory processing (e.g., keeping track of music in time) (Plakke & Romanski, 2014; Särkämö et al., 2013). Recruitment of this structure in the processing music, may allow cognitive resources to be directed, without effort, to this region. Other NST target sites are also activated during music processing (Alluri et al., 2015; Brown et al., 2004; Keller et al., 2013). NST require trained individuals to administer treatment. Excluding music therapy, musical interventions do not require trained facilitators nor are they associated with the costs and side effects of NST. NST sites that are shown to be effective in an individual disease typically lay within the same brain network (Fox et al., 2014) whereas the processing of music recruits multiple areas of the brain and networks (Särkämö et al., 2013).

Combining ABM with music may be particularly useful for people with AD. Firstly, ABM involves implicit learning (Clarke et al., 2014) which is relatively spared in AD. Secondly, ABM encourages the disengagement from negative stimuli, but inhibitory control is also required to switch attention, stop the negative stimuli re/gaining the attentional focus, and to override its attentional interference (Koster et al., 2011). Switching attention, and inhibitory and interference resolution processes are less efficient in AD (Collette et al., 2009; Pekkala et al., 2008), and could be exacerbated by the presence of anxiety and/or depression (Tales & Basoudan, 2016; Warren et al., 2021). This could potentially impact ABM treatment outcomes. However, Cohen et al. (2015) showed that ruminators exposed to executive control activating stimuli (arrow version of the flanker task) exerted executive control when exposed to negative stimuli. Having exerted executive control, the interference caused by the negative stimuli was reduced leading to a reduction in state rumination. Using the Stroop task (Stroop, 1992), Masataka & Perlovsky

(2013) showed that music can reduce cognitive interference. This is without the use of an effortful task like the flanker task used in the Cohen et al. (2015) study which could prove beneficial in AD by reducing cognitive load. Lastly, studies have indicated that PwAD may have preserved semantic memory for music even up to the severe stage (Cuddy et al., 2015; Vanstone et al., 2012). Jacobsen et al. (2015) reported that brain regions, including the dACC, involved in long-term musical memory are relatively spared from characteristic AD pathology. Vanderhasselt et al. (2013) demonstrated that brooders need to recruit more activation in the posterior part of the dACC to successfully inhibit negative information. In AD, the dACC can be accessed and stimulated via music. However, if the structures associated with ruminative processes in persons without dementia are not representative in AD, music can modulate activity, particularly familiar music, in a variety of brain regions (Shahinfard et al., 2016; L. M. J. Yang et al., 2015). Preserved musical memory pathways, even in severe stages of dementia, could provide an alternate route to modulate activity in brain areas involved in dysfunctional emotional regulation.

The potential of music to facilitate a reduction in AB in social anxiety disorder and MDD has been demonstrated (Lazarov et al., 2017; Shamai-Leshem et al., 2021). Using a free viewing paradigm, music was used as a reward when the participant fixated on the target stimuli (e.g., neutral faces) and was removed (stopped playing) when they fixated on the to be avoided stimuli (e.g., faces portraying disgust). Clinically significant reductions in symptoms were shown post-intervention. Rumination was not assessed in these studies.

2.2.2.1 Attentional bias modification in AD

It has previously been suggested that PwD may benefit from ABM due to the implicit learning aspect of the intervention (Almeida et al., 2014). Interestingly, ABM training increases resting-state connectivity within the dACC (SN) and precuneus (DMN) and this correlated with depressive symptom reduction (Beevers et al., 2015). The ACC is thought to play an important role in emotional processing (Etkin et al., 2011). AD is associated with enhanced SN connectivity, and decreased connectivity in the precuneus in AD (Damoiseaux et al., 2012; Zhou & Seeley, 2014). Another benefit of ABM training in AD could possibly be the facilitation of a more naturalistic balance between the DMN and SN.

However, ABM typically involves the viewing of facial or word pairings of different emotional types (e.g., sad-neutral, or threat-neutral), although other types of stimuli (e.g., pictorial scenes) are also used (Fodor et al., 2020). While it is currently unknown whether facial, word, or non-face images would be more effective in ABM interventions involving PwD, facial images were used in this thesis as faces are a key aspect of emotional processing, communication (social and emotional), and psychosocial functioning which can positively or negatively influence anxiety and depression (Attwood et al., 2017; Barnett & Gotlib, 1988). Further, emotion recognition difficulties can be related to negative biases, mood, and insufficient viewing of the facial regions which aid recognition (e.g., the eyes, which is important in angry and sad face recognition) (Demenescu et al., 2010; Ogrocki et al., 2000; Phillips et al., 2010). Modifying an experimental paradigm to facilitate engagement with facial stimuli, could be a potential solution. For example, revealing the eye area first for fear faces, an expression which is difficult for PwAD to recognise, improved emotion recognition (Hot et al., 2013). While further research is necessary to investigate the type of music that may or may not affect older adults' attentional processing, music has been shown to improve emotion recognition, implicit processing of facial emotion, reduce cognitive interference (Masataka & Perlovsky, 2013; Quarto et al., 2014; Ramirez-Melendez et al., 2022) in other populations, and reduce cognitive interference in older adults (Cloutier et al., 2020; Fernandez et al., 2020).

2.2.3 Summary

ABM using the dot-probe methodology and facial images may have the potential to modify depression, anxiety, and rumination, and may be appropriate for PwAD, particularly when paired with music.

Chapter 3

Rumination in dementia and its relationship with depression, anxiety, and attentional biases

This chapter has been published in Aging, Neuropsychology, and Cognition.

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The reliability of three rumination scales was examined and confirmed in this chapter. The relationships between rumination, depression, anxiety, and AB were also examined, and rumination was determined a potential intervention target for PwD. These findings could prove useful to future research/interventions involving PwD. WBET measures of AB were touched upon in this chapter but are discussed in more detail in Chapter 4.

Abstract

Rumination (self-referential and repetitive thinking), attentional biases (AB), and impaired cognitive control are theorised as being integral factors in depression and anxiety. Yet, research examining the relationship between rumination, mood, and AB for populations with reduced cognitive control, e.g., people living with dementia (PwD), is lacking.

To explore whether literature-based relationships are demonstrated in dementia, PwD (n = 64) and healthy controls (HC) (n = 75) completed an online self-report survey measuring rumination and mood (twice), and a telephone cognitive status interview (once). Rumination was measured as an emotion-regulation style, thinking style, and response to depression. We examined the test-retest reliability of PwD's (n = 50) ruminative-scale responses, ruminative-scale internal consistency, and correlations between rumination, age, cognitive ability, and mood scores. Also, nine participants (PwD = 6, HC = 3) completed an AB measure via eye-tracking. Participants fixated on a cross, naturally viewed pairs of facial images conveying sad, angry, happy, and neutral emotions, and then fixated on a dot. Exploratory analyses of emotional-face dwell-times versus rumination and mood scores were conducted.

Except for the HC group's reflective response to depression measure, rumination measures were reliable, and correlation strengths between rumination and mood scores (.29 to .79) were in line with literature for both groups. For the AB measure subgroup, ruminative thinking style scores and angry-face metrics were negatively correlated.

The results of this study show that literature-based relationships between rumination, depression, and anxiety are demonstrated in dementia, but the relationship between rumination and AB requires further investigation.

Keywords: dementia, rumination, depression, anxiety, brooding, reflection

Introduction

People living with dementia (PwD) are likely to experience one or more behavioural and psychological symptoms such as anxiety, depression, irritation, and aberrant motor behaviours during disease progression (Staedtler & Nunez, 2015). Of these, depression and anxiety are commonly experienced, often co-occur, have moderate persistence, and are associated with an increased rate of cognitive decline and reduced quality of life (Breitve et al., 2016; Gonfrier et al., 2012; Ryu et al., 2005; Seignourel et al., 2008; Spalletta et al., 2012; van der Linde et al., 2016). Although depression, anxiety, and dementia have a complex relationship in terms of their biological basis and symptoms, recent research suggests that repetitive negative thinking (RNT) may be a core process linking dementia with depression and anxiety (Goyal et al., 2019; Marchant et al., 2017, 2020; Seignourel et al., 2008). Repetitive thinking, an umbrella construct for discrete types of self-referential, repetitive, and/or frequent thoughts, is thought to be a transdiagnostic process contributing to the association between depression and anxiety symptoms (Segerstrom et al., 2010; Spinhoven, van Hemert, et al., 2018). Repetitive thinking can vary by valence (positivity/negativity), its volitional basis (intrusive vs. directed), focus and purpose amongst many other qualities which correlate with different physical and psychological outcomes (Ehring & Watkins, 2008; Segerstrom et al., 2010; Smith & Alloy, 2009; Watkins, 2008).

In terms of the relationship between repetitive thinking and dementia, the type of repetitive thinking and when it occurs may be important. Repetitive thinking in mid-life can be associated with a lower incidence of dementia, which is indicative of a protective factor (Ravona-Springer et al., 2009), whereas increased RNT has been associated with risk factors of Alzheimer's Disease (AD) dementia (greater declines in memory and elevated levels of protein deposits) (Marchant et al., 2017, 2020). However, there is limited research regarding the types of repetitive thinking used by people with a diagnosis of dementia, and their association with depression and anxiety. While PwD engage in repetitive thinking (e.g., pessimistic future-orientated thoughts (El Haj et al., 2021)), and reminiscence about past memories (Woods et al., 2018)), it is unclear whether distinct cognitive processes are involved in the different types of repetitive thinking (Mandell et al., 2014). Consequently, the capacity or tendency for one type of repetitive thinking may not reveal the capacity or tendency for other types, nor their distinct relationship with depression and anxiety in dementia.

Types of rumination

The current study focuses on a type of repetitive thinking called rumination (Martin & Tesser, 1996). While rumination is suggested to be more evident in depression than in anxiety (Olatunji et al., 2013; Spinhoven et al., 2015), it is assessed with the Ruminative Response Scale (RRS) (Nolen-Hoeksema, 1991) in the majority of studies (Olatunji et al., 2013). As the RRS measures rumination in response to a depressed or dysphoric mood, it is possible that the relationship between rumination and anxiety may be obscured within anxiety studies. Moreover, the RRS total score (combined depressive, brooding and reflection subscales scores) is most often used in studies which focus on, or include older adults (Chen et al., 2020; Fernández-Fernández et al., 2014; McLaughlin & Nolen-Hoeksema, 2011; Nolen-Hoeksema & Aldao, 2011; Opdebeeck et al., 2015; Ramirez-Ruiz et al., 2019; Romero-Moreno et al., 2016; Von Hippel et al., 2008). Yet, the contributions of the RRS subscales to depression and anxiety in older adults may be important to understand. For example, participants with higher global cognition scores (less cognitive impairment) can use reflection to a greater extent than those with lower global cognition scores (more cognitive impairment) (Demnitz-King et al., 2021). Based on these findings, we could have hypothesised that a difference in the levels of reflective rumination could therefore be present between PwD and healthy older adults; PwD, having higher levels of cognitive impairment, may engage in less reflective rumination. Still, anxiety was not controlled for within these studies, and higher levels of reflective rumination are associated with higher levels of anxiety in older adults (D'Hudson & Saling, 2010). Consequently, an investigation of how different types of rumination, including brooding and reflective rumination, relate to depression and anxiety in older adults living with and without dementia is warranted.

Rumination and dementia

While rumination has been shown to be an important factor in late-life depression in people living without dementia (Tang et al., 2022), to our knowledge, the use of rumination as an emotion regulation style (RUM-EMO-REG), thinking style (RUM-THINK), and response to depression (RUM-RESP-DEP) by PwD has not been investigated to-date. Rumination is commonly associated with difficulties in inhibiting information and mental set switching (poor attentional control) (Koster, De Lissnyder, Derakshan, & De Raedt, 2011). Depending upon the pathological process of AD, attentional control difficulties such as the disengagement and shifting of attention, can be the first non-memory deficits following the hallmark episodic memory deficits associated with AD (Amieva et al., 2004; Parasuraman & Haxby, 1993; Pekkala et al., 2008; Weintraub et al., 2012), and inhibitory control deficits may increase with disease severity (Kaiser et al., 2018). Poor attentional control is associated with higher levels of rumination and in turn, more severe symptoms of depression and anxiety in people living without dementia (Hsu et al., 2015; Von Hippel et al., 2008). An underlying impairment in attentional control may make it harder to reroute cognitive resources away from the ruminative thoughts toward task-relevant information (Levens et al., 2009). Being in a ruminative state can prolong depressed and anxious moods (Michl et al., 2013). Therefore, once a ruminative cycle is entered, disengaging from ruminative thinking may be more difficult for people living with AD (PwAD) leading to a longer depressed or anxious mood compared to people living without AD who ruminate.

Although the question of whether the inhibitory control deficits associated with AD could modulate the capacity for rumination has been posed (Nash et al., 2007), an appropriate measure of rumination for PwAD to use is required. Investigating the reliability of rumination measures for PwAD in the current study is a step towards addressing this question.

Rumination and attentional biases

Cognitive inhibition impairment is central to both rumination and cognitive biases (i.e., attention, memory, and interpretation) (Joormann, 2010). While PwAD display biases in memory, emotion recognition/discrimination, and attentional biases (AB) (the tendency for a person to attend to, or avoid, a certain type or types of information) (Boller et al., 2002; Bourgin et al., 2020; Chau et al., 2016; Greenaway et al., 2024; LaBar et al., 2000; Maria & Juan, 2017; Werheid et al., 2011), research examining how these biases, and older adults' AB more generally, relate to mood or rumination is lacking (Cabrera et al., 2020; Demeyer et al., 2017; Isaacowitz et al., 2008; Lee & Knight, 2009; Mohlman et al., 2013). The current study sought to examine the relationship between rumination and AB as a ruminative disposition is characterised by AB (Grafton et al., 2016; Koster et al., 2011; Mogg & Bradley, 2018). Depressed and anxious individuals can take longer to disengage (shift) their attention from negative stimuli, thus displaying negative AB (Donaldson et al., 2007; Georgiou et al., 2005; Grafton et al., 2016; Koster et al., 2011). AB are thought to have a bi-directional relationship with rumination (see Figure 1) in that negative AB may lead to rumination, which in turn increases negative AB (LeMoult & Gotlib, 2018). In older adults, reduced executive function, which includes inhibition and shifting ability, can predict higher levels of rumination (Ng et al., 2022), and negative AB can be more pronounced in habitual ruminators (albeit middle-aged adults) (Donaldson et al., 2007). Given that attentional control is required to disengage attention (Ng et al., 2022) and control deficits may increase with AD severity (Kaiser et al., 2018), it is possible that AB could be (1) pronounced for some PwAD (with and without high rumination levels), and (2) modulated by disease severity. As such, studies exploring the relationship between rumination and AB for PwAD are warranted.

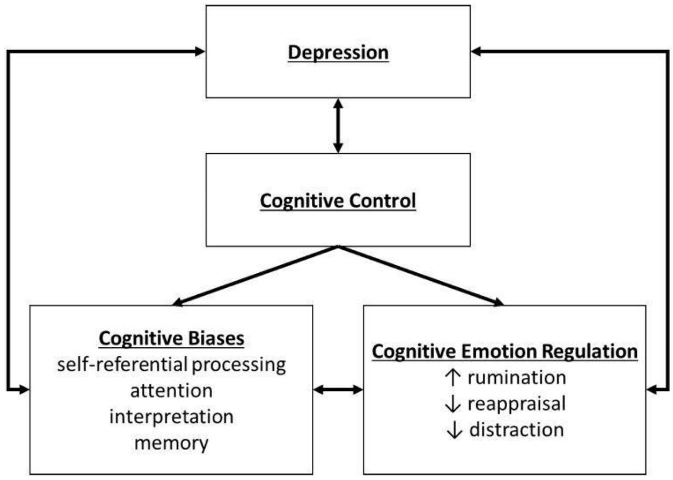

Figure 1. Cognitive perspective of the relationship between cognitive control, AB, and rumination (reprinted from Clinical Psychology Review, 69, LeMoult & Gotlib, Depression: A cognitive perspective, 51-66, Copyright (2023), with permission from Elsevier).

In summary, while repetitive thinking such as rumination and AB are thought to be key processes in the development and maintenance of depression and anxiety, the consequences of repetitive thinking for PwD is rarely studied and the clinical significance of rumination and AB for older adults is also lacking (Mohlman et al., 2013; Schneider et al., 2023). Exploring the relationship between depression, anxiety, rumination, and AB within the current study is a step towards addressing the aforementioned research gaps.

Study aims

The current study had the following aims:

1. To investigate the reliability of the selected rumination measures for PwD
2. To compare the level of rumination types used by PwD versus cognitively healthy controls (HC)
3. To examine the relationships between rumination measures and age, cognitive ability, depression, anxiety, and AB scores

Materials and methods

Participants

The survey recipients (*N* = 143) were recruited via the Join Dementia Research platform (https://www.joindementiaresearch.nihr.ac.uk/) and from the community using newsletter advertisements, of which 139 participants aged between 60 and 96 years old completed the survey (64 with a diagnosis of dementia [PwD], 75 healthy controls [HC] without a diagnosis of dementia nor mild cognitive impairment). Diagnosis status (i.e., presence of dementia/dementia type) was self-/representative-reported. All PwD were recruited via Join Dementia Research which operates as a self, representative, or health professional research volunteer registration platform. Volunteer records must contain demographic details and specify if there is a diagnosis of dementia (diagnosis date is optional), the type of dementia diagnosed (option for unknown), the dementia medication type (if taken), any medical conditions/disabilities (specific options and other), and carer/representative support (yes or no). Volunteer records for potential PwD were screened and only those (1) specifying a diagnosis date and dementia type, (2) without a Mini Mental State Examination score of < 20 points (obtained from the most recent volunteer and/or unrelated study assessment data entries), and (3) with a spouse/partner/carer/representative, were considered for the study. Volunteer information was verified via the volunteer's representative during the enrolment process.

The PwD group comprised participants with different types of dementia (AD = 42, AD/Vascular = 6, AD/Lewy Bodies = 1, AD/Mixed = 1, Vascular = 9, Lewy Bodies = 3, and Mixed [of unknown types] = 2), 36 males and 28 females, aged 60 to 96 years old (see Table 1. for demographic information). Approximately half (53%) of the PwD were classified as non-depressed/non-anxious, 25% as having comorbid depression and anxiety, 17% as having depression with no anxiety, and 5% as having anxiety with no depression (see Table 2. for group symptom status). Few PwD (*n* = 7, 11%) were taking anti-depressant medication, and 78% were taking cognitive medication (Donepezil = 42, Rivastigmine = 4, Memantine = 3, and Galantamine = 1). The HC group comprised 30 males and 45 females, aged 60 to 88 years old. The majority (81%) of the HC group were classified as non-depressed/non-anxious, 9% as having comorbid depression and anxiety, 7% as having depression with no anxiety, and 3% as having anxiety with no depression. No participants in the HC group were taking cognitive nor anti-depressant medication.

All participants with dementia were required to have a spouse/partner/carer/representative provide written or verbal confirmation of the participant's ability to provide informed consent. Each participant provided written or verbal consent before the telephone section of the study and consented via a checked tick box at the start of each online questionnaire.

Procedure

Participants completed the Telephone Interview for Cognitive Status (TICS) (Brandt et al., 1988) and received a personalised link to Online surveys (https://www.onlinesurveys.ac.uk/) via email to complete a self-report questionnaire (timepoint 1 [T1]) which measured their level of rumination and screened for the presence of depression and anxiety. To examine test-retest reliability participants completed the online questionnaire a second time (timepoint 2 [T2]), two weeks after they submitted the first questionnaire. Participants were instructed to finish the questionnaire within 48 hours of receiving their links. The participants who consented to participate in the webcam-based AB assessment (*n* = 11), completed the TICS via a Microsoft Teams meeting and were emailed a link to access Gorilla (Anwyl-Irvine et al., 2020), a web-based eye-tracking platform to complete the AB task. These participants did not complete T2 questionnaires as AB measures may be associated with an interventional effect (Blackwell et al., 2017).

Participating, for any given participant, took no longer than 2 hours in total. The study was reviewed in accordance with the procedures of the University of Reading's Research Ethics Committee and received a favourable ethical opinion for conduct (UREC 18/27; UREC 19/71).

Measures

Cognitive status

Memory, orientation, attention, and language were assessed via the 11-item Telephone Interview for Cognitive Status (TICS). Scores range from 0 to 41 with scores ≤30 indicating cognitive impairment. The TICS has demonstrated a high correlation with the commonly used Mini Mental State Exam (MMSE) (Folstein et al., 1975) without the ceiling and floor effects associated with the MMSE (Brandt et al., 1988; Sheehan, 2012) and has a discriminative ability (those with and without dementia) comparable to the MMSE (Seo et al., 2011).

Rumination

Rumination as an emotion regulation style. Four items (3, 12, 21 and 30) from the 36- item Cognitive Emotion Regulation Questionnaire (CERQ) (Garnefski, Kraaij, & Spinhoven, 2001) measures the extent to which a ruminative coping strategy is used by an individual. Responses to statements such as ‘I dwell upon the feelings the situation has evoked in me’ were given on a five-point scale from ‘almost never’ (1), to ‘almost always’ (5). The CERQ is standardised and suitable for use in populations that include older adults and psychiatric patients. The CERQ has good to very good factorial validity and reliability (Cronbach's αs between .75 and .87) (Garnefski & Kraaij, 2007). Convergent and criterion validity has generally been supported (Ireland et al., 2017; Jermann et al., 2006; Megreya et al., 2016).

Rumination as a thinking style. The Ruminative Thought Style Questionnaire (RTSQ) (Brinker & Dozois, 2009) was used to assess rumination as a style of thinking. The 20- item scale consists of statements of ruminative behaviours such as ‘I can’t stop thinking about some things’. Respondents rated the items in terms of the statements’ self- descriptiveness on a 7-point scale ranging from 1 (not at all descriptive of me) to 7 (describes me very well). The RTSQ has shown good convergent validity with a global rumination measure (McIntosh et al., 1995) and the Response Style Questionnaire, adequate test-retest reliability, and high internal consistency (Brinker & Dozois, 2009; Tanner, Voon, Hasking, & Martin, 2013).

Rumination as a response to depression. The 22-item Ruminative Response Scale

(RRS) (Nolen-Hoeksema, 1991) was used to assess rumination in response to depression levels. Respondents indicated what they generally think or do in relation to items such as ‘Think “What am I doing to deserve this?”’ and ‘Go someplace alone to think about your feelings’, using a four-point Likert scale ranging from ‘almost never’ (1) to ‘almost always’ (4). The score for each item was summed to obtain a total score ranging from 22 to 88. Higher scores indicate a higher level of ruminative response. Items reflect three sub-types of responses: depressive, brooding, and reflective rumination. The scale shows excellent internal consistency as well as adequate convergent and predictive validity (Nolen-Hoeksema et al., 1993, 1994).

Mood

Depression. The presence and severity of depression over the preceding fortnight were assessed using 8 items from the Patient Health Questionnaire 9 (PHQ-9) (Kroenke & Spitzer, 2002). A score of 0 (not at all) to 3 (nearly every day) is assigned for each item giving a total of between 0 and 24. A score of 5 represents the lower cut-off point for mild depression, 10 for moderate depression, 15 for moderately severe depression, and 20 for severe depression. The suicidal ideation item, removed for ethical concerns, did not affect the interpretation of final scores (Kroenke & Spitzer, 2002). A score of ≥ 10 has a specificity and sensitivity of 88% for major depression disorder (MDD) (Kroenke & Spitzer, 2002). The screen has been validated for people living with cognitive impairment and is widely used in United Kingdom primary care psychological therapy services (Bell et al., 2022; Wong et al., 2022).

Anxiety. The presence and severity of anxiety over the preceding fortnight were assessed using the 7-item Generalized Anxiety Disorder Scale (GAD-7) (Spitzer et al., 2006). A score of 0 (not at all) to 3 (nearly every day) is assigned for each item giving a total of between 0 and 21. A score of 5 represents the lower cut-off point for mild anxiety, 10 for moderate anxiety, and 15 for severe anxiety. A score of ≥ 10 is suggestive of GAD and other anxiety disorders. It has high internal consistency ($\alpha = 0.89$), has been standardised with a community sample of 5030 participants aged 14 to ≥75 years (Löwe et al., 2008), validated for people living with cognitive impairment, and is widely used in United Kingdom primary care psychological therapy services (Bell et al., 2022; Wild et al., 2014).

Eye tracking

Positioning. Participants positioned themselves directly in front of their webcam and used their video feed (presented in the top left corner of their screen) to align themselves such that (1) their faces appeared in the middle of a black box outline overlaid in the center of the feed, and (2) the green face-mesh within the feed which detects users' faces, matched their features. Participants were told the box outline must turn green, and face-meshing must occur to enable a start button (see Greenaway et al., (2021) for a detailed face-meshing description).

Calibration and validation. Participants were instructed to remain still, blink as little as possible, and only move their eyes (rather than their head or body) to look at a 50 × 50- pixel red dot which appeared consecutively in each of 9 fixed locations (a 3 × 3 grid spanning the screen's height and width) in a random order (see Greenaway et al., (2021); Semmelmann & Weigelt, (2018) for detailed descriptions). The participants were told to look at the dot as quickly as possible and fixate on it until it disappeared. The calibration and validation phases were identical, except that the validation phase displayed a green dot (instead of a red one).

Attentional bias measure

The AB measure involved a modified dot-probe task (MacLeod et al., 2002). The dot-probe was used as a foil task in the current study and the critical display was the facial stimuli slide that precedes dot-probe. Each trial began with a blank screen for 500 ms. A fixation cross then appeared in the center of the screen for 500 ms. Two faces from the same actor were then presented in sad-neutral, angry-neutral, happy-neutral, sad-happy, angry-happy, and sad-angry expression pairings for 2000 ms. The faces were selected from the FACES database (Ebner et al., 2010). When the faces had disappeared, a black dot was displayed in the center of one of the face's previous locations for 1000 ms. Participants were instructed to look at the cross and the dot as quickly as possible and fixate on them until they disappeared, and to view the facial stimuli naturally when they appeared. Trials (N = 96) were shown randomly, with each facial emotion type being presented 48 times by 24 actors. Each actor was displayed four times. Actor gender and the side of the screen the facial emotion type and dot appeared on were counter-balanced across the trials.

The left and right facial stimuli dimensions were set as 5-45% and 55-95% of the screen width, respectively, and 10-90% of the screen height to aid viewing. The dot was presented at the centre of these facial stimuli areas.

Data quality

Participants who wanted assistance (n = 7) from a representative to navigate the questionnaire stated that they were able to disclose their thoughts and feelings to their representatives. All participants were (1) informed that providing open and honest responses would help to improve data quality (Lu et al., 2022), (2) advised to start the survey when they were most alert and (at least) the suggested completion time could be accommodated, and (3) asked to take a break when required. All items in the survey were set to ‘required’ (see Appendix C [pg. 284 to 285] for detailed data quality improvement information).

Data analysis

Data quality

Straightlining (SL) (i.e., responses with little variation within a set of items), an indicator of low attentiveness (Buchanan & Scofield, 2018; Silber et al., 2019), was examined in T1 surveys via graphs (Buchanan & Scofield, 2018). Each participant’s relative frequency of SL across the rumination measures was computed (i.e., the number of measures with SL divided by the number of measures [three]) generating a score between 0 and 1 (Gummer et al., 2021). The percentage of participants scoring ≥0.33 was calculated and reported, and the T1 and T2 responses of these participants were then compared, where possible, as a consistency check.

Rumination

The median rumination score was computed to distinguish low (< median score) and high ruminators (> median score) (Watkins & Mason, 2002).

Attentional biases

A total dwell-time was computed for each emotional face and its corresponding neutral face in emotional-neutral pairings by summing the dwell-time in ms across each trial and converting the resulting total to seconds (s). Total dwell-time was selected rather than fixational metrics due to the limitations of the eye-tracking method (i.e., a low sampling rate). As several (total dwell-time) metrics can be used to indicate AB, biases have been reported as total dwell-time, and as a commonly used bias score computed by subtracting the neutral total dwell-time from the corresponding emotional total dwell- time. A bias score computed as the proportion of the total dwell-time on emotional face relative to the total dwell-time on both the emotional face plus its corresponding neutral face was also used for exploratory purposes (i.e., for angry-face biases). Scores above zero were interpreted as a bias towards the emotional face, and scores below zero as a bias away from the emotional face (Duque & Vázquez, 2015). Emotional-emotional pairings data will continue to be collected and analysed at a later date as the magnitude of AB in these pairings are reduced (Blanco et al., 2019). As such, it is unclear whether the eye-tracking method is sensitive enough to detect small AB differences at present.

Statistical analysis

Statistical analyses were performed with SPSS version 27 (IBM Corp, 2017). Non-parametric methods were mainly used to analyse the rumination questionnaires and mood data and a two-tailed critical alpha level of $p < .05$ was used for all significance tests. Mann-Whitney U (U) and t-tests (t) were used to compare the PwD and HC group in terms of age, cognitive ability (TICS), depression (PHQ-9), and anxiety (GAD-7) scores where appropriate. These tests were conducted using the full T1 dataset as this was the larger of the two ($N_{T1} = 139$ versus $N_{T2} = 117$). Wilcoxon signed-ranks tests (T), paired-sample t-test, and Spearman rho bivariate correlations (r_s) were used to assess the test-retest reliability of T1 versus T2 rumination measure (CERQ, RTSQ and RRS combined-types [combined depressive, brooding, and reflection subscale scores], brooding and reflection subscales) responses of the first 50 PwD participants who completed the questionnaires at both timepoints. Adequate Cronbach’s alphas and correlation strengths in line with those previously reported for these questionnaires (.60 to .80) were considered acceptable and permitted further data collection and analyses (Brinker & Dozois, 2009; Garnefski & Kraaij, 2007; McLaughlin & Nolen-Hoeksema, 2011). Cronbach’s alpha calculations, rumination level comparisons (CERQ, RTSQ, RRS scales), and the following bivariate zero-order and partial correlation analyses were conducted using the full T1 dataset.

Zero-order r_s assessed the relationship between cognitive, rumination, and mood scores. Rank analysis of covariance (Quade, 1967) was used to investigate rumination levels (dependent variables) while controlling for depression using the following method:

(1) The dependent variables and covariates were ranked.
(2) A linear regression of the ranks of dependent variables on the ranks of the covariates was performed and the residuals (raw or unstandardized) were saved.
(3) Using the saved residuals as the dependent variable, a one-way analysis of variance (ANOVA) with group as the factor was conducted.

Ranked partial correlation coefficients (Conover, 1999) were performed to assess the strength of the relationship between rumination and one mood type while controlling for the other. Effect size (ES) (r) was calculated for significant U and T differences using the formula as seen in (1) (z = z-value; N = observation number).

$$r = \frac{z}{\sqrt{N}} \tag{1}$$

ES (r^2) were calculated for significant bivariate correlations by squaring the correlation coefficient.

Results

Data quality

Survey response rates

A high survey response (139/143 = 97% of surveys were started; study drop-outs: PwD = 3, HC = 1) and completion (139/139 = 100%) rate was achieved for T1 surveys. T2 survey responses were not required from 11 PwD participants as they attempted or completed AB measures. Of the remaining T1 PwD participants (n = 53), a high survey response (50/53 = 98% of surveys were started; study drop-outs = 3) and completion (50/50 = 100%) rate was achieved.

Participants with dementia's data quality

No data were removed due to data quality concerns due to the consistency shown between T1 and T2 (see Appendix C [pgs. 284 to 285] for further details). While there was some evidence of SL in PwD T1 surveys (9/63 = 14%), the T1 versus T2 Cronbach alpha and/or correlations coefficients, as discussed later, are in line with the test-retest reliabilities of responses obtained via postal response (Garnefski & Kraaij, 2007), in the presence of a researcher and via telephone (Brinker & Dozois, 2009), and face-to-face interview (McLaughlin & Nolen-Hoeksema, 2011) with cognitively healthy adults.

There was a higher occurrence of SL in HC T1 surveys (21/75 = 28%). As an inattentiveness level of 25% may impact data quality (Silber et al., 2019), analyses were also conducted on the HC dataset after removing the SL participants (non-SL dataset, $n = 54$) as a matter of precaution (see Appendix C [pg. 286] for descriptive, reliability, and zero-order correlation data). Higher SL in the full HC dataset was not associated with reduced data quality, and in general, demonstrated slightly higher reliability than the non-SL dataset.

Participant characteristics

There was no significant difference between the PwD and HC groups in terms of age, $U(N_{\text{PwD}} = 64, N_{\text{HC}} = 75) = 2{,}170.00$, $z = -.97$, $p = .33$) (see Table 1. for descriptive, mood, and rumination measures analyses). The PwD group had significantly higher levels of cognitive impairment, $U(N_{\text{PwD}} = 64, N_{\text{HC}} = 75) = 4{,}190.00$, $z = 7.59$, $p < .001$ (ES, $r = .64$), depression, $U(N_{\text{PwD}} = 64, N_{\text{HC}} = 75) = 1{,}731.00$, $z = -2.86$, $p = .004$ (ES, $r = -.24$), and anxiety, $U(N_{\text{PwD}} = 64, N_{\text{HC}} = 75) = 1{,}627.50$, $z = -3.37$, $p < .001$ (ES, $r = -.29$), then the HC group (see Table 2. for symptom status information).

The PwD group used RUM-EMO-REG style to the same extent as the HC group, $U(N_{\text{PwD}} = 64, N_{\text{HC}} = 75) = 2{,}256.50$, $z = -.61$, $p = .54$, but used a ruminative RUM-THINK style significantly more than the HC group, $U(N_{\text{PwD}} = 64, N_{\text{HC}} = 75) = 1{,}908.50$, $z = -2.08$, $p = .04$ (ES, $r = -.18$) (see Table 1. for descriptive analysis). In terms of ruminative responses to depression, the PwD group used combined-types, $U(N_{\text{PwD}} = 64, N_{\text{HC}} = 75) = 1{,}632.00$, $z = -3.25$, $p = .001$ (ES, $r = -.28$), and brooding, $U(N_{\text{PwD}} = 64, N_{\text{HC}} = 75) = 1{,}830.50$, $z = -2.44$, $p = .02$ (ES, $r = -.21$), significantly more than the HC group, but used reflection, $U(N_{\text{PwD}} = 64, N_{\text{HC}} = 75) = 2238.50$, $z = -.71$, $p = .48$), to the same extent as the HC group.

Table 1. Descriptive statistics and Cronbach's alpha for group demographic, cognitive ability, rumination, and mood measure scores.

	PwD (n = 64)				**HC** (n = 75)			
Measures	Median (mean)	*IQR* (*SD*)	Mean rank	α	Median (mean)	*IQR* (*SD*)	Mean rank	α
Age	73	9	74	N/A	71	9	67	N/A
TICS**	28	10	42	.72	35	4	94	.22
Rumination								
Emotion regulation style **(**CERQ)	7	4	72	.87	7	4	68	.73
Thinking style (RTSQ)*	(65)	(25)	78	.94	55	29	63	.93
Response to depression (RRS)								
*Combined-type***	35	13	82	.92	29	10	60	.89
*Brooding**	8	4	79	.72	7	3	62	.77
Reflection	6	3	73	.82	6	3	68	.59
Mood								
Depression (PHQ-9)**	3	7	80	.88	2	3	61	.78
Anxiety (GAD-7)**	2	5	82	.93	0	3	60	.89

Notes. PwD = people living with dementia; HC = healthy controls; α = Cronbach's alpha; TICS = Telephone interview for cognitive status; CERQ = Cognitive Emotion Regulation Questionnaire; RTSQ = Ruminative Thought Style Questionnaire; RRS = Ruminative Response Scale; PHQ-9 = Patient Health Questionnaire 9; GAD-7 = Generalized Anxiety Disorder scale.
RRS combined-type = combined depressive, brooding and reflection subscale scores.
* significant difference at the .05 level (2-tailed).
** significant difference at the .01 level (2-tailed).

Table 2. Group depression and anxiety symptom status

	n	
Symptom status (scale points)	PwD	HC
Comorbid depression and anxiety (PHQ-9 ≥5 and GAD-7 ≥5)	15	7
Depression with no anxiety (PHQ-9 ≥5 and GAD-7 <5)	11	5
Anxiety with no depression (GAD-7 ≥5 and PHQ-9 <5)	3	2
Non-depressed/non-anxious (PHQ-9 <5 and GAD-7 <5)	34	59

Notes. PwD = people living with dementia; HC = healthy controls; PHQ-9 = Patient Health Questionnaire 9; GAD-7 = Generalized Anxiety Disorder scale.

Rumination measure reliability for participants living with dementia

Test-retest reliability

Significance tests were conducted for each rumination measure for the first 50 participants to have completed both T1 and T2 surveys (see Table 3. for descriptive analysis). No significant differences were found between T1 and T2 rumination scores (RUM-EMO-REG, T = 275.50, z = -1.39, p = .16, RUM-THINK, t(49) = 1.42, p = .16, RUM-RESP-DEP combined-types, T = 378.50, z = -1.77, p = .08; brooding, T = 205.00, z = -1.82, p = .07, and reflection, T = 130.00, z = -1.68, p = .09).

Bivariate correlations between T1 and T2 scores were moderate to strong (see Table 3.).

Table 3. Timepoint 1 (T1) and Timepoint 2 (T2) descriptive and correlational comparison data for 50 PwD's rumination measure scores.

	T1			**T2**			**T1 vs T2**	**95% CI**
Rumination measures	Median (mean)	*IQR* (*SD)*	**α**	Median (mean)	*IQR* (*SD)*	**α**	r_s (r)	Lower, upper (limit)
Emotion regulation style (CERQ)	8	4	.84	6	3	.82	.69**	.49, .83
Thinking style (RTSQ)	(64)	(24)	.94	(60)	(26)	.96	(.68**)	.49, .80
Response to depression (RRS)								
Combined-type	35	12	.92	33	11	.92	.77**	.60, .87
Brooding	8	4	.73	8	3	.79	.67**	.45, .81
Reflection	6	4	.83	6	3	.70	.71**	.52, .84

Notes. PwD = people living with dementia, CI = confidence interval; **α** = Cronbach's alpha; CERQ = Cognitive Emotion Regulation Questionnaire; RTSQ = Ruminative Thought Style Questionnaire; RRS = Ruminative Response Scale. RRS combined-type = combined depressive, brooding and reflection subscale scores. ** significant at the .01 level (2-tailed).

Cronbach's alpha

The internal consistency of the PwD group's T1 and T2 rumination measures was acceptable to high (Greco et al., 2018) (see Table 1. and Table 3.).

Relationship between rumination, age, cognitive ability, depression, and anxiety

Age versus cognitive ability, rumination, and mood

Being older was associated with less use of RUM-EMO-REG (r_s = -.29, p = .02, 95% CI [-.51, -.05]), RUM-RESP-DEP reflection (r_s = -.26, p = .04, 95% CI [-.48, -.01]), and lower levels of anxiety (r_s = -.28, p = .03, 95% CI [-.50, -.03]) with small effects (ES, r^2 = .07 to .08) for the PwD group (see Appendix C [pg. 286] for individual ES). Partial correlation analyses showed that these relationships were not independent of cognitive ability and/or mood (see Appendix C [pgs. 287-288] for partial correlational data).

Being older was associated with higher levels of cognitive impairment (r_s = -.24, p = .04, 95% CI [-.44, -.01]), less use of RUM-EMO-REG (r_s = -.31, p = .01, 95% CI [-.51, -.09]), and lower levels of depression (r_s = -.27, p = .02, 95% CI [-.47, -.04]) with small effects (ES, r^2 = .06 to.10) for the HC group (see Appendix C [pg.

286] for individual ES). Partial correlation analyses showed that the relationship between age and (1) cognitive ability was independent of mood, (2) RUM-EMO-REG was independent of cognitive ability and mood, and (3) depression was not independent of anxiety (see Appendix C [pgs. 289-290] for partial correlational data).

Cognitive ability versus rumination and mood

Having less cognitive impairment (higher TICS scores) was associated with greater use of RUM-EMO-REG (95% CI [.08, .53]), RUM-THINK (95% CI [.02, .49]), RUM-RESP-DEP reflection (95% CI [.08, .54]), and higher levels of anxiety (95% CI [.04, .50]), with small effects (ES, r^2 = .07 to .10) for the PwD group (see Table 4. and Appendix C [pg. 286] for individual ES). Partial correlation analyses showed that these relationships were not independent of age and/or mood (see Table 4.). No significant correlations were found between cognitive ability and any type of rumination, nor mood for the HC group.

Table 4. Spearman rho zero-order and partial correlations between cognitive ability, rumination, and mood measure scores.

	TICS							
	PwD (n = 64)				**HC** (n = 75)			
Measures	ZO	AgC	DC	AC	ZO	AgC	DC	AC
Rumination								
Emotion regulation style (CERQ)	.32**	.28*	.23	.19	.14	.07	.13	.18
Thinking style (RTSQ)	.27*	.24	.19	.08	.08	.05	.07	.18
Response to depression (RRS)								
Combined-type	.12	.09	-.01	-.08	.05	-.002	.02	.19
Brooding	.02	-.003	-.10	-.17	-.03	-.05	-.06	.06
Reflection	.33**	.29*	.26*	.22	.12	.08	.11	.18
Mood								
Depression (PHQ-9)	.24	.21	-	.09	.05	-.01	-	.16
Anxiety (GAD-7)	.28*	.24	.18	-	-.11	-.17	-.20	-

Notes. TICS = Telephone interview for cognitive status; PwD = people living with dementia; HC = healthy controls; ZO = zero-order correlation; AgC = age as a covariate (partial-correlation); DC = depression as a covariate (partial-correlation); AC = anxiety as a covariate (partial-correlation); CERQ = Cognitive Emotion Regulation Questionnaire; RTSQ = Ruminative Thought Style Questionnaire; RRS = Ruminative Response Scale; PHQ-9 = Patient Health Questionnaire 9; GAD-7 = Generalized Anxiety Disorder scale. RRS combined-type = combined depressive, brooding and reflection subscale scores.
*significant at the .05 level (2-tailed).
** significant at the .01 level (2-tailed).

Rumination and depression

Increased use of each type of rumination was associated with increased levels of depression with small to moderate effects for both the PwD (95% CI range = .18 to .71, ES, r^2 = .18 to .31) and HC group (95% CI range = .10 to .80, ES, r^2 = .11; to

.48) (see Table 5. and Appendix C [pgs. 287 and 291] for individual CIs and ES). Partial correlation analyses showed that the relationship between depression and (1) RUM-THINK and, (2) RUM-RESP-DEP brooding and reflection were not independent of anxiety, but RUM-EMO-REG and RUM-RESP-DEP combined-types independently explained some of the variance in depression with small effects (RUM-EMO-REG style, r^2 = .08; combined-types, r^2 = .07) for the PwD group. For the HC group, the relationship between depression and (1) RUM-EMO-REG, and (2) RUM-RESP-DEP brooding were not independent of anxiety, but RUM-THINK, and RUM-RESP-DEP combined-types and reflection independently explained some of the variance in depression with small effects (RUM-THINK, r^2 = .06; combined-types, r^2 = .14; reflection, r^2 = .07).

Table 5. Spearman rho zero-order and partial correlations between rumination and depression scores.

	Depression (PHQ-9)							
	PwD (*n* = 64)				**HC** (*n* = 75)			
Measures	ZO	CAC	AgC	AC	ZO	CAC	AgC	AC
Rumination								
Emotion regulation style (CERQ)	.56**	.52**	.53**	.29*	.33**	.32**	.27*	.18
Thinking style (RTSQ)	.46**	.42**	.43**	-.02	.48**	.48**	.46**	.24*
Response to depression (RRS)								
Combined-types	.55**	.54**	.53**	.27*	.69**	.69**	.66**	.38**
Brooding	.42**	.43**	.41**	.14	.45**	.45**	.44**	.16
Reflection	.45**	.40**	.42**	.20	.51**	.51**	.49**	.27*
Mood								
Anxiety (GAD-7)	.59**	.56**	.57**	-	.70**	.70**	.67**	-

Notes. PHQ-9 = Patient Health Questionnaire 9; PwD = people living with dementia; HC = healthy controls; ZO = zero-order correlation; CAC = cognitive ability as a covariate (partial-correlation); AgC = age as a covariate (partial-correlation); AC = anxiety as a covariate (partial-correlation); DC = depression as a covariate (partial-correlation); CERQ = Cognitive Emotion Regulation Questionnaire; RTSQ = Ruminative Thought Style Questionnaire; RRS = Ruminative Response Scale; GAD-7 = Generalized Anxiety Disorder scale.
RRS combined-types = combined depressive, brooding and reflection subscale scores.
* significant at the .05 level (2-tailed).
** significant at the .01 level (2-tailed).

Rumination and anxiety

Increased use of each type of rumination was associated with increased levels of anxiety with small to moderate effects for both the PwD (95% CI range = .30 to .88, ES, r^2 = .27 to .62) and HC group (95% CI range = .07 to .82, ES, r^2 = .08 to .53) (see Table 6. and Appendix C [pgs. 287 and 291] for individual CIs and ES). Partial correlation analyses showed that each type of rumination independently explained some of the variance in anxiety with small and moderate effects (RUM-EMO-REG style, r^2 = .21; RUM- THINK, r^2 = .52; RUM-RESP-DEP combined-types, r^2 = .22, brooding, r^2 = .17, and reflection, r^2 = .13) for the PwD group. For the HC group, the relationship between anxiety and (1) RUM-EMO-REG style, and (2) RUM-THINK were not independent of depression, but all of the types of RUM-RESP-DEP independently explained some of the variance in anxiety with small effects (combined-types, r^2 = .23, brooding, r^2 = .09, and reflection, r^2 = .06).

Table 6. Spearman rho zero-order and partial correlations between rumination and anxiety scores.

	Anxiety (GAD-7)							
	PwD (*n* = 64)				**HC** (*n* = 75)			
Measures	ZO	CAC	AgC	DC	ZO	CAC	AgC	DC
Rumination								
Emotion regulation style (CERQ)	.64**	.60**	.60**	.46**	.29*	.32**	.25*	.10
Thinking style (RTSQ)	.79**	.77**	.77**	.72**	.47**	.48**	.45**	.21
Response to depression (RRS)								
Combined-types	.64**	.63**	.62**	.47**	.73**	.74**	.72**	.48**
Brooding	.55**	.57**	.55**	.41**	.50**	.50**	.48**	.30*
Reflection	.52**	.47**	.49**	.36**	.50**	.52**	.48**	.24*
Mood								
Depression (PHQ-9)	.59**	.56**	.57**	-	.70**	.70**	.67**	-

Notes. GAD-7 = Generalized Anxiety Disorder scale; PwD = people living with dementia; HC = healthy controls; ZO = zero-order correlation; CAC = cognitive ability as a covariate (partial-correlation); AgC = age as a covariate (partial-correlation); AC = anxiety as a covariate (partial-correlation); DC = depression as a covariate (partial-correlation); CERQ = Cognitive Emotion Regulation Questionnaire; RTSQ = Ruminative Thought Style Questionnaire; RRS = Ruminative Response Scale; PHQ-9 = Patient Health Questionnaire 9.
RRS combined-types = combined depressive, brooding and reflection subscale scores.
* significant at the .05 level (2-tailed).
** significant at the .01 level (2- tailed).

Relationship between rumination and attentional biases

Full eye-tracking datasets were obtained from nine of the 11 participants within the AB subgroup. Exploratory analyses were conducted to provide estimate data for future larger-scale studies (see Table 7.). Bivariate correlation analyses only yielded one significant correlation between RUM-THINK scores and angry-face dwell-times (r_s = -.80, p = 0.01, 95% CI [-.97, -.17], power = .64) with a moderate effect (r^2 = .64) (see Figure 2.). Higher use of a ruminative thinking style was associated with less dwelling on angry faces. As we could have missed other relationships by not examining a relative bias metric, relative bias scores were then computed and explored. The only significant correlation yielded was between ruminative RUM-THINK and angry-face bias scores (r_s = -.79, p = 0.01, 95% CI [-.96, -.15], power = .62) with a moderate effect (r^2 = .62). Higher use of a ruminative thinking style (high ruminators) was associated with a bias away from angry faces, and lower use (low ruminators) with a bias towards angry faces (see Figure 3.).

Table 7. Descriptive analyses of the attentional bias sub-group's age, cognitive ability, rumination, mood, dwell-time, and attentional bias scores.

	N = 9	
Measures	Mean	*SD*
Age	67	5
Cognitive status (TICS)	32	5
Rumination		
Emotional regulation style (CERQ)	11	5
Thinking style (RTSQ)	87	22
Response to depression (RRS)		
Combined-type	45	11
Brooding	11	3
Reflection	6	2
Mood		
Depression (PHQ-9)	10	8
Anxiety (GAD-7)	9	6
Total dwell-time (s)		
Sad face	15	2
Neutral (versus sad faces)	16	2
Angry face	16	2
Neutral (versus angry faces)	15	2
Happy face	16	2
Neutral (versus happy faces)	15	2
Bias score (s)		
Sad face	-2	3
Angry face	1	3
Happy face	1	4

Notes. TICS = Telephone interview for cognitive status; CERQ = Cognitive Emotion Regulation Questionnaire; RTSQ = Ruminative Thought Style Questionnaire; RRS = Ruminative Response Scale; PHQ-9 = Patient Health Questionnaire 9; GAD-7 = Generalized Anxiety Disorder scale.

RRS combined-type = combined depressive, brooding and reflection subscale scores.

Bias scores (the total dwell–time on the emotional face minus the total dwell–time on its corresponding neutral face [figures rounded to the nearest whole number]). Scores of >0 indicate longer dwelling on the emotional face, and <0 indicate less dwelling on the emotional face.

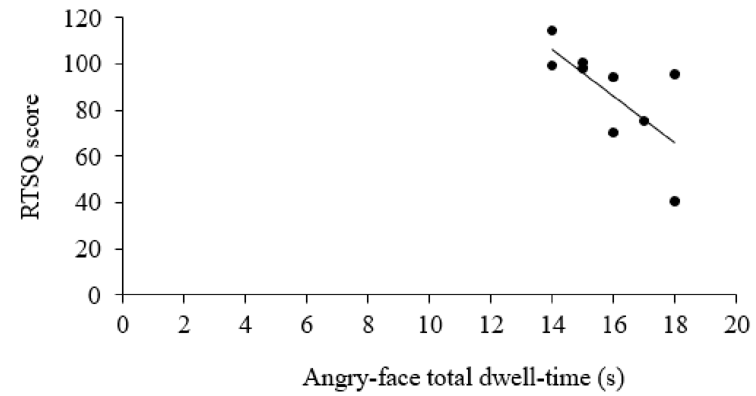

Figure 2. Participants' (N = 9) RTSQ (Ruminative thought style questionnaire) scores against their angry-face dwell-time. R^2 = effect size.

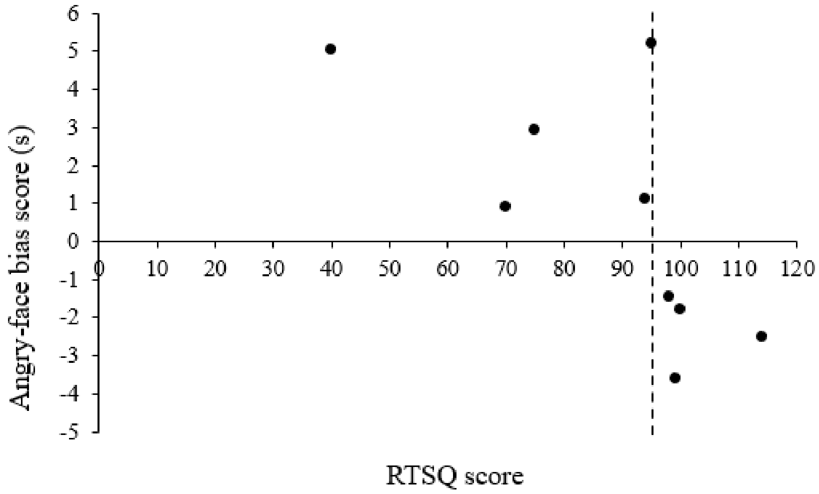

Figure 3. Participants' (N = 9) angry-face bias scores (proportion of the total dwell-time on the angry face relative to the total dwell-time on both the angry face plus its corresponding neutral face) against their RTSQ (Ruminative thought style questionnaire) scores. Bias scores of >0 indicate longer dwelling on angry faces, <0 indicate less dwelling on angry faces, and 0 indicates no bias. The dashed vertical line represents the median RTSQ score of 95. Scores below and above the median indicate low and high ruminators, respectively.

Discussion

This study investigated the reliability of the Cognitive Emotion Regulation Questionnaire (CERQ), Ruminative Thought Style Questionnaire (RTSQ), and the Ruminative Response Scale (RRS) as rumination measures for people living with dementia (PwD), the level of rumination observed in people living with and without dementia, and the relationships between rumination, age, cognitive ability, mood, and attentional biases (AB) in these populations. Our findings contribute to the sparse literature that focusses on old to very-old older adults (below and above 80 years old respectively) (Kunzmann et al., 2023), and to our knowledge, this is the first study to present a cross-sectional picture of these types of ruminative processing in dementia. Our findings suggest that rumination as an emotion-regulation style (RUM-EMO-REG), thinking style (RUM-THINK), and response to depression (RUM-RESP-DEP) can be reliably assessed in dementia using the CERQ, RTSQ, and RRS respectively, and that PwD ruminate in these ways. The question of whether the inhibitory control deficits associated with AD would correspond with higher or lower levels of rumination had been posed (Nash et al., 2007). While the PwD in the current study reported significantly higher levels of RUM-THINK and RUM-RESP-DEP (combined-type and brooding) than did healthy controls (HC) participants, this would be expected (based on cognitively healthy population literature) as they reported significantly higher levels of depression and anxiety. However, future studies should specifically investigate participants with AD, assess AD severity, include individuals with AD ranging from mild to severe, and assess cognitive inhibition and rumination levels concurrently to directly address this question.

In line with findings relating to participants living without dementia (Demnitz- King et al., 2021), we found that higher levels of reflective rumination were associated with better cognition after controlling for depression for the PwD group. However, this relationship diminished after controlling for anxiety. Based on previous findings (Marchant et al., 2017, 2020) of increased repetitive negative thinking (RNT) being independently associated with greater declines in memory, we could have expected the relationship between cognitive ability and rumination for the PwD group within the current study to be evident after controlling for anxiety (or depression) symptoms.

However, our studies differ in terms of (1) study cohorts (e.g., PwD versus people living without dementia and sample sizes), (2) cognitive focus (memory versus a multi-domain score), and (3) the type/valence of repetitive thinking being assessed (CERQ, RTSQ, and RRS versus the Perseverative Thinking Questionnaire (Ehring et al., 2011)). The Perseverative Thinking Questionnaire was specifically designed to assess content-independent dysfunctional repetitive thinking and is more associated with the negative aspects of repetitive thinking. The RTSQ and RRS used in the current study contain neutral (i.e., RTSQ) and (relatively more) positive aspects of repetitive thinking which are considered (relatively) less dysfunctional (e.g., RRS reflective rumination). And while RRS brooding rumination is considered dysfunctional RNT, it is content specific (i.e., RNT focussed on depression). It may therefore be possible that different types of repetitive thinking may be associated with dementia (or cognitive ability) to differing degrees, with different consequences, at different stages of life (e.g., a protective factor in mid-life (Ravona-Springer et al., 2009) or associated with AD risk factors in later life (Marchant et al., 2020)).

Our finding that increased rumination is associated with increased levels of depression and anxiety for the PwD group corresponds with the literature involving older adults living without dementia (Chen et al., 2020; McLaughlin & Nolen-Hoeksema, 2011; Nolen-Hoeksema & Aldao, 2011; Opdebeeck et al., 2015; Philippot & Agrigoroaei, 2017; Ramirez-Ruiz et al., 2019; Ricarte et al., 2016; Romero-Moreno et al., 2016; Von Hippel et al., 2008), with the strongest relationship being seen between RUM-THINK and anxiety for the PwD group, and RUM-RESP-DEP and anxiety for the HC group. The RRS, used to measure RUM-RESP-DEP, is typically used in rumination studies involving both depression and anxiety (Chen et al., 2020; Olatunji et al., 2013; Opdebeeck et al., 2015). Our findings suggest that the use of the RRS may be appropriate in mood studies involving cognitively healthy older adults given the higher amount of the variance accounted for by RUM-RESP-DEP in both depression and anxiety, compared to RUM-EMO-REG or RUM-THINK in this group. RUM-EMO- REG and RUM-RESP-DEP accounted for virtually the same amount of the variance in depression and anxiety as measured by the CERQ and RRS, respectively, for the PwD group. The CERQ contains 4 items and the RRS contains 22 items. If future studies have a large number of scales to administer, they may wish to consider using the CERQ as participant burden may be lessened, unless they were specifically interested in examining the types of rumination assessed within the RRS. Still, as RUM-THINK accounted for a higher amount of the variance in anxiety than any other type of rumination for PwD group, future anxiety studies involving PwD should consider including the RTSQ measure of rumination.

To the best of our knowledge, this is the first study to explore the relationship between rumination, depression, anxiety, and AB in a cohort that includes PwD. Although we found that a negative relationship between RTSQ scores and (1) angry- face dwell-time, and (2) angry-face bias scores (i.e., high ruminators dwelled less on angry faces/displayed an AB away from angry faces whereas low ruminators dwelled on angry faces more/displayed an AB towards angry faces), we acknowledge the preliminary nature of these findings, and that they should be interpreted with caution. While a negative relationship contrasts with theoretical accounts of rumination and findings showing a positive relationship between AB and rumination for participants with major depression or experiencing state anxiety (De Raedt & Koster, 2010; Donaldson et al., 2007; Vălenaş et al., 2017), these relationships need to be robustly explored in older adults living with and without cognitive impairment to examine whether existing theoretical accounts hold within these populations. Additionally, given the number of tests conducted in the analyses of the participant survey responses, there is the possibility of type one errors, so further investigation is warranted.

Clinical/research relevance

Our findings show that it is prudent to use multiple rumination measures when examining the relationship between rumination and neuropsychiatric symptoms in populations where these relationships have not been previously examined. As we have established that there are moderate to strong relationships between rumination, depression, and anxiety for PwD, developing, or adapting interventions that target rumination for this population could potentially increase treatment options, particularly for anxiety. In general, rumination-based interventions should be further explored within older-adult populations (Tang et al., 2022). Moreover, measuring AB within these intervention studies could evaluate the theoretical relationship between rumination, mood, and AB in older adults.

Study limitations

One limitation is that our cross-sectional and correlational study design is insufficient to establish causality. Other limitations include our sample size, use of self-/representative-reported diagnoses, and the fact that a dementia severity assessment was not conducted. Our sample size did not allow for sub-group analysis (dementia type, or symptom status). While 66% of our PwD group had a diagnosis of AD, it is possible our results were influenced by the combination of different types of dementia in this group (i.e., the varying types of cognitive impairment associated with each dementia). Further, our analysis was conducted on groups comprising individuals with varying symptomology (i.e., with and without depression and/or anxiety, and within score ranges indicative of subclinical and clinical depression [MDD] and anxiety [GAD]), and possibly different symptom histories (e.g., never, or formally experienced depressed and/or anxious episodes). This is likely to have affected our findings as rumination levels have been shown to differ between groups with subclinical and clinical levels of depression or anxiety, and those with comorbid depression and anxiety (Aldao et al., 2010; McEvoy et al., 2013), and symptom history can affect findings (Whitmer & Gotlib, 2011). In terms of dementia diagnosis and severity, our study sample might have been better characterised if the dementia diagnosis and severity were confirmed within the current study. While our findings provide preliminary data for future studies, the reliability of the examined rumination measures for participants with more clearly defined characteristics is required.

Lastly, a potential limitation could stem from the rumination types/measures that were investigated in our study. We were very conscious of participant overload so limited the number of rumination types/measures to be investigated. It would be worth investigating other types of ruminative or repetitive thinking not studied here, and their corresponding measures, to compare their suitability for examining the relationship between depression and anxiety in dementia.

Future studies

Future studies are needed to replicate these findings, with larger samples to enable sub-group analysis (e.g., dementia type and severity, symptom status [subclinical, clinical, or comorbid], and symptom history [i.e., no previous episode versus repeated episodes]). Further research (e.g., symptom criteria, cut-off scores, and validation in different settings and populations) is needed regarding the assessment of depression and anxiety in older adults (Balsamo, Cataldi, Carlucci, & Fairfield, 2018; Balsamo, Cataldi, Carlucci, Padulo, et al., 2018; Gerolimatos et al., 2015; Goodarzi et al., 2019). Moreover, future studies could incorporate a variety of measures (e.g., proxy and clinical interview) to examine the relationships between rumination, depression, anxiety, and AB. As RNT, depression and anxiety have been linked to AD risk, and we have established a relationship between rumination, depression, and anxiety for PwD, longitudinal studies are necessary to better examine these relationships, and assess their cognitive and biological impact (i.e., rate of cognitive decline and plaque formation). AB and rumination have already become intervention targets for depression and anxiety in cognitively healthy individuals (Spinhoven, Klein, et al., 2018; Yang et al., 2015). Experimental studies ought to be conducted to investigate whether a reduction in negative AB and rumination in dementia affects depression and anxiety symptoms, and perhaps the rate of cognitive decline and disease progression.

Conclusion

The Cognitive Emotion Regulation Questionnaire, Ruminative Thought Style Questionnaire, and Ruminative Response Scale are reliable measures of rumination in dementia. Our findings suggest that these types of rumination may be an important factor in anxiety in this population. They also highlight the need for further investigation of how different types of repetitive or ruminative thinking may affect individuals, pre- and post-diagnosis. The findings from this study support the idea that rumination could be a promising target for interventions intended to reduce depression and anxiety in PwD.

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Data availability statement

The data that support the findings of this study are available from the corresponding author, AG, upon reasonable request.

Disclosure of interest

No reported conflict of interests.

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3.1 Thesis aims and key study findings

Thesis aims 1 (to identify a reliable rumination measurement tool for use with PwAD) and 2 (to determine the level of rumination in AD, and the relationship between rumination, depression, anxiety, and AB in AD) were explored within this chapter. Thesis aim 1 was achieved as all of the investigated rumination measures demonstrated adequate to excellent reliability, and convergent validity as demonstrated by the correlations in the table below.

Table showing zero-order bivariate correlation between rumination scale scores

Rumination type	Spearman's rho	Significance (2-tailed)	95% Confidence Intervals	
			Lower	Upper
CERQ - RTSQ	0.568	0.000	0.358	0.723
CERQ - RRS (combined-type)	0.654	0.000	0.466	0.785
CERQ - BROOD	0.584	0.000	0.377	0.735
CERQ - REFLECT	0.668	0.000	0.485	0.795
RTSQ - RRS (combined-type)	0.619	0.000	0.421	0.760
RTSQ - BROOD	0.549	0.000	0.334	0.709
RTSQ - REFLECT	0.522	0.000	0.302	0.690
BROOD - RRS (combined-type)	0.884	0.000	0.800	0.934
BROOD - REFLECT	0.571	0.000	0.362	0.726
REFLECT - RRS (combined-type)	0.747	0.000	0.593	0.848

However, as the different rumination types had different strengths of relationships with depression and anxiety, all of the measures were retained for the studies described in Chapters 4, and 5, allowing for comparison with the literature. Thesis aim 2 was achieved, and importantly, the targeting of rumination for PwD within the intervention study described in Chapter 4 (4.4) was justified given, for example, the moderate effect size that was found (r^2 = .62) between rumination as a thinking style and anxiety. Still, the relationships between AB, rumination, depression, and anxiety were only explored to a limited extent given the sample size.

Chapter 4

Technology use, and attentional bias measure and modification using webcam-based eye tracking: Usability, reliability, and feasibility

This chapter contains four manuscripts. The first manuscript examines the spontaneous use of technologies by older persons living with and without cognitive impairment. The second manuscript explores the usability of WBET by older persons living with and without cognitive impairment. The third manuscript explores the reliability of WBET measures of older persons' AB, and the fourth, the feasibility of multi-session ABM using WBET for persons living with and without cognitive impairment.

4.1 Technology use, ownership, and spontaneous use by people living with and without cognitive impairment

This section of the chapter will be submitted to XXX.

Greenaway, A.-M., Nasuto, S., Ho, A., & Hwang, F. (2024). Technology use, ownership, and spontaneous use by people living with and without cognitive impairment, *XXX* 1-24.

This section of the chapter reviewed literature related to the use of technologies for mental-health interventions for older persons. As a limited number of studies had investigated everyday technology use in older adults with cognitive impairment, particularly in the United Kingdom, this chapter provided much needed data surrounding spontaneous technologies use, and data from PwD in the United Kingdom.
The most frequently owned and used technologies by PwD compared to older persons without dementia, and most frequently conducted tasks on these technologies were identified. These findings provided a better understanding of study accessibility (i.e., webcam-ready device availability).

Abstract

Objectives

To identify the technologies owned by older adults with and without cognitive impairment, their frequency of use, and which tasks were carried out on these devices.

Methods

The telephone interview for cognitive status and a telephone-based technology survey were completed by 121 participants with and without cognitive impairment. Participants were asked if they owned specific devices (e.g., a smartphone). Device owners were asked whether they used their device “most days”, “some days”, “rarely”, or “never”, and carried out specific tasks (e.g., emailing) on those devices. Participants could report other items/tasks that they were not specifically asked about.

Results

Comparing smartphones, tablets, laptops, and desktop-PCs, tablets were the most owned device for participants with cognitive impairment, and smartphones for participants without cognitive impairment. Across all participants, smartphones were the most frequently used and tablets the least. Social media was accessed more than Skype, and more smart-TV owners with cognitive impairment used a Smart-TV app than participants without cognitive impairment.

Conclusion

Considering levels of ownership and usage, mental-healthcare delivery modes that include smartphones, seem appropriate for both populations. Smart-TV- and social media-based mental-healthcare delivery also have potential.

Keywords: mental health, e-Health, smart-TV, social media, gaming

4.1.1 Introduction

Depression and anxiety are risk factors of dementia and are associated with higher rates of progression from mild cognitive impairment (MCI) to Alzheimer's disease, an increased rate of cognitive decline and reduced quality of life (Breitve et al., 2016; Spalletta et al., 2012). Concerningly, a recent study (Gaber et al., 2020) found that out-of-home therapy was the most abandoned out-of-home activity by older adults with and without dementia. Although research regarding technology-based depression and anxiety interventions for older adults is limited (Riadi et al., 2022), there is preliminary evidence from systematic reviews and meta-analyses supporting the effectiveness of computer-based cognitive behavioural therapy and other approaches (e.g., positive psychology) in reducing depressive symptoms among older adults (Dworschak et al., 2022; Xiang et al., 2020). However, non-significant effects have been found for anxiety symptom severity (Dworschak et al., 2022), and inconsistent findings have been found regarding interventions for people with cognitive impairment. Positive effects on depressive symptoms seem more consistent for people with cognitive impairment than anxiety symptoms for informal caregivers (Dequanter et al., 2021; Nkodo et al., 2022; Zhu et al., 2021).

The factors affecting successful digital mental-health interventions for older adults include ease of use and adjusting the intervention to meet the needs of the participants (Riadi et al., 2022). However, technology-based interventions rarely consider older adults' previous experience with technology although this may affect the efficacy of an intervention (Chiu et al., 2016). For example, internet-based cognitive behavioural therapy interventions are delivered more often on a web browser (51%) than a mobile app (30%), or combined browser and app (14%) (McCall et al., 2021).

Still, some older adults use smartphones more than computers and tablets (Menéndez Álvarez-Dardet et al., 2020). Intervention delivery should be informed by older adults' 'technological dispositions' (Arthanat et al., 2019, p. 460), yet few studies have explored the every-day use of smartphones by people with dementia (PwD) though ownership of these devices has increased in this population (Klimova, 2017; Palmdorf et al., 2021; Wilson et al., 2022).

4.1.1.1 Potential mental-healthcare devices/applications

Smartphones, tablets, laptops, and desktop-PCs are currently-used devices (CUDs) for digitalised mental-healthcare and platforms such as Skype can be employed as therapeutic technology (Moyle, 2019). However, though 70–80% of PwD are community-dwelling (Livingston et al., 2014), less e-Health research has been devoted to community-dwelling PwD compared to PwD in residential care. Moreover, every-day, rather than dementia-specific, technologies are preferred by PwD (Evans et al., 2022). Therefore, limited research in relation to community-dwelling PwD may hamper the identification of potential e-Health solutions (Dequanter et al., 2021). Recent research involving community-dwelling older adults with cognitive impairment found that a television set (TV) was the most used device during COVID-19 lockdown for information, cognitive, and entertainment purposes (Dura-Perez et al., 2022). Unfortunately, it was undisclosed whether the TVs were smart devices or not. Older community-dwelling adults can prefer smart-TVs for serious gaming (interactive games with additional elements e.g., mental-health treatment [Fleming et al., 2017]) compared to CUDs – tablets being the least preferred CUDs (Costa et al., 2017). Although smart-TV-based healthcare research is increasing (Wong et al., 2022), increased collection and examination of spontaneous use and preferences data could facilitate, for example, the design of serious games on the devices that older adults with cognitive impairment prefer for gaming or smart-TV assessment/interventions.

Moreover, older adults' use of social media, particularly Facebook, has increased and can be used for finding support and self-help by people with depression and/or neurogenerative disease (Martínez-Pérez et al., 2015; Ofcom, 2019). Its spontaneous use can have positive effects on factors such as physical activity levels (Wang et al., 2022). Conversation analysis of social media posts demonstrates the potential of social media to provide an indicator of psychological well-being and support needs (Bachmann & Hruska, 2022; Lagervall et al., 2019).

As the use of technologies is not equally suitable for all older adults (Chen & Schulz, 2016), providing services on devices/applications that older adults with and without cognitive impairment already use may support e-Health adoption (De Veer et al., 2015), and could increase participant numbers within technology-based randomised controlled trials which are lacking in numbers and require larger sample sizes (Bateman et al., 2017; Moyle, 2019). Our study's aim was to examine the technologies owned by community-dwelling older adults with and without cognitive impairment and their usage, with a view to supporting inclusive service design and to inform the mode of digitalised mental-health intervention delivery.

4.1.2 Materials and methods

4.1.2.1 Participants

We recruited 121 participants (55 with cognitive impairment [CI], 66 without cognitive impairment [HC group]) via the Join Dementia Research platform (https://www.joindementiaresearch.nihr.ac.uk/) and community newsletter advertisements between November 2018 and November 2019. The inclusion criteria for people with cognitive impairment were: (1) aged ≥ 60 years, (2) a formal diagnosis of dementia (any type) or MCI, (3) have a nominated person who can provide confirmatory consent, (4) not diagnosed with another neurological disease or disorder (e.g., Parkinson disease or epilepsy). The CI group (AD = 49, MCI = 6; 23 females, 32 males) were aged between 61 and 85 years old (see Table 1). Over half of the participants in the CI group were classified as having no depression or anxiety (58%), 20% as having comorbid depression and anxiety, 20% as being depressed, and 2% as being anxious (see Table 2. for group symptom status).

Few participants (n = 5; 9%) were taking anti-depressant medication, and 75% were taking cognitive medication (Donepezil = 34; Rivastigmine = 3; Memantine = 3; Galantamine = 1). The inclusion criteria for the HC group were: (1) aged ≥ 60 years, (2) no diagnosis of dementia (any type) nor MCI, nor (3) another neurological disease or disorder (e.g., Parkinson disease or epilepsy). The HC group (39 females, 27 males) were aged between 60 and 88 years old. The majority the participants in the HC group were classified as having no depression or anxiety (83%), 8% as having comorbid depression and anxiety, 6% as being depressed, and 3% as being anxious. All participants had at least 12 years education/technical training. All participants provided written or verbal consent before the start of the study.

4.1.2.2 Procedure

Participants completed the Telephone Interview for Cognitive Status (TICS) (Brandt et al., 1988) and a technology survey during a phone call. Participants then received an email with a link to JISC Online surveys (https://www.onlinesurveys.ac.uk/) to complete a self-report questionnaire to screen for the presence of depression and anxiety. Participating took up to 1 hour in total. The study was reviewed in accordance with the procedures of the [blinded for review] Research Ethics Committee and received a favourable ethical opinion for conduct [blinded for review].

Table 1. Group descriptive analyses

	CI			HC		
n	55 (F = 23 , M = 32)			66 (F = 39, M = 27)		
Measures	Mean/ (Median)	*SD* (*IQR*)	Mean rank	Mean/ (Median)	*SD* (*IQR*)	Mean rank
Age	72.7	5.2	65.4	(71.0)	(8.8)	57.3
TICS	28.9	5.5	-	34.7	2.5	-
PHQ-9	(3.0)	(6.0)	69.5	(2.0)	(3.3)	53.9
GAD-7	(2.0)	(4.0)	70.7	(0.5)	(3.0)	52.9
Devices owned	(5.0)	(3.0)	51.6	(6.0)	(2.0)	68.9
By gender						
Age males	72.3	4.7	-	72.1	7	-
Age females	73.1	6	-	71.7	7	-
TICS males	(31.0)	(8.0)	29.7	34.3	1.9	29.3
TICS females	28.3	5.1	25.6	(35.0)	(3.0)	36.4
Devices owned by males	5.3	1.6	-	6.6	1.8	36.6
Devices owned by females	5.4	1.5	-	(6.0)	(2.0)	31.4

Notes. CI = participants with cognitive impairment; HC = participants without cognitive impairment; F = females; M = males; TICS = Telephone interview for cognitive status; PHQ-9 = Patient Health Questionnaire 9; GAD-7 = Generalized Anxiety Disorder scale.

Table 2. Group depression and anxiety symptom status

	n	
Symptom status (scale points)	CI	HC
Comorbid depression and anxiety (PHQ-9 ≥5 and GAD-7 ≥5)	11	5
Depressed (PHQ-9 ≥5 and GAD-7 <5)	11	4
Anxious (GAD-7 ≥5 and PHQ-9 <5)	1	2
No depression nor anxiety (PHQ-9 <5 and GAD-7 <5)	32	55

Notes. CI = participants with cognitive impairment; HC = participants without cognitive impairment; PHQ-9 = Patient Health Questionnaire 9; GAD-7 = Generalized Anxiety Disorder scale.

4.1.2.3 Measures

Cognitive status

The 11-item Telephone Interview for Cognitive Status (TICS), developed as a screen for dementia, was used to assess the cognitive domains of memory, orientation, attention, and language. Scores range from 0 to 41 with scores ≤30 indicating cognitive impairment. The TICS has a discriminative ability (people with versus without dementia) comparable to the Mini Mental State Exam (Folstein et al., 1975) (Seo et al., 2011).

Technology survey

A technology survey was designed for our study as there is currently no standard practice for reporting the use of technology by older adults (Colbourne et al., 2021) (see Appendix C [pg. 292 to 297] for the survey questions). Participants were asked if they owned specific technologies (e.g., a mobile phone or tablet). For each device they reported owning, participants were asked whether they used it “most days”, “some days”, “rarely”, or “never”, and whether they carried out specific tasks (e.g., emailing) on those devices. If a smart TV was owned, participants were asked what smart TV apps, if any, they used. We described social media as the use of Facebook, Twitter, and/or YouTube. Participants could also report other items and tasks that they were not specifically asked about.

Mood

Depression. The 9-item Patient Health Questionnaire 9 (PHQ-9) (Kroenke & Spitzer, 2002) was used to screen for the presence and severity of depression. The suicidal ideation item was removed due to ethical concerns. The removal of this item does not affect the interpretation of final scores (Kroenke & Spitzer, 2002). A score of 0 (not at all) to 3 (nearly every day) is assigned for each item giving a total of between 0 and 24. Scores of 5, 10, 15, and 20 represent the lower cut-off points for mild, moderate, moderately severe, and severe depression respectively. A score of ≥ 10 has a specificity and sensitivity of 88% for major depression disorder (MDD) (Kroenke & Spitzer, 2002).

Anxiety. The 7-item Generalized Anxiety Disorder Scale (GAD-7) (Löwe et al., 2008) was used to screen for the presence and severity of anxiety. A score of 0 (not at all) to 3 (nearly every day) is assigned for each item giving a total of between 0 and 21. Scores of

5, 10 and 15 represent the lower cut-off point for mild, moderate, and severe anxiety, respectively. A score of ≥ 10 is suggestive of GAD and other anxiety disorders. It has high internal consistency ($\alpha = 0.89$) (Löwe et al., 2008).

4.1.2.4 Data analysis

Descriptive, significance, and bivariate correlation analyses were performed with the Statistical Package for the Social Sciences, version 25 (IBM Corp, 2017). Mann-Whitney U (*U*) and independent samples *t*-tests (*t*) were used to compare the groups and gender groupings in terms of age, cognitive ability, mood, and the number of devices owned where appropriate. Zero-order Spearman rho bivariate correlations were used to examine the relationship between age, cognitive ability and the number of devices owned where appropriate.

Symptom status

Participants who scored <5 on both the PHQ-9 and the GAD-7 scales were classified as having no depression nor anxiety. A score of ≥5 on the PHQ-9 and <5 on the GAD-7 scales was used to classify participants as depressed. A score of <5 on the PHQ-9 and ≥5 on the GAD-7 scales was used to classify participants as anxious. Participants who scored ≥5 on both the PHQ-9 and the GAD-7 scales were classified as comorbid.

Devices and tasks/activities

The percentage of participants owning each device in each group was calculated. Of the participants who reported using any of the CUDs, the percentage who (1) used a device for each frequency category (e.g., most days, some days, rarely, and never), and (2) carried out each activity/task (whether asked directly or spontaneously mentioned) were calculated for each group. The percentage of smart-TV owners (1) using at least one smart-TV app, and (2) reporting the use of each app were calculated for each group.

4.1.3 Results

4.1.3.1 Participant characteristics

There was no significant difference in age between the groups, $U(N_{CI} = 55, N_{HC} = 66) = 1{,}572.00$, $z = -1.27$, $p = .21$ (Table 1.). Participants in the CI group were significantly more cognitively impaired, $t(73) = -7.27$, $p < .001$), depressed, $U(N_{CI} = 55, N_{HC} = 66) = 1{,}348.50$, $z = -2.46$, $p = .01$, and anxious, $U(N_{CI} = 55, N_{HC} = 66) = 1{,}283.00$, $z = -2.86$, p

= .004, and owned significantly fewer devices, $U(N_{\mathrm{CI}} = 55, N_{\mathrm{HC}} = 66) = 2{,}335.00$, $z = 2.76$, $p = .01$, than participants in the HC group.

In terms of gender, there was no significant difference between males and females in age, $t(53) = .55$, $p = .59$, cognitive ability, $U(N_{\mathrm{Female}} = 23, N_{\mathrm{Male}} = 32) = 423.50$, $z = .95$, $p = .34$, nor the number of devices, $t(53) = .19$, $p = .85$, in the CI group. There was also no significant difference between males and females in age, $t(64) = -.26$, $p = .80$, cognitive ability, $U(N_{\mathrm{Female}} = 39, N_{\mathrm{Male}} = 27) = 413.50$, $z = -1.49$, $p = .14$, nor the number of devices, $U(N_{\mathrm{Female}} = 39, N_{\mathrm{Male}} = 27) = 609.00$, $z = 1.10$, $p = .27$, in the HC group.

There were no significant relationships between age and the number of devices owned by participants in the CI, $r_s(53) = -.08$, $p = .54$, and HC, $r_s(64) = -.004$, $p = .98$, groups, nor between cognitive ability and the number of devices owned by participants in the CI, $r_s(53) = .24$, $p = .08$, and HC, $r_s(64) = .24$, $p = .05$, groups.

4.1.3.2 Technology

Ownership and usage of the currently-used devices

The majority (93%) of participants in the CI group owned at least 1 of the CUDs (Figure 2a.) while all (100%) of the participants in the HC group owned at least 1 of the CUDs (Figure 2b.). Tablets were the most frequently owned CUDs for the CI group whereas smartphones were the most frequently owned CUDs for the HC group (Figure 1.). A larger percentage of smartphone owners in the CI and HC groups used their devices “most days”, compared to owners of the other CUDs, with tablets being the least frequently used (Figure 3.). This pattern was also demonstrated by the participants in the CI group who owned all of the CUDs (Figure 4.). Tablets were also the least frequently used device by the participants in the HC group who owned all of the CUDs.

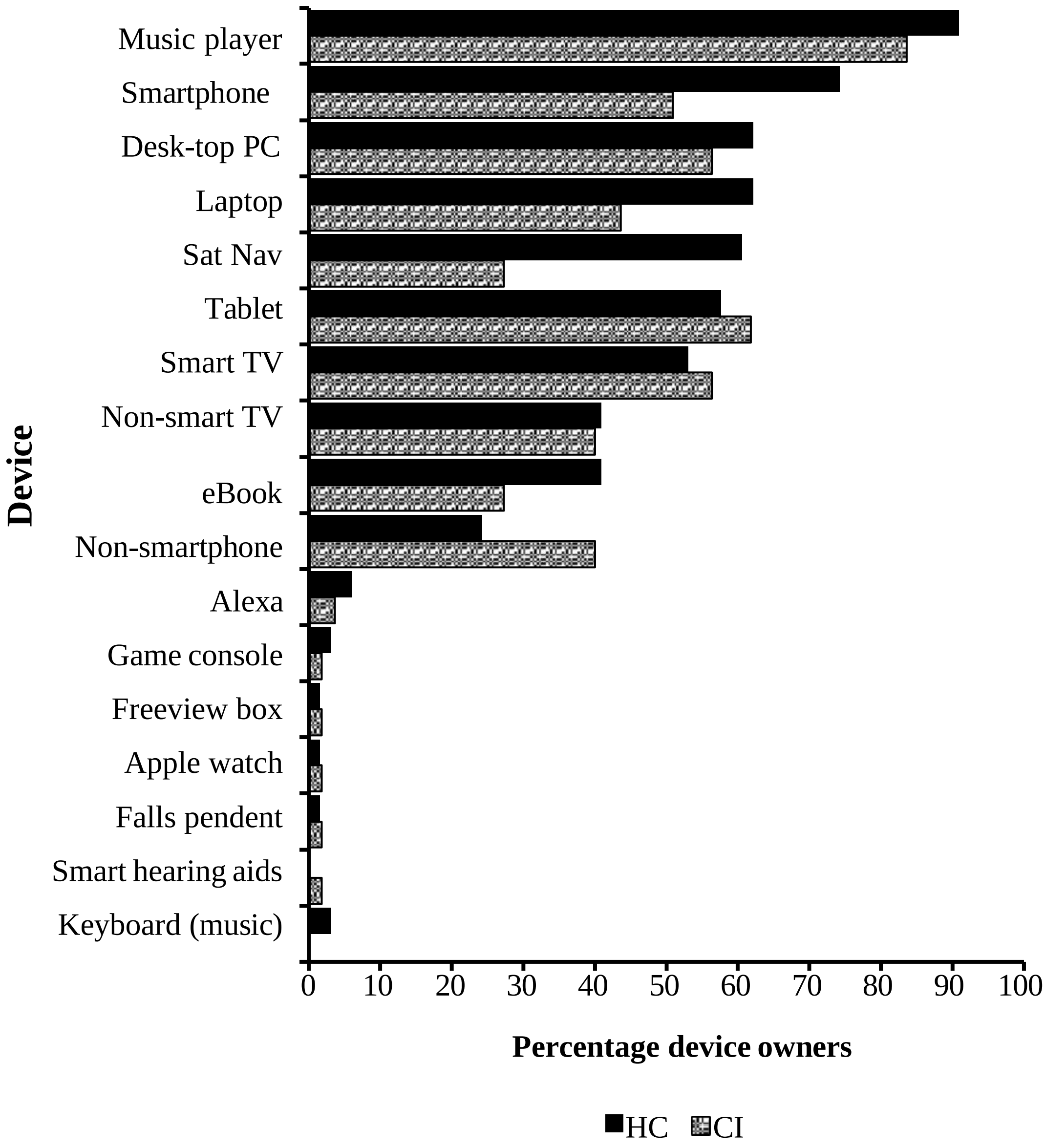
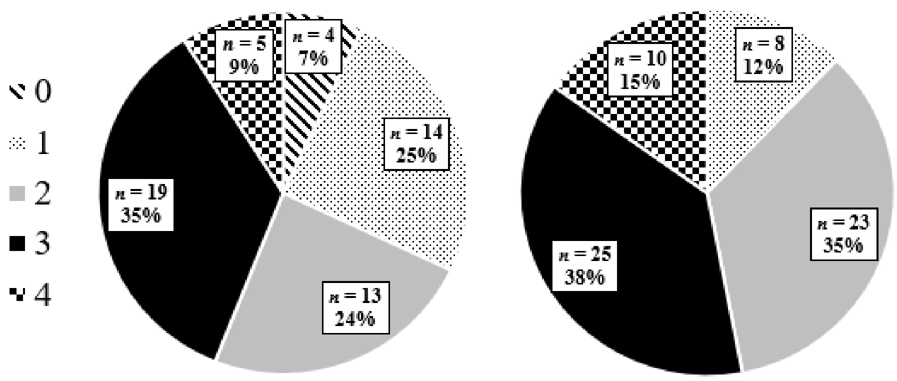


Figure 1. Percentage of participants with (CI = 55) and without (HC = 66) cognitive impairment owning each device.



Figures 2a., and 2b. Percentage of participants with (2a. left) and without (2b. right), cognitive impairment, owning none to all four of the currently-used devices (i.e., smartphone, tablet, laptop, and desktop-PC)

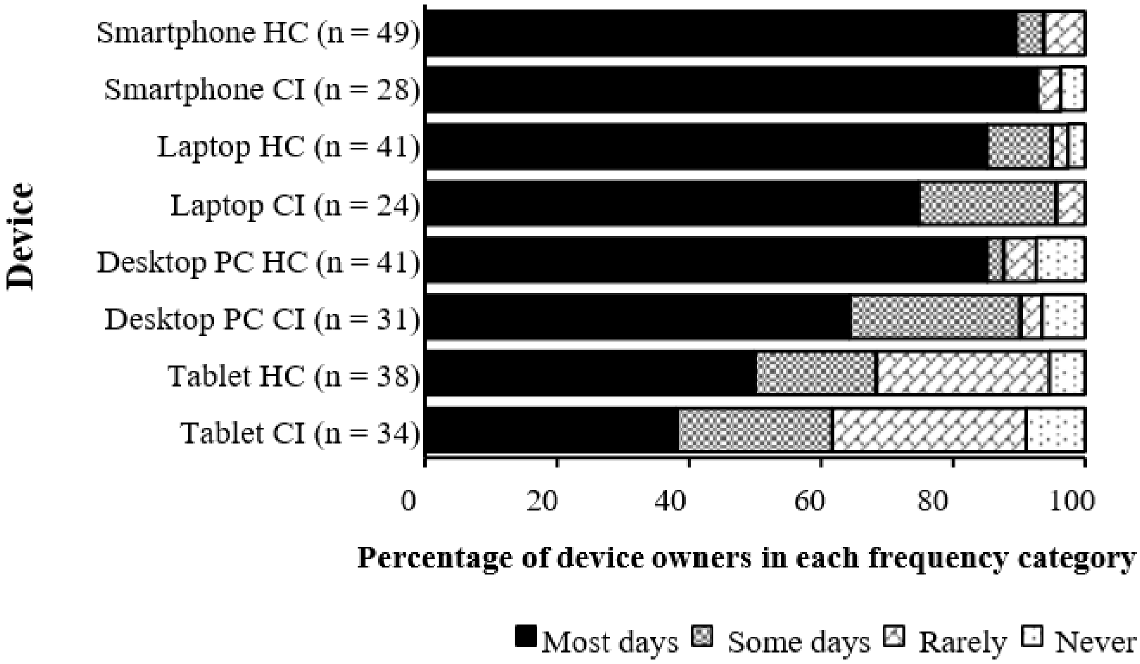


Figure 3. Percentage of device owners with (CI) and without (HC) cognitive impairment, using that device within each frequency category (e.g., most days, some days, rarely, and never).

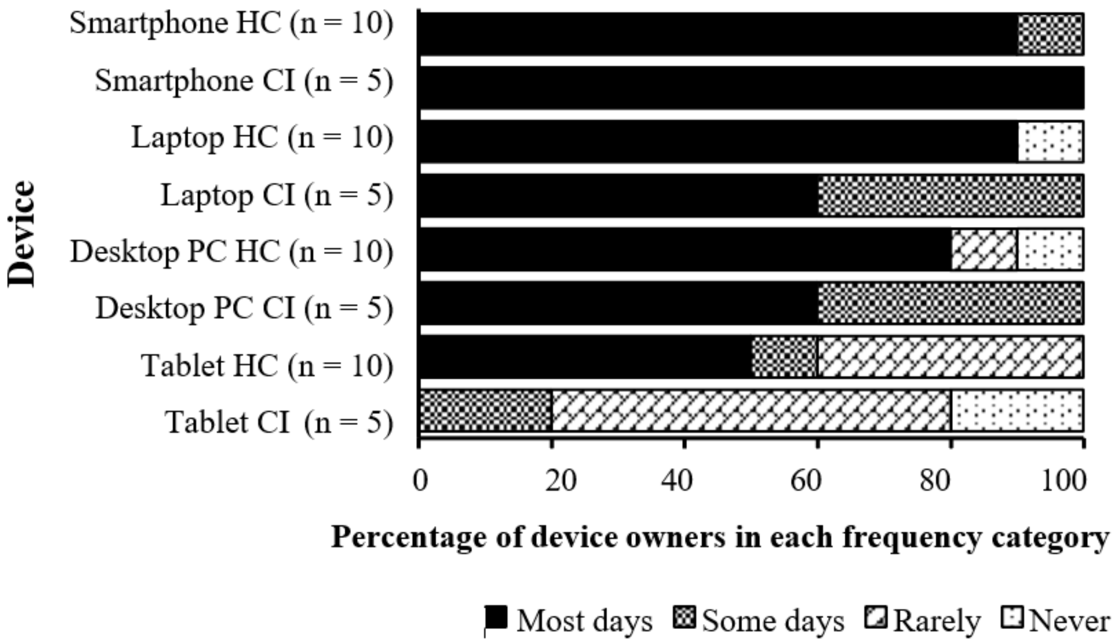


Figure 4. Percentage of participants who own all four devices (smartphone, tablet, laptop, *and* desktop-PC), using each device within each frequency category (e.g., most days, some days, rarely, and never).

Smart-TVs, gaming, and social media

Almost half (14/31 = 45%) of the smart-TV owners in the CI group and just over a third (13/35 = 37%) in the HC group used at least one app on this device. Both groups mentioned the iPlayer app the most ([CI] 11/31 = 35%; [HC] 9/35 = 26%), with YouTube ([CI] 1/31 = 3%; [HC] 1/35 = 3%), Netflix ([CI] 1/31 = 3%; [HC] 2/35 = 6%), and music apps ([CI] 2/31 = 7%; [HC] 2/35 = 6%) being mentioned to a lesser extent. Only HC group owners mentioned using photo (1/35 = 3%) and Prime Time apps (1/35 = 3%) on their smart-TVs. Overall, fewer participants in the CI group accessed games on each device (smartphones = 1; tablets = 6; laptops = 2; desktop-PCs = 2; games consoles = 1) than in the HC group (smartphones = 11; tablets = 8; laptops = 3; desktop-PCs = 2; games consoles = 2). One participant in the HC group played a game designed to examine cognitive health, the GameChanger app, while all other gameplayers accessed leisure games (e.g., Sudoku, and Solitaire) which were predominantly word-based (e.g., Scrabble, Wordfeud, and Word Cookies) (see Appendix C [pg. 292]). The CI and HC groups accessed social media platforms to a greater extent than they accessed Skype and FaceTime (see Table 3.).

Table 3. Percentage of device owners carrying out each specified task and spontaneously provided response on that device

	Smartphone		**Tablet**		**Laptop**		**Desktop-PC**	
Group	CI	HC	CI	HC	CI	HC	CI	HC
Device owners	28	49	34	38	24	41	31	41
Tasks that respondents were directly asked if they completed								
Emailing	79%	78%	65%	82%	92%	95%	84%	98%
Talking	96	100	6	21	13	10	6	10
Messaging	93	98	6	29	13	12	10	22
Reading	39	39	29	58	17	39	10	49
Shopping	39	39	35	66	54	80	55	83
Banking	43	43	26	45	46	73	48	76
Social media	46	45	29	53	42	37	29	37
Listen to music	4	12	9	3	13	7	6	5
Gaming	4	22	18	21	8	7	6	5
Skype	18	29	15	39	13	32	16	32
Tasks that respondents spontaneously mentioned completing								
Maps	-	14	-	-	-	-	-	-
Photos	-	2	-	-	-	-	-	7
Watching TV	-	-	-	5	-	-	-	-
iPlayer	-	-	-	5	-	-	-	-
Hearing	4	-	-	-	-	-	-	-
Finding friends	4	-	-	-	-	-	-	-
FaceTime	7	22	6	5	-	-	-	-
WhatsApp	29	55	-	3	-	-	-	-
Writing	-	-	-	-	-	2	-	-
Work	-	-	-	-	-	2	-	-
MS Office	-	-	-	-	-	17	13	15
Research study	-	-	-	-	-	-	-	5

Notes. CI = participants with cognitive impairment; HC = participants without cognitive impairment; MS = Microsoft.

4.1.4 Discussion

The aim of our study was to address the current knowledge gap that exists surrounding the spontaneous use of technologies, particularly smartphones, by older adults with (CI) and without (HC) cognitive impairment, with the view that these data facilitate the identification of useful mental-health service or research delivery modes. Palmdorf et al., (2021) found that 82% of studies investigating assistive technology involving people with dementia (PwD) used a tablet. Although we found that tablets were the most frequently *owned* device for the CI group compared to the other currently-used devices (CUDs) (e.g., smartphones, tablets, laptops, and desk-top PCs), they were the least frequently *used* CUDs by this group, even when all CUDs were owned. Smartphones were the most frequently used CUDs by this group and the ownership level (51%) is comparable to previously reported international levels (55.5%) (LaMonica et al., 2017). Our finding that CI and HC smartphone owners used their smartphones at a similar frequency is also in-line with previously reported international findings (Benge et al., 2020). Based on frequency of use, more smartphone-based mental-health studies involving PwD could be developed, and studies should consider older adults' every-day experience with smartphones and tablets (Wilson et al., 2022).

While smartphones were also the most frequently used of the CUDs in the HC group, laptop and desktop-PC owners in this group also used their devices to a high extent. Thus, service providers should ensure that (1) services are accessible via all of the CUDs (e.g., by using responsive web platforms that adapt to device screen size and orientation etc. [Patel et al., 2015]), (2) users can perform the required tasks efficiently via each device (Adepu & Adler, 2016), and (3) the content is accessible and relevant to older adults with and without cognitive impairment. Nevertheless, none of the participants within our study spontaneously reported accessing mental-health treatment from any device. Although there are evidence-based mental-health apps endorsed by the National Health Service, such as Mindshift CBT ™ (Paul & Eubanks Fleming, 2019; Sharma et al., 2022), barriers to their access for older adults include a lack of awareness of availability and trust in the intervention (Pywell et al., 2020). More research involving older adults and better promotion of technology-based options in these populations from trusted sources may facilitate adoption.

In terms of potential delivery modes, smart-TVs have the capacity for wide reach, particularly for the CI group. More participants in the CI group owned smart-TVs compared to smartphones and laptops, and a higher percentage of smart-TV owners in this group used a TV app than smart-TV owners in the HC group. A TV-based platform (Goodman-

Casanova et al., 2019) has been developed to improve quality of life for people with MCI and mild dementia. While a specific mental-health intervention feature has not been reported for this platform, the TV-based platform users played significantly more cognitive games, a platform feature, than a control group (non-TV- based platform users/treatment as usual). The platform's cognitive game was originally designed for mobile app use then specifically adapted for use on the platform (Goodman-Casanova et al., 2019). Specifically adapting mental-health apps endorsed by the National Health Service for smart-TV use could be useful for people with MCI and mild dementia as our results show that apps are being accessed on this device by almost half of the smart-TV owners. Providing services on devices/applications that older adults with and without cognitive impairment already use may support adoption (De Veer et al., 2015).

When *asked* about their preferences for potential delivery modes, older adults preferred smart-TVs over CUDs for a newer method of assessment/intervention - serious gaming (Costa et al., 2017). Though a significant reduction in depression with moderate effect was found in a recent systematic review and metanalysis of serious game trials involving older adults (Kim et al., 2022), a games console (e.g., a Microsoft Xbox or Nintendo Wii) was often required within the studies. As only 2% of the participants in our study owned a games console, the real-world applicability of these interventions for older adults could be affected by lack of ownership. Kim et al., (2022) suggest that serious games for other devices should be examined, as well as the type of content that could be effective for older adults. Our findings could be useful for those seeking to address these suggestions. In terms of devices, none of our participants reported engaging in gameplay via smart-TVs. Games were mainly being played on tablets by the CI group and on smartphones by the HC group. In terms of game type, the participants in our study played predominantly word-based games. Hence, a word-based depression and/or anxiety serious game could be useful for older adults. A word-based serious game has recently been piloted with younger adults (Salemink et al., 2022). It is important to consider the potential use of interventions aimed at younger adults for use with older adults, where it may suit older adults' preferences.

Social media also has the capacity for wide reach for both the CI and the HC groups. More participants reported its use than gameplay, and the use of Skype and FaceTime, with usage levels (CI = 46%; HC = 45%) being comparable with the UK average for 50+ year-olds (48%) and Facebook usage within an international study (PwD = 21%; MCI = 41%) (LaMonica et al., 2017; Ofcom, 2019). However, any prospective social media-based delivered e-Health, studies, or interventions, should carefully consider how older adults use social media, and any associated mental-health links. Though we did not collect data regarding the activities being conducted on social media in our study, commenting on photos and posts is one of the most common activities that older adults engage in on social media (Clark & Moloney, 2020), but they may not actively share their own information (Hargittai et al., 2019). And answering questions posted by others can be positively associated with depression, whereas looking at status updates can be negatively associated with anxiety (Hofer & Hargittai, 2021). Therefore, the spontaneous use of social media by older adults and their association with mental-health status may require further investigation. Still, these types of platforms, internet-based solutions, and smart-TVs can be inaccessible to some older adults (Chirico et al., 2022; Ouyang & Zhou, 2019) so, it is important that non-digital healthcare and research options should remain available.

Limitations and future studies

A potential limitation of our study is that the participant sample was biased towards older adults who were already actively using technology, as these data were collected as part of a larger online study. Still, we actively recruited via telephone without an indication of current online activity (e.g., an email address), participants were not required to personally own technologies to participate, and all participants could have assistance from another person with the technology-based aspects of the larger study. The study therefore had the scope to recruit participants with a range of device ownership and usage. Other limitations of our study are that our data are only representative of participants with mild Alzheimer's dementia/mild cognitive impairment, we did not conduct analyses based on education and income status, and we did not investigate the effect of internet access on responses. It is, however, well- established that technology ownership and usage is affected by education, income, cognitive status, and internet access (Benge et al., 2020; LaMonica et al., 2017; Menéndez Álvarez-Dardet et al., 2020; Taylor & Silver, 2019). Thus, larger telephone and/or paper-based studies in the UK that include people with other types of dementia and with more cognitive impairment, would be required to assess technology use more comprehensively.

Clinical/research implications

Based on usage, more smartphone-based studies/intervention trials could be delivered for older adults with and without cognitive impairment, and smart-TVs and social media could be potential service delivery modes. Tablets are not the preferred computer-based device for all older adults. Moreover, a range of technologies should be assessed when investigating technology use in these populations, as focussing on a single/few devices may present only a partial understanding of the opportunities for technology-based interventions.

4.1.5 Acknowledgements

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4.1.6 Declaration of interest statement

No competing interests.

4.1.7 Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

4.1.8 References

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4.1.9 Thesis aims and key study findings

Thesis aim 3 (to explore the technologies used spontaneously in dementia) was explored within this section of the chapter. The important findings were that laptops and desk-top computers were being used most days (75% and 65% respectively) by PwCI and mostly for emailing. These factors were key for the delivery of the subsequent studies as the eye-tracking platform's eye-tracking program was only compatible with these devices, and study components were accessed via emailed links. Whilst the participants were able to have assistance from a person of their choice during the WBET studies described in this chapter (sections 4.2, 4.3, and 4.4) and Chapters 5, using familiar devices and completing familiar tasks within the study (e.g., accessing email) increased participant numbers. A home-based WBET task was created via Gorilla (Anwyl-Irvine et al., 2020), the eye-tracking platform, and trialled within the study described next in this chapter.

4.2 Is home-based webcam eye-tracking with older adults living with and without Alzheimer's disease feasible?

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This section of the chapter explored how older persons with and without cognitive impairment navigated the tasks involved in WBET (e.g., positioning of the face and body), providing novel information on set-up times, calibration failures (e.g., number and factors that may contribute to failure), and barriers to usage in these populations to inform future studies. Confirmation of the feasibility of WBET use with PwD is provided given that the WBET tasks (e.g. modifying lighting levels, positioning the laptop and body, and eye gaze location) could be completed (with and without assistance), notwithstanding technical limitations (e.g., internet speed), and typical eye tracking issues (e.g., participant eye shape, movement, and blinking).

Is home-based webcam eye-tracking with older adults living with and without Alzheimer's disease feasible?

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ABSTRACT

Home-based eye tracking studies using built-in webcams are typically conducted with younger people and incur long set-up times and a large number of calibration failures. We investigated the set- up time, number of calibration failures and issues faced by twelve older adults living with and without Alzheimer's disease during home-based eye tracking. We found that home-based eye tracking is feasible with set-up support and we provide recommendations for future studies of this nature.

CCS CONCEPTS

• **Human-centered computing** → Accessibility; Empirical studies in accessibility.

KEYWORDS

aging, dementia, usability, Gorilla

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1 INTRODUCTION

Webcam-based eye-tracking solutions are not currently capable of the accuracy needed to detect fine-grained or very rapid eye movement but comparable results to lab-grade eye tracker data have been produced in, for example, free-viewing and visual paired comparison tasks [1–6]. There are, however, challenges such as extended calibration/validation times and numerous calibration failures. This study investigates home-based eye tracking using webcams with older adults living with and without Alzheimer's disease (AD), examining the type of assistance needed, set-up and calibration/validation times, calibration failures and the obstacles to successful eye-tracking. The findings can inform the development of eye-tracking solutions as well as other research investigating eye-tracking with these populations.

2 METHODS

2.1 Participants

Twelve participants (7 diagnosed with AD, 5 living without a diagnosis of AD; 6 females, 6 males) aged 60 to 81 yrs old (mean = 69.1; standard deviation = 6.66) participated in the study. All participants were recruited via the Join Dementia Research platform (https://www.joindementiaresearch.nihr.ac.uk). Written informed consent was obtained from each participant, and for participants living with AD, confirmation of their ability to consent was also obtained from a nominated person.

2.2 Procedure

Each session was conducted on a laptop with a built-in webcam and Microsoft Teams browser version. The participant's screen was shared with the researcher and recorded for later analysis. Eye tracking was conducted via Gorilla (https://app.gorilla.sc) which is a platform for web-based studies [7]. The study platform was accessed via personalized links which were emailed to the participants, and the participants proceeded with the experiment as directed in the instruction screens. The participants received preparation notes via email and could have assistance from another person. The researcher responded to questions and assisted as required.

1.1.1 *Positioning the face/eyes.* Participants were instructed to sit directly in front of their webcam, to only move their eyes to look at the different parts of the screen, to remain still and blink as little as possible. A screen was presented showing their video feed in the top left corner of the screen (Figure 1, left image). Gorilla displays the video in such a way that a head-movement to the right results in the head in the video feed moving to the left. A black box outline was overlaid in the center of the video feed, and participants were asked to align themselves, using the video feed to guide them, such that their faces appeared in the middle of the box (see supplementary video).
Gorilla also overlays a green face-mesh onto the part of the video feed that it has detected as the user's face. The instructions to participants stated that the box outline must turn green, and the green face outline must match their features (face-mesh) (Figure 2, left image) to enable a start button. Participants who wore glasses were asked to remove their glasses if their eyes were not face- meshing correctly due to lens reflection. Once the start button was

Figure 1: Left image showing a participant's video feed box. Right image illustrating the nine dot locations.

enabled (indicated by the button changing color to a deeper shade of red), the participants were to click the button to advance to a calibration and validation phase.

1.1.2 Calibration and validation (CV).. During the calibration phase, a 50 × 50-pixel red dot appeared consecutively in each of 9 fixed locations in a random order (see supplementary video). The 9 locations were arranged in a 3x3 grid spanning the screen's height and width (Figure 1, right image). Once a dot appeared, there was a 750-ms delay and then 20 calibrations samples were taken to train the eye-gaze location prediction model. The dot then appeared in the next location. The participants were to look at the dot as quickly as possible and fixate on it until it disappeared. The validation phase was identical to the calibration phase, except the dot was green. The purpose of the validation phase was to calculate the difference (in pixels) between the model's predicted gaze location and the expected gaze location (the target dot location). Calibration failure occurred when four predicted locations were closer to non-target locations. The study protocol included 6 calibration/validation sets (CV1 to CV6) in total, conducted at the start of 6 sub-blocks of 32 experimental trials each. CV1 was attempted up to 6 times before the participant was unable to continue participating. CV2 to CV6 were attempted as many times as the participant desired.

2 RESULTS

2.1 Assistance required for positioning the face and eyes

Eleven participants required assistance to gauge the size and direction of movement that was needed to achieve face-meshing. Prompts to pause between position changes to allow the face-mesh model to be generated and help to locate the face-mesh outline were also needed. Three participants living with AD attempted to follow the movement of the face-mesh outline with their own head movements, yet the face-mesh as displayed does not represent the required direction of motion nor where the person should position themselves. Face-meshing was unsuccessful for 1 participant living with AD.

2.2 Set-up and calibration/validation time, and calibration failures

Set-up time (SUT) was measured as the time taken from the presentation of the positioning screen until the first calibration attempt. SUT ranged from 0 (0 = face-meshing was achieved from the onset of the positioning screen) to 19 minutes. SUTs were totalled (TSUT) for each participant who completed at least one sub-block. TSUT ranged from 0.75 to 32.5 minutes, representing 10 to 56% of the participant's overall study duration. Their calibration/validation time (CVT) was measured as the time taken from the start of the first calibration attempt until a successful calibration. CVTs were totalled for each participant and ranged from 1 to 10.5 minutes.

CV1 was unsuccessful for three participants living with AD, where head movements, blinking, and eye shape (occlusion of the pupil) resulted in there being insufficient data for the prediction model to work. Only one participant living without AD was unsuccessful during CV1. In this case, this participant's face-mesh was lost as another person came into frame. Three participants (1 living with AD) completed 1 to 3 CV sets (6 successful calibrations between them), and experienced 0, 6 and 9 calibration failures respectively (15 in total). CV sets for the participant with 9 failures were affected by eye-watering before we identified this as an issue. They had 1 subsequent incomplete attempt with 3 calibration failures in total. Four participants (2 living with AD) completed all six CV phases. Of those, the participants living with AD had more calibration failures than participants living without AD (4 and 2 respectively).

2.3 Obstacles to successful face-meshing, positioning and calibration

Of the 9 participants who wore glasses, only 2 were able to be face-meshed wearing their glasses and only 1 went on to a successful CV (Figure 2, left image). Fortunately, the remaining participants could see the stimuli clearly without their glasses and calibrated successfully. Participant's direction of movement and/ or head positioning were found to be influenced by the location of the video feed box on the screen. Five participants either shifted to the left to align with the video feed box or unconsciously turned their head to face the video feed box, and movement (i.e., to recenter) during calibration results in data loss. Two participants requested that the video feed box be larger and centralised on the screen (appendix A.1).

Estimating the size and direction of movement to obtain good face-meshing was difficult for participants. This difficulty was exacerbated by any delay in the face-mesh outline appearing or by its size, contrast and/or brightness (Figure 2, middle image; appendices A.2 and A.3). The participant would change position, move continuously and/or make unnecessarily large position adjustments when they had no feedback (the face-mesh) to signal if they were in the right/better position (see supplementary video).

The faces of participants in the background were meshed if they came into frame (Figure 2, right image). The Start button could be enabled under this condition as well as in conditions with no face-meshing at all (Figure 2, middle image). Participants also tried to press the button when it was not yet enabled (i.e., only the green box outline criterion was met). The Start button was clicked 6 times in total under the aforementioned conditions.

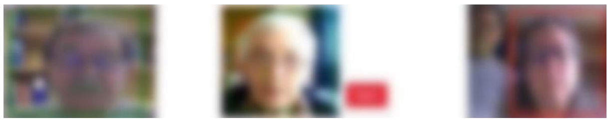

Figure 2: Left image showing successful face-meshing with glasses. Middle image showing a small face outline (be- low the right eye) and inaccurate face-meshing enabling the start button. Right image showing a participant face-meshing in the background.

3 DISCUSSION

Our findings suggest that home-based webcam eye tracking is feasible in older adults living with and without AD if face-meshing support is provided. Although we had more calibration failures than [6], our participants had the opportunity to make more attempts, had more calibration/validation phases, and may have completed more attempts due to the presence of the researcher. The causes of calibration failures are in line with previous literature except for eye watering. However, we cannot confirm whether this affected the ability of the software to detect the pupils or if the participant blinked more to clear the eyes causing data loss. In any case, it is a factor that may be more prevalent in older adults and therefore should be addressed in future studies.

We make the following recommendations based on participant experiences. Study design should include at least 40 minutes for setting up and the calibration/ validation process. The video feed box should be large and centralized to aid better positioning and potentially face-meshing. The facial outline should be thicker or a deeper shade of green to aid visibility. The 'Start' enabling process needs to be finetuned to avoid false starts and therefore calibration failures. The people providing aid in the same room as the participant should be advised to stay out-of-frame. As twice as many participants were glasses wearers in our study than [6], we challenge web-based eye tracker developers to create a package which corrects for lens reflection and provides positioning advice as this could hinder the participation of many older adults in web-based eye-tracking studies.

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Supplementary video link
https://dl.acm.org/doi/10.1145/3441852.3476565

A APPENDICES

A A.1 PARTICIPANT FEEDBACK STATEMENTS REGARDING THE VIDEO FEED BOX SIZE AND POSITION

'Can we get that screen [video feed box] bigger… [it] is quite tiny'.

'Can you change the position of the tracking [video feed] box? It would be easier in the middle'.

B A.2 PARTICIPANT STATEMENTS IN RELATION TO THE FAINTNESS OF THE GREEN FACE OUTLINE.

Participant: 'Note the green box is around me and my face [box overlay]…'.

Researcher: 'Is there a green outline around your own face?'.

Participant: 'I do not know.

C A.3 PARTICIPANT NOT BEING ABLE TO SEE THE GREEN FACE OUTLINE UNTIL EXPLICITLY BEING DIRECTED TO IT.

Researcher: 'Can you see the little green face… on your cheek at the moment?'

Participant: Pause/ views video feed… [unintelligible sound]… 'oh yes'.

4.2.1 Thesis aims and key study findings

Thesis aims 4 (to explore remotely-delivered music research with WBET involving older persons with and without AD) and 5 (to explore the feasibility of remotely-delivered multi-session ABM with WBET involving persons with and without AD) were partially explored in this section of the chapter. The important findings were that WBET was feasible to conduct with PwCI, and few issues were encountered that had not been previously reported in research involving younger persons. Novel data on why calibration failure may have occurred (e.g., the face-mesh not matching the user's face at all but having the ability to proceed in this circumstance) was also provided for future webcam-based eye-tracking research to investigate.

4.3 Webcam-Based Eye-Tracking of Attentional Biases in Alzheimer's Disease : A Proof-Of-Concept Study.

This section of the chapter has been published as:

Greenaway, A.-M., Hwang, F., Nasuto, S., & Ho, A. (2023). Webcam-Based Eye-Tracking of Attentional Biases in Alzheimer's Disease : A Proof-Of-Concept Study. *Clinical Gerontologist*, 47(1), 98–109. https://doi.org/10.1080/07317115.2023.2240783

This section of the chapter explored the reliability of AB measures using WBET. Findings showed that the reliability of WBET measured AB are in line with lab-based research using similar AB measure parameters.

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Webcam-Based Eye-Tracking of Attentional Biases in Alzheimer's Disease: A Proof-Of-Concept Study

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ABSTRACT

Objectives: To measure home-based older adults' attentional biases (AB) using webcam-based eye-tracking (WBET) and examine internal consistency.
Methods: Twelve participants with and without cognitive impairment completed online self-report anxiety and depression screens, and a 96-trial dot-probe task with eye-gaze tracking. For each trial, participants fixated on a cross, free-viewed sad-neutral, sad-angry, sad-happy, angry-neutral, angry-happy, and happy-neutral facial expression pairings, and then fixated on a dot. In emotional-neutral pairings, the time spent looking (dwell-time) at neutral was averaged and subtracted from the emotional average to indicate biases "away from" (negative score) and "toward" (positive score) each emotional face. Internal consistency was estimated for dwell-times and bias scores using Cronbach's alpha and Spearman – Brown corrected split-half coefficients.
Results: The full-cohort and a comorbid anxious and depressed sub-group ($n = 6$) displayed AB away from sad faces, and toward angry and happy faces, with happy-face AB being more pronounced. AB indices demonstrated low reliability except sub-group happy-face indices. Happy-face AB demonstrated the highest reliability.
Conclusions: AB measures were in-line with lab-based eye-tracking literature, providing some support for WBET-based measurement.
Clinical Implications: Establishing the feasibility of WBET-based measures is a step toward an objective home-based clinical tool. Literature-based suggestions are provided to improve reliability.

KEYWORDS Alzheimer's disease; anxiety; attentional biases; depression

Introduction

By the year 2050, it is expected that 131.5 million people worldwide will be living with dementia (Barbarino, 2017). Alzheimer's disease (AD), which accounts for 60–70% of all cases, is often accompanied by neuropsychiatric symptoms such as anxiety and depression (Botto et al., 2022). Anxiety and depression can increase the rate of cognitive decline, reduces quality of life (Breitve et al., 2016; Gonfrier et al., 2012; Spalletta et al., 2012), and are associated with higher rates of conversion from mild cognitive impairment (MCI) to AD (Gallagher et al., 2011). Given these implications, it is important to effectively detect and monitor symptoms and evaluate treatment. Self-report measures are widely used. However, difficulties can arise from their use for older adults with and without cognitive impairment such as scale accessibility (e.g., wording, or the need for verbal or written responses), a reluctance to report and endorse negative emotions or items, and the respondent's level of awareness (Balsamo, Cataldi, Carlucci, & Fairfield, 2018; Balsamo, Cataldi, Carlucci, Padulo, et al., 2018). Moreover, age-/cognitive status-appropriate measures employing dichotomous scale formats reveal less information (i.e., incremental change) (Kolanowski et al., 2019). Therefore, additional non-verbal objective assessment methods may be useful for clinicians, particularly when self-report is not possible (Kolanowski et al., 2019).

The usefulness of eye gaze data

Eye-movement data could provide an objective measure of disease status and symptom progression monitoring (Anderson & MacAskill, 2013). People with AD (pwAD) have been differentiated from people with other types of dementias and cognitively healthy (HC) participants by their eye movements, and alterations can correlate with disease severity (see Molitor et al., 2015 for a detailed review). The types of visual stimuli that an individual looks toward or away from, i.e., their attentional bias (AB), can also correlate with health outcomes, and anxiety and depression severity (De Raedt & Koster, 2010; MacLeod & Clarke, 2015). Looking longer at positive stimuli, as demonstrated by some cognitively healthy older adults (Demeyer et al., 2017), has been linked to experiencing a positive mood and greater life satisfaction (Sanchez & Vazquez, 2014). Positive biases in relation to recall have also been demonstrated by non-depressed older adults with MCI (Callahan et al., 2016). Negative AB (looking longer at negative stimuli) may be demonstrated by depressed or clinically anxious older adults, and pwAD in relation to recall and emotion discrimination (Armstrong & Olatunji, 2012; Cabrera et al., 2020; Maria & Juan, 2017). Negative AB can represent a trait depression vulnerability marker (Harmer et al., 2009). Therefore, eye movement and AB may have the potential to help clinicians identify at-risk individuals. Anxiety and depression often co-occur in dementia (Ryu et al., 2005) and comorbidity can modulate AB. In the few dot-probe response-time/button-press studies examining comorbidity in younger individuals, findings are mixed showing that clinically comorbid individuals may show no bias or a bias toward sad faces (Hankin et al., 2010; Kishimoto et al., 2021; LeMoult & Joormann, 2012), show a bias away from (Kishimoto et al., 2021; LeMoult & Joormann, 2012) or toward angry faces (Hankin et al., 2010; Kishimoto et al., 2021), or show a bias toward or away from happy faces depending on their clinical history (i.e., current versus lifetime symptoms respectively) (Hankin et al., 2010). Understanding an individual's attentional bias, especially using a more direct measure such as eye-tracking (Arditte & Joormann, 2014), could inform treatment.

Webcam-based eye-tracking of attentional biases

Webcam-based eye-tracking (WBET) research has increased, and comparable results to those obtained by other eye-tracking devices have been produced (Bott et al., 2020; Semmelmann & Weigelt, 2018). WBET removes the need for travel, expensive equipment and eye-tracking specialists, and potentially enables regular and longitudinal assessment of AB. WBET could therefore facilitate timely intervention as negative AB can prospectively predict higher depressive symptom scores (Beevers et al., 2011) and enable clinicians to objectively monitor intervention effects as changes in positive AB can occur after antidepressant treatment (Zhang et al., 2020). Changes in AB may be seen before subjective mood improvements and can correlate with successful anti-depressant treatment (Harmer et al., 2009).WBET measures of attentional biases could benefit pwAD. Internet-based dot-probe paradigms (MacLeod et al., 2002) include a response- time/button-press task which involves several complex cognitive processes (Gratton et al., 2018). A response-time/button-press element is unnecessary using eye-tracking, and therefore cognitive load can be reduced for pwAD (Bourgin et al., 2018). However, AB would need to be examined in a large number of pwAD (Kruijt et al., 2019), and unfortunately, many studies recruit a low number of participants with dementia (Mooldijk et al., 2021). WBET could enable more pwAD to access eye-tracking studies thereby facilitating statistically powered findings. A recent study (Greenaway et al., 2021) examined WBET (i.e., set-up/time, calibration failures, and related issues) with older adults living with and without AD. The authors found that WBET is feasible when assistance is provided, particularly when positioning the face and the eyes. Utilizing this information, we measured the AB of older adults living with and without AD using WBET, and examined the reliability of WBET-measured AB.

Table 1. Descriptive analyses of age, cognitive, mood, and bias data.

	Full cohort		Comorbid	
	N = 12, F = 4, M = 8		*n* = 6, F = 2, M = 4	
Measures	Mean (Median)	*SD* (*IQR*)	Mean (Median)	*SD* (*IQR*)
Age	68	5	66	7
TICS	32	4	31	5
GAD-7	7	6	10	5
PHQ-9	9	8	14	6
Bias score (ms)				
Sad faces	(−32)	(1092)	(−33)	(1026)
Angry faces	(45)	(1338)	61	1000
Happy faces	(172)	(1254)	96	988

Comorbid = anxious and depressed; *N*/*n* = number of participants; F = females; M = males; *SD* = standard deviation; *IQR* = interquartile range; TICS = Telephone interview for cognitive status; GAD-7 = Generalized Anxiety Disorder scale; PHQ-9 = Patient Health Questionnaire 9 scale. Bias score averages (emotional dwell-time minus the corresponding neutral dwell-time across trials) below zero represent a bias away from the emotional expressions and those above zero, a bias towards the emotional expressions.

Methods

Participants

We recruited 22 participants to the study. Full eye-tracking datasets were obtained from 12 participants (AD = 6, MCI = 3, HC = 3; 4 females, 8 males) aged 60 to 79 yrs old (see Table 1 for descriptive data). Participant TICS scores fell within cognitively non-impaired (*n* = 5), ambiguously impaired (*n* = 6), and mildly impaired (*n* = 1) ranges. Four participants were classified as being non-anxious/non-depressed (MCI = 2; HC = 2), one as anxious (pwAD), one as depressed (pwAD), and six as having comorbid anxiety and depression (pwAD = 4; MCI = 1; HC = 1). Five participants with cognitive impairment (pwAD = 3, MCI = 2) were taking cognitive medication (Donepezil) and one participant (pwAD group) was taking anti-depressant medication. All participants with cognitive impairment (pwAD and MCI) were required to have a carer or representative provide written or verbal confirmation of the participant's ability to provide informed consent. All participants provided written or verbal consent before the start of the study.

Procedure

Participants received preparation notes, a link to JISC Online surveys (https://www.onlinesurveys.ac.uk/) to complete a self-report questionnaire assessing their levels of anxiety and depression, and a Microsoft Teams meeting link via e-mail.

Participants joined the Microsoft Teams meeting for the eye-tracking session and shared their laptop screens with the researcher throughout the session for eye-tracking set-up support (e.g., lighting and positioning), and conditions monitoring (e.g., noise or interruptions during trials). During the session, the Telephone Interview for Cognitive Status (TICS) (Brandt et al., 1988) was conducted and a link was emailed to the participant to access Gorilla (Anwyl-Irvine et al., 2020), the web-based eye-tracking platform used in the study, to complete an attentional bias measure task. Participating took up to 1.5 hours in total. The participants could have assistance from another person to navigate the study's technical requirements (e.g., accessing Microsoft Teams without software download). The study was reviewed in accordance with the procedures of the University of Reading's Research Ethics Committee and received a favorable ethical opinion for conduct (UREC 19/71).

Measures

Anxiety

The 7-item Generalized Anxiety Disorder Scale (GAD-7) (Löwe et al., 2008) was used to screen for anxiety symptoms. A score of 0 (not at all) to 3 (nearly every day) is assigned for each item giving a total of between 0 and 21. Scores of 5, 10 and 15 represent the lower cutoff point for mild, moderate, and severe anxiety, respectively. It has high internal consistency (α = 0.89) (Löwe et al., 2008).

Depression

The 9-item Patient Health Questionnaire 9 (PHQ-9) (Kroenke & Spitzer, 2002) was used to screen for depressive symptoms. The suicidal ideation item was removed due to ethical concerns. The removal of this item does not affect the interpretation of final scores (Kroenke & Spitzer, 2002). A score of 0 (not at all) to 3 (nearly every day) is assigned for each item giving a total of between 0 and 24. Scores of 5, 10, 15, and 20 represent the lower cutoff points for mild, moderate, moderately severe, and severe depression respectively. A score of ≥ 10 has a specificity and sensitivity of 88% for major depression disorder (MDD) (Kroenke & Spitzer, 2002).

Cognitive status

The 11-item Telephone Interview for Cognitive Status (TICS), developed as a screen for dementia, was used to assess the cognitive domains of memory, orientation, attention, and language. Scores range from 0 to 41 with scores ≤ 30 indicating cognitive impairment. The TICS has a discriminative ability (those with and without dementia) comparable to the Mini Mental State Exam (Folstein et al., 1975; Seo et al., 2011).

Eye tracking

Positioning the face/eyes. Participants were instructed to sit directly in front of their webcam, to only move their eyes (rather than their head or body) to look at the different parts of the screen, and to remain still and blink as little as possible. Participants viewed their video feed which was presented in the top left corner of their screens. A black box outline was overlaid in the center of the video feed, and a green face-mesh, which detects the user's face, was also displayed in the video feed. Using their video feed as a guide, participants were asked to align themselves such the video feed, and a green face-mesh, which detects the user's face, was also displayed in the video feed. Using their video feed as a guide, participants were asked to align themselves such that their faces appeared in the middle of the box. Participants were told the box outline must turn green, and the green face outline must match their features (face-mesh) (Figure 1a) to enable a start button (see Greenaway et al., 2021 for detailed face- meshing information). Glasses were only removed (where possible) if a participant's eyes were not face-meshing correctly due to lens reflection. The start button changed color to a deeper shade of red when enabled, and once clicked, the participants advanced to a calibration and validation phase.

Calibration and validation. Within the calibration phase, a 50 × 50-pixel red dot appeared consecutively in each of 9 fixed locations in a random order. The 9 locations were arranged in a 3 × 3 grid spanning the screen's height and width (Figure 1b) (see Greenaway et al., 2021; Semmelmann & Weigelt, 2018 for detailed calibration and validation phase descriptions). The participants were instructed to look at the dot as quickly as possible and fixate on it until it disappeared. The validation phase was identical to the calibration phase, except the dot was green.

Attentional bias measure

A modified dot-probe task (MacLeod et al., 2002) was used to measure AB. Each trial began with a blank screen for 500 ms. A fixation cross then appeared in the center of the screen for a fixation of 500 ms. Two faces from the same actor were then presented for 2000 ms, to the left and right of where

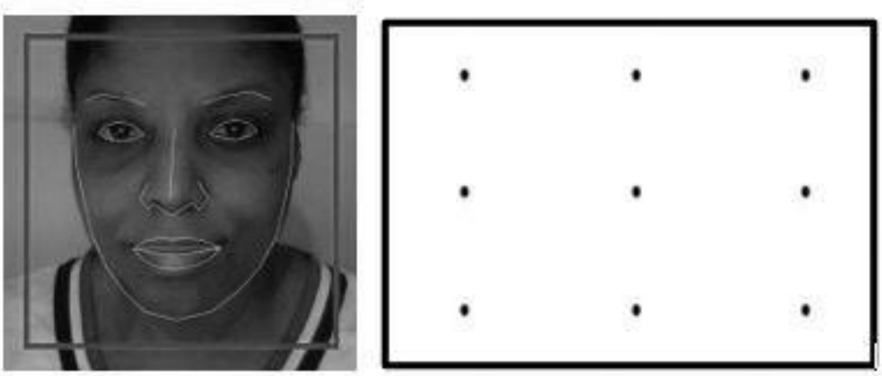

Figure 1. a). (left) showing successful face-meshing, and 1b). (right) illustrating the dot locations.

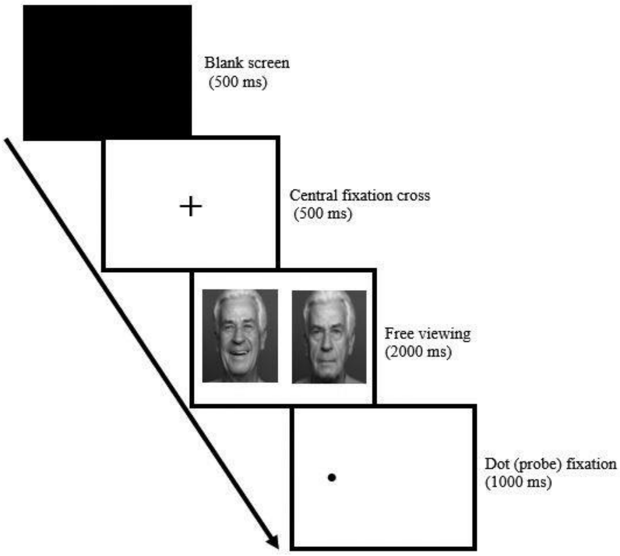

Figure 2. Showing the trial presentation.

the fixation cross had been located. The faces, selected from the FACES database (Ebner et al., 2010), were presented in sad-angry, sad- happy, sad-neutral, angry-happy, angry-neutral and, happy-neutral facial emotion pairings. Once the faces had disappeared, a black dot appeared in the center of one of the face's previous location for 1000 ms (Figure 2). Participants were instructed to look at the cross and the dot quickly and fixate on them, and to naturally view the facial stimuli when presented. A total of 96 trials were shown randomly. Each facial emotion type was presented 48 times by a total of 24 actors. Each actor was presented four times. The trials were counterbalanced for actor gender, and the side of the screen the facial emotion type and dot appeared on.

Data analysis

Descriptive and reliability analyses were performed with the Statistical Package for the Social Sciences, version 25 (IBM Corp, 2017). Significance testing and correlational analyses of AB and mood measures were not conducted due to sample size.

Cognitive status

Participants who scored between 33–41 points on the TICS were classed as cognitively non-impaired, between 26–32 points as ambiguously impaired, between 21–25 points as mildly impaired, and ≤ 20 as moderately to severely impaired (Chappelle et al., 2022).

Symptom status

Participants who scored < 5 on both the GAD-7 and the PHQ-9 scales were classified as non-anxious/non-depressed, ≥5 on the GAD-7 and < 5 on the PHQ-9 scales as anxious, and < 5 on the GAD-7 and ≥ 5 on the PHQ-9 scales as depressed. Participants who scored ≥ 5 on both the GAD-7 and PHQ-9 were classified as comorbid (anxious and depressed).

Attentional biases

The time spent looking at (dwell time in ms) each half of the screen per trial, per participant, was selected from the metrics provided by the eye-tracking platform. The dwell time was summed and averaged for each expression type in sad-neutral, angry-neutral, and happy-neutral pairings. Emotional-emotional pairings data was not analysed as the AB magnitude in these pairings can be reduced (Blanco et al., 2019). It is unclear if WBET can detect small AB differences at present. Data collection continues.

Bias scores were calculated (the emotional expression average minus the corresponding neutral expression average). Scores below zero represented a bias away from the emotional expressions and those above zero, a bias toward the emotional expressions (Duque & Vázquez, 2015; Lazarov et al., 2018).

Reliability

Internal consistency was estimated for sad, angry, and happy face dwell-times and bias scores from emotional-neutral trials using Cronbach's alpha (CA) and the Spearman – Brown corrected split- half (S-BCS-H) reliability coefficients (Sears et al., 2019; Waechter et al., 2014). Split-half reliability was based on the first half (i.e., trials 1 to 8) and second half (i.e., trials 9 to 16) of the trial dwell-times and bias scores.

Results

Participant characteristics

Due to the small sample size, group comparisons (e.g., by cognitive or mood status) were not conducted. Analyses were conducted for the full cohort, a comorbid sub-group as anxiety and depression symptoms often co-occur and can persist for older adults (Almeida et al., 2012; Braam et al., 2014), and individual participant bias scores. The average cognitive status scores for the full cohort and for the comorbid sub-group fell within the ambiguously impaired range and, on average, participants in the full cohort were also comorbid anxious and depressed (see Table 1 for descriptive data). Eight of 12 participants were classified as having mild to severe anxiety and/or depression, three of whom had scores indicative of comorbid generalized anxiety disorder (GAD) and major depressive disorder (MDD) (see Table 2 for participant data).

Attentional biases

The full-cohort and comorbid sub-group, on average, displayed a bias away from sad faces, and toward angry and happy faces, with the AB toward happy faces being more pronounced (see Table 1. for bias scores, and Figures 3. and 4. for dwell-time averages). While individual participants displayed differences in terms of bias direction and/or magnitude to each of the emotional faces, the pronounced full-cohort and comorbid sub-group average bias toward happy faces relative to sad and faces was mainly driven by participants with anxiety and/or depression (see Table 2.). Individual participants with potential comorbid GAD and MDD displayed a bias toward sad faces, and both away and toward angry and happy faces.

Reliability

For the full cohort, dwell-time CA scores (sad = −.48, angry = −.49, happy = −.49) and S-BCS-H

Table 2. Individual participants' symptom status, mood, and bias data.

		Mood		Bias score (ms)		
Participant	Symptom status	GAD-7	PHQ-9	Sad	Angry	Happy
HC1	NAD	0	1	−80	314	114
HC2	NAD	4	2	75	−92	−61
HC3	C	5	9	−567	58	−30
MCI1	NAD	0	0	27	424	338
MCI2	NAD	1	4	−177	−55	16
MCI3	C	19	24	24	184	313
pwAD1	A	17	2	−186	−225	128
pwAD2	D	4	8	154	16	393
pwAD3	C	14	20	152	324	−172
pwAD4	C	7	9	−276	69	−200
pwAD5	C	10	11	67	−245	143
pwAD6	C	7	12	−139	−158	507

GAD-7 = Generalized Anxiety Disorder scale; PHQ-9 = Patient Health Questionnaire 9 scale; HC = cognitively healthy; MCI = mild cognitive impairment; pwAD = people with Alzheimer's disease; NAD = non-anxious/non-depressed; C = comorbid anxious and depressed; A = anxious; D = depressed. Bias scores (emotional expression average minus the corresponding neutral expression average) below zero represent a bias away from the emotional expressions and those above zero, a bias toward

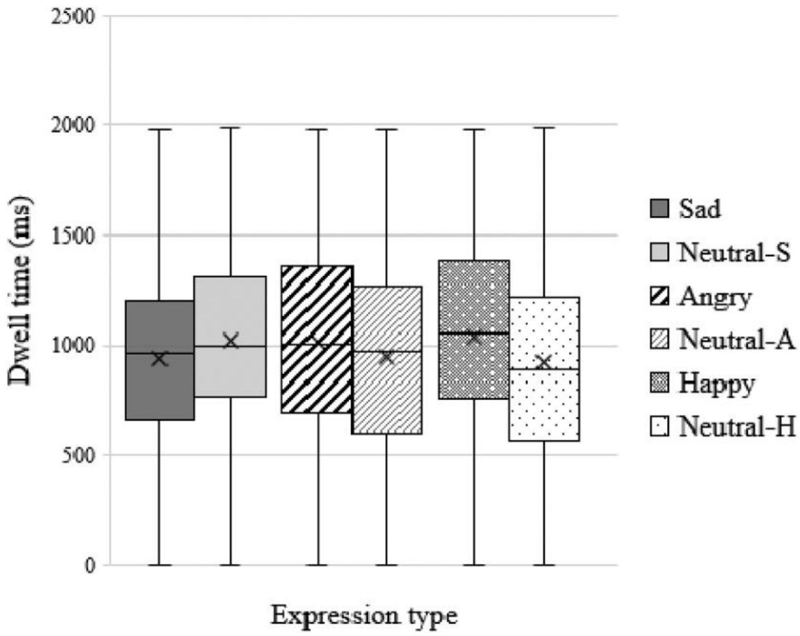

Figure 3. Showing the full cohort's (N = 12) average dwell-time data for emotional-neutral pairings. A hyphen followed by S, A, or H denotes the corresponding neutral face data for sad, angry, and happy pairings respectively. Dwell-time data were non-normally distributed.

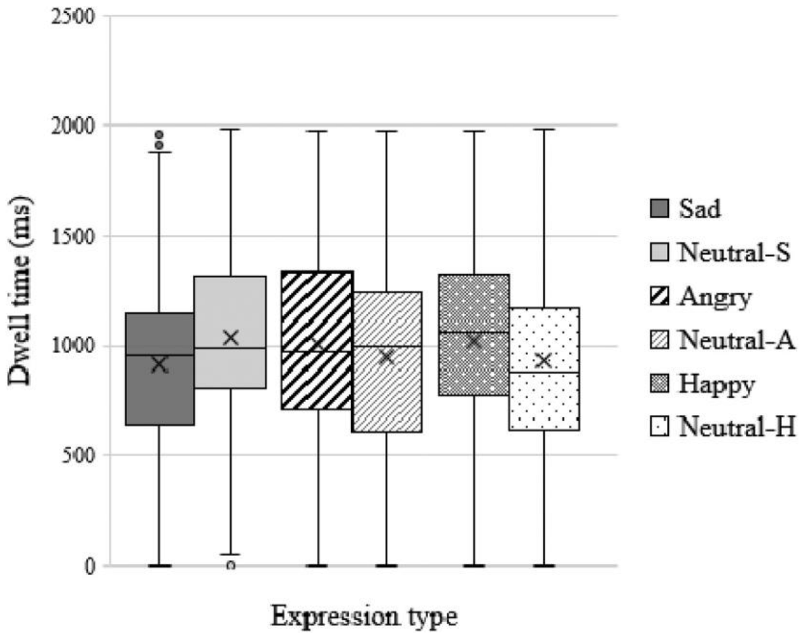

Figure 4. Showing the comorbid (anxious and depressed) group's (n = 6) average dwell-time data for emotional-neutral pairings. A hyphen followed by S, A, or H denotes the corresponding neutral face data for sad, angry, and happy pairings respectively. Dwell- time data were non-normally distributed except for angry, happy, and neutral-H face data.

estimates (sad = −.61, angry = .40, happy = .59) demonstrated low reliability. Bias score CA scores (sad = −.33, angry = −.44, happy = −.33) and S-BCS-H estimates (sad = −.42, angry = 40, happy = .62) also demonstrated low reliability (see Table 3 for reliability scores and estimates). For the comorbid sub-group, dwell-time CA scores (sad = .06, angry = −1.12, happy = .12), and

Table 3. Reliability analyses.

		Reliability			
		Dwell time		Bias score	
Expression type	*N/n*	α	r_{SB}	α	r_{SB}
Overall sample					
Sad	12	-.48	-.61	-.33	-.42
Angry	11	-.49	.40	-.44	.40
Happy	11	-.49	.59	-.33	.62
Comorbid					
Sad	6	.06	.45	.21	.56
Angry	6	−1.12	.54	−1.16	.55
Happy	5	.12	.87	.21	.87

N/n = number of participants; α = Cronbach's alpha; r_{SB}= Spearman – Brown corrected split-half coefficient.

S-BCS-H estimates for sad and angry faces (sad = .45, angry = .54) demonstrated low reliability, whereas S-BCS-H estimate for happy faces (.87) demonstrated good reliability. Bias score CA scores (sad = .21, angry = −1.16, happy = .21) and S-BCS- H estimates for sad and angry faces (sad = .56, angry = .55) demonstrated low reliability, whereas S-BCS-H estimate for happy faces (.87) demonstrated good reliability (see Table 3 for reliability scores and estimates).

Discussion

To our knowledge, this is the first study to measure the attentional biases (AB) of older adults living with and without Alzheimer's disease using webcam-based eye-tracking (WBET). Our study lays the foundation for further research exploring the potential of WBET-measured AB by providing preliminary data to inform future study design. Our study findings also contribute to the sparse older adult AB literature. We found that, on average, the full cohort and comorbid (anxious and depressed) sub-group displayed a relatively positive AB – looking at happy faces longer than sad and angry faces. While healthy older adults are thought to demonstrate a "positivity effect" (i.e., preferentially attending to positive over negative material) (Carstensen & Mikels, 2005), it was predominantly the anxious and/or depressed participants within the current study who displayed prominent, relatively positive AB, with biases toward happy faces possibly indicating increased emotional regulation strategy use (Demeyer et al., 2017). However, our findings should be interpreted with caution given the small sample size and further research is required to directly explore how older adults' AB relate to emotional regulation/dysregulation.

Although our findings for participants with mood scores indicative of comorbid GAD and MDD within the current study are in-line with previous studies (Hankin et al., 2010; Kishimoto et al., 2021; LeMoult & Joormann, 2012), the literature presents mixed results and is therefore likely to support most findings. As demonstrated by our individual participant AB data, ABs are complex and personalized (Zvielli et al., 2014) in that no two biases are the same in terms of direction and/or magnitude. Still, AB profiles were observable using WBET. The non-anxious/non-depressed participants displaying prominent AB toward angry faces relative to sad and happy faces (HC1 and MCI1) could represent individuals at risk. Biases toward angry faces can occur prior to the onset of anxiety and in individuals who have experienced past depression and are at risk of recurrence (Barry et al., 2015; Woody et al., 2016). WBET could potentially be used to monitor change in such individuals.

Though it is unclear what level of reliability is appropriate for eye-tracking measures (Waechter et al., 2014), in-line with lab-based eye-tracking studies analyzing stimuli presentation durations between 0–2000 ms with younger adults (Price et al., 2015; Sears et al., 2019; Waechter et al., 2014), WBET-measured AB generally demonstrated low dwell-time and bias score reliabilities. However, AB indices at short stimuli presentation duration tend to demonstrate low reliability whereas longer presentation durations demonstrate higher reliability in regard to word-based threat stimuli). Similarly to Sears et al. (2019), WBET AB reliability (i.e., Spearman-Brown corrected split-half estimates) was higher for happy faces than angry and sad faces.

Limitations and future studies

While we hope that our study prompts further (WBET) research examining (1) AB, anxiety, and depression in older adults which is lacking (Baruch et al., 2021; Cabrera et al., 2020), and (2) the general clinical utility of WBET, our study design (i.e., stimuli number and presentation duration) and sample size did not allow for a fuller investigation of internal consistency, and test-retest reliability was not examined. Future WBET measured AB studies may consider incorporating a large number of trials containing the contrast under focus (e.g., threat-neutral), longer stimuli presentation times (e.g., 3.5 to 8 seconds), and also conduct analyses relating to the entire stimuli time-course (e.g., total dwell-time) as these study parameters have exhibited moderate to excellent internal consistency, and adequate to high test–retest reliability of AB measures collected 30 minutes, one week, or 6 months apart (Blanco et al., 2019; Lazarov et al., 2016; Molloy & Anderson, 2020; Rodebaugh et al., 2016; Sears et al., 2019; Skinner et al., 2018; Waechter et al., 2014). However, there is still a need to establish which parameters (e.g., stimuli type [words, natural scenes, or faces], stimuli categories [dysphoric, threat, pleasant, social, illness], and contrasts [emotional-neutral, or emotional-emotional]), are more relevant and reliable in late-life depression and/or anxiety, and to investigate the reliability of AB indices using multiple test-retest points across time in depression and/or anxiety (Sears et al., 2019; Skinner et al., 2018).

Other limitations of our study are that visuospatial disturbances, and emotion study are that visuospatial disturbances, and emotion recognition capability were not assessed. Older adults with and without cognitive impairment may exhibit emotional recognition difficulties, to differing extents for different emotion types (Weiss et al., 2008). While longer looking may be associated with correct and incorrect recognition responses (Low et al., 2022), recognition errors occurring *within* attentional bias measure trials could potentially impact relative bias scores (e.g., if neutral faces were mistaken for sad faces) and therefore should be assessed. Neuropsychiatric symptom history was also not assessed but could have influenced our findings (Hankin et al., 2010). Future larger studies should allow for subgroup analysis (e.g., neuropsychiatric symptom history and symptom status), and assess visuospatial and emotion recognition capabilities. Future studies should also directly compare WBET data against data obtained from other eye-trackers.

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Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article's supplementary materials.

Clinical Implications

- Older adults' AB are measurable via WBET and may demonstrate similar reliability to lab-based studies
- With careful measurement design, WBET may provide clinicians with an additional objective tool for screening, monitoring, and evaluating

treatment response either virtually or with patients in their homes.

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4.3.1 Thesis aims and key study findings

Thesis aims 4 (to explore remotely-delivered music research with WBET involving older persons with and without AD) and 5 (to explore the feasibility of remotely-delivered multi-session ABM with WBET involving persons with and without AD) were partially explored in this section of the chapter. Importantly, findings showed that WBET measures of AB were in line with lab-based research using similar AB measure parameters. This suggested that WBET was a viable tool for measuring AB in the subsequent studies within this thesis. Following this study, Figure 1 shown in section 4.4 in this chapter was incorporated into the study design to further assist participants to position themselves and their laptop as, for example, some participants were unaware of their lap-top camera location.

4.4 Multi-session attentional bias modification using webcam-based eye-tracking. Feasibility and impact on mood for persons with and without cognitive impairment.

This section of the chapter has been submitted to the International Journal of Human-Computer Interaction.

Greenaway, A.-M., Hwang, F., Nasuto, S., & Ho, A. (2024). Multi-session attentional bias modification using webcam-based eye- tracking. Feasibility and impact on mood for persons with and without cognitive impairment. *International Journal of Human-Computer Interaction*, 0(0), 1-36.

This section of the chapter explored and confirmed the feasibility of remotely-delivered ABM with WBET for older persons with and without AD over single and repeated sessions. The impact of multi-session ABM using WBET was also explored. Findings revealed that the lowered positive affect within-sessions did not impact the overall ability of the intervention to reduce rumination levels, and yield clinically relevant changes in depression and anxiety.

Abstract

People with dementia, over time, leave their homes less for therapeutic activities and widely-administered anti-depressant treatments show low efficacy in this population. As remotely-delivered attentional bias modification (ABM) may reduce depression and anxiety in younger populations, this study investigates the feasibility of multi-session dot-probe ABM using webcam eye-tracking and its effect on participant's (Alzheimer's disease = 5, mild cognitive impairment = 3, cognitively healthy = 1) pre- and post- session/intervention mood.

Results showed that while pre- to post-session positive and negative affect scores fluctuated (reduced and increased), pre- to post-intervention reductions in anxiety, depression, and rumination scores were found. Affect change was unrelated to eye-gaze location failure. Study adherence was impacted by the participants' ability to complete tasks independently.

To conclude, multi-session ABM using webcam eye-tracking with persons with and without cognitive impairment was feasible and positively affected mood post-intervention, in spite of negative effects on momentary mood.

Keywords: Alzheimer's disease; attentional biases; anxiety; depression

Introduction

Anxiety and depression are common, often co-occurring, and difficult to treat in dementia (Bennett & Thomas, 2014; Costello et al., 2023; Goyal et al., 2019). Although the National Institute for Health and Care Excellence (NICE) dementia guideline (NICE, 2018) recommends that anti-depressant treatment should not be routinely offered to people with dementia (PwD), anti-depressant treatment is often a front-line intervention for PwD, with little efficacy (Banerjee et al., 2011; Costello et al., 2023). NICE recommends that psychological therapy should be considered for PwD in the mild to moderate stage with mild to moderate anxiety and/or depression. While recent reviews (Bell et al., 2022; Orgeta et al., 2022) suggests that psychological therapy may be more effective than anti-depressant treatment and treatment as usual, fewer PwD access psychological therapy and reliable (clinically significant) improvement and recovery is less likely for PwD compared to matched older adults without dementia (Bell et al., 2022). Though a 'something is better than nothing' stance may have be adopted by clinicians at present given the paucity of treatments (Costello et al., 2023), alternative interventions which are (1) low-cost, given the numbers that could be affected by anxiety and depression, (2) effective, and (3) lack side-effects should be explored. Potential interventions could be informed by an individual's negative biases (Costello et al., 2023).

Attentional bias modification (ABM) is a low-cost intervention based on implicit learning (Bø et al., 2021; Clarke et al., 2014) which is relatively spared in Alzheimer's disease (AD) (Choi & Twamley, 2013). ABM paradigms are based on the premise that negative attentional biases (NAB) play a core role in the aetiology, maintenance, and recurrence of anxiety and depression and encouraging attentional disengagement from negative stimuli should be associated with a reduction in NAB and symptoms levels (De Raedt & Koster, 2010; MacLeod & Clarke, 2015; Sanchez & Vazquez, 2014). Cognitive bias research with older adults living with and without dementia is scarce, particularly research examining the relationship between mood and AB using a more direct measure of AB such as eye-tracking (Arditte & Joormann, 2014; Bourgin et al., 2020; Cabrera et al., 2020). Still, studies have found that participants with Alzheimer's disease (PwAD) may dwell on or have difficulty disengaging their attention from negative stimuli (Bourgin et al., 2020; LaBar et al., 2000). Apathetic PwAD can display reduced AB towards social stimuli, and anxious and/or depressed PwAD may vary in the direction (i.e., towards or away) and magnitude of AB to sad, angry, and happy faces (Chau et al., 2016; Greenaway et al., 2023). To our knowledge, investigations of internet-based ABM interventions, with or without eye tracking, involving PwAD are lacking.

Remotely-delivered technology-based solutions are needed given recent findings (Gaber et al., 2020) that out-of-home therapy was the most abandoned out-of-home activity by community-based older persons with and without dementia. Some positive effects on depression and anxiety symptoms have been found within technology-based interventions involving participants with cognitive impairment, and the interventions have been deemed acceptable (Dequanter et al., 2021; Zhu et al., 2021). Importantly for the current study, prior work has reported that some community-based older adults living with and without cognitive impairment are willing to engage in home-based eye- tracking via their webcams (Greenaway et al., 2021, 2023). ABM using eye tracking avoids the complex cognitive processing associated with the reaction-time methodology commonly used for internet-based delivery, which could prove beneficial for PwD (Bourgin et al., 2018; Gratton et al., 2018). However, webcam-based eye tracking is associated with a high number of calibration failures (CF) (Semmelmann & Weigelt, 2018), which may lead to irritation or frustration. ABM typically involves multiple sessions, with a greater number of sessions being associated with larger effect sizes (Jones & Sharpe, 2017). Yet, a greater number of sessions potentially exposes the individual to a greater number of CF. We hypothesised that CF would have a negative impact on momentary mood (i.e., increases in CF would correspond with decreased positive affect [PA], and increased negative affect [NA]). This could negatively affect an individual's mood, potentially negating the intended intervention effect. Consequently, the current study examined the impact of completing multi-session ABM on participant mood (i.e., PA, NA, rumination, depression, and anxiety levels), and study adherence. Additionally, as the ABM paradigm used in the current study contained background music, we recorded any spontaneous comments made by the participants about the background music (e.g., its effect on mood, and potential to be distracting).

Materials and methods

Participants

Eight participants (AD = 5, MCI = 3) were recruited via the Join Dementia Research platform (https://www.joindementiaresearch.nihr.ac.uk/), and one student via a departmental recruitment platform for course credits. One participant (AD = 1) withdrew from the study during session 1. Eye-tracking datasets, from at least one full session, were obtained from five participants (AD = 3, MCI = 1, student = 1). The participants with cognitive impairment (4 males, aged 61 to 76 yrs old) were classified as being non-anxious/non-depressed (NAD) (MCI = 1), depressed (AD = 1), or having comorbid depression and anxiety (comorbid) (AD = 2). Two participants (AD = 1, MCI = 1) were taking cognitive medication (Donepezil). The student (male aged 32 yrs old) was classified as comorbid. None of the participants were taking anti-depressant medication.

All participants provided written or verbal consent before the study commenced, and participants with cognitive impairment were also required to have a carer or representative provide written or verbal confirmation of the participant's ability to provide informed consent.

Procedure

Participants completed self-report anxiety and depression screens hosted on Online surveys (https://www.onlinesurveys.ac.uk/) before their first (time point 1 [T1]) and after their last (time point 2 [T2]) ABM session. Participants joined a Microsoft Teams meeting and shared their lap-top screens with the researcher in each session. During session one, the participant's cognitive status was assessed via an interview, and they received an emailed link to Gorilla (Anwyl-Irvine et al., 2020), the web-based eye-tracking platform used in the study (see Figure 1.). Participants completed an initial eye-gaze location phase, and if eye-gaze location was successful, participants continued on the study. Participants then completed a momentary mood measure and an attentional bias measure (ABmeasure) in silence. After a 5-minute break in which the participants were free to move around, two ABM blocks were conducted with background music, with a 5-minute break following each ABM block. The same ABmeasure and momentary mood measure were then completed again, in that order.

For sessions 2 to 4, the participant received an emailed link to the eye tracking platform at a pre-set time of 10 am each day for the relevant ABM session, and a Microsoft Teams meeting reminder prior to the scheduled meeting time. The participants were informed of the eye-tracking protocol whereby the eye-tracking tasks were to be completed (1) during their scheduled Microsoft Teams meeting, and (2) in the presence of the researcher as the researcher would check for issues (e.g., with internet connections or eye-gaze location). The eye-tracking and mood tasks were conducted in the same manner as session one without the initial eye gaze location phase and an ABmeasure at the start of the session.

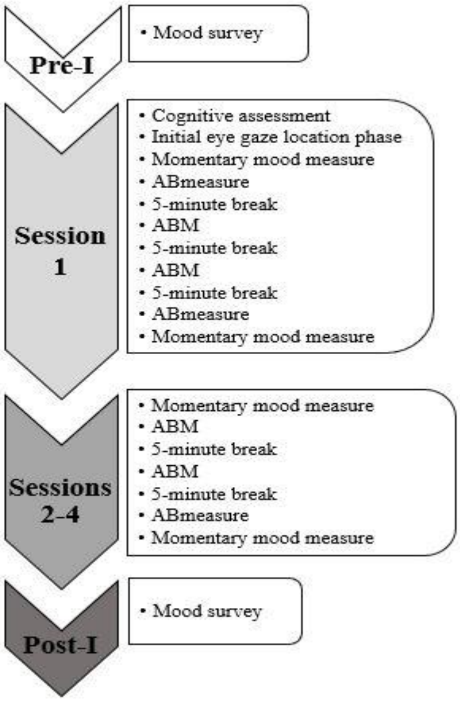


Figure 1. An outline of the online study tasks completed by the participants across the study (Pre-I = pre-intervention; Post-I = post-intervention).

Participants received support (e.g., technical, lighting, and positioning) from the researcher or their nominated person as required. The participant and their environmental conditions were monitored by the researcher (e.g., for noise or interruptions during trials) during the scheduled eye-tracking sessions. Each session lasted up to 2 hours. The study was reviewed in accordance with the procedures of the University of Reading's Research Ethics Committee and received a favourable ethical opinion for conduct (UREC 19/71).

Measures

Cognitive status

The Telephone Interview for Cognitive Status (TICS) was used to assess memory, orientation, attention, and language. A total score ranging from 0 to 41 can be generated from the summed scores from each of the 11 items, with a score of ≤30 being indicative of cognitive impairment. The TICS and the Mini Mental State Exam (Folstein et al., 1975) have comparable discriminative abilities (individuals with and without dementia) (Seo et al., 2011).

Momentary mood

The Positive Affect Negative Affect Scales (PANAS) (Watson et al., 1988) was used to measure the extent to which 10 positive and 10 negative affective states were being experienced, in the moment. A score of 1 (very slightly or not at all) to 5 (extremely) is assigned for each item. PA item scores were totalled to provide the PA score, and NA item scores totalled to provide the NA score. The total affect scores ranged from 10 to 50, with higher scores representing higher levels of affect.

Anxiety

The Generalized Anxiety Disorder Scale (GAD-7) (Löwe et al., 2008) was used to screen for anxiety symptoms. A score of 0 (not at all) to 3 (nearly every day) is assigned for each of the 7 items, with 5-9 points representing mild, 10-14 moderate, and ≥ 15 severe anxiety. The GAD-7 demonstrates high internal consistency ($\alpha = 0.89$), and a score of ≥ 10 is suggestive of generalized anxiety disorder (GAD) and other anxiety disorders (Löwe et al., 2008).

Depression

The Patient Health Questionnaire 9 (PHQ-9) (Kroenke & Spitzer, 2002) (without the suicidal ideation item) was used to screen for depressive symptoms. A score of 0 (not at all) to 3 (nearly every day) is assigned for each of the 8 items, with 5-9 points representing mild, 10-14 moderate, 15-19 moderately severe, and 20-24 severe depression. Removal of the suicidal ideation item did not affect the interpretation of total scores, and a score of ≥ 10 has a specificity and sensitivity of 88% for major depression disorder (MDD) (Kroenke & Spitzer, 2002).

Rumination

The Ruminative Response Scale (RRS) (Nolen-Hoeksema, 1991) was used to measure rumination as a response to depression levels. A score of 1 (almost never) to 4 (almost always) is assigned for each of the 22 items. The summed item scores generate a total score ranging from 22 to 88, with higher scores being indicative of higher levels of ruminative response. Items reflect three sub-types of responses: depressive, brooding, and reflective rumination. The scale shows excellent internal consistency, adequate convergent and predictive validity (Nolen-Hoeksema et al., 1993, 1994) in cognitively healthy participants, and excellent internal consistency (α = .92) and adequate test-retest reliability (r = .77) for people living with mild dementia (Greenaway et al., 2024).

Eye tracking

Detailed information regarding the calibration and validation process can be found elsewhere (see Greenaway et al., (2021) and Semmelmann & Weigelt, (2018)), and the general eye-tracking procedure summarised here, has previously been described in (Greenaway et al., 2023).

Face-meshing. A positioning slide was displayed (see Figure 2.) to help the participants position themselves. The video feed, displayed in the top-left corner of the participant's screen, contained a box outline overlaid in the center and a green face outline which detects the user's face. Participants were instructed to align themselves such that (1) their faces appeared in the middle of the box outline (the box outline would appear green if they were in the correct position), and (2) their features were matched by the face outline (face-mesh). Glasses were removed, where possible, if lens reflection interfered with face-meshing.

Figure 2. Diagram presented to participants to assist with laptop and body positioning.

Eye-gaze location (calibration and validation). Briefly, in both the calibration (first) and validation (second) phase, a 50 × 50-pixel dot appeared consecutively in nine fixed locations (a 3 × 3 grid spanning the screen's height and width) in a random order. Participants were instructed to look at the dot as quickly as possible and fixate on it until it disappeared. A red dot appeared in the calibration phase and a green dot appeared in the validation phase. The calibration and validation phases were completed three times within each ABmeasure and

ABM block (i.e., at the start of the block and two sub-block) (total across the four intervention sessions = 39).

Attentional bias measure

AB were assessed via a modified dot-probe task (MacLeod et al., 2002). Each trial began with a blank screen (500 ms), followed by a fixation cross which appeared in the centre of the screen (500 ms). Emotional-neutral and emotional-emotional facial pairings were then presented to the left and right of where the fixation cross had been located (2000 ms). The pairings, from the same actor, were selected from the FACES database (Ebner et al., 2010) and consisted of sad, angry, happy, and neutral facial expressions. Once the faces had disappeared, a black dot appeared in the centre of one of the face's previous locations (1000 ms) (see Figure 3.). Participants were instructed to (1) look at the cross and the dot as quickly as possible and to fixate on them, and (2) to naturally view the faces when they appeared. The ABmeasure block contained 96 trials which were divided into three sub-blocks, each containing 32 trials. Each emotion type was presented 48 times by 24 actors who were each displayed four times. The dot was presented in the previous location of each emotion an equal number of times. The trials were shown randomly and counterbalanced for actor gender, and the side of the screen the emotion type and dot appeared on.

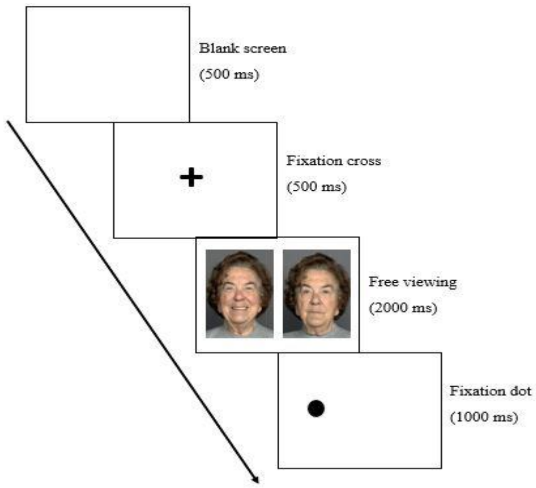


Figure 3. Diagram of stimuli position, order, and presentation duration in an example trial. The facial images and cross positions were consistent across trial, and the dot was displayed in the same position on the right side of the screen at an equivalent frequency to the left side of the screen.

Attentional bias modification

The ABM block was conducted in the same manner as the ABmeasure block except (1) background music was played from the onset of the first slide in the block until the end of the last side in the block, (2) the faces were only presented in sad-happy, sad-neutral, angry-happy, and angry-neutral emotion pairings, (3) a total of 48 actors were each presented twice, and (4) the dot only appeared in the previous location of happy and neutral faces.

Music stimuli

The participants were played two music tracks, one per ABM block. Both of these tracks were created using consonant intervals which is typically associated with positive emotions and rated as pleasant (Blood et al., 1999). One track was created in a romantic period style using string sounds, had a consonant interval sets of thirds, fourths and fifths, and a tempo of quarter note = 36, and the other was algorithmically generated using harp sounds, had a consonant interval sets of perfect fourths, perfect fifths, and octaves, and a tempo of seven notes per second (see Bravo et al., (2017) and Bravo et al., (2020) for detailed composition information, respectively).

Data analysis

Symptom status

The presence of anxiety (GAD-7) and depression (PHQ-9) was indicated by ≥5 points on each scale (Kroenke & Spitzer, 2002; Löwe et al., 2008). As such, participants who scored <5 on both the PHQ-9 and the GAD-7 were classified as NAD. Participants were classified as anxious if they scored <5 on the PHQ-9 and ≥5 on the GAD-7, and depressed if they scored ≥5 on the PHQ-9 and <5 on the GAD-7. Participants were classified as comorbid if they scored ≥5 on both the PHQ-9 and GAD-7.

Rumination

A median split RRS score of 47 was used to classify participants as low and high ruminators (below and above the median score, respectively) (Watkins & Mason, 2002).

Clinically significant change

A change (plus or minus) of 4 points on the GAD-7 and 5 points on the PHQ-9 was used to indicate clinically significant changes in anxiety and depression, respectively (Kroenke, 2012; Toussaint et al., 2020).

Momentary mood

Pre to post-session affect comparisons. Each participant's pre- and post-session PA and NA scores were plotted for each session. The number of post-session measures that were completed across the cohort was totalled, and the number of instances in which the post-session score increased and decreased from the pre-session score, was summed and reported.

Pre to post-intervention affect comparisons. Each participant's post-intervention (i.e., the last momentary mood measure) (T2) PA and NA scores were subtracted from their pre-intervention (i.e., the first momentary mood measure) (T1) PA and NA scores.

Calibration failures and momentary mood

For each participant, the calibration failures (CF) which occurred within each of the ABmeasure and ABM blocks that the participant completed, were totalled for each session. The CF total was then plotted against the participant's PA and NA scores for the corresponding session.

Eye-gaze accuracy

The Support Vector Machine (SVM) classifier score provided within the Gorilla output data rates how strongly the image in the model resembles a face (0 [no fit] to 1 [perfect fit]) and therefore provides an indicator of how accurately eye movements are being predicted. Gorilla advises that a score above 0.5 is considered ideal. The SVM scores for the eye-tracking tasks completed during the scheduled sessions where the researcher was present (protocol) were compared to scores obtained when the participant deviated from the protocol and completed these tasks before the scheduled session, in the researcher's absence. The pre-session (baseline) ABmeasure was excluded from relevant comparisons as it was only conducted once, in the presence of the researcher.

Results

Significance testing and correlational analyses of attentional bias and mood measures were not conducted due to the small sample size.

Participant characteristics

The NAD and depressed participants had the lowest levels of anxiety and depression and were classified as low ruminators (see Table 1. for descriptive data). The comorbid participants reported depressive symptoms indicative of MDD, two of whom also reported anxiety symptoms indicative of GAD and were classified as high ruminators.

Table 1. Participant demographic, mood, and calibration failure data

			PA		NA		GAD-7		PHQ-9		RRS	
Participant	Age	TICS	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
MCI	73	32	34	37	11	10	1	2	4	3	30	29
PwAD 1	67	33	26	27	12	10	4	2	8	7	35	28
PwAD 2	76	34	45	45	34	30	10	5	11	1	50	38
PwAD 3	61	26	39	40	10	10	7	-	12	-	47	-
YA	32	-	24	34	12	10	15	11	13	11	66	65

Notes. PA = positive affect; NA = negative affect; GAD-7 = Generalized Anxiety Disorder scale; PHQ-9 = Patient Health Questionnaire 9 scale; RRS = Ruminative Response Scale; T1 = timepoint one; T1 = timepoint two; TICS = Telephone interview for cognitive status; MCI = mild cognitive impairment; PwAD = participant with Alzheimer's disease; YA = younger adult.

Momentary affect

Pre-session and post-session momentary mood comparisons. Seventeen post-session momentary mood measures were completed in total across the cohort. PA scores were reduced more often (n = 10) than they were increased (n = 6) or showed no change (n = 1) within these measures (see Figures 4.a-e)). Reductions in PA scores of up to 14 points and increases of up to 6 points were reported in post-session measures when compared to pre-session measure scores. NA scores were reduced (n = 7) or showed no change (n = 7) more often than they increased (n = 3) (see Figures 4.a-e)). Reductions in NA scores of up to 9 points and increases of up to 6 points were reported in post- session measures when compared to pre-session measure scores.

Pre-intervention and post-intervention momentary mood comparisons. Post-intervention PA scores increased by between 1-10 points for three of the four participant who completed the full intervention, whilst the remaining participant reported the same pre- and post-intervention score (see Table 1. for pre- (T1) and post-intervention (T2) affect scores). NA scores decreased by between 1-4 points for all four participants. The PA type which most often increased post-intervention was ‘proud’, and the types which most often decreased were ‘interested’ and ‘alert’ (see Table 2. for PA and NA item change scores). The only NA type which increased post-intervention, in one instance, was ‘scared’, and the type which most often decreased was ‘nervous’.

Table 2. Participant momentary mood change data

		Change in affect				
	Affect type	MCI	PwAD 1	PwAD 2	PwAD 3	YA
PA	Interested	-1	-2	0	0	2
	Excited	0	0	0	1	1
	Strong	0	2	1	0	1
	Enthusiastic	1	-1	0	0	1
	Proud	1	2	-1	1	2
	Alert	1	0	0	-1	-2
	Inspired	0	1	-1	0	1
	Determined	-1	1	1	0	1
	Attentive	1	-1	0	0	1
	Active	1	-1	0	0	2
NA	Distressed	0	0	0	0	0
	Upset	0	0	0	0	-2
	Guilty	0	0	-1	0	0
	Scared	0	0	2	0	-2
	Hostile	0	0	-1	0	0
	Irritable	0	0	-2	0	-1
	Ashamed	0	0	-2	0	0
	Nervous	-1	-1	0	0	-2
	Jittery	0	-1	0	0	-2
	Afraid	0	0	0	0	0

Notes. MCI = mild cognitive impairment; PwAD = participant with Alzheimer’s disease; YA = younger adult; PA = positive affect; NA = negative affect. Change in affect = post-intervention score minus pre-intervention score.

Anxiety, depression, and rumination

Four participants completed T1 and T2 anxiety and depression measures. The NAD participant reported an increase (1 point) in anxiety whereas the depressed and comorbid participants reported reductions (2-5 points) in anxiety post-intervention, with the comorbid participants showing clinically significant reductions (4 and 5 points). All of the participants reported lower depression levels post-intervention, with one participant showing a clinically significant reduction (10 points).

All participants reported reductions (1-12 points) in rumination levels post-intervention.

Calibration failure and momentary mood

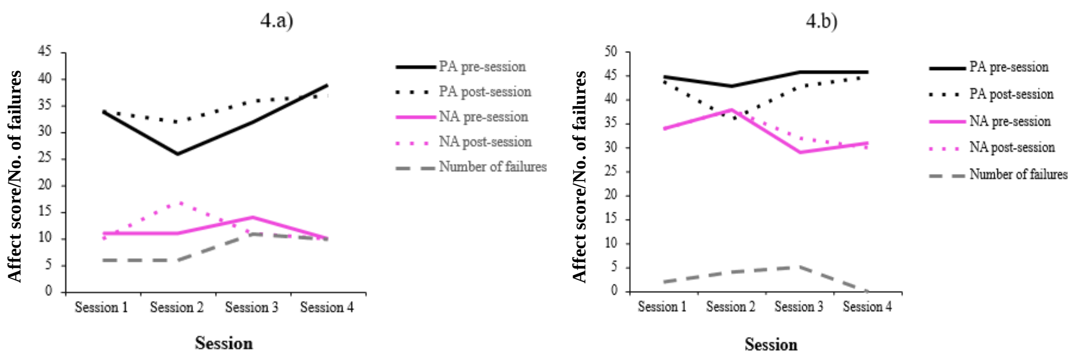
The number of calibration failures (CF) varied across blocks and sessions, showing no pattern to their occurrence (e.g., a higher number of CF during the latter AB tasks/sessions) (see Table 3.). At least one CF occurred in 54-100% of the blocks conducted by the participants, with only one participant experiencing no CF, in a single session. The largest number of CF were due to slow internet connection. For the two participants (PwAD 1 and YA) who completed all sessions without internet issues and adhered to the study protocol, the older participant incurred fewer (n = 11) CF than the younger participant (n = 18) (see Table 1. for participant CF totals).

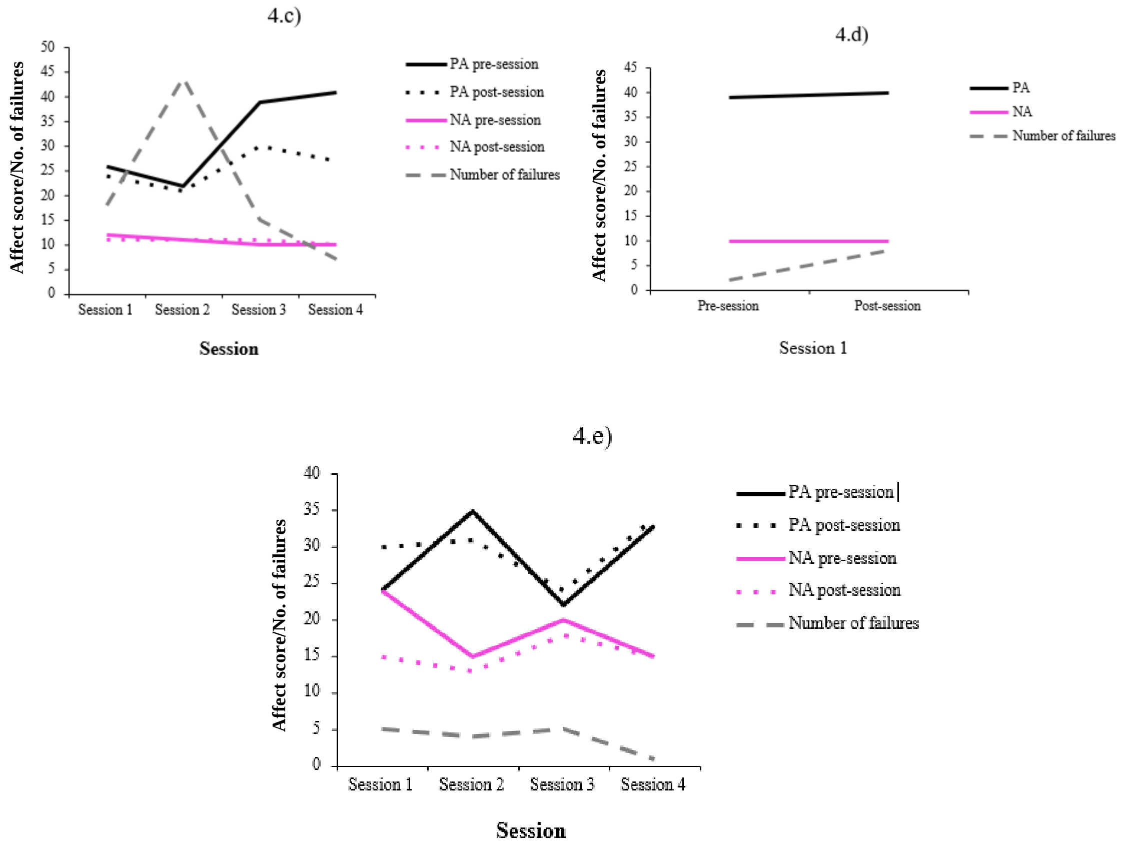
With the exception of PwAD 1 (i.e., session 3 NA score), the largest negative changes (reduction in PA, increase in NA) did not correspond with the highest number of CF, and both negative and positive (increase in PA, reduction in NA) changes in PA and NA were seen in the sessions with the highest number of CF (see Figures 4.a to 4.e.). However, CF resulted in one participant's withdrawal from the study during session 1. Although withdrawal occurred before the post-session momentary measure, the researcher noted signs of a negative impact such as the participant 'sighing' upon CF, furrowed eyebrows, and showing increased slumping of the body over time (Kohler et al., 2004; Nair et al., 2015). The participant with the highest number (n = 84) of CF chose to continue participating each time they were asked if they wished to continue with the task. Although their CF did not correspond with their momentary mood scores, the participant stated, '[CF] starts to make you feel like you're doing something wrong'.

Table 3. Participant calibration failure data

		Calibration failure				
		Session 1	Session 2	Session 3	Session 4	Total
MCI	ABmeasure 1	4				
	ABM block 1	1	**2**	**5**	4	
	ABM block 2	0	**1**	**0**	5	
	ABmeasure 2	1	**3**	**6**	1	33
PwAD 1	ABmeasure 1	0				
	ABM block 1	0	1	2	0	
	ABM block 2	2	1	1	0	
	ABmeasure 2	0	2	2	0	11
PwAD 2	ABmeasure 1	4				
	ABM block 1	6	4	3	**4**	
	ABM block 2	6	*21*	2	2	
	ABmeasure 2	2	*19*	*10*	1	84
PwAD 3	ABmeasure 1	2				
	ABM block 1	1				
	ABM block 2	4				
	ABmeasure 2	8				15
YA	ABmeasure 1	3				
	ABM block 1	0	2	3	0	
	ABM block 2	2	0	0	0	
	ABmeasure 2	0	5	2	1	18
PwAD 4	ABmeasure 1	4				
	ABM block 1	21				
	ABM block 2	Withdrew				
	ABmeasure 2					25

Notes. MCI = mild cognitive impairment; PwAD = participant with Alzheimer's disease; YA = younger adult; AB = attentional bias; ABM = attentional bias modification; bold text = calibration failures occurred when the researcher was absent; italic text = calibration failures occurred due to slow internet connection.





Figures 4.a) to 4.e). Positive and negative affect scores against the number of calibration failures per session for the participants who completed at least one full session (participant with mild cognitive impairment = 4.a); participants with Alzheimer's disease 1 = 4.b), 2 = 4.c), and 3 = 4.d); younger adult = 4.e).

Study adherence, calibration failure, and eye-gaze accuracy

Adherence. All of the scheduled meeting sessions were attended by the participants. Two participants deviated from the study protocol of completing the eye-tracking tasks in the presence of the researcher during their scheduled Microsoft Teams meeting. One participant (MCI) completed the eye-tracking tasks independently on two occasions (sessions 2 and 3). After the first occasion (session 2), the participant advised that they had received the eye-tracking task invite email in the morning so had 'got it [the task] out of the way'. After the second occasion (session 3), the researcher was advised that the eye-tracking tasks had been completed earlier due to an impromptu event. However, two ABmeasure sub-blocks were in fact outstanding and the participant was prompted to complete these tasks. Participants could return to the point where they left off via the session's eye-tracking invite email. The second participant (PwAD 2) completed the first sub-block of the ABM task before the start of session 4's scheduled meeting to, 'save time'. Due to this, we had the opportunity to compare the number of calibration failures and eye-gaze accuracy for the tasks completed in the presence and absence of the researcher. For MCI, fewer CF occurred when the researcher was present (*n* = 12) than when absent (*n* = 17), but the average post-session ABmeasure SVM scores showed little difference (researcher present = 0.70, and 0.74, researcher absent (0.74 and 0.70) (see Table 3. for CF data and Appendix C [pg. 298] for SVM data). For PwAD 2, the same number of CF occurred when the researcher was present (sub-block 2, *n* = 2) as when absent (sub-block 1, *n* = 2), and the SVM scores also showed little difference (researcher present = 0.77, researcher absent = 0.74). All of the independent session/tasks SVM scores were above the ideal score of 0.5.

Participant spontaneous comments

Although none of the participants spontaneously stated that the background music was distracting, liked, or disliked, one participant commented on the effect of the music on their mood stating, ‘it’s calming’. They also commented on their ability to conduct the eye-tracking tasks stating, ‘I needed support on the first day but I was confident for the other days. But it was good to have someone to hand [if anything went wrong]’. This participant also commented on their physiological state stating, ‘I’m a bit tired’ towards the end of session 3, and ‘my eyes are a bit tired’ at the end of session 4.

Another participant commented on their within-trial experience stating, ‘I’m finding it difficult not to pre-empt where the dot will appear’ after the first ABmeasure sub-block, but that they were ‘responding more naturally’ during the subsequent ABM task. They also reported daydreaming and familiarity in the facial stimuli stating, ‘I found my mind was wandering’, and that, ‘I’m starting to see some of my friends’ faces [in the facial stimuli]’ at the end of Session 4.

Another participant commented on how they were interacting with the study paradigm stating, ‘I like to understand how things tick’ and reported using strategies, ‘I always looked at the negative faces, then only looked at the positive faces but that didn’t work’, in attempts to solve the paradigm contingency during their unsupervised eye-tracking sessions.

Discussion

The aims of the current study were to examine the feasibility and effect of completing multi-session attentional bias modification (ABM) on participant mood (i.e., positive affect [PA], negative affect [NA], rumination, depression, and anxiety levels), whether calibrations failures corresponded with fluctuations in PA and NA, and study adherence. Our findings are important as few studies report on the potentially negative effects of internet-based interventions (Boettcher et al., 2014). Our pre- and post-session momentary mood data suggests that task completion generally (1) affected PA more than NA, (2) reduced PA, and (3) reduced or had no effect on NA. However, it is possible that the music modulated the effect of task completion on participant mood, and the net result (e.g., positive music effects minus negative task effects or vice versa) was measured. It is also possible that NA was buffered by the researcher's presence as the participants knew the researcher was 'to hand' should anything go wrong. Our pre- and post-intervention data suggests that task completion positively affected (1) (increased) PA (e.g., 'proud'), (2) (reduced) NA (e.g., 'nervous'), and (3) (reduced) anxiety, depression, and rumination levels. Although these findings are promising in that mood was improved post-intervention rather than deteriorating, we caution against making ABM efficacy inferences based on our findings. Future larger studies are required to replicate these findings and to ascertain which of the intervention components (e.g., AB change, and/or the music, and/or researcher contact) are associated with mood change.

While our findings suggest that CF and affect change did not correspond, participants who withdraw from studies such as this, such as the one participant who withdrew from the present study, may be more affected by CF. Future study design should provide an opportunity for the withdrawing participant to complete a mood measurement at their given exit point. It is possible that the background music modulated the effect of CF on participant mood. For example, the only participant to comment on the music, stating, 'it's calming', had the highest number of CF. Additionally, the number of ABM sessions can vary greatly (e.g., 1-28 session (Mogoaşe et al., 2014)) in research. Conducting a larger number of sessions than was done for the current study, and therefore exposing participants to more CF, could possibly lead to different findings.

Our findings show that study adherence was affected by the participant's (1) access to the tasks, (2) ability to complete the tasks independently, (3) choice, and (4) scheduling needs. Non-adherence to the eye-tracking task protocol (i.e., completing the eye-tracking tasks during scheduled meeting with the researcher) affected task completion (i.e., a delay between the start of a task and its completion and an error in the completion status of said task). However, non-adherence allowed us to present novel and important findings that after some exposure to the experimental paradigm (one session), some participants with Alzheimer's disease (PwAD) and mild cognitive impairment (MCI) could/selected to conduct the task independently, and that independent completion had minimal impact on eye-tracking accuracy as assessed by the face-meshing model's accuracy of face detection. Though it is important to monitor the participant (e.g., for distractions) during attention tasks, these findings may be useful for studies in which participant observation is less important. In terms of ABM using eye-tracking, there is, as an example, the potential for one clinician/researcher to oversee multiple participants in one session who are completing tasks independently after one training session. This could be achieved simply via the use of multiple laptops, each conducting a single meeting session, with the clinician's/researcher's meeting microphones on mute unless they need to address a particular participant.

Although only one PwAD spontaneously reported mind-wandering, it is possible that other participants experienced mind-wandering but were unaware or did not report it (Smallwood & Schooler, 2015). Mind-wandering is the switching of attention from an external current task to self-generated thoughts, and can be related to task monotony, depression, and rumination (Smallwood & Schooler, 2015; Thomson et al., 2015; van Vugt & van der Velde, 2018). PwAD have been shown to intentionally and unintentionally experience a higher occurrence of mind-wandering than age-matched control participants, and a higher occurrence of mind-wandering can be associated with a higher level of depression (El Haj et al., 2019). It is possible that higher levels of mind-wandering during an ABM intervention could be associated with diminished intervention effects if being on-task delivers the anxiolytic effects. Still, the mind- wandering content in itself, e.g., if it is future-related, could have positive effects on subsequent negative mood, social problem solving, and cortisol levels (Ruby et al., 2013; Smallwood & Schooler, 2015). Nonetheless, mind-wandering may need to be a consideration in future studies.

One participant reported familiarity in the study images stating, 'I'm starting to see some of my friends' faces'. Repeated exposure of the same actor with different facial expression may become familiar/recognised by participants (Kramer et al., 2018). As the effect of ABM could be affected by the repeated use of the same trials (Heeren et al., 2015), it may be beneficial to use distinct trials (i.e., as many different actors as possible) to avoid familiarity effects while potentially increasing intervention efficacy.

Limitations and future studies

The limitations of our study include sample size and that the effect of muti-session ABM without background music was not assessed. While our focus was to examine the feasibility of the specific paradigm used in the current study, the inclusion of music may have possibly reduced/obscured the negative impact of CF on mood. Future studies could replicate the study without the use of background music to gain a clearer picture of the impact of CF on mood. Another possible limitation may be the timing of the mood assessment. As the number of CF varied throughout the sub-blocks, it is possible the effect of CF on momentary mood varied throughout the task, and only the effect of the final sub-block was measured. Future studies may wish to conduct a mood assessment after each sub-block.

Recommendations

In this study, it was possible for participants to perform the eye-tracking tasks independently as access was not restricted, however, any studies in which participant observation is important should ensure to restrict access to the eye-tracking task. Successful eye-gaze location at the initial calibration/validation stage did not guarantee in-task calibration/validation success, nor did a high number of CF during one session necessarily mean a high number of CF during the subsequent session. As such, we recommend that an initial calibration/validation phase could be included for participant practice, and that all participants should be given multiple opportunities to complete study tasks, particularly as the interval between ABM sessions may not influence the intervention effect size (Cristea et al., 2015; Mogoaşe et al., 2014). We also recommend the use of distinct trials (i.e., a different actor expressing the emotional pair in each of the trials) in an attempt to avoid thoughts about stimuli familiarity.

Gorilla, the eye-tracking platform used in the current study, recommends that a calibration/validation phase should be conducted approximately every three minutes/10 trials to help account for participant movement. Given that experiencing zero CF within a session was the exception in the current study, multiple calibration/validation phases are indeed necessary. However, future versions of webcam-based eye-tracking programs could be designed to indicate when recalibration is necessary (i.e., drift/movement detection and notification message), rather than researchers having to rely on pre-determined calibration/validation phase occurrences.

Conclusion

Our findings indicate that multi-session ABM using eye-tracking is feasible for persons with and without Alzheimer’s disease and could be associated with post-intervention improvement in mood, in spite of momentary negative mood effects. While calibration failure and momentary mood fluctuation did not seem to correspond, this may be a result of study design. Encouragingly, some participants with cognitive impairment (AD and MCI) conducted eye-tracking tasks independently under their own volition, with minimal impact on eye-tracking accuracy as assessed by the face-meshing model's accuracy of face detection. Although this may not be true in all future instances, it is a promising indicator for webcam-based eye-tracking studies with persons with cognitive impairment that do not require observation.

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Disclosure statement

The authors report there are no competing interests to declare.

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

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4.4.1 Thesis aims and key study findings

Thesis aim 5 (to explore the feasibility of remotely-delivered multi-session ABM with WBET involving persons with and without AD) was explored in this section of the chapter. Importantly, conducting multiple sessions of WBET AB measures and ABM was feasible and tolerated by PwAD, and findings showed the potential of ABM with music as an intervention to reduce rumination, depression, and anxiety for PwAD and younger persons.

Chapter 5

Music and attentional biases

This chapter has been submitted to Sage Open.

Greenaway, A.-M., Hwang, F., Nasuto, S., & Ho, A. (2024). Increased attention to the eye region when playing background music in Alzheimer's disease: A webcam eye-tracking proof-of-concept study, *Sage Open*, 1–34.

This chapter explored the incorporation of WBET into remotely-delivered music research involving older persons with and without cognitive impairment. The experimental procedure was designed to explore the effect of music on the AB of older persons with and without cognitive impairment by comparing the dwell-time on emotional facial expressions and two regions (i.e., containing the eyes and the mouth) of these images when viewed in silence and when background music was played. This remotely-delivered music research with WBET was feasible (i.e., full and usable datasets were obtained for some participants). While the differences in AB found between the silence and music conditions for high and low ruminators requires further investigation in appropriately powered studies, preliminary data for such studies were now provided.

Increased attention to the eye region when playing background music in Alzheimer's disease: A webcam eye-tracking proof-of-concept study

Paying less attention to discriminating facial features, e.g., the eyes, has been linked to impaired social interaction and depression. Music is commonly used in dementia-care to facilitate social interaction and reduce depression, but a limited amount of music research has been conducted outside of care settings. And while dwell-time on discriminating facial features can change after music exposure/interventions, and rumination levels can effect what is attended to and responses to music, research involving older-persons/with dementia is lacking. To this end, the feasibility of incorporating webcam-based eye-tracking (WBET) within remotely delivered music-based research was explored. Older persons completed online self-report mood/rumination measures and a cognitive status interview. Dwell-time on facial images was measured via home-based WBET in silence and then with background music. Participants fixated on a cross, naturally viewed pairings of sad, angry, happy, and neutral faces, and then fixated on a dot. The percentage dwell-time on emotional faces, and the top-half versus the bottom-half of these images (i.e., discriminating feature regions containing the eye and the mouth, respectively) were compared. Our findings show that it is feasible (i.e., full datasets were collected for both conditions) to use WBET in remotely-delivered music-based research involving older persons with and without AD or MCI (albeit for a limited number of individuals). In the background-music condition, dwell-time (1) increased on sad faces but reduced on angry faces for participants with and without cognitive impairment, (2) increased on happy faces and the top-half of images for participants with cognitive impairment but reduced for participants without cognitive impairment, and (3) high and low ruminators displayed opposing changes (reduced and increased dwelling, respectively). Hypotheses based on these findings were generated for future in-lab versus remote WBET testing. In conclusion, we provide descriptive data showing that older persons' AB to emotional faces and facial feature regions may be altered by music. Our findings support the notion that rumination should be considered within older-person music interventions/studies. As the study attracted participants who had not previously taken part in an eye-tracking study, WBET may be an accessible way to engage in eye-tracking studies for some individuals. Practical recommendations are provided for future WBET research.

Keywords: Alzheimer's disease, attentional biases, mood, rumination, webcam eye-tracking

Increased attention to the eye region when playing background music in Alzheimer's disease: A webcam eye-tracking proof-of-concept study

Persons with dementia and mild cognitive impairment often experience depression and anxiety (Botto et al., 2022; Ma, 2020), which are associated with adverse effects such as an increased risk of Alzheimer's disease for individuals with mild cognitive impairment, increased cognitive decline, a reduced quality of life, and higher residential care-home admissions (Breitve et al., 2016; Gallagher et al., 2011; Gonfrier et al., 2012; Spalletta et al., 2012). Music (listening or making) is commonly used as a non-pharmacological approach to alleviate the neuropsychiatric symptoms experienced by persons with cognitive impairment due to its accessibility and lack of/minimal side-effects (Garrido, Dunne, et al., 2017; Ito et al., 2022). Music studies involving older adults are conducted in a variety of settings such as hospitals, nursing homes, psychiatric wards, and in the community (e.g., daycare centres, singing clubs, and participant homes) (Dhippayom et al., 2022; Moreno-Morales et al., 2020; Sousa et al., 2020; Zhang et al., 2017). However, a Cochrane systematic review (van der Steen et al., 2018) found no clinical trials that had been conducted in the homes of persons with dementia, stating that future studies could focus on persons with early dementia residing at home as all the studies included in the review were conducted in nursing/residential care homes or hospital settings. While the choice of setting may be determined by factors such as resources (e.g., financial and/or researchers/staff), gaining access to participants, and/or the increased level of symptoms (e.g., depression and anxiety) experienced by persons in these settings, a larger proportion (up to 80%) of persons with dementia are community-dwelling (Livingston et al., 2014). Therefore, the literature base may not be representative of the majority of persons with dementia.

Alongside the relatively understudied community-dwelling population, we also find that the effect of music on visual attention and/or attentional biases (AB) (the types of visual stimuli that individuals attend to or avoid) has been understudied in dementia. Although studies report that music can affect attention (e.g., processing speed and attentional switching) for persons with dementia and mild cognitive impairment as measured by standard cognitive tests (Ito et al., 2022; Jordan et al., 2022), little focus has been devoted to exploring how music may alter what is attended to using real world imagery, e.g., faces and scenes. In fact, few studies in general examine the effect of music on facial (image) viewing (Kallinen, 2017).

Older persons' attentional biases

AB are thought to play a key role in the aetiology, maintenance, and recurrence of anxiety and depression, yet AB research with older persons with and without dementia is scarce (Arditte & Joormann, 2014; Bourgin et al., 2020; De Raedt & Koster, 2010; MacLeod & Clarke, 2015; Sanchez & Vazquez, 2014). Using eye-tracking, an ecologically valid assessment of AB (Arditte & Joormann, 2014; Bantin et al., 2016), studies have shown that cognitively healthy older adults can demonstrate AB for positive stimuli (Demeyer et al., 2017). Persons with Alzheimer's disease can look longer at and have shown difficulty disengaging their gaze from negative stimuli compared to neutral stimuli (Bourgin et al., 2020; LaBar et al., 2000). Others have found that persons with Alzheimer's disease experiencing apathy can display reduced AB towards social stimuli (Chau et al., 2016). Investigating the AB of persons with dementia using eye-tracking could prove beneficial to clinicians (Greenaway et al., 2023) as depression and anxiety treatment response can be difficult to assess (e.g., relating to the type of outcome measure used [self-report, or proxy]) (Dudas et al., 2018). Although anti-depressant treatment is the front-line intervention for persons with dementia experiencing depression (Banerjee et al., 2011), the National Institute for Health and Care Excellence dementia guidelines (NICE, 2018) recommends that psychological therapy should be considered for individuals with mild to moderate depression. However, some of the evidence for psychological therapy has been of low quality and scientific rigour in this area of study could be improved (Cheston & Ivanecka, 2017; Pink et al., 2018; Regan & Varanelli, 2013). As AB can be modified following cognitive behavioural therapy in cognitively healthy older adults, and anti-depressant treatment in other populations, with early changes in AB being associated with successful anti-depressant treatment (Godlewska & Harmer, 2021; Harmer et al., 2009; Mohlman et al., 2013; Zhang et al., 2020), there is the potential for AB to provide an objective outcome measure. To our knowledge, it is yet to be established if the AB of persons with dementia or mild cognitive impairment are modified during or after psychological, non-/pharmacological intervention. Here, we focus on music, a commonly used non-pharmacological intervention delivered to persons with dementia.

Music and visual attention

Music may impart therapeutic effects on depression and anxiety by, for example, modulating the stress response, regulating emotion, inducing positive affect, and modulating the production of neurotransmitters (e.g., dopamine and serotonin) which can be depleted in depression and anxiety (Chanda & Levitin, 2013; Evers & Suhr, 2000; Menon & Levitin, 2005; Schäfer et al., 2013; Thoma et al., 2013; Xing et al., 2016; Zarrindast & Khakpai, 2015). These neurotransmitters, amongst others (e.g., acetylcholine, and oxytocin), play important roles in attention allocation/visual processing (e.g., perception, social cue and stimuli processing, and saliency detection) (Lockhofen & Mulert, 2021). Eye tracking using lab-based or mobile eye-tracking technology (e.g., glasses) is increasingly used within music-based research to examine, for example, music reading ability, ensemble members' eye gaze, and the effect of music on scene perception (Frank et al, 2019; Petružálek et al., 2018; Puurtinen, 2018; Vandemoortele et al., 2018). Music can implicitly modulate attention allocation (e.g., fixations) and AB for emotional stimuli for younger adults (Arriaga et al., 2014; Bravo, 2014; Invitto et al., 2017; Mera & Stumpf, 2014; Millet et al., 2021) and increase emotion recognition accuracy and dwell-time on the face for individuals on the autistic spectrum (Ramirez-Melendez et al., 2022; Thompson & Abel, 2018).

Similarly to individuals on the autistic spectrum who dwell less on the face and the eyes (Tanaka et al., 2017; Thompson & Abel, 2018), emotional recognition can be impaired for individuals with depression and older persons with and without cognitive impairment, and could be linked, in part, to insufficient viewing of facial regions used in emotional discrimination (e.g., the eyes) (Low et al., 2022; Noiret et al., 2015; Ogrocki et al., 2000; Phillips et al., 2010; Weiss et al., 2008). Looking at the upper half of the face, particularly the eyes, is thought to facilitate the identification of anger and sadness, whereas the lower half of the face, particularly the mouth, facilitates the identification of happiness (Ebner et al., 2011; Eisenbarth & Alpers, 2011; Low et al., 2022). Increased viewing of the eye region can improve emotional recognition for persons with Alzheimer's disease (Hot et al., 2013). While eye contact can be assessed within music-based research for persons with dementia (Clare et al., 2020), to our knowledge, it is yet to be established if music modulates the relative dwell-time on facial regions important in emotional discrimination, and whether different effects are seen for different emotional expressions via eye tracking.

However, recruitment of older persons with dementia in lab or clinic-based research, such as eye tracking, may be hampered by mobility and travel issues (Bartlett et al., 2019). Eye-tracking studies that can be conducted remotely could be an option for some individuals. Researchers have used portable eye-tracking devices and utilised device-embedded cameras (e.g., tablets) to assess the cognitive status of community-based persons with dementia (Paletta et al., 2020). Calibration (eye-gaze location) issues/failure due to glasses wearing, irregular pupil shape, and cataract, for instance, can result in a loss of participants (Davis, 2019). Still, issues such as these can hamper data collection in studies using traditional eye trackers (Murray, et al., 2017; Nyström et al., 2013). Remote webcam-based eye tracking (WBET) was explored in the current study as it is feasible for some persons with and without Alzheimer's disease to perform from their homes via their personal devices (Greenaway et al., 2021). While there are additional issues with the use of WBET for data collection (e.g., participants owning the right equipment and having a good internet connection), there was the potential to reach individuals who may not take part in lab-based eye-tracking studies, who may avoid exposure to unfamiliar devices (e.g., eye-tracking glasses or remote trackers), and/or those who may feel uncomfortable having a researcher in their homes.

Webcam-based eye tracking in music research

Researchers may be reluctant to use WBET due to the lower sampling rate/data quality associated with this technology compared to traditional eye trackers (Van der Cruyssen et al., 2024). Still, similar patterns of results and reliability levels comparable to lab-grade or remote eye-tracker data have been found in, for example, free-viewing, visual paired comparison, and AB research (Bott et al., 2020; Greenaway et al., 2023; Semmelmann & Weigelt, 2018; Wisiecka et al., 2022). Importantly, the feasibility of using WBET in (music-based) research depends on the study's experimental design and the phenomenon being measured (Van der Cruyssen et al., 2024). In the current study, the data from a maximum of four areas of interest (AOI) were assessed (i.e., left and right side of the screen [two AOIs] and the top and bottom half of each side of the screen [four AOIs]), and the total dwell-time on these large AOIs were compared. Research suggests that having up to six AOIs should not result in a degradation of data quality and the lower sampling rate associated with WBET should be sufficient for collecting data from the AOI placement described in the current study (Prystauka et al., 2024; Yang & Krajbich, 2021). The timing of the music(/audio) sample needs to be considered as there may be a lag between the audio and visual stimuli presentation time (Prystauka et al., 2024). This may be important, for instance, in studies examining the effect of specific segments of the music on attention. In the current study, an uninterrupted music track was played throughout the experimental condition which began playing before the first facial stimuli was presented. Our focus related to whether any issues occurred with music delivery (e.g., lack of auto-play) and if these issues could be resolved with (remote) assistance.

Although an exhaustive search was not conducted, remotely-delivered studies utilising music and WBET seemed to be scarce. One study was found which explored the feasibility of unmoderated WBET of infants' gaze during a preferential looking task assessing audio-visual synchrony perception (Bánki, et al., 2022). High attrition (~50%) was reported which was attributed to issues surrounding calibration and potentially the fact that the study was unmoderated (i.e., no immediate technical support was available). Some participants reported problems with face recognition and internet connection, long stimuli loading/upload times, and lags in video play. The authors concluded that WBET (with infants) is a promising path for research and warrants further investigation. The participants in the current study had the opportunity for technical support from a researcher throughout the study. This could mitigate some issues if, for instance, face recognition was being hampered by environmental conditions (e.g., poor lighting) or confusion regarding the technical procedure.

To our knowledge, the current study is the first to explore the feasibility of conducting music-based (AB) research with WBET involving persons with and without Alzheimer's disease from their homes. Additionally, the current study is the first to explore rumination, music, and AB, in combination, for persons with dementia. A person's rumination level, that is their tendency to think repetitively about the causes and consequences of a low mood or depression (Nolen-Hoeksema, 1991), can affect their response to music, and they may ruminate to the (sad) music (Garrido, 2009; Garrido, Eerola, et al., 2017). Potentially, negative AB may increase if rumination levels increase (LeMoult & Gotlib, 2018). As such, rumination should be considered in music-based research/interventions (Garrido et al., 2020).

In sum, AB are linked to depression, anxiety, and rumination, and AB can be modified by music. While music is a commonly used non-pharmacological approach to alleviate neuropsychiatric symptoms, particularly for persons with dementia, little focus has been given to how older persons' AB may be modified by music and how rumination may be implicated. Eye tracking is considered an ecologically valid measure of AB and measures are typically conducted in a controlled setting. In the hope of engaging community-based older persons with and without dementia to address the aforementioned literature gaps, the aim of the current study was to explore the feasibility of incorporating WBET within remotely delivered music-based research. To this end, the current study used WBET to measure in older persons the AB to emotional expressions, and the dwell-time on the top-half (containing the eye area) and bottom-half (containing the mouth area) of these images when viewing in silence and with background music, and (2) compared baseline rumination levels against AB change. Although it was likely that we would observe AB changes based on literature involving younger adults (Arriaga et al., 2014; Lazarov et al., 2017; Shamai-Leshem et al., 2021), we did not set a priori hypothesis as older persons' response to music may be different to younger persons' responses (i.e., more positively focussed) (Isaacowitz et al., 2006;

Vieillard & Gilet, 2013), and older persons can increase viewing of positive stimuli as an emotional regulation strategy if a negative mood is induced (Demeyer et al., 2017) (by the music or task completion). Instead, hypotheses were generated in the current study from the descriptive analysis of the eye-tracking data for testing in appropriately-powered future studies (Puurtinen, 2018).

Materials and methods

Participants

Eighteen participants were recruited via the Join Dementia Research platform (https://www.joindementiaresearch.nihr.ac.uk/). Persons with Alzheimer's disease and mild cognitive impairment were combined to form a participants with cognitive impairment (PwCI) group. The inclusion criteria for the PwCI group were: (1) aged ≥ 60 years, (2) a formal diagnosis of Alzheimer's disease or mild cognitive impairment, (3) not diagnosed with another neurological disease or disorder (e.g., Parkinson disease or epilepsy), and (4) has a carer or representative who can confirm the participant's ability to provide informed consent. The inclusion criteria for the cognitively healthy controls (HC) were: (1) aged ≥ 60 years, (2) no diagnosis of dementia (any type) or mild cognitive impairment, nor (3) another neurological disease or disorder (e.g., Parkinson disease or epilepsy). Calibration (eye-gaze location) was unsuccessful for six participants (PwCI = 5, HC = 1), partial eye-tracking datasets were obtain from five participants (PwCI = 2, HC = 3), and full eye-tracking datasets were obtained from seven participants (female = 4, male = 3; Alzheimer's disease = 4, mild cognitive impairment = 1, HC = 2). The PwCI group (two females and three males aged 60 to 74 yrs old) were classified as being non-depressed/non-anxious (mild cognitive impairment = 1), anxious (AD = 1), or having comorbid depression and anxiety (Alzheimer's disease = 3) (see Table 1. for descriptive data). Three participants with Alzheimer's disease were taking cognitive medication (Donepezil), and one was taking anti-depressant medication. The HC participants (two females aged 64 and 74 yrs old) were classified as being non-depressed/non-anxious.

Four of the seven participants (Alzheimer's disease = 2, HC = 2) wore reading glasses and removed them for the eye-tracking task. All of the participants confirmed they could see the eye-tracking stimuli clearly.

Procedure

The general webcam-based eye-tracking procedure has been previously reported (Greenaway et al., 2023) and is summarised here. Prior to the eye-tracking session, participants received preparation notes, a personalised link to JISC Online surveys (https://www.onlinesurveys.ac.uk/) to complete self-report depression and anxiety screens, and a Microsoft Teams meeting link via email. The participants could receive assistance from another person to navigate the study's technical requirements. Participants joined the Microsoft Teams meeting for a cognitive status interview and the eye-tracking session and shared their laptop screens with the researcher. They received an emailed link to Gorilla (Anwyl-Irvine et al., 2020), the web-based eye-tracking platform used in the study, to complete the AB tasks during the session. Participants completed two attentional bias measure (ABmeasure) blocks, the first block conducted in silence and the second block with background music.

The researcher provided eye-tracking set-up support (e.g., body and face positioning) as required and monitored the participant and their environmental conditions (e.g., for distractions during trials) throughout the session which lasted up to 2 hours in total. The study was reviewed in accordance with the procedures of the [details omitted for peer review] Research Ethics Committee and received a favourable ethical opinion for conduct (details omitted for peer review) on 29/10/2021. All participants provided written or verbal consent before the start of the study. All PwCI were required to have a carer or representative provide written or verbal confirmation of the participant's ability to provide informed consent.

Measures

Cognitive status

The 11-item Telephone Interview for Cognitive Status (TICS) dementia screen was used to assess memory, orientation, attention, and language. Scores could range from 0 to 41. A total score of ≤30 indicated cognitive impairment. The discriminative ability of the TICS is comparable to the Mini Mental State Exam (Folstein et al., 1975) (Seo et al., 2011).

Depression

Eight items of the 9-item Patient Health Questionnaire 9 (PHQ-9) (Kroenke & Spitzer, 2002) were used to screen for the presence of depressive symptoms. Removal of suicidal ideation item due to ethical concerns, did not affect the interpretation of final scores (Kroenke & Spitzer, 2002). A score of 0 to 3 ('not at all' to 'nearly every day', respectively) is assigned for each item giving a total of between 0 and 24. Scores of 5, 10, 15, and 20 represent the lower cut-off points for mild, moderate, moderately severe, and severe depression, respectively. A score of ≥ 10 has a specificity and sensitivity of 88% for major depression disorder (Kroenke & Spitzer, 2002).

Anxiety

The 7-item Generalised Anxiety Disorder Scale (GAD-7) (Spitzer et al., 2006) was used to screen for the presence of anxiety symptoms. A score of 0 to 3 (‘not at all’ to ‘nearly every day’, respectively) is assigned for each item giving a total of between 0 and 21. Scores of 5, 10 and 15 represent the lower cut-off point for mild, moderate, and severe anxiety, respectively. The scale has high internal consistency (α = .89) (Löwe et al., 2008).

Rumination

The 22-item Ruminative Response Scale (RRS) (Nolen-Hoeksema, 1991) was used to assess rumination in response to depression levels. Respondents indicated what they generally think or do for each item. A score of 1 to 4 (‘almost never’ to ‘almost always’, respectively) is assigned for each item giving a total score of between 22 to 88, with higher scores indicating a higher level of ruminative response. The scale shows excellent internal consistency as well as adequate convergent and predictive validity (Nolen-Hoeksema et al., 1993, 1994). The RRS has demonstrated excellent internal consistency (α = .92) and adequate test-retest reliability (r = .77) for persons with dementia [details omitted for peer review].

Eye tracking

Detailed positioning, calibration, and validation information have been previously described (see Greenaway et al., (2021) and Semmelmann & Weigelt, (2018)). Briefly, participants were instructed to sit directly in front of their webcam and to use their video feed presented in the top left corner of their screens to position themselves. Participants were told (1) to align themselves such that their faces appeared in the middle of a box outline overlaid in the center of the video feed, (2) that the box outline must turn green, and (3) that the green face outline displayed in the video feed (which detects the user’s face) must match their features (face-mesh) to enable a start button. The start button changed from faint red in colour to a deeper shade of red when enabled, and once clicked, the participants advanced to a calibration and validation phase.

Within the calibration phase, a 50 × 50-pixel red dot appeared consecutively in 9 fixed locations (a 3 × 3 grid spanning the height and width of the screen) in a random order. Participants were instructed to look at the dot as quickly as possible and fixate on it until it disappeared. The validation phase was identical to the calibration phase, except the dot was green. A calibration and validation phase was completed at the start of each ABmeasure block and their sub-blocks (described next).

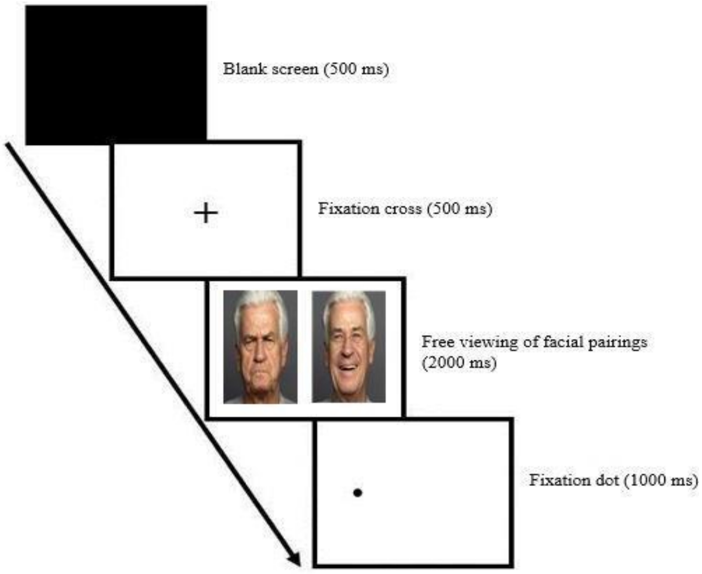
Attentional biases

A modified dot-probe task (MacLeod et al., 2002) was used to measure AB (see Figure 1). Each trial began with a blank screen for 500 ms. A cross then appeared in the centre of the screen for a fixation (500 ms). Sad, angry, happy, and neutral facial expressions, selected from the FACES database (Ebner et al., 2010), were then displayed in emotional-neutral and emotional-emotional pairings. The pairings, from the same actor, were presented to the left and right of where the fixation cross had been located for 2000 ms. Once the faces had disappeared, a black dot appeared in the centre of one of the face's previous location for a fixation (1000 ms). Screen timings were based on prosaccade latencies (i.e., time taken for the fast eye movements that shift the gaze from one spatial location towards a target) ranging from 178 to 385 ms, for persons with mild cognitive impairment and Alzheimer's disease (Opwonya et al., 2022).

Participants were instructed to look at the cross and the dot quickly and fixate until they disappeared, and to naturally view the facial stimuli when presented. A total of 96 trials were shown randomly in a block, and the block was divided into three sub-blocks each containing 32 trials. Each emotion type was presented 48 times by a total of 24 actors. Each actor was presented four times. The dot appeared an equal number of times in the previous location of each emotion, and the trials were counterbalanced for actor gender, and the side of the screen the emotion type and dot appeared on. Participants completed two ABmeasure blocks, the first being conducted in silence and the second being conducted with background music which began playing at the onset of the first slide in this block.

Figure 1

Trial Presentation Details.



Music samples

One music track was algorithmically generated using harp sounds with consonant interval sets of perfect fourths, perfect fifths, and octaves, and tempo defined as seven notes per second (see Bravo et al., [2017]) for detailed composition information). The other was a choral piece composed in a romantic period style using string sounds (e.g., violin and viola), with consonant interval sets of thirds, fourths and fifths, and tempo defined as quarter note = 36 (see Bravo et al., [2020] for detailed composition information). Consonant music correlates with positive emotions and is typically rated as pleasant (Blood et al., 1999).

Data analysis

Descriptive analysis was performed with the Statistical Package for the Social Sciences, version 25 (IBM Corp, 2017).

Symptom status

As a cut-off of ≥5 points on each scale represented the presence of depression (PHQ-9) and anxiety (GAD-7) (Kroenke & Spitzer, 2002; Löwe et al., 2008), participants who scored <5 on both the PHQ-9 and the GAD-7 were classified as non-depressed/non-anxious, <5 on the PHQ-9 and ≥5 on the GAD-7 as anxious, and ≥5 on the PHQ-9 and <5 on the GAD-7 as depressed. Participants who scored ≥5 on both the PHQ-9 and GAD-7 were classified as comorbid (depressed and anxious).

Attentional biases

The time spent looking (dwell-time in ms) at each half of the screen per trial was collated from the metrics provided by the eye-tracking platform. For each participant, the dwell-time was averaged for each emotion type in sad-neutral, angry-neutral, and happy-neutral pairings. AB scores (relative dwell-time) were calculated as the proportion of the averaged dwell-time on the emotional face relative to the average dwell-time on both the emotional face plus its corresponding neutral face (Lazarov et al., 2017). The average relative dwell-time for a group was calculated as the average relative dwell-time of the participants within that group. A score above 50% indicated longer dwelling on the emotional face as compared with the neutral face, whereas a score below 50% indicated less dwelling on the emotional face (Shamai- Leshem et al., 2021). Emotional-emotional pairing data will continue to be collected and analysed at a later date as the magnitude of AB in these pairings are reduced (Blanco et al., 2019). As such, it is unclear whether the eye-tracking method is sensitive enough to detect small AB differences at present.

Percentage dwell-time

The relative percentage of time spent looking at each quadrant (top left and right, and bottom left and right) of the screen, per trial, is provided by the eye-tracking platform. To assess participants' AB to the top-half (containing the eye region) relative to the bottom-half (containing the mouth region) of emotional facial images, the relative percentage dwell-time on the top-half and the bottom-half of the screen for sad, angry, and happy-face image locations were collated. For each group, these top-half and bottom-half relative percentage dwell-times were averaged and reported as average percentage dwell-times. As the emotional-face quadrant dwell-times are relative to neutral-face quadrant dwell-times, the reported results for sad, angry, and happy faces should not be compared against each other.

Feasibility

Feasibility was defined as the successful calibration and collection of eye-tracking data (Davis, 2021) from the participants under both conditions.

Results

Participant characteristics

On average, the PwCI were younger, more cognitively impaired, depressed, and anxious than the HC participants (see Table 1 for descriptive data). They also used a ruminative response to depression to a greater extent than the HC participants.

Table 1

Descriptive Age, Cognitive, Mood, and Bias Score Data

Measures	PwCI (*n* = 5)		HC (*n* = 2)	
	Mean	*SD*	Mean	*SD*
Age	66	5	69	7
Cognitive status (TICS)	30	4	35	4
Depression (PHQ-9)	11	11	2	1
Anxiety (GAD-7)	11	8	2	3
Rumination	47	15	31	2
Bias score (% dwell-time)				
Sad faces				
Silence	49	5	50	3
Music	50	7	53	3
Angry faces				
Silence	54	7	53	7
Music	48	6	50	4
Happy faces				
Silence	52	7	51	4
Music	54	9	47	2

Note. PwCI: participants with cognitive impairment; HC: cognitively healthy control; TICS: Telephone interview for cognitive status; PHQ-9: Patient Health Questionnaire 9 scale; GAD-7: Generalised Anxiety Disorder 7 scale; % dwell-time: proportion of the average dwell-time on emotional face relative to the average dwell-time on both the emotional face plus its corresponding neutral face.
Bias scores represent the averaged % dwell-time of the participants within that group, with scores of >50% indicating longer dwelling on the emotional face, and scores <50% less dwelling on the emotional face.

Eye tracking

None of the participants had previously taken part in an eye-tracking study. Four PwCI had assistance from their spouse/friend (full assistance = 2, partial = 2). Usable eye-tracking data from both conditions was obtained from 39% of participants. Partial eye-tracking datasets were obtain from 28% of participants (PwCI = 2, HC = 3). Reasons included internet connection instability/within block calibration failure (PwCI = 1, HC = 1), study time (i.e., study overran/conflict with other commitment) (PwCI = 1, HC = 1), and a sampling issue (i.e., a lag before the first eye-gaze prediction was generated across all slides within the music condition) (HC = 1). Calibration was unsuccessful for 33% of participants (PwCI = 5, HC = 1) and attributed to face-meshing difficulties (PwCI = 3), head movement and/or blinking (PwCI = 2), and internet connection (PwCI = 2, HC = 1). It should be noted that we successfully face-meshed a spouse/friend in the same spot as the participant experiencing face-meshing difficulties (n = 3) to rule out possible factors (e.g., internet connection).

Technical issues, solutions, and other observations

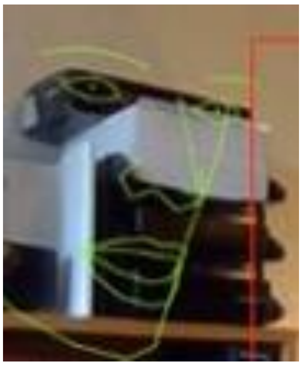
Initially, participants were emailed their link to the Gorilla platform at the point the hosted tasks needed to be completed. As one participant experienced a 5-minute delay to receive the email, the links where subsequently sent at the start of the Microsoft Teams session. Two participants with Apple Mac devices dropped out of the share screen function in Microsoft Teams when the WBET task initiated. An additional device (e.g., mobile phone) was needed to communicate with these participants. A Google search revealed that this is a common issue and the simplest solution was to use more than one device. Two participants had camera feed issues (i.e., camera feed box appeared but was blacked out, and no camera feed box appeared) which were unrelated to enabling camera use. A new Gorilla link was sent for the former issue, and the refresh button was pressed in the latter. Importantly, there were no issues with music play for the participants who attempted this condition (n = 9).

Participants were given the option to rest their chin on their hands (which requires leaning over). Having a make-shift chin rest could reduce head movement, a factor which reduces data quality (Semmelmann et al., 2018). Three participants attempted to rest their chin on their hands. When the researcher checked these participants' level of comfort, the participants opted to remove their chins from their hands.

The WBET program, at times, could try to face-mesh a background object (see Figure 2). Although we did not ask the participant to move location, having participants think about their backgrounds in advance, e.g., having a plain wall behind them (if possible), could facilitate the face-meshing process.

Figure 2

WBET Program Attempting To Face-mesh A Background Object



The right light source direction also facilitated the face-meshing process. We observed that light sources behind, directly above, or to the side of participants could cause light or heavy shadowing on the face affecting face-meshing. Two spouses of PwCI who had face-meshing/internet difficulties/unsuccessful calibration enquired if a downloadable eye-tracking package was an option.

Attentional biases

Increases in relative dwell-time on sad and happy faces (1% and 2%, respectively), and a reduction on angry faces (6%) were found when viewing occurred with background music compared to when viewing in silence for PwCI (see Table 1 for average relative dwell-time scores). An increase in relative dwell-time on sad faces (3%), and reductions on angry and happy faces (3% and 4%, respectively) were found when viewing occurred with background music for the HC participants (see Table 1 for average relative dwell-time scores). In terms of individual participants' rumination levels (i.e., high versus low), increases in relative dwell-time on sad faces were found for low ruminators (3 to 5% and 15%, respectively) when viewing occurred with background music, whereas reductions in relative dwell-time were found for the high ruminators (1 to 7%) (see Table 2 for mood information and Figure 3).

If a change in relative dwell-time was found when viewing angry faces with background music, increases in relative dwell-time on angry faces (5%) were found for participants with silent-condition relative dwell-times below 50% (i.e., an AB away from angry faces) (see Table 2 for individual relative dwell-time scores and Figure 4). In contrast, reductions in relative dwell-time on angry faces (10 to 14%) were found for participants with silent-condition relative dwell-times above 50% (i.e., an AB towards angry faces). Increases (5% and 11%) and reductions (2 to 5%) in relative dwell-times were found when viewing happy faces with background music.

Table 2

Individual Participants' Mood, Symptom Status, and Bias Score data

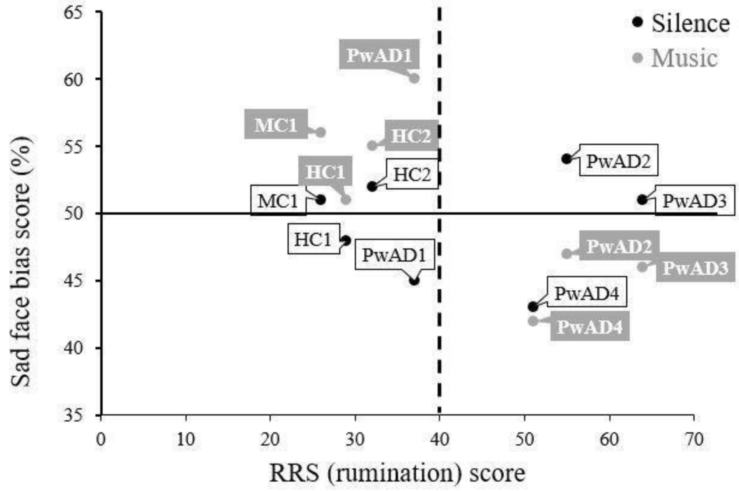
Participant	PHQ-9	GAD-7	SS	Condition	**Bias Score** (% dwell-time)		
					Sad	Angry	Happy
HC1	1	0	NDA	Silence	48	58	53
				Music	51	47	48
HC2	2	4	NDA	Silence	52	48	48
				Music	55	53	45
MCI	0	0	NDA	Silence	51	61	59
				Music	56	49	70
PwAD1	2	17	A	Silence	45	44	53
				Music	60	49	51
PwAD2	20	14	C	Silence	54	58	46
				Music	47	48	51
PwAD3	24	19	C	Silence	51	55	58
				Music	46	55	54
PwAD4	9	7	C	Silence	43	52	45
				Music	42	38	45

Note. PHQ-9: Patient Health Questionnaire 9 scale; GAD-7: Generalised Anxiety Disorder 7 scale; SS: symptom status; HC: cognitively healthy control; MCI: mild cognitive impairment; PwAD: participants with Alzheimer's disease; NDA: non-depressed/non-anxious; A: anxious; C: comorbid (depressed and anxious); % dwell-time: proportion of the average dwell-time on emotional face relative to the average dwell-time on both the emotional face plus its corresponding neutral face.

Bias scores of >50% indicate longer dwelling on the emotional face, and scores <50% less dwelling on the emotional face.

Figure 3

Individual Participants' Sad Bias Scores Against Ruminative Response Scale (RRS) Scores For Silence and Background Music Conditions



Note. Bias score: proportion of the average dwell-time on the sad face relative to the average dwell-time on both the sad face plus its corresponding neutral face.

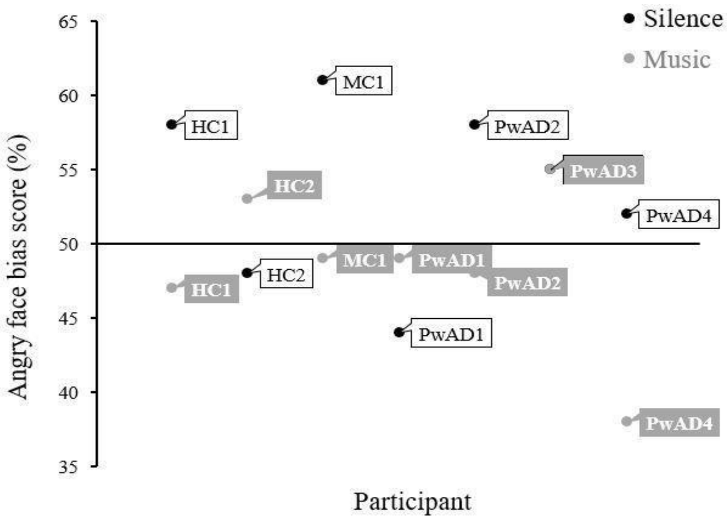
Bias scores of >50% indicate longer dwelling on sad faces, <50% less dwelling on sad faces, and the horizontal line at 50%, no bias.

The dashed vertical line represents the cohort median RRS score. Scores of <40 or >40 indicate low and high ruminators respectively.

Low ruminators displayed increased dwelling on sad faces in the background music condition whereas high ruminators displayed reduced dwelling.

Figure 4

Individual Participants' Angry Bias Scores For The Silence and Music Conditions.



Note. Bias score: proportion of the average dwell-time on the angry face relative to the average dwell-time on both the angry face plus its corresponding neutral face.

Bias scores of >50% indicate longer dwelling on angry faces, <50% less dwelling on angry faces, and the horizontal line at 50%, no bias.

Longer dwelling in the silent condition corresponded with reduced dwelling in the music condition and vice versa. Participant PwAD3 showed no change.

Dwell-time on facial regions with discriminating features

Overall, the PwCI and HC participants had a lower average percentage dwell-time on the top-half of the images (containing the eye region), for all of the emotional expression types, compared to the bottom-half (containing the mouth region) (see Figures 5, 6 [PwCI], 7, and 8 [HC] for average percentage dwell-time data). For the PwCI, increases (1 to 4%) on the top-half of the images were found for all of the emotional expressions when viewing occurred with background music compared to when viewing in silence. In contrast, reductions (1 to 24%) on the top-half of the images, for all of the emotional expressions, were found for the HC group.

For the PwCI group, reductions (1 to 7%) in average percentage dwell-time on the bottom-half of the images for all of the emotional expressions were found when viewing occurred with background music compared to when viewing in silence. For the HC group, increases on the bottom-half of sad and angry faces, (5% and 12%, respectively), and a reduction (4%) for happy faces were found when viewing occurred with background music.

Figure 5

Average Percentage Dwell-time On The Top-half Of Emotional Facial Images For Participant's With Cognitive Impairment (n = 5).

Note. % dwell-time: the percentage dwell-time on the top-half of the emotional image relative to the dwell-time on the bottom-half of the emotional image and its corresponding neutral-face image top-half and bottom-half dwell-times, averaged for the group.
On average, a higher percentage of dwelling on the top-half of the emotional images was found in the music condition.

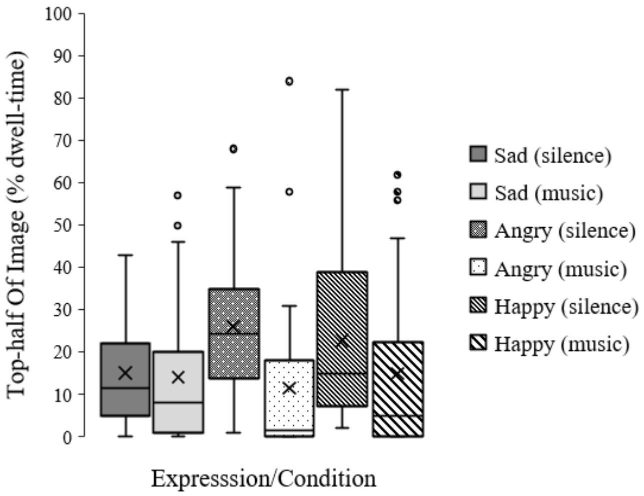
Figure 6

Average Percentage Dwell-time On The Bottom-half Of Emotional Facial Images For Participant's With Cognitive Impairment (n = 5)

Note. % dwell-time: the percentage dwell-time on the bottom-half of the emotional image relative to the dwell-time on the top-half of the emotional image and its corresponding neutral-face image top-half and bottom-half dwell-times, averaged for the group.
On average, a lower percentage of dwelling on the bottom-half of the emotional images was found in the music condition.

Figure 7

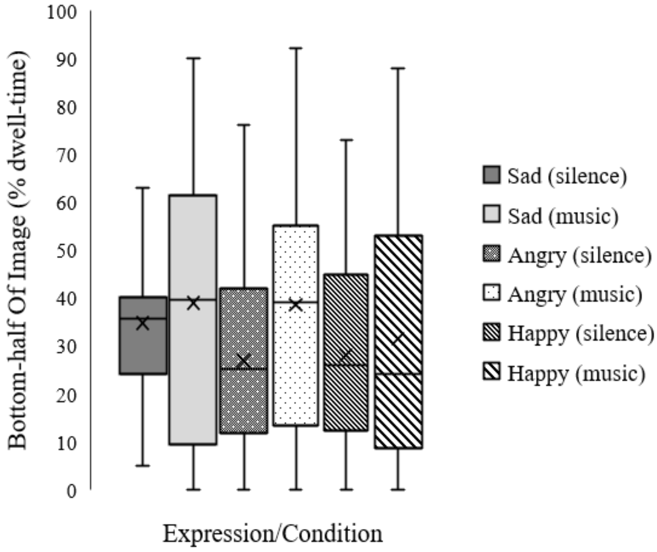
Average Percentage Dwell-time On The Top-half Of Emotional Facial Images For Cognitively Healthy Participants (n = 2)



Note. % dwell-time: the percentage dwell-time on the top-half of the emotional image relative to the dwell-time on the bottom-half of the emotional image and its corresponding neutral-face image top-half and bottom-half dwell-times, averaged for the group.
On average, a lower percentage of dwelling on the top-half of the emotional images was found in the music condition.

Figure 8

Average Percentage Dwell-time On The Bottom-half Of Emotional Facial Images For Cognitively Healthy Participants (n = 2)



Note. % dwell-time: the percentage dwell-time on the bottom-half of the emotional image relative to the dwell-time on the top-half of the emotional image and its corresponding neutral-face image top-half and bottom-half dwell-times, averaged for the group.
On average, a higher percentage of dwelling on the bottom-half of sad and angry images was found in the music condition, and a lower percentage of dwelling on the bottom-half of happy images.

Discussion

The aim of the current study was to explore the feasibility of incorporating WBET within remotely delivered music-based research. As little focus had been given to how older persons' AB may be modified by music and how rumination levels may be implicated, older persons' rumination levels were assessed and their AB to emotional facial images and the relative attention to the top-half and bottom-half of these images (i.e., discriminating features regions containing the eye and the mouth) when viewing in silence and with background music were measured using WBET. The process was feasible (i.e., full datasets were collected for both conditions) for 39% of the participants which is in line with previous research (Yang & Krajbich, 2021). Although higher levels (up to 80%) have been reported (Bánki, et al., 2022; Prystauka et al., 2024), participant age and observation in the current study may have impacted data collection. Face detection models have difficulty with some populations' characteristics (e.g., older persons and black females) due to them being trained on a limited range of faces (Buolamwini & Gebru, 2018; Gentzel, 2021; Saxena et al., 2023;

Stypinska, 2023). Consequently, in-lab eye-tracking studies involving older persons also encounter a high level of participant loss (e.g., 45% [Allard et al., 2010]).

In terms of participant observation, the Microsoft Teams meeting potentially contributed to participant/data loss by reducing the processing capacity of the participants' devices whilst the eye-tracking task was being conducted. Studies have set initial minimum requirements in terms of hardware and internet connection in an attempt to reduce dropout/data loss (Bertrand & Chapman, 2023;Yang & Krajbich, 2021). Unfortunately, we did not investigate the minimum requirements for running the eye-tracking and Microsoft Teams programs simultaneously. As observation was necessary (e.g., to assist with positioning/lighting), it is encouraging that participants in the current study were willing to use a second device to interact with/be monitored by the researcher. Future WBET studies using observation should advise participants that this may be a potential problem-solving option and to have a second device to hand.

Another encouraging finding here was that some older persons with internet connection issues were open to a downloadable eye-tracking option. How the eye-tracking data would be managed/transferred once generated would require a great deal of thought but a downloadable offline eye-tracking option is currently available via the LabVanced platform (Kaduk, et al., 2023). Additionally, the make-shift chin rest (i.e., resting the chin on the hands) option used in the current study would be unnecessary as the platform provides a virtual chin-rest function. Importantly, there is the potential for participants to be more autonomous as positioning prompts (visual and text) can be provided and movement away from this virtual chin-rest position is detected by the program. Still, this platform was not utilised in the current study thus its usability with older persons with cognitive impairment or dementia would need to be explored.

Generating hypotheses

Our findings from the usable WBET data that older persons dwelled less on the top-half (i.e., eye region) of emotional faces in the silent condition is in line with previous lab-based research (Low et al., 2022; Noiret et al., 2015; Ogrocki et al., 2000), thus lending some support for WBET of these metrics. Moreover, our finding for PwCI of reduced dwelling on angry faces when viewing with background music is in line with a study (Lazarov et al., 2017) involving younger adults who were also anxious/comorbid depressed and anxious. Still, we also found reduced dwelling for the HC group who were non-depressed/non-anxious. As our findings were descriptive, the differences in the dwell time that were logged by the WBET program when viewing occurred with background music were used to generate the following hypotheses for future in-lab versus remote WBET testing:

> H_1: Low ruminators will dwell more on sad faces when viewing with background music whereas the high ruminators will dwell less
>
> H_2: Participants displaying a silent-condition AB away from angry faces (i.e., threat avoidant individuals) will dwell more on angry faces when viewing with background music, and those displaying silent-condition AB towards angry faces will dwell less
>
> H_3: Participants with Alzheimer's disease (AD) with comorbid depression and anxiety will dwell longer on the top half of sad, angry, and happy faces when viewing with background music compared to when viewing in silence
>
> H_4: Non-depressed/anxious cognitively healthy (HC) participants will dwell less on the top half of sad, angry, and happy faces when viewing with background music compared to when viewing in silence

This is a slightly different approach to previous WBET studies which have sought to replicate phenomena observed from in-lab studies. Replication studies have shown that even small effects found in lab-based data can also be found within WBET data, although effects sizes can be greatly reduced compared to lab-based data (Prystauka et al., 2024;Van der Cruyssen et al., 2024). WBET studies testing our generated hypotheses should consider this, alongside the high participant loss discussed earlier, when calculating study sample sizes.

Forward thinking

While the main focus of the current study was to explore the feasibility of remotely-delivered music research with WBET involving older persons with and without cognitive impairment, the impact of the music on participant mood requires consideration in future WBET studies. Participants with a bias away from angry faces (i.e., threat-avoidant) look away from threat to reduce immediate distress (Mogg & Bradley, 2018). It is possible that the music reduced the negative feelings (e.g., anxiety/stress [Thoma et al., 2013]) typically associated with looking towards the threat stimuli for these individuals, increasing dwell-time. Moreover, as reduced viewing of the eyes can occur in both depression and anxiety, the music may have facilitated increased viewing of this region by reducing the negative emotions associated with their viewing (Chris, 2000; Schneier et al., 2011). While we could not locate research data regarding contemporaneous music and happy-neutral stimuli for comparative purposes, AB toward happy faces may be linked to emotional regulation strategy use in older persons (Demeyer et al., 2017). Increases or decreases in happy-face dwell-time could possibly be related to the emotional consequences of (1) the music (Juslin & Västfjäll, 2008), and (2) the AB changes seen for sad and angry faces (MacLeod et al., 2002).

At present, an online momentary mood scale could be completed by the participants in a remotely-delivered music study, and/or a specific measure of musically-induced emotions (Coutinho & Scherer, 2017) if validated for use with PwCI. Encouragingly, researchers are developing analysis tools to extract, for example, heart rate/variability and respiration rate from facial video recordings which could allow remote data collection without additional/specialised recording equipment (e.g., sensors) in the future (Yu et al., 2023). These are some of the metrics used to assess musically-induced emotional responses and, preferably, physiological measures should be used in conjunction with self-report measures to establish whether an emotional response to music has occurred (Juslin & Laukka, 2004). Developers/researchers should ensure that older persons faces are included in analysis tool training sets and, ideally, that these types of analysis tools are able to process, in real-time, low-quality videos obtained from device-embedded webcams akin to WBET programs. It would be advantageous for (music) researchers without programming experience to be able to access an experimental platform capable of collecting WBET and physiological data at different points from the same video feed (with local data storage to reduce data security breaches). The researcher merely selects when this should occur within the experimental paradigm (e.g., before and after each eye-tracking/music block and/or before each re/calibration).

Another factor to consider is the impact of dual processing (i.e., the visual stimuli and the musical stimuli). Knight et al., (2007) found that older persons can display a reversal of emotional biases under a divided attention task (i.e., a dot-probe task with a tone sequence discrimination task) whereby a participant displaying a negative AB during the full attention condition could display a positive AB under the divided attention condition and vice versa. While the participants in the current study did not report being distracted or impeded by the background music, the participants may have divided their attention as they were not instructed to ignore the music. Nonetheless, rumination levels were not assessed in the Knight et al., (2007) study (and persons with [possible] cognitive impairment were excluded) thus rumination cannot be ruled out as a contributing factor in their results. In contrast, the cognitive interference from threat stimuli, which is associated with AB toward threat (Macleod et al., 2019), can be reduced by music (Masataka & Perlovsky, 2013). This could potentially reduce dwell-time. The inclusion of an eye-tracking metric, e.g., pupil size (dilation), which has been associated with cognitive processing effort/load of older persons with and without cognitive impairment (El Haj et al., 2022; Ranchet et al., 2017; van der Wel & van Steenbergen, 2018) is one potential way to remotely assess cognitive processing effort/load. Unfortunately, current WBET technology may not be able to accurately assess pupil dilation changes due to a reliance on visible light (Kaduk, et al., 2023). However, this metric could be collected from participants using traditional/mobile infrared trackers who are able/willing to use two different trackers within a remote WBET versus traditional/mobile infrared tracker comparison study. Futures studies, which include PwCI, are still required to examine the interplay between attentional control, cognitive load, rumination, AB, and music.

Futures studies should also examine any short- and long-term impacts of music exposure/musically-induced viewing shifts (which could be feasible with WBET should H_3 and H_4 be explored and confirmed). For example, increasing eye contact could be beneficial as eye contact is an important factor in non-verbal communication, may implicitly elicit positive affective reactions, can increase ratings of the likeability of static images, and can improve memory for concomitant information (i.e., written names presented with faces) for participant's with Alzheimer's disease (Hietanen, 2018; Kleinke, 1968; Lopis & Conty, 2019). Although emotion recognition capability was not assessed in the current study, insufficient viewing of facial regions, such as the eyes, could contribute to the emotional recognition difficulties seen in these populations, and impact self-reported quality of life (Noiret et al., 2015; Phillips et al., 2010). Research has shown that encouraging older persons to attend to such regions (i.e., revealing the eye region first, or only showing the eye region) can improve emotional recognition for participants with AD (Hot et al., 2013), whilst no improvement was found for HC participants (Low et al., 2022). Should H_4 be confirmed, reduced viewing of the eye region could negatively impact the recognition of sad and angry faces.

Limitations

While the current study is a first step towards exploring music, rumination, and AB in combination for older persons with and without cognitive impairment, individuals without access to a device with WBET capability were unable to take part in our study. Time (i.e., long set-up times and calibration issues associated with WBET) was a barrier for some care-givers in our study (i.e., as a participant and assistance provider). Encouragingly, researchers are developing techniques intended to remove the need for a calibration process from WBET data collection (Hutt & D'Mello; 2022). As such, future WBET study times could potentially be reduced as the time taken for calibration (and failures) would be removed. A limitation of our study is that repeated dot-probe measures may be associated with a small effect in itself (Beevers et al., 2021; Blackwell et al., 2017). Thus, the dwell-time changes logged by the WBET program in our second AB measure (i.e., the background music condition) may include the potential effect of the dot-probe measurement. Additionally, the top-half and bottom-half AB data is relative to the neutral face in the facial pairings. Our findings need to be replicated using an alternative eye-tracking AB task, and order effects and the relative AB to the top-half and bottom-half of emotional images presented individually should be examined within future studies.

Other potential limitations of the study are that the intensity of the facial stimuli, and the valence of the study-selected music samples were not rated by the cohort. As there may be an own-age bias in visual attention allocation (e.g., older persons may look at younger faces for less time than own-age faces) (Bortolon et al., 2015; Ebner et al., 2011), we only used older-person images and used all of the older-person images that were available within the FACES database (Ebner et al., 2010). It is therefore possible that including the images with lower-rated intensities, which may affect identification and consequently dwell-time (Low et al., 2022; Phillips et al., 2010), could have influenced our findings.

In regard to the valence of the study-selected music samples, the effects of the (1) music's valence on the participant's mood, and (2) perceived valence rating on AB were not explored. Although it was likely that we would observe AB changes based on literature (Arriaga et al., 2014; Lazarov et al., 2017; Shamai-Leshem et al., 2021), if negative feelings were evoked or the tracks were perceived as negative, increased dwell-time on negative stimuli may have been displayed, with the reverse being seen for positive feelings/perception and positive stimuli (Arriaga et al., 2014). The composer, F. Bravo (personal communication, November 13, 2019), stated that the piece may evoke a feeling of nostalgia (a tender longing or affection for a past event or period) which can be rated as positively- or negatively-valenced (Newman & Sachs, 2022). Future larger studies should allow the effect of expression intensity and music valence ratings to be examined, and subgroup analyses (e.g., cognitive and symptom status) to be performed. Future studies should also directly compare WBET data against data obtained from other eye-trackers.

Clinical and research implications, and recommendations

Our findings show that it is feasible to use WBET in remotely-delivered music-based research involving older persons with and without AD or MCI (albeit for a limited number of individuals). As the study attracted participants who had not previously taken part in an eye-tracking study, WBET may be an accessible way to engage in eye-tracking studies for some individuals. We provide descriptive data showing that older persons' AB may be altered by music, and that dwell-time on facial regions with features that are important in the recognition of sad and angry faces (i.e., the eyes), may increase during music exposure for PwCI. Should the hypotheses based on these data be confirmed in sufficiently-powered studies, findings could prove useful for individuals (1) conducting music-based research and interventions (e.g., potential objective outcome measures), and (2) engaging in musical activities with persons with cognitive impairment (e.g., being aware of their own facial positioning or expressions, and using direct rather than averted gaze). Our findings support the notion that rumination should be considered within older-person music interventions/studies.

Our practical recommendations are that (where possible) participants should have a second embedded-camera device to hand for observation to take place, particularly Apple Mac users. As the WBET program could try to face-mesh a background object, having participants think about their backgrounds in advance (e.g., if possible, having a plain wall behind them) could facilitate the face-meshing process. Having good lighting is essential for WBET and participants can be advised not to have too much or too little light, and a light source behind them (Bánki, et al., 2022; Van der Cruyssen et al., 2024). From our observations, additional instructions may be warranted to include explicit information about the appearance of their face in their video stream. For example, the light source should not be behind the participant if this causes face shadowing (as when taking a photograph), at an intensity in front of the face which causes squinting, and not directly above or to the side if this causes shadowing around the eyes (by the eye-brows/forehead) or on one side of the face, respectively. Additionally, to be prepared (e.g., have an additional light source to hand) when conducting WBET at times where large changes in light levels occur (e.g., around sunset), or avoid such times.

Although we were able to keep to the expected study time in most instances, participants should be advised during the enrolment process to leave a gap between the suggested study end and subsequent engagements in case of unexpected issues.

Conclusion

Remotely-delivered music-based research with WBET involving older persons with and without AD or MCI is feasible, and differences in older-persons' dwell-time on emotional faces and facial feature regions were logged by the program when viewing occurred in silence and with background music. Further studies are required to determine whether these differences are robust using the hypotheses that we generated from these data, and if so, to examine the factors associated with these differences. These studies should factor in the large level of participant loss.

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Conflicts of Interests

The Author(s) declare(s) that there is no conflict of interest.

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Data availability statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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5.1.1 Thesis aims and key study findings

Thesis aim 4 (to explore remotely-delivered music research with WBET involving older persons with and without AD) was explored in this chapter of the thesis. These findings demonstrate that it is feasible to incorporate WBET into remotely-delivered music-based research involving older persons with and without AD and that music, AB, and rumination can be examined simultaneously in research involving these populations. However, WBET specific issues (e.g., internet connection requirement and a high rate of eye-gaze location failure), as outlined in sections 4.2 and 4.4 of this thesis, resulted in a loss of approximately 50% of participants. This finding will be incorporated into future sample size calculations. Still, none of the participants that engaged with this research had previously taken part in an eye-tracking study. Therefore, WBET facilitated the participation of some individuals that may not have otherwise taken part in an eye-tracking study.

Chapter 6

Clinically-relevant reductions in depression, anxiety, and rumination levels following gaze-contingent musical attentional bias modification: Feasibility studies

This chapter has been submitted to Cognition and Emotion.

Greenaway, A.-M., Hwang, F., Nasuto, S., & Ho, A. (2024). Clinically-relevant reductions in depression, anxiety, and rumination levels following gaze-contingent musical attentional bias modification: A pilot study. *Cognition and Emotion*, 1-33.

This chapter 6 explored the effect of a technology-based music-mediated intervention, created as part of this thesis, on younger adults' momentary mood and AB after a single session of the intervention, and momentary mood, depression, anxiety, rumination and AB after multiple sessions of the intervention. Clinically relevant changes in depression, anxiety, and rumination in relation to the multi-sessioned intervention were yielded.

Abstract

Attentional bias modification (ABM) is a cost-effective, and accessible intervention for depression and anxiety that could meet the increasing demand for mental-health treatment. However, ABM paradigms that reliably modify attentional biases (AB) and symptoms are still required.

Consequently, we examined the feasibility (i.e., can it be done, should it continue, and if so, how) of a novel ABM intervention (gaze-contingent consonant and dissonant music heard when looking at positive and negative faces, respectively). Contingency awareness and use, and participant adherence and dropout assessed if the intervention could be done. Negative affect, state rumination, and negative AB after a single session (Study 1, N = 13), and negative affect, trait rumination, depression, anxiety, and negative AB after four sessions (Study 2, N = 10) assessed whether the intervention should continue. An evaluation of findings informed how to proceed. The relative dwell-time in emotional-neutral (the proportion of the total fixation durations on the emotional face relative to the combined total fixation durations on both the emotional and neutral faces) and emotional-emotional (the proportion of the total fixation durations on the negative face relative to the combined total fixation durations on both the negative and happy faces) pairings were computed. Scores above 50% indicated longer dwelling on emotional or negative faces whereas a score below 50% indicated less dwelling these faces.

The intervention could be done as (1) the music versions and their contingency were discerned and deliberately controlled by some participants, and (2) the participants adhered to the study with no dropouts. Although reductions in positive affect were seen across the studies, the intervention should continue to be explored as on the whole, reduced negative affect (or no change), state and trait rumination, depression, anxiety, and baseline negative AB were found post-intervention in descriptive data. Clinically-relevant changes in rumination, depression, and anxiety scores were reported by some participants. However, the change in AB (i.e., attenuation/reversal/increase) depended on the contrast (emotional-neutral and/or emotional-emotional) for each participant post-intervention (Study 1 and 2). The evaluation showed that task instructions, music selection, and the number of sessions to be delivered requires further exploration.

In conclusion, our descriptive findings and evaluation show that gaze-contingent music ABM is feasible and should be further explored to ensure it works as intended for a larger number of individuals and to confirm what effects it has on mood and AB. Both emotional-neutral and emotional-emotional contrasts should be assessed to better understand the relationship between AB, symptoms, and therapeutic effects. Encouragingly, clinically-relevant reductions in rumination, depression, and anxiety levels were reported after multiple sessions of the intervention in its current form.

Keywords: Rumination, depression, anxiety, eye tracking, gaze-contingent music.

Introduction

In the 2022 wave of the UK Mental Health of Children and Young People surveys (Newlove-Delgado et al., 2022), the likelihood (i.e., "unlikely", "possible", or "probable") of a child or young person having a mental health disorder was estimated from Strengths and Weaknesses Questionnaire (Goodman & Goodman, 2011) responses. It was reported that almost a quarter (22%) of the 17–24-year-olds had a "probable" mental-health disorder, with a further 14% "possibly" having a mental- health disorder. Although, the National Institute for Health and Care Excellence recommends psychological intervention (e.g., cognitive behavioural therapy), few access these types of services. For example, only 3% of the 18 – 24-year-olds with a probable mental-health disorder, accessed psychological therapy in the UK in 2017 to 2018 (Rzepnicka et al., 2022). In reality, there are long waiting lists, a lack of engagement during treatment, a high rate of attrition, and up to 50% of those who engage in treatment do not achieve satisfactory treatment responses (Colizzi et al., 2020; Craske & Stein, 2016; Punton et al., 2022; Rodwin et al., 2022). There is also a high risk of relapse associated with depression and anxiety in young adults (39-72%) (Robberegt et al., 2022). As the mental-health needs of many young adults are still unmet, alternative interventions that increase accessibility and engagement are needed (Colizzi et al., 2020; Hollis et al., 2017). An intervention would also need to be low-cost given the potential numbers in need and high reoccurrence rates. Attentional bias modification (ABM) interventions are considered to be cost-effective, able to increase accessibility, and meet the increasing demand for mental-health treatment, especially when used as a first-line tool or in conjunction with other approaches (Blackwell, 2020; Gober et al., 2021).

Modifying attentional biases

An attentional bias (AB) is the tendency for a person to attend to a certain type or types of information whilst ignoring other types of information. Attending to positive information (i.e., positive attentional biases) versus negative information (i.e., negative attentional biases [NAB]) has been shown to have differential consequences on emotional functioning (Arditte & Joormann, 2014; Koster et al., 2011). While NAB have been linked to depression and anxiety (Kircanski et al., 2012; McLaughlin et al., 2007; Mogg & Bradley, 2016), it should be noted that some individuals with depression and anxiety may not display NAB, and some may show a bias away from negative stimuli (i.e., avoidance) (Krings et al., 2020; Mogg & Bradley, 2018). When present, NAB are thought to involve a reduced ability to disengage attention from, and inhibit, negative information (Koster et al., 2011). ABM interventions aim to alleviate symptoms by encouraging a shift in attention from negative stimuli to positive stimuli. With repeated enforcement, disengagement from negative stimuli becomes implicitly learnt.

ABM has not proven to be universally effective. While some studies have shown that a reduction in NAB has correlated with a reduction in symptoms of depression and anxiety (Hsu et al., 2021; Jones & Sharpe, 2017; Lazarov et al., 2017; Yang et al., 2015), others have found no change (Duque & Vazquez, 2018) or a reduction in symptoms without AB change (Baert et al., 2010). Further, the effectiveness of ABM in terms of symptom reduction varies with, for example, symptom severity (subclinical versus disorder level), disorder type (social or general anxiety versus post-traumatic stress disorder), and bias direction (towards or away) (Baert et al., 2010; Boettcher et al., 2012; Duque & Vazquez, 2018; Fodor et al., 2020; Jones & Sharpe, 2017; Li et al., 2023).

Unsuccessful ABM interventions on depression and anxiety may result from the complexity or combinations of cognitive processes involved in depression and anxiety. For instance, AB in anxiety can present as a bias towards and/or away from threat (i.e., they fluctuate over early versus late information processing stages) and can be influenced by factors such as an individual's goals (e.g., achieving a desired emotional state) (Bantin et al., 2016; Kruijt et al., 2019; Lisk et al., 2020; Mogg & Bradley, 2016). Irrespective of the AB presentation, ABM may be unsuccessful due to a lack of engagement and/or boredom as ABM paradigms are repetitive in nature (Beard et al., 2012; Kuckertz et al., 2020). As such, there is still a need for procedures that more reliably lead to a shift in biases and further studies to determine the most effective clinical applications (Hang et al., 2021; Jones & Sharpe, 2017). The cognitive-motivational framework of anxiety (Mogg & Bradley, 2018) suggests that an ABM intervention targeting a variety of cognitive processes within its paradigm (e.g., goal- directed attentional orienting and switching, implicit and/or explicit learning, and motivational engagement) may increase its efficacy. To this end, we combined ABM with music to facilitate an implicit and goal-directed reduction in the time spent attending to threat/dysphoric stimuli and to motivate increased time attending to more positive stimuli.

Music and attentional bias modification

Music can have an implicit effect on visual attention. The emotional tone conveyed by the music influences emotional perception, affecting fixation latency, duration and number, and the saliency of objects (Bravo, 2014; Invitto et al., 2017; Mera & Stumpf, 2014; Millet et al., 2021). Emotionally congruent information (i.e., happy face–major chords and sad face–minor chords) facilitates the processing of each type of visual stimuli (Bakker & Martin, 2014). When negative and positive pictures are presented simultaneously, participants spend less time looking at, and fixating on, negative pictures when positive background music is played. Conversely, participants spend less time looking at, and fixating on, positive pictures when negative background music is played (Arriaga et al., 2014).

Consonant and dissonant music have been shown to differentially affect emotional responses. Consonant music correlates with positive emotions and is rated as pleasant, whereas increasing levels of dissonance are associated with negative emotions and adjectives such as unpleasant, irritating, annoying, and angry (Blood et al., 1999). In the current studies, we hoped to utilise the emotional congruency effect and the differing emotional responses to consonant and dissonant music to modify participants' AB. The initial playing of the consonant version of a music track may facilitate viewing of the more positive face in a pairing (emotional congruency). As the participants are instructed to view the faces naturally, it is likely that the negative face in the pairing would also be viewed. When the participant's gaze was detected on the negative stimulus (sad or angry face) area of interest (AOI), a dissonant version of a music track would be heard. It was hypothesised that a negative emotional response would be elicited, motivating participants to direct their gaze away from negative stimuli. Goals related to the avoidance of negative consequences can be motivating (Godara et al., 2019). Once their attention was disengaged from the negative stimulus AOI, a consonant version of the same track would be heard again. Increased gazing at the positive stimulus (neutral and happy faces) AOI, and therefore a reduction in NAB, would be motivated by the relatively positive emotional effects elicited from the consonant music (associated with positive stimuli/AOI). With repeated exposure, the participant would implicitly learn to disengage their attention from negative stimuli in favour of positive stimuli.

However, it is possible that some individuals may not be deterred by the dissonant version of the music track. Depressed and/or anxious individuals, in particular, may use maladaptive coping styles such as rumination, which involves self-referential, repetitive, and/or frequent thoughts (Koster et al., 2011). Previous research suggests that ruminators have a bias towards negative (sad) music and attend to positive (joyful) music for less time than non-ruminators (Garrido, 2009; Lei et al., 2007). It is therefore possible that ruminators in the current study may be attracted to the negative valence associated with dissonant music, as with sad music (Garrido, 2009) and not be deterred by it. NAB may increase due to a congruency effect (i.e., dissonant music-negative faces). To this end, two feasibility studies were conducted with the aims of identifying whether gaze-contingent musical ABM (GCM-ABM) could be done, whether GCM-ABM should continue to be explored, and if so, how (Eldridge et al., 2016). Our trial design (i.e., exposure to consonant and dissonant versions of a music track in the same trial) had not been previously investigated so it was unknown whether 1) the switch between each version would generally be discerned, 2) the contingency could be discerned and used, 3) dissonance exposure would negatively affect mood overall, 4) participants would engage in multiple sessions of exposure, and 5) any changes in NAB would be displayed.

To assess whether GCM-ABM could be done, a semi-structured interview was conducted in Study 1, and participant comments and dropouts were recorded in Study 2. GCM-ABM could be done if there was an awareness of the consonant and dissonant track versions and their contingency, deliberate gaze-control was attempted, and there was low participant dropout. To assess whether GCM-ABM should continue to be explored, we measured positive affect [PA], negative affect [NA], state rumination [SR], and the relative percentage dwell-time (RPD-T) on negative faces when paired with neutral faces (negative-neutral contrasts) and happy faces (negative-happy contrasts) over a single session (Study 1). Exploration would continue in Study 2 if a positive impact on participants (i.e., reduced NA, SR, and baseline NAB) was found post-intervention in descriptive data. To assess whether GCM-ABM should continue to be explored after Study 2, we focussed on changes in PA, NA, trait rumination (TR), depression, anxiety, and baseline NAB after four daily sessions. Exploration would continue if a positive impact on participants (i.e., reduced NA, TR, depression, anxiety, and baseline NAB) was found post-intervention in descriptive data. If GCM-ABM was deemed feasible (i.e., it could be done and should be proceeded with), an evaluation of what did and did not work in Study 1 and 2 would guide how to proceed further.

Study 1

The aims of Study 1 was to assess whether GCM-ABM could be done and should continue to be explored. We examined participant awareness of the consonant and dissonant track versions and their contingency, whether deliberate gaze-control was attempted, and if there was any modulation of momentary mood and NAB after a single session of GCM-ABM.

Study 1 Materials and methods

Participants

A convenience sample of 13 university students were recruited to the study via a departmental recruitment platform for course credits in November 2020. Usable eye- tracking datasets were obtained from nine participants (eight females and one male aged between 18 and 43 years old) (see Table 1.). Three participants were classified as being non-depressed/non-anxious (NDNA), two as being anxious, and four as having comorbid depression and anxiety (comorbid). All participants had normal/corrected-to- normal vision.

Procedure

Participants completed an online self-report questionnaire via JISC Online surveys (https://www.onlinesurveys.ac.uk/) to screen for depression, anxiety, and TR, 1 to 3 days before a lab-based study session. At the start of the lab-based session, participants completed paper-based momentary mood measures, followed by an attentional bias measure (AB-measure). After a five-minute break, participants received two blocks of GCM-ABM. The participants had another five-minute break before completing the AB-measure and momentary mood measures again, in that order. A semi-structured interview was then conducted. Participating took approximately 1.5 hours in total. Consent was provided during study enrolment (written), at the start of the online survey (checked tick box), and at the start of the lab- based session (written). The study was reviewed in accordance with the procedures of the University of Reading's Research Ethics Committee and received a favourable ethical opinion for conduct (UREC 19/71).

Measures

Mood

Depression. The Patient Health Questionnaire 9 (PHQ-9) (Kroenke & Spitzer, 2002) was used to screen for the presence and severity of depression after the removal of the suicidal ideation item. A score of 0 (not at all) to 3 (nearly every day) is assigned for each item giving a total of between 0 and 24. The lower cut-off point for mild, moderate, moderately severe, and severe depression are scores of 5, 10, 15, and 20, respectively, with a score of ≥ 10 having a specificity and sensitivity of 88% for major depression disorder (MDD) (Kroenke & Spitzer, 2002). Although the suicidal ideation item was removed due to ethical concerns, the interpretation of final scores remains the same (Kroenke & Spitzer, 2002).

Anxiety. The Generalized Anxiety Disorder Scale (GAD-7) (Löwe et al., 2008) was used to screen for the presence and severity of anxiety. A score of 0 (not at all) to 3 (nearly every day) is assigned for each of the 7 items, giving a total of between 0 and 21. The lower cut-off point for mild, moderate, and severe anxiety are scores of 5, 10 and 15, respectively, with a score of ≥ 10 suggesting the presence of GAD and other anxiety disorders. The scale demonstrates high internal consistency ($\alpha = 0.89$) (Löwe et al., 2008).

Momentary mood

Positive and negative affect. The Positive Affect Negative Affect Scales (PANAS) (Watson et al., 1988) measured how much each participant was experiencing 20 emotions (10 positive and 10 negative items) in the moment. Each item, an affective state such as ‘distressed’, was rated on a 5-point scale (very slightly or not at all = 1 to extremely = 5). The scores for positive items were totalled to provide the positive affect (PA) score and the scores for negative items were totalled to provide negative affect (NA) score. Each totalled affect score ranged from 10 to 50, with higher scores representing higher levels of affect.

State rumination. The 8-item Brief State Rumination Inventory (BSRI) (Marchetti et al., 2018) measured the level of self-reported rumination being experienced in the moment (SR). Participants drew a vertical line on a horizontal line to indicate the degree to which they disagree or agree (0 to 100% respectively) with each statement. A higher total score represented higher level of SR.

Rumination

We measured trait rumination (TR) as a response to depression using the Ruminative Response Scale (RRS) (Nolen-Hoeksema, 1991). The RRS required respondents to indicate how they had responded to 22 items over the previous fortnight using a 4-point Likert scale ranging from 1 (‘almost never’) to 4 (‘almost always’). The score for each item was summed to obtain a total score ranging from 22 to 88. Higher scores indicate a higher level of TR. The scale shows excellent internal consistency as well as adequate convergent and predictive validity (Nolen-Hoeksema et al., 1993, 1994).

Gaze location

Participants were seated between 59 and 66 cms away from a desk. A keyboard, Tobii TX300 eye-tracker and a 21-inch monitor were positioned on top of the desk (see Appendix C [pg. 301] for hardware details). The standard 5-point calibration procedure for the Tobii system was conducted before each AB-measure and GCM-ABM block.

Attentional bias measure

A modified dot-probe task (MacLeod et al., 2002) was presented via E-Prime 2.0 software (Schneider et al., 2002) to measure participant AB. An instruction slide was presented at the start of the task asking participants to (1) look at the cross and the dot as quickly as possible when they appeared, (2) view the facial stimuli in a natural way when presented, and (3) press the ‘space bar’ to start the task when they were ready. Each trial of the AB-measure task began with a blank screen for 500 ms. A fixation cross then appeared in the centre of the screen until there was a fixation of 100 ms. Two faces from the same actor were then presented to the left and right of where the fixation cross had been located for 1000 ms. The faces, selected from the FACES database (Ebner et al., 2010), were presented in sad-angry, sad-happy, sad-neutral, angry-happy, angry-neutral, and happy-neutral facial expression pairings. Once the faces had disappeared, a white dot appeared in the centre of one of the face’s previous location until there was a fixation of 100 ms. The trial presentation is shown in Figure 1. (see Appendix C [pgs. 301 to 302] for stimuli details). The AB-measure block comprised 96 trials which were shown randomly. The same block was used for both of the AB-measures (2 x 96 = 192 trials in total). The trials were counterbalanced for stimulus gender, and the side of the screen the facial expression type and dot appeared on.

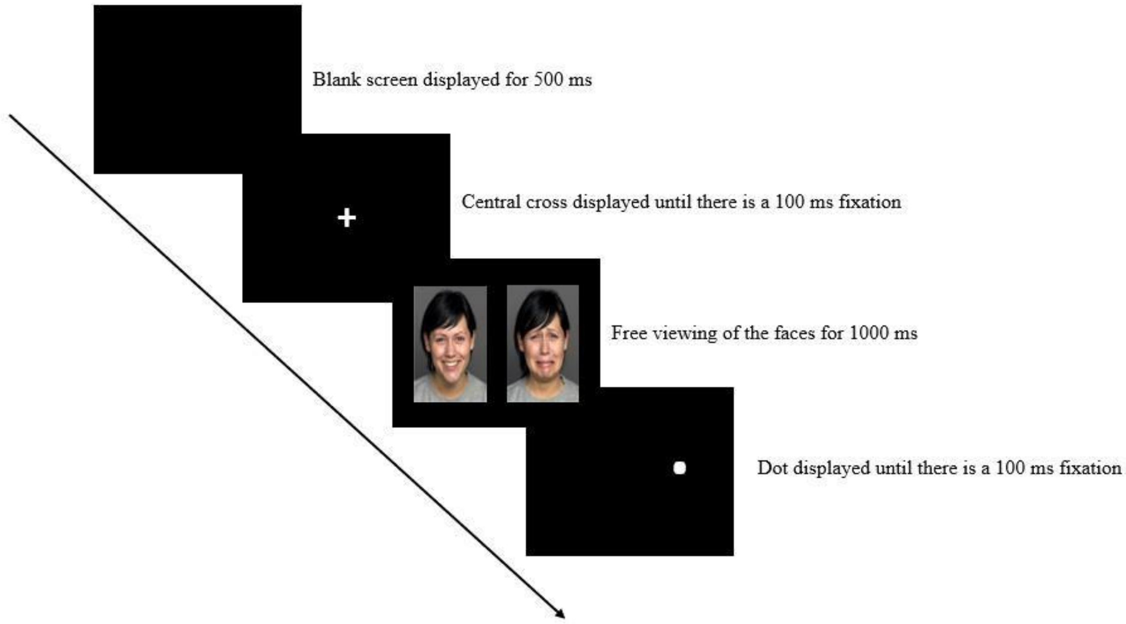

Figure 1. Trial presentation details

Gaze-contingent musical attentional bias modification

The same instruction screen as the AB-measure blocks was presented, and a music track began playing contemporaneously at the onset of the instruction screen and played continuously throughout each of the two GCM-ABM blocks. A consonant and dissonant version of an algorithmically generated music track (harps) accompanied one of the GCM-ABM blocks, and a consonant and dissonant version of a music track composed in a romantic period style (violins) accompanied the other (see Appendix C [pg. 302] and Bravo, (2013) and Bravo et al., (2020) for a detailed description of the music tracks' musical structure). The default setting for the music was that the consonant version of the track was audible and the dissonant version was inaudible during music play without gaze-contingency (see Figure 2.). Each trial began with the blank screen (500 ms) followed by the fixation cross (500 ms). The facial slide was then presented for 2500 ms and consisted of sad-neutral, angry-neutral, sad-happy, and angry-happy facial expression pairings. During this slide, the consonant and dissonant tracks' audibility was controlled by the participant's eye-gaze location. The participants were not informed of the gaze-contingent control/contingency. When the participant looked at the sad or angry faces, the dissonant version became audible and the consonant version became inaudible. The music setting returned to default (consonant version audible/dissonant version inaudible) when the participant looked away from the sad or angry faces, and at the end of the facial slide presentation. The GCM-ABM block contained 96 trials which were shown randomly. Each participant received two GCM-ABM blocks (2 x 96

= 192 trials in total). The trials were counterbalanced for stimulus gender, and the side of the screen the facial expression type appeared on.

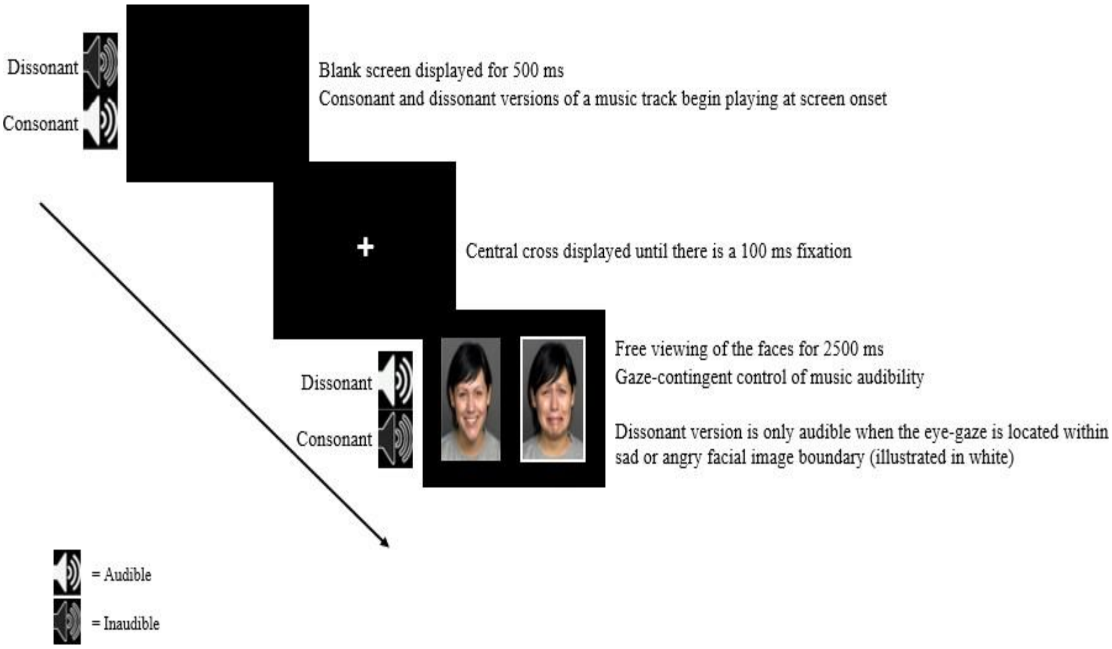

Figure 2. GCM-ABM trial presentation and music play information

Semi-structured interview

Participants were asked about their 1) awareness of the music (i.e., attention drawing/distractibility, and how many types of music they heard), 2) thoughts and feelings about the music (probes: [dis]likes, preference, emotions, and description of changes [if mentioned]), and 3) overall experience (probes: engagement, enjoyment level, and mood after taking part). We report on 1), 2) (i.e., changes), and 3) as they directly relate to our feasibility aims.

Data analysis

Descriptive analyses were performed with the Statistical Package for the Social Sciences, version 25 (IBM Corp, 2017).

Symptom status

A cut-off of ≥5 points on each scale represented the presence of depression (PHQ-9) and anxiety (GAD-7) (Kroenke & Spitzer, 2002; Löwe et al., 2008). Therefore, participants who scored <5 on both the PHQ-9 and the GAD-7 scales were classified as being non-depressed/non-anxious. Participants who scored ≥5 on the PHQ-9 and <5 on the GAD-7 scales were classified as depressed, or anxious if they scored <5 on the PHQ-9 and ≥5 on the GAD-7 scales. Participants who scored ≥5 on both the PHQ-9 and the GAD-7 scales were classified as having comorbid depression and anxiety.

Rumination

The median RRS (TR) score (47 points) was used to classify participants as low (below median score) and high (above median score) ruminators (Watkins & Mason, 2002).

Attentional biases

Fixations in the eye-tracking data were detected using the saccades package (Titus von der Malsburg, 2019) within R Studio (R Core Team, 2021), and only fixations with a minimum duration of 100 ms were used in later computations (Ferrari et al., 2016). For each participant, the fixation durations for each expression type in negative-neutral and negative-happy pairings were summed to provide the total dwell-time (TD-T). For negative-neutral pairings, the AB scores were calculated as the proportion of the TD-T on the negative face relative to the TD-T on both the negative face and its corresponding neutral face (i.e., the relative percentage dwell-time [RPD-T]). For negative-happy pairings, AB scores were calculated as the proportion of the TD-T on the negative face relative to the combined TD-T on both the negative face and happy face. Scores above 50% indicated longer dwelling on emotional or negative faces whereas a score below 50% indicated less dwelling these faces (Lazarov et al., 2017; Shamai-Leshem et al., 2021).

Study 1 Results

Descriptive comparisons are reported. Statistical and correlational analyses were not conducted due to the small sample size.

Participant characteristics

The NDNA participants (three females aged between 18 and 19 years old) were classified as low trait ruminators (see Table 1.). The anxious participants (two females aged 19 years old) were mixed in terms of their trait rumination classification (i.e., high and low trait ruminators). The comorbid participants (three females and one male aged between 18 and 43 years old) were mostly classified as high trait ruminators. PA and NA scores were mostly higher for the comorbid participants compared to the NDNA and anxious participants.

Table 1. Study 1 – Participant mood and bias score data

	Momentary mood			Mood			Bias score (% dwell-time) Neutral pairing		Happy pairing	
Participant	PA	NA	SR	TR	DEP	ANX	Sad	Angry	Sad	Angry
NDNA 1										
Baseline	30	12	29	31	4	1	53	49	61	53
Post-intervention	29	11	27				69	64	48	40
NDNA 2										
Baseline	25	14	38	43	1	3	36	54	60	32
Post-intervention	28	10	8				51	63	51	54
NDNA 3										
Baseline	16	12	40	47	3	4	49	71	36	-
Post-intervention	20	10	33				50	79	55	-
Anxious 1										
Baseline	32	14	34	48	4	8	42	48	46	56
Post-intervention	22	10	22				45	49	46	44
Anxious 2										
Baseline	29	11	8	46	2	5	55	59	42	47
Post-intervention	19	13	9				47	53	52	47
Comorbid 1										
Baseline	35	25	32	46	8	7	50	53	48	43
Post-intervention	33	23	35				55	48	56	45
Comorbid 2										
Baseline	38	15	13	55	16	7	51	45	53	47
Post-intervention	30	14	8				47	41	44	47
Comorbid 3										
Baseline	22	13	25	62	15	10	41	43	53	43
Post-intervention	13	13	19				58	54	40	47
Comorbid 4										
Baseline	35	14	2	58	11	10	59	47	53	58
Post-intervention	21	10	1				50	49	50	56

Notes. PA = positive affect; NA = negative affect; SR = state rumination; TR = trait rumination; NDNA = non- depressed/non-anxious; Comorbid = anxious and depressed.
Bias score = the proportion of the total dwell time (TD-T) on the negative face relative to the TD-T on both the negative face and its corresponding neutral face (or happy face).

Music and contingency awareness, and deliberate gaze-control

All of the participants were aware of and paid attention to the music, with the harps track being preferred by more participants (*n* = 5) than the violins track (*n* = 3) (liked both = 1). One participant was not distracted by the music while the remaining eight described it as being distracting in relation to the task (facial viewing = 2, having more focus than the task = 1, something to do alongside the task = 1), and the dissonant music versions (*n* = 4). Participants reported hearing 2 to 4 (2 = 6, 3 = 1, 4 = 2) music tracks, with the dissonant versions being counted as separate tracks by some (*n* = 3). Eight of nine participants were aware of the dissonant versions/a change, with the dissonant version being described as such (*n* = 1) or with other descriptors (*n* = 7) (e.g., 'discordant', 'off key', and 'unpleasant [one]').

Of these eight participants, three participants described a link between the music and their viewing pattern/gaze but not the contingency (e.g., '…it seemed the minute the music changed, my eyes moved or was it my eyes were moving and the music changed', and, 'especially because it [the music] sounded kind of scary and like sad so I would tend to notice the faces that were kind of…more like angry and emotions like that.'). Three others were explicitly aware of the music contingency, with two applying gaze-control to stop hearing the dissonant versions (e.g., 'When I looked at the unhappy it [the music] was just like not in tune so it did make me annoyed. So, I would look at the happy face more.'). The third used gaze-control a little but stopped due to task conflict (i.e., 'I tried to concentrate on the task [viewing the faces naturally] but my brain wanted to like look in a way to create some nice addition to the music. But I was trying to concentrate on the task, I was trying to generalise to the faces.').

Of note, the aversiveness of the dissonant versions could lead to avoidance and playing around (e.g., '...the sad [dissonant] part felt like it was in the [violins] song, it was part of the song whereas the second one [harps dissonant version] it was just so annoying. You would look at the sad face, it was so out of tune I would look immediately at the happy one [face]. Whereas the first song [violins], I was going backwards and forward between them [consonant and dissonant versions] because I liked to hear, it felt like it just went well together.'). And, rather than aversiveness, a participant found the switch 'interesting'.

Overall experience

Participants reporting having an 'interesting' (*n* = 4) or 'okay' experience (*n* = 2) overall. Three participants stated they enjoyed taking part, while another did not due to the dissonant music. All of the participants reported being engaged in the task, although the majority (*n* = 7) noted that engagement levels were lower at the end of the session compared to the start. Reasons included fatigue, difficulties focussing/concentrating, mind wandering, and boredom. Some participants found that the music increased engagement (*n* = 2), or that the music blocks felt quicker (*n* = 1), were preferred (*n* = 1) or were more engaging (*n* = 2) than the AB-measure blocks. Four participants did not feel their mood had changed after taking part, while others felt they were less anxious (*n* = 2), had fatigue/tiredness/less energy (*n* = 2), felt less attentive (*n* = 1), or were irritated as a result of the dissonant music versions (*n* = 1).

Three participants reported tiredness of the eyes post-intervention, with one reporting that the AB-measure was harder on the eyes.

Momentary mood

With the exception of one participant (NDNA 1 [showed reduced PA]), PA scores in affect such as ‘alert’ , ‘attentive’, and ‘active’, increased post-intervention for NDNA participants but decreased for the anxious and comorbid participants (see Table 1.) (see Appendix C [pg. 304] for PA and NA item scores). With the exception of two participants (Anxious 2 [increased in NA] and Comorbid 3 [showed no change in NA]), NA scores decreased post-intervention. With the exception of one participant (Anxious 2 [increased in SR]) SR scores decreased post-intervention.

Attentional biases

Emotional versus neutral comparisons

For the NDNA participants, increases in RPD-T on sad (1 to 16%) and angry (8 to 15%) faces were found post-intervention (see Table 1.). For the anxious and comorbid participants (except Comorbid 2), reductions in RPD-T on sad (4 to 9%) and angry (5 to 6%) were found post-intervention for the participants with baseline NAB (an AB score above 50%), whereas increases in RPD-T on sad (3 to 17%) and angry (1 to 11%) were found post-intervention for those without baseline NAB (an AB score ≤50%).

Negative versus happy comparisons

For the participants with baseline NAB, reductions in RPD-T on sad (3% to 13%) and angry (2% to 13%) faces were found post-intervention, whereas increases in RPD-T on sad (8% to 19%) and angry (2% to 22%) faces were found post-intervention for those without baseline

NAB (see Table 1.). No post-intervention change was seen for three individuals (i.e., Anxious 1 [sad-happy pairings], Anxious 2, and Comorbid 2 [angry-happy pairings]).

Study 1 discussion

The aims of Study 1 were to assess whether GCM-ABM could be done and should continue to be explored as our trial design (i.e., potential exposure to both consonant and dissonant music) had not been previously investigated. GCM-ABM could be done if there was an awareness of the consonant and dissonant track versions(/a change) and their contingency, and deliberate gaze-control was attempted. Exploration would continue in Study 2 if reduced NA, SR, and NAB were found post-intervention in descriptive data. Our findings show that GCM-ABM can be done as the majority of participants were aware of the dissonant versions/a change, their contingency (or a gaze-music link), and some used gaze-control to deliberately avoid the dissonant version of the music track. Further, that exploration should continue in Study 2 as reductions in NA, SR, and baseline NAB were found post-intervention in descriptive data. This was important given that some of the theoretical outcomes of ABM are a reduction in NAB and rumination.

However, as our findings are only descriptive, we do not know if the AB changes described here are a result of GCM-ABM or other factors such as cognitive load. For example, the emotional processing of negative stimuli and the experience of negative emotions can be attenuated by introducing high task demand/cognitive load (Maranges et al., 2017; Sebastian et al., 2017; Wang et al., 2016). Dissonant music's unexpected and complex structure requires a greater degree of information integration during its processing, imposing greater demands on existing cognitive resources than consonant music (Bonin & Smilek, 2016; Bravo et al., 2020; Yoo et al., 2022). The effect of music on cognition may last 10-15 minutes after exposure (Schellenberg, 2005) and our post-intervention AB measure was conducted within this time frame (i.e., five minutes post-intervention). Our descriptive data are similar in nature to the attenuation, or reversal of emotional biases observed under divided attention conditions in that NAB can be displayed during a full attention condition but a positive AB under a divided attention condition and vice versa (Knight et al., 2007). It is therefore possible that the anxious and comorbid participants' cognitive processing/load was impacted at the outset of the AB measure thus displaying the same pattern of response for negative-neutral and negative-emotional pairings. In contrast, the NDNA participants cognitive processing/load could have been impacted during negative-happy (emotional-emotional) pairings as there is higher conflict between the negative versus positive emotional valences (in emotional-emotional pairings) resulting in higher cognitive load, compared to emotional versus neutral emotional valences (in emotional-neutral pairings) (Greif & Waring, 2018). Thus, for the NDNA participants, the impact of the music on cognitive processing/load was potentially only evident when the cognitive processing demands of the task increased (Bonin & Smilek, 2016) (i.e., during negative-happy AB measure trials). If GCM-ABM was deemed feasible overall, cognitive load would be considered when determining how to proceed with the intervention.

Another factor that could be considered is arousal. While arousal levels were not directly assessed, increased arousal, indirectly demonstrated by the NDNA participants' higher post-intervention scores for affective states such as 'alert' (Posner et al., 2005), may have increased the saliency of emotional faces when paired with neutral faces (Mather & Sutherland, 2011), and possibly resulted in the uniformed increase in RPD-T on emotional faces. In contrast, the anxious and comorbid participants reported reductions in PA levels (i.e., less arousal) and did not show this uniformed increase in RPD-T on emotional faces. While these reductions may be in line with the lowered energy levels/fatigue and boredom reported in the semi-structured interview, it could also be associated with depression- and/or anxiety-related factors, such as an inability to maintain (initial) positive affect levels over time (i.e., the course of the session), and a high level of instability in the experience of positive affect (Heller et al., 2009; Pawluk et al., 2021). The consequence of PA reduction on depression and anxiety levels should be considered, and PA would be assessed in Study 2.

Encouragingly, the music/GCM-ABM blocks were more engaging, increased engagement, or were preferred by the majority of participants, even though the dissonant music version was included in these blocks. However, task instruction and the level of dislike of the dissonant music version would need to be considered when determining how to proceed with the intervention as it may influence if and how much deliberate gaze-control is used. And while we only had one report of irritableness and lack of enjoyment on account of the dissonant music and the participant's (Comorbid 3) NA/irritable score did not increase post-intervention, proceeding with multiple sessions of GCM-ABM in Study 2 would provide an opportunity to examine repeated exposure to the dissonant music versions.

Study 2

The aims of Study 2 were to assess whether GCM-ABM could be done and should continue to be explored in a larger study. We examined participant adherence and if there was any modulation of momentary mood, TR, depression, anxiety, and baseline NAB after four daily sessions. Four sessions were conducted as a previous ABM study (Wells & Beevers, 2010) showed significant reductions in symptoms following four sessions, and the number of training sessions can significantly influence post-intervention effects, with a larger number of training sessions being associated with larger effects (Hang et al., 2021; Jones & Sharpe, 2017).

Study 2 Materials and methods

Participants

One community-based participant and nine university students were recruited as a convenience sample via a departmental recruitment platform for course credits. They participated in the study between May and November 2021. The inclusion criteria remained the same as Study 1. Usable eye-tracking datasets were obtained from eight participants (six females and two males aged between 18 and 49 years old) (see Table 2.). Two participants were classified as NDNA, one as depressed, and five as comorbid. All participants had normal/corrected-to-normal vision.

Procedure

The participants in Study 2 completed the same tasks, in the same order, as outlined in Study 1's procedure except (1) the SR measure was not completed, (2) the tasks were completed once a day, for four days, and (3) the online self-report questionnaire was completed at home, for a second time, after the lab-based session on the 4th day. The depressed participant completed 3 sessions (due to the researcher's absence) and completed their second online survey at home, after the lab-based session on the 3rd day.

Measures

Participants completed the same (1) momentary mood (PANAS), TR (RRS), depression (PHQ-9), and anxiety (GAD-7) scales, (2) AB-measures, and (3) GCM-ABM blocks as described in Study 1, and they were conducted in the same manner.

Gaze location

Eye-gaze location was conducted in the same manner as described in Study 1. In the current study, participants were seated between 52 and 66 cms away from the desk.

Table 2. Study 2 – Participant mood and bias score data

	Momentary mood		Mood			Bias score (% dwell-time) Neutral pairings		Bias score (% dwell-time) Happy pairings	
Participant	PA	NA	TR	DEP	ANX	Sad	Angry	Sad	Angry
NDNA 1									
Baseline	38	10	23	0	0	49	45	51	71
Post-intervention	32	10	23	0	0	52	42	49	48
NDNA 2									
Baseline	21	10	34	4	1	40	45	33	39
Post-intervention	15	10	35	4	1	52	52	46	42
Depressed									
Baseline	29	10	59	14	3	50	57	49	51
Post-intervention	21	10	72*	14	4	50	52	54	46
Comorbid 1									
Baseline	29	11	65	10	9	50	59	45	38
Post-intervention	23	10	44*	4*	3*	39	46	16	19
Comorbid 2									
Baseline	29	10	58	7	8	46	47	51	37
Post-intervention	21	10	55	8	9	45	52	56	40
Comorbid 3									
Baseline	39	16	71	17	15	48	53	51	50
Post-intervention	43	22	57*	11*	9*	55	55	53	53
Comorbid 4									
Baseline	36	11	49	6	5	45	19	22	34
Post-intervention	30	13	49	5	4	42	54	33	28
Comorbid 5									
Baseline	39	11	49	12	10	84	47	25	22
Post-intervention	35	10	41	11	9	63	49	47	36

Notes. PA = positive affect; NA = negative affect; TR = trait rumination; DEP = depression, ANX = anxiety; NDNA = non- depressed/non-anxious; Comorbid = anxious and depressed.
Bias score = the proportion of the total dwell time (TD-T) on the negative face relative to the TD-T on both the negative face and its corresponding neutral face (or happy face).
*Clinically significant reduction.

Thoughts and feelings about the music

Participants were provided an opportunity during debriefing to share their thoughts and feelings on the music should they wish.

Data analysis

Data analysis was conducted in the same manner as described in Study 1. As pre- and post-intervention depression, anxiety, TR scores were collected in Study 2, clinically-relevant changes in these scores were examined in line with previous ABM and rumination studies (Roberts et al., 2021; Yang et al., 2015).

Rumination

As per Study 1, the median RRS (TR) score (54 points) was used to classify participants as low (below median score) or high (above median score) ruminators. To examine clinically-relevant changes in TR scores, RRS averages were calculated for each symptom status group to perform reliable change index (RC) calculations (Jacobson & Truax, 1991) (see Appendix C [pg. 305] for group averages). An RC score of >1.96 indicated a clinically-relevant change (Jacobson & Truax, 1991) in RRS scores. RC scores were computed using the formula as seen in (1) (X_2 = post-intervention score; X_1 = pre-intervention score; S_{diff} = the standard error of the difference between the pre- and post-intervention scores).

$$RC = \frac{X_2 - X_1}{S_{diff}} \tag{1}$$

Clinically-relevant changes

Mood. Based on psychotherapy literature (Kroenke, 2012; Toussaint et al., 2020), a reduction of 5 points on the PHQ-9 and 4 points on the GAD-7 was used to indicate clinically-relevant changes. Based on ABM literature (Yang et al., 2015), a post-intervention score falling within ± 2 standard deviations of the nonclinical group's mean depression score was used to indicate clinically-relevant changes.

Study 2 Results

Descriptive comparisons between the groups are reported. Statistical and correlational analyses were not conducted due to the small sample size.

Participant characteristics

The NDNA participants (one female and one male aged 32 and 36 years old) were classified as low trait ruminators (see Table 2.). The depressed participant (one female aged 18 years old) was classified as a high trait ruminator. The comorbid participants (four females and one male aged between 19 and 49 years old) reported the highest levels of rumination overall and consisted of more high trait ruminators (three of the five), than those classified as low ruminators (two of the five). PA and NA scores were mostly higher for comorbid participants compared to NDNA and anxious participants.

Adherence

With the exception of the depressed participant who was unable to complete all of the sessions due to the researcher's absence, all of the sessions and study components were completed.

Thoughts and feelings about the music

Five participants opted to/had time to provide comments about the music. All of these participants were aware of the dissonant version/a change. None of these participants used the term dissonant, rather, terms such as 'distorted', 'disconcerting', 'key change', and 'minor' were used. Three participants described the contingency, with two applying gaze-control to avoid the dissonant versions (e.g., '…I realised that the music changed according to the image I looked at….so it made me avoid looking at the sad images.'). Of note, one participant with contingency awareness and deliberate gaze-control described differing responses to the dissonant music versions and consequential use of gaze-control (i.e., 'Harps made me anxious. Harps made me want to avoid the expression that were sad or not neutral. Whereas with violins, I was able to look at both [faces] and was able to look at the sad expressions longer').

Momentary mood

With the exception of one participant (Comorbid 3 [showed increased PA]), PA (particularly in affect such as 'enthusiasm' and 'active') reduced post-intervention. NA was either unchanged (four of the eight participants), increased (two of the eight participants), or reduced (two of the eight participants) post-intervention (see Table 2. and Appendix C [pg. 306] for PA and NA item scores).

Trait rumination

If a change occurred, TR scores increased for NDNA and depressed participants post-intervention and reduced for comorbid participants. The depressed participant's TR increase (13 points), and Comorbid 1 and 3's TR reductions (6 points) were considered clinically significant changes.

Depression and anxiety symptoms

There was no change in depression and anxiety levels for the NDNA participants post-intervention (see Table 2.). There was also no change in the depressed participant's depression level post-intervention, but their anxiety level increased (1 point). With the exception of one participant (Comorbid 2 [1 point increase in depression and anxiety scores]), depression and anxiety levels reduced for the comorbid participants post-intervention. Comorbid 1 and 3 showed clinically significant reductions in both depression and anxiety symptoms (i.e., a 6-point reduction was above the literature-based thresholds [Kroenke, 2012; Toussaint et al., 2020], and equivalent to 2 standard deviations of the nonclinical participants' mean depression score [Yang et al., 2015]) (see Appendix C [pg. 305] for group averages).

Attentional biases

Emotional versus neutral comparisons

With the exception of one participant (Comorbid 3), reductions in RPD-T on sad (21%) and angry (5 to 13%) faces were found post-intervention for participants with baseline NAB (see Table 2.). Although in the majority of instances increases in RPD-T on sad (3 to 12%) and angry (2 to 35%) faces were found post-intervention for those without baseline NAB, there were also instances of increased biases away from negative faces (i.e., reductions in RPD-T on sad [1 to 11%] and angry [3%]) post-intervention.

Negative versus happy comparisons

With the exception of two participants (Comorbid 2 and 3), reductions in RPD-T on sad (2%) and angry (5 to 23%) faces were found post-intervention for participants with baseline NAB (see Table 2.). Although in the majority of instances increases in RPD-T on sad (5 to 22%) and angry (3 to 14%) faces were found post-intervention for those without baseline NAB, there were also instances of increased biases away from negative faces (i.e., reductions in RPD-T on sad [29%] and angry [3%]) post-intervention.

Study 2 Discussion

The aims of Study 2 were to assess whether GCM-ABM could be done and should continue to be explored in a larger study as it was unknown whether participants would engage in multiple sessions of exposure to the paradigm, and changes in PA, NA, TR, depression, anxiety, and NAB after four daily sessions would be found. GCM-ABM could be done if there was adherence to the study, and exploration would continue if reduced NA, TR, depression, anxiety, and baseline NAB were found post-intervention in descriptive data. Our findings show that GCM-ABM can be done as the participants adhered to the study (i.e., participants attended all sessions, completed all self-report measures, and there were no dropouts). Further, reductions in NA, TR, depression, anxiety, and NAB were found post-intervention for some participants in the descriptive data.

We generally found reductions in the PA levels post-intervention, even for the participants reporting lower depression and anxiety scores post-intervention. The largest reductions were seen in ‘enthusiasm’ and ‘active’ which could be in line with literature (Beard et al., 2012; Chan et al., 2022; Kuckertz et al., 2020) outlining participant boredom and fatigue/tiredness when taking part in ABM interventions. TR reduction was more evident in comorbid participants (seen in four out of the five participants). The comorbid participants with clinically-relevant reductions in TR also showed clinically-relevant reductions in depression and anxiety. The participant with a clinically-relevant increase in TR also showed a 1-point increase in their anxiety score. This participant completed three of the four GCM-ABM sessions due to researcher absence so it is unknown whether post-intervention TR and/or symptoms would have been higher or lower after the full number of GCM-ABM sessions.

NAB were reduced post-intervention in the majority of instances (one exception in negative-neutral pairings and two in negative-happy pairings). While increases in RPD-T on negative faces were found post-intervention for those without a baseline NAB, there were also findings in-keeping with traditional ABM responding (i.e., training away from negative faces for initially avoidant individuals) (Eldar et al., 2012). Although it is undesirable to increase avoidance, as avoidance is associated with poor outcomes (Eldar et al., 2012; Waters & Kershaw, 2015), our findings show that an individual can show NAB in negative-neutral pairings, but avoidance in negative-happy pairings (and vice versa) (e.g., NDNA 1 and Comorbid 5). As such, future research should explore which emotional contrasts (negative-neutral or negative-happy) are more closely associated with an individual’s depression and anxiety symptoms/post-intervention changes.

GCM-ABM evaluation

The findings from Study 1 and 2 showed that GCM-ABM was feasible. As such, an evaluation (i.e., what did and did not work) was performed to guide how to proceed further.

Music switch, its contingency, and use

All of the participants were aware of the dissonant version/a change occurring across the studies demonstrating that having consonant and dissonant versions of a track in one trial can work. Moreover, some participants were indeed motivated to look towards the more positive faces to avoid hearing the dissonant version/s. However, only a minority of participants were aware of the contingency and used deliberate gaze-control to avoid the dissonant versions. Consequently, allowing the participants to discern the contingency and their control over the music, and understand they could override the explicit task instructions did not work so well. Further, deliberate gaze-control to avoid the dissonant versions may, for some, be linked to how aversive the dissonant track was to the participant (i.e., the less aversive dissonant version was tolerated or played with and so viewing of the negative faces proceeded).

As such, the following research questions could be addressed to better understand how to proceed with GCM-ABM:

1. Does explicit instructions regarding gaze-control and the music (e.g., 'Your gaze controls the pleasantness of the music. Please keep the music as pleasant as possible') effect mood and NAB post-intervention?
2. Would the use of the participant's most disliked dissonant version across the GCM-ABM blocks have a positive effect on mood and NAB post-intervention?

Point 2 raises a more general questions about the number of tracks to be used moving forward. One participant liked both tracks and found their dissonance versions 'interesting' rather than aversive. The music tracks used in these studies were specifically created with the intention to control their dissonance level. While it may be too difficult/time consuming to create a dissonant version of each participant's own choice of music, their preference/most disliked/discernible in terms of change could potentially be obtained/selected from a wider range of created tracks. Thus, a music selection phase would need to be incorporated into the study design.

Number of sessions

While it was encouraging that participants reported lowered NA, SR, TR, depression, and anxiety scores after single- and/or multi-session GCM-ABM (Study 1 and 2, respectively), clinically-relevant reductions in depression and anxiety were seen in only two participants (Study 2). One explanation could be that the low number of sessions did not work so well. It is possible that more than four training sessions are required to reduce TR, depression, and anxiety levels in some participants. The number of training sessions, which can vary across interventions, has been shown to be a significant moderator in ABM (Hang et al., 2021; Jones & Sharpe, 2017). As such, the following research questions could be addressed to better understand how to proceed with GCM-ABM:

1. Should the number of GCM-ABM sessions be personalised (i.e., participant response-led)?
2. Should the number of GCM-ABM sessions be defined from a GCM-ABM study-specific or literature-based average?

The GCM-ABM study design would need to be modified to include multiple/periodic depression and anxiety assessments across the intervention to assess whether to continue or discontinue the GCM-ABM sessions. Eight sessions have been used and produced clinically-relevant results in other music-based studies (Lazarov et al., 2017; Shamai-Leshem et al., 2021), thus eight GCM-ABM sessions with a mood assessment in session 4 and 8 is a justifiable procedural change.

Additional measures

There is a potential for cognitive load to be a contributing/explanatory factor when comparing our descriptive findings with previous research (Knight et al., 2007), and as such, a measure of cognitive load would be incorporated into the study design. Pupil size (dilation) is a metric associated with cognitive load/effort that could be incorporated with minimal effort for the participant (e.g., recording the pupil for 500 ms before the target slide onset to establish a baseline pupil diameter) (Lisi et al., 2015; van der Wel & van Steenbergen, 2018).

Overall discussion

Two feasibility studies (Study 1 and 2) were conducted with the aims of identifying whether gaze-contingent musical ABM (GCM-ABM) could be done, whether GCM-ABM should continue to be explored, and if so, how. Previous studies examining music and visual attention (Arriaga et al., 2014; Bonin & Smilek, 2016) have exposed participants to either positive or negative music when viewing stimuli in a single trial – not both. Our finding show that GCM-ABM can be done as there was an awareness of the consonant and dissonant track versions(/a change) and their contingency, deliberate gaze-control was attempted, and participants adhered to the study with no participant dropout. Further, GCM-ABM should continue to be explored as on the whole, reduced negative affect (NA) (or no change), state rumination (SR), trait rumination (TR), depression, anxiety, and baseline NAB were found post-intervention in descriptive data. The clinically-relevant reductions in TR, depression, and anxiety levels is in line with research suggesting that ABM's effect on anxiety and depression is mediated by rumination (W. Yang et al., 2015). The potentially negative reports specifically about the dissonant music and lowered PA scores seen across Study 1 and 2, did not increase NA scores, and in terms of the latter, may possibly be attributed to general feelings related to ABM procedures (e.g., boredom and tiredness) that have previously been reported (Beard et al., 2012; Chan et al., 2022; Kuckertz et al., 2020). All-in-all, GCM-ABM was deemed feasible. As such, an evaluation of the findings from Study 1 and 2 was conducted to guide how to proceed with GCM-ABM. The outcome of this evaluation was that further development of GCM-ABM was required in that task instructions, dissonant track selection, and the number of sessions to be administered should be explored.

Should our single-session GCM-ABM (Study 1) descriptive findings of increased looking towards negative stimuli for participants without a baseline NAB (avoidant) be confirmed in a sufficiently powered study, there may be the potential for application. ABM avoidance training for individuals who do not display a NAB, or show attentional avoidance, is not ideal as avoidance is associated with poor interventional outcomes (Eldar et al., 2012; Waters & Kershaw, 2015). While an avoidant AB may reduce distress in the short term, it is maladaptive in the long term (Mogg & Bradley, 2018) and therefore requires treatment. It has been suggested that ABM treatment to correct avoidance in avoidant individuals, prior to exposure therapy, could potentially increase exposure therapy's treatment effects (Waters & Kershaw, 2015). GCM-ABM disruption of avoidant AB, as seen in the current descriptive data by participants receiving single-session GCM-ABM, could prove useful. In contrast, multiple of sessions of GCM-ABM showed instances of the traditional ABM 'training away' for some avoidant participants.

However, a participant could display no baseline NAB and a post-intervention NAB within emotional-neutral pairings, but a baseline NAB which was reduced post-intervention within emotional-emotional pairings. The majority of AB research stems from emotional-neutral experimental paradigms (Blanco et al., 2019). Our findings contribute to the limited emotional-emotional (e.g., angry-happy) AB data, and highlight the need to examine different types of contrasts. Examining emotional-neutral alongside emotional-emotional contrasts may lead to a better understanding of the relationship between AB and symptoms, and ABM therapeutic effects (Lazarov et al., 2017).

Limitations and future studies

Limitations of these studies include the lack of participants with only depression in Study 1 and with only anxiety in Study 2, the lack of a clinical diagnoses of neuropsychiatric symptoms, and that clinical history was not assessed. Future larger studies should screen and select participants based on neuropsychiatric status to allow for subgroup analysis (e.g., single diagnosis of depression or anxiety versus comorbid participants, and first episode versus multiple episode participants). Another potential limitation of our study is the number of training sessions as it has been shown to be a significant moderator in ABM (Hang et al., 2021; Jones & Sharpe, 2017). It is possible that more than four training sessions are required to reduce TR, depression, and anxiety levels in some participants. Additionally, a longer stimuli presentation duration could be incorporated within the GCM-ABM and AB measurement tasks. It may be possible that a longer stimuli presentation time may increase the effect of GCM-ABM, and longer stimuli presentation durations within AB measures are more reliable and demonstrate strong test-retest reliability (Lazarov et al., 2016; Sears et al., 2019).

Clinical/research implications

Our descriptive findings suggest that the same emotional expression can show opposing AB direction (towards or away) at baseline in negative-neutral pairings and negative-happy pairings, and AB change (increase or decrease) can be opposing for the same expression in negative-neutral pairings compared to negative-happy pairings following an intervention. Consequently, emotional-neutral and emotional-emotional contrasts should be examined in future AB studies to better understand the relationship between AB, symptoms, and therapeutic effects.

GCM-ABM was deemed feasible and should be further explored to ensure it works as intended for a larger number of individuals and to confirm what effects it has on mood and AB. Encouragingly, clinically-relevant reductions in rumination, depression, and anxiety levels were reported after multi-session GCM-ABM in its current form for some comorbid individuals.

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[Blinded for peer-review]

Disclosure of interest

The authors report there are no competing interests to declare.

Data availability statement

The data that support the findings of this study are available from the corresponding author, [X], upon reasonable request.

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6.1.1 Thesis aims and key study findings

Thesis aim 6 (to develop a music-based ABM intervention) and 7 (to explore the feasibility of the music-based ABM intervention with younger persons prior to future testing with older persons with and without AD) were explored in this chapter. While the findings suggest that GCM-ABM has the ability to reduce NAB, and rumination, depression, and anxiety to a clinically-relevant level in some individuals post-intervention, further exploration is required and some modifications would be needed moving forward.

Chapter 7

General Discussion

The broad range of literature reviewed within this thesis underpinned that depression and anxiety are prevalent and difficult to treat for PwD, is associated with increased cognitive decline, poor quality of life and outcomes, and that recommended treatments can be underutilised by PwD (i.e., psychological therapy) or over utilised by professionals (i.e., pharmacological treatment) although their efficacy is reduced for PwD. Moreover, PwD may leave their homes less over time to obtain therapy. Consequently, there was still a need for efficacious treatment options for depression and anxiety in dementia that could potentially be delivered from the home. The literature review also revealed that rumination and AB were understudied in dementia, and specific gaps pertaining to the reliability of rumination measures, the relationship between (1) rumination and anxiety, and (2) AB and mood, the effect of depression and anxiety interventions on rumination levels and AB, and the use of ABM interventions in this population were identified. And while the type of rumination one engages in can negatively interact (e.g., increase sad ruminations and a negative mood) with commonly used interventions in dementia (e.g., music and reminiscence) and music is known to affect AB in other populations, a consideration of ruminative tendencies in music-based interventions for PwD is in its infancy and studies examining rumination, music, and AB simultaneously were lacking.

As steps towards addressing the aforementioned gaps in knowledge, the overarching aims of this thesis was to design a technology-based intervention for depression and anxiety for PwAD, to explore rumination as a potential intervention target and the use of ABM with PwAD given that ABM can be used to reduce depression and anxiety via NAB and rumination reduction. Additional aims were required to fulfil the overarching aims. These aims were to:

1. Identify a reliable rumination measurement tool for use with PwAD
2. Determine the level of rumination in AD, and the relationship between rumination, depression, anxiety, and AB in AD
3. Explore the technologies used spontaneously in dementia

4. Explore remotely-delivered music research with WBET involving older persons with and without AD
5. Explore the feasibility of remotely-delivered multi-session ABM with WBET involving persons with and without AD
6. Develop a music-based ABM intervention, and
7. Explore the feasibility of the music-based ABM intervention with younger persons prior to future testing with older persons with and without AD

The key findings and novel contribution related to each of these aims are discussed next.

7.1 Rumination is a potential intervention target

The first study, 'Rumination in dementia and its relationship with depression, anxiety, and attentional biases', presented in Chapter 3 of this thesis addressed thesis aims 1 and 2. Examining and confirming participant attentiveness in responding and the test-retest reliability of three rumination scales (i.e., CERQ, RTSQ, and RRS) for PwD allowed the relationship between rumination, mood, and AB to be more confidently explored, and constituted new information in this sparse area of literature. Moreover, the relationship between rumination and anxiety was more appropriately explored via a more generalised rumination scale (i.e., RTSQ) given that the most extensively used scale (i.e., RRS) focuses on depression. This proved to be the right choice given that rumination as a thinking style (measured by the RTSQ) accounted for a higher amount of the variance in anxiety than rumination as a response to depression (measured by the RRS) for PwD. These findings constituted new knowledge regarding rumination and anxiety in dementia. All of the rumination measures were selected for use within the studies presented in Chapter 4 [section 4.4] and 5 of this thesis for comparative purposes and based on the variance accounted for in depression and anxiety for both groups.

These findings are also corroborated by recent literature (Keune et al., 2023) showing a positive relationship between rumination (as measured via the RRS) and depression for PwD and previous literature involving cognitively healthy older persons (Chen et al., 2020; Fernández-Fernández et al., 2014; McLaughlin & Nolen-Hoeksema, 2011; Nolen-Hoeksema & Aldao, 2011; Opdebeeck et al., 2015; Ramirez-Ruiz et al., 2019; Romero-Moreno et al., 2016; Von Hippel et al., 2008). Importantly, the relationship between rumination, depression, and anxiety found in this study suggested that rumination was a potential intervention target for PwD (explored in Chapter 4 [section 4.4]) which was of clinical relevance. Moreover, the relationship between rumination and AB for PwAD had not been explored prior to this thesis. Thus, the novel contributions from the findings in this chapter are:

1. Evidence that rumination can be reliably assessed for persons with a diagnosis of dementia has now been provided (based on internal and external reliability results)
2. The CERQ and RTSQ have now been validated for use with PwD (based on convergent validity results)
3. The relationship between rumination and anxiety has been determined for PwD, and data for estimating future study parameters has now been provided
4. The first step in exploring the relationship between AB and rumination for PwAD has been taken, and exploratory findings have now been provided for estimating future study parameters

7.2 Technologies use

The second study, 'Technology use, ownership, and spontaneous use by people living with and without cognitive impairment', presented in Chapter 4 (section 4.1) of this thesis addressed thesis aim 3. A telephone-based study-specific survey was created as there was no standard practice for reporting the use of technology by older persons. The survey was designed to examine the typical technologies (e.g., smartphones and tablets) used in this population and other items and activities which did not solely relate to cognitive aid functions, thus deviating from the norm. Due to the lack of UK literature relating to the spontaneous use of technologies by PwD, the findings in this chapter presented much needed data and allowed a better understanding of WBET study accessibility (i.e., webcam-ready device availability) to be gained for the subsequent thesis studies. The findings were in line with the literature from other countries showing that the information in this thesis is a reliable source on which future technology-based studies could be based. Importantly, the hardware for WBET (e.g., laptops) were owned by ~50% of PwD/PwCI and were used most days. As familiarity aids the adoption of technology-based health interventions and no additional/new devices were required (i.e., a specific eye-tracking device), there is the potential for WBET interventions to reach a large number of PwD/PwCI if these figures are represented at population-level. Conversely, the findings also show that WBET interventions would be inaccessible to ~50% of PwD/PwCI if they did not have a family member or representative with a laptop or PC with an embedded camera/separate webcam.

Fortunately, there have been recent studies examining tablet- and smartphone-based eye tracking (de Villers-Sidani et al., 2023; Valliappan et al., 2020). Although tablets were used least frequently here, smart phones were the most owned and most frequently used device compared to laptops, PCs, and tablets. Hence, if the underlying package behind the smartphone-based eye tracking is commercially available and validated for use with PwD, there may be a greater potential to reach PwD for remote eye-tracking-based interventions. Alternatively, researchers (and potentially healthcare providers in the future) could use their own devices and visit the participant in their own home as recently demonstrated by one study (Romeo et al., 2024).

7.3 Remotely-delivered research with webcam-based eye tracking

The manuscripts presented in Chapters 4 and 5 of this thesis addressed thesis aims 4 and 5 and explored the use of WBET in much needed AB research involving community-based older persons with and without dementia. Eye-tracking measures of AB are thought to be a more direct measure of AB and could potentially benefit PwD as it removes the need for the additional processing related to response-time paradigms (e.g., decision making and a motor response). However, WBET research is in its infancy and studies had not involved PwD. As such, the usability of WBET with older persons with and without dementia and the reliability of AB measures were explored in Chapter 4 (sections 4.2 and 4.3). The feasibility of multi-session ABM and music-based research with WBET was also explored in Chapters 4 (section 4.4) and 5, respectively. The findings across these manuscripts (section 4.2, 4.4, and Chapter 5) showed that remotely-delivered research with WBET was feasible for some individuals (i.e., study tasks could be completed, full and usable datasets were obtained for some participants, and issues could be resolved with [remote] assistance). These findings constituted new information in this research area and the feasibility of WBET as a tool for single and multi-session measures of AB for home-based older persons with and without cognitive impairment had now been established. Recommendations were also provided for developers and future researchers based on participant observation (e.g., improving face-mesh outline visibility and lighting direction) and desirable future functionality (e.g., pupil dilation measures). What can be measured using WBET is limited at present (e.g., the number of AOIs). While study design as discussed in Chapter 5 was constructed around WBET limitations, the findings presented here could be a promising indicator for attentional research involving dichotomous selection paradigms (e.g., visual paired comparison tasks), the results from which have been associated cognitive impairment levels (Bott et al., 2020).

Findings also showed that WBET AB metrics demonstrated similar reliability to lab-based eye-tracking studies with similar parameters (e.g., stimuli presentation duration) as those described in this thesis (section 4.3) and contribute to the limited but growing number of studies exploring the utility of WBET in psychological research. The potentially negative impact of calibration failure, which is higher with WBET than lab-based studies, was explored (section 4.4) in conjunction with multi-session ABM. Preliminary evidence supporting the use of an ABM paradigm, with music in this case, to reduce rumination, depression, and anxiety to a clinically-relevant degree for some PwAD in spite of repeated calibration failures across sessions has now been provided. An opportunistic and potentially useful finding for clinical/research purposes was that PwCI were able to conduct WBET independently without degradation of eye-gaze location accuracy (i.e., support vector machine classifier scores) after the first ABM with WBET session.

The descriptive data obtained in Chapter 5 were used to formulate hypotheses for future testing. The relative attention to different regions of the face, for different facial expressions, had not previously been explored nor had music, rumination, and AB for PwD been simultaneously explored prior to this thesis. Consequently, these studies represented new line of enquiries in the dementia-related (music) research field and exploratory data were now provided for estimating the study parameters of future hypotheses testing studies. Similarly to the descriptive findings in this chapter of the thesis, a previous study (Hot et al., 2013) found a difference in the response between PwAD compared to cognitively healthy older persons when increased dwelling on the eye region was forced (revealing the eye region first). Emotional recognition improved for PwAD but not for cognitively healthy older persons. The finding for a lack of improvement for cognitively healthy older persons has been recently replicated in another study using facial images wearing mouth masks (Carbon, 2020). If the hypotheses generated from the descriptive findings in this thesis are confirmed, it begs the question as to whether the music-related increases in attention to the eye region for PwAD improves emotional recognition ability for PwAD, and the increases in attention to the mouth region improves or impairs emotional recognition ability for cognitively healthy older persons, given the findings in the aforementioned recognition studies. Thus, the effect of music-related changes in AB on other cognitive domains (e.g., social cognition, and emotional regulation) should also be investigated in dementia.

7.4 Gaze-contingent attentional bias modification

The final study presented in Chapter 6 of this thesis describes two feasibility studies (Study 1 and 2) which addressed thesis aims 6 and 7. A music-based ABM intervention was developed (gaze-contingent musical ABM [GCM-ABM]), and the feasibility studies identified whether GCM-ABM could be done (via semi-structured interviews and adherence/dropout levels), whether GCM-ABM should continue to be explored (via mood and AB measures), and if so, how (via an evaluation of Study 1 and 2 findings). GCM-ABM was deemed feasible as it could be done (i.e., there was an awareness of the consonant and dissonant track versions/a change and their contingency, deliberate gaze-control was attempted, and participants adhered to the study with no participant dropout). Further, GCM-ABM should continue to be explored as on the whole, reductions in negative affect (or no change), state and trait rumination, depression, anxiety, and baseline NAB were found post-intervention in descriptive data. Importantly, findings suggested that GCM-ABM showed promise in reducing rumination, depression, and anxiety to a clinically-relevant degree for some individuals. However, the evaluation (i.e., examining what did and did not work) showed that some areas required further consideration (e.g., task instructions, dissonant track selection, and the number of sessions to be administered).

While gaze-contingent music has previously been used to reduce attention to negative stimuli (Lazarov et al., 2017; Shamai-Leshem et al., 2021), the findings in this thesis contributed new knowledge to this field of research by exploring the effect of gaze-contingent music on rumination levels. The participants in the aforementioned studies received more sessions (i.e., eight 20-minute sessions) than the participants who received GCM-ABM here (i.e., four 20-minute sessions). It is possible that a more intensive GCM-ABM intervention could achieve the effectiveness shown using gaze-contingent music for participants with anxiety (i.e., a clinically-relevant reduction in anxiety symptoms in 70% of participants post-intervention). However, GCM-ABM is qualitatively different from other paradigms utilising gaze-contingent music (Lazarov et al., 2017; Shamai-Leshem et al., 2021) in the treatment of depression and anxiety. GCM-ABM provides a continuous stream of music, which has been shown to be as effective as gaze-contingent music in a previous study (Shamai-Leshem et al., 2021) for participants with MDD, but also uses a quality of the music (level of dissonance) to enact a gaze-contingent element. Having gaze-contingent music was previously shown to be more effective than continuous music for participants with anxiety (Lazarov et al., 2017). Moreover, GCM-ABM included stimuli associated with both depression and anxiety (i.e., sad and angry faces, respectively). Although this has the potential to reduce the potency of training for some participants (e.g., depressed individuals) if training includes non-mood congruent stimuli (i.e., angry faces) within some trials, comorbid depression and depression is common and should be treated simultaneously, particularly in dementia (Neville & Teri, 2011; Sibley et al., 2021) (the intended population for GCM-ABM treatment).

7.5 Limitations

The limitations across the studies contained in this thesis are associated with sample size and characteristics, and study design and stimuli. The low number of participants, particularly in the eye-tracking studies, limited the type of analyses that could be conducted and resulted in a lack of power for some computations. It also resulted in a degree of overlap between some participants in the WBET studies although their data were analysed in different ways. For example, a participant's observational data relating to WBET usability could be included in Chapter 4 (section 4.2), and their AB data could be used in correlational analyses with rumination scores in Chapter 3 and/or WBET measured AB reliability analyses in Chapter 4 (section 4.3). The number of participants that could be recruited was impacted by the limited timeframe over which recruitment could be conducted and possibly the mode of recruitment (i.e., one online source of advertising). A long recruitment timeframe should be planned for and more targeted recruitment (e.g., a wider variety of study advert outlets and advertising via organisations related to computing with older persons such as AbilityNet) could alleviate these issues in future studies. There was also limited diversity within participant samples (e.g., ethnicity and neuropsychiatric symptoms). Advertising via community-based organisations and selecting participants based on their symptom status should alleviate these issues in future studies. The study's requirement for a representative to confirm a participant's capacity for consent was a barrier for some participants. Although more research is required to provide a gold standard way to assess capacity to consent in research for persons with dementia (Pennington et al., 2018), this study requirement will not be used in futures studies as it reduces participant autonomy.

In terms of study design, the online components of the studies within this thesis are a barrier to those without online access or access to suitable devices and/or support (e.g., isolated individuals). While this limitation is not easily overcome for all individuals, WBET via a researcher laptop with a portable web-access device (i.e., a dongle) and visits to a suitable location of the participant's choice, widens the scope of who can take part in this type of research. Similarly to lab-based eye-tracking studies, there were participants who were unable to complete the eye-tracking tasks due to unsuccessful face/eye detection or calibration failure, and as such, eye-tracking measures of AB, whether WBET or not, are inaccessible to some individuals. While the recent developments in the programming underneath WBET is leading to more accurate gaze location estimates, improved face detection models are also needed that are trained on a wider variety of ethnicities and ages (Saxena et al., 2023) to allow more, and a wider range of individuals to participate in WBET studies.

In terms of study's stimuli, there was limited number of older-person images that could be used, a lack of diversity of the actors featured within the image sets, and a limited choice of music was presented to the participants. The first two limitations are research-wide issues and an increased number of older-person image sets are required which include persons from a wider range of ethnicities. In terms of the music tracks that were presented, the samples were specifically created to alter their dissonance levels and were kindly made available by the composer for the studies in this thesis. A musician would need to be employed or be part of the research team in future studies to allow a wider selection of music to be presented/selected from as discussed in Chapter 6.

7.6 Conclusions

To conclude, the findings in this thesis suggest that rumination (1) should be assessed in interventions involving PwD, (2) is a potential treatment target which can be reliably assessed in dementia using the CERQ, RTSQ, and RRS, and (3) is reduced following ABM with music. The clinically-relevant reductions in depression and anxiety that were found following ABM with music for some PwAD warrants further investigation of this intervention. This is important given the lack of efficacy and side effect associated with current treatments. Moreover, confirming the feasibility of WBET use with some older persons with and without dementia, particularly across multiple sessions, is an important and promising indicator for AB research in this population as well as other research domains in dementia that could utilise eye-tracking data to monitor change over time. Confirming the feasibility of GCM-ABM and the clinically-relevant reductions in depression, anxiety, and rumination that were found following GCM-ABM for younger persons warrants further exploration of this intervention to ensure it works as intended for a larger number of individuals and to confirm what effects it has on mood and AB before being piloted with PwAD. However, more work is required to ensure that this type of research is more inclusive (e.g., recruitment processes, improved face detection models, and image datasets).

7.7 Impact

The usability study presented in Chapter 4 (4.2) has proved useful to the wider research community, being cited by six publications (see Appendix A).

The reliability study presented in Chapter 4 (4.3) has garnered a lot of interest, being the most-read article in the issue in which it was published, and article has been reported by a news outlet (https://www.alzforum.org).

7.8 Future directions

7.8.1 Further exploration of GCM-ABM

The feasibility studies of GCM-ABM with young persons identified that GCM-ABM could be done and should continue to be explored. As such, a lab-based feasibility study will now be conducted to explore task instructions as discussed in Chapter 6. The following research questions will be explored - does explicit instructions regarding gaze-control and the music (e.g., 'Your gaze controls the pleasantness of the music. Please keep the music as pleasant as possible') effect mood and NAB post-intervention?.

7.8.2 Image set creation and WBET

Given the inclusion barriers of age and ethnicity in regard to face-meshing/eye-gaze location, a multi-site, cross-cultural project could be designed to generate a large, validated image set specifically for older-person research that is ethnically diverse. This dataset could then be used in future AB research and for model training. In the meanwhile, WBET will continue to be explored with PwD to better understand its utility in psychological research. As outlined in Chapter 4 (section 4.3), the reliability of WBET measures of AB with longer stimulus presentations times, and test-retest reliability will be explored. More emotional-emotional facial pairings data will be collected and explored, and a comparative in-lab versus WBET study needs to be conducted to investigate the AB magnitude of these data.

7.8.3 The neural correlates of rumination in Alzheimer's disease

The potential overlap between the neural correlates of rumination from MDD literature and those obtained from AD literature was discussed in Chapter 2 (section 2.1.3.2), but it is yet to be determined whether the neural correlates of rumination in AD actually reflect or differ from the exiting literature in MDD. A future study could investigate the differences between resting and an induced ruminative state for depressed and non-depressed PwAD versus depressed and non-depressed older persons (see Ferdek et al. (2016) for a similar investigation involving younger persons). Identifying a directional pathway between brain regions (effective connectivity) could elucidate potential targets for interventions such as rTMS (Wu et al., 2015).

It was also speculated in Chapter 3 that once a ruminative state is entered, that it may be harder for PwAD to disengage from ruminative thinking, leading to a longer depressed or anxious mood. Examining the effect of an induced ruminative state on attentional disengagement and mood could be conducted within the same study.

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Appendix A Citations

1. Wisiecka, K., Krejtz, K., Krejtz, I., Sromek, D., Cellary, A., Lewandowska, B., & Duchowski, A. (2022, June). Comparison of webcam and remote eye tracking. *In 2022 Symposium on Eye Tracking Research and Applications* (pp. 1-7). https://dl.acm.org/doi/abs/10.1145/3517031.3529615
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Appendix B Symposiums and conference presentations

- Physiological Society Symposium 2018: From Lab to Clinic – Pathways to Translational Brain Machine Interfaces for Rehabilitation – lighting round talk and poster presentation
- Reading University School of Biological Sciences Symposium 2019 – poster presentation.
- Alzheimer’s Annual Conference 2020 - poster presentation
- ARUK 2020 - poster presentation
- The 23rd International ACM SIGACCESS Conference on Computers and Accessibility **(**ASSETs 2021) – Video poster presentation
- Reading University School of Biological Sciences Symposium 2022 – poster presentation.
- British Geriatric Society Conference 2023 – video abstract and poster presented in collaboration with Royal Berkshire Hospital elderly care-ward staff.

Appendix C Manuscript supplementary materials

Chapter 3

Rumination in dementia and its relationship with depression, anxiety, and attentional biases

Data quality

Explicit requests/instruction (i.e., informing participants that provide open and honest responses would help to improve data quality) can reduce, for example, social desirability biases (Lu et al., 2022).

Item non-response can be an indicator of inattentiveness and it reduces data quality (Gummer et al., 2021; Silber et al., 2022). As item non-response can be due to fatigue/lengthy surveys (Mody et al., 2008), a 'finish later' facility allowed participants to save their responses and return to finish the survey if a break was needed.

Within the survey, each item was set as required (i.e., a response had to be entered). If the participant clicked the 'Next' button while having missing items on the current page, a prompt was generated (i.e., a notification appeared with a hyperlink to any missed items, and the word 'Required' appeared beside each item).

An indirect measure of data quality, straightlining, was employed in the current study as it does not (1) increase the number of survey items, and (2) have the potential to impact a participant's behaviour/latter responses (Gummer et al., 2021). No data was removed from our PwD group's dataset as (1) the consistency shown between T1 and T2 responses (i.e., similar items being scored/little variation in the SL areas occurring within both surveys) suggests that responses were intentional, (2) a degree of SL can be seen in respondents with high attentiveness, (3) analyses which include a low proportion of potentially inattentive respondent's responses reduces bias and should not severely affect data quality (Gummer et al., 2021; Silber et al., 2019), and (4) T1 versus T2 Cronbach alpha and/or correlations coefficients, as discussed later, are in line with the test-retest reliabilities of responses obtained via postal response (Garnefski & Kraaij, 2007), in the presence of a researcher and via telephone (Brinker & Dozois, 2009), and face-to-face interview (McLaughlin & Nolen-Hoeksema, 2011) with cognitively healthy adults.

Inattentiveness has been shown to reduce correlational strengths (Silber et al., 2019), yet this was not demonstrated within the full HC dataset. Zero-order bivariate correlations between rumination and depression scores only marginally differed between the datasets, but correlation strengths were greatly reduced between rumination (i.e., RUM-EMO-REG style, and RUM-RESP-DEP brooding and reflection) and anxiety scores for the non-SL dataset.

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Table 1. Descriptive statistics, Cronbach's alpha, and correlations for the non-straightlining HC participants' demographic, cognitive ability, rumination, and mood data

	HC (n = 54)					
	Median (mean)	*IQR* (*SD*)	α	Zero-order correlations		
Measures				TICS	PHQ-9	GAD-7
Age	70	8	N/A	-.28*	-.24	-.002
TICS	(35)	(2)	.35	-	-.03	-.22
Rumination						
Emotion regulation style						
CERQ	8	4	.71	.08	.28*	.19
Thinking style						
RTSQ	(60)	(20)	.92	.03	.51**	.50**
Response to depression						
RRS total	32	8	.86	-.07	.76**	.68**
RRS brooding	8	2	.78	-.05	.46**	.38**
RRS reflection	6	3	.54	.03	.47**	.43**
Mood						
Depression						
PHQ-9	2	3	.78	-.03	-	.70**
Anxiety						
GAD-7	2	3	.88	-.22	.70**	-

Notes. HC = healthy controls; **α** = Cronbach's alpha; TICS = Telephone interview for cognitive status; PHQ-9 = Patient Health Questionnaire 9; GAD-7 = Generalized Anxiety Disorder scale; CERQ = Cognitive Emotion Regulation Questionnaire; RTSQ = Ruminative Thought Style Questionnaire; RRS = Ruminative Response Scale
RRS total = combined depressive, brooding and reflection subscale scores.
* significant at the .05 level (2-tailed)
** significant at the .01 level (2-tailed

Individual effect sizes (EF)

Age versus cognitive ability, rumination, and mood

PwD group - RUM-EMO-REG, r^2 = .08; RUM-RESP-DEP reflection, r^2 = .07; anxiety, r^2 = .08.

HC group - TICS = r^2 = .06, RUM-EMO-REG, r^2 = .10; depression, r^2 = .07.

Cognitive ability versus rumination and mood

PwD group - RUM-EMO-REG, r^2 = .10; RUM-THINK, r^2 = .07; RUM-RESP-DEP reflection, r^2 = .10; anxiety, r^2 = .08).

Rumination and depression

PwD group - RUM-EMO-REG, r^2 = .31; RUM-THINK, r^2 = .21; RUM-RESP-DEP combined-types, r^2 = .30, brooding, r^2 = .18, and reflection, r^2 = .20.

HC group - RUM-EMO-REG, r^2 = .11; RUM-THINK, r^2 = .23; RUM-RESP-DEP combined-types, r^2 = .48, brooding, r^2 = .20, and reflection, r^2 = .26.

Rumination and anxiety

PwD group - RUM-EMO-REG style, r^2 = .41; RUM-THINK, r^2 = .62; RUM-RESP-DEP combined-types, r^2 = .41, brooding, r^2 = .30, and reflection, r^2 = .27.

HC group - RUM-EMO-REG style, r^2 = .08; RUM-THINK, r^2 = .22; RUM-RESP-DEP combined-types, r^2 = .53, brooding, r^2 = .25, and reflection, r^2 = .25.

Partial correlations

PWD

Correlations

Control Variables			Age	CERQ	RTSQ	Brooding	Reflection	RRS-combined	PHQ9	GAD7
TICS	Age	Correlation	1.000	-0.249	-0.199	-0.101	-0.212	-0.158	-0.182	-0.239
		Significance (2-tailed)		0.049	0.118	0.433	0.095	0.217	0.153	0.059
		df	0	61	61	61	61	61	61	61
	CERQ	Correlation	-0.249	1.000	0.527	0.611	0.628	0.654	0.524	0.600
		Significance (2-tailed)	0.049		0.000	0.000	0.000	0.000	0.000	0.000
		df	61	0	61	61	61	61	61	61
	RTSQ	Correlation	-0.199	0.527	1.000	0.566	0.476	0.613	0.419	0.771
		Significance (2-tailed)	0.118	0.000		0.000	0.000	0.000	0.001	0.000
		df	61	61	0	61	61	61	61	61
	Brooding	Correlation	-0.101	0.611	0.566	1.000	0.599	0.889	0.429	0.568
		Significance (2-tailed)	0.433	0.000	0.000		0.000	0.000	0.000	0.000
		df	61	61	61	0	61	61	61	61
	Reflection	Correlation	-0.212	0.628	0.476	0.599	1.000	0.754	0.404	0.474
		Significance (2-tailed)	0.095	0.000	0.000	0.000		0.000	0.001	0.000
		df	61	61	61	61	0	61	61	61
	RRS-combined	Correlation	-0.158	0.654	0.613	0.889	0.754	1.000	0.535	0.633
		Significance (2-tailed)	0.217	0.000	0.000	0.000	0.000		0.000	0.000
		df	61	61	61	61	61	0	61	61
	PHQ9	Correlation	-0.182	0.524	0.419	0.429	0.404	0.535	1.000	0.563
		Significance (2-tailed)	0.153	0.000	0.001	0.000	0.001	0.000		0.000
		df	61	61	61	61	61	61	0	61
	GAD7	Correlation	-0.239	0.600	0.771	0.568	0.474	0.633	0.563	1.000
		Significance (2-tailed)	0.059	0.000	0.000	0.000	0.000	0.000	0.000	
		df	61	61	61	61	61	61	61	0

Correlations

Control Variables			Age	TICS	CERQ	RTSQ	Brooding	Reflection	RRS-combined	GAD7
PHQ9	Age	Correlation	1.000	-0.150	-0.211	-0.162	-0.011	-0.186	-0.070	-0.190
		Significance (2-tailed)		0.240	0.097	0.206	0.935	0.145	0.585	0.135
		df	0	61	61	61	61	61	61	61
	TICS	Correlation	-0.150	1.000	0.233	0.187	-0.096	0.255	-0.010	0.181
		Significance (2-tailed)	0.240		0.066	0.141	0.456	0.044	0.936	0.155
		df	61	0	61	61	61	61	61	61
	CERQ	Correlation	-0.211	0.233	1.000	0.424	0.463	0.562	0.502	0.457
		Significance (2-tailed)	0.097	0.066		0.001	0.000	0.000	0.000	0.000
		df	61	61	0	61	61	61	61	61
	RTSQ	Correlation	-0.162	0.187	0.424	1.000	0.442	0.399	0.496	0.723
		Significance (2-tailed)	0.206	0.141	0.001		0.000	0.001	0.000	0.000
		df	61	61	61	0	61	61	61	61
	Brooding	Correlation	-0.011	-0.096	0.463	0.442	1.000	0.472	0.861	0.410
		Significance (2-tailed)	0.935	0.456	0.000	0.000		0.000	0.000	0.001
		df	61	61	61	61	0	61	61	61
	Reflection	Correlation	-0.186	0.255	0.562	0.399	0.472	1.000	0.670	0.356
		Significance (2-tailed)	0.145	0.044	0.000	0.001	0.000		0.000	0.004
		df	61	61	61	61	61	0	61	61
	RRS-combined	Correlation	-0.070	-0.010	0.502	0.496	0.861	0.670	1.000	0.466
		Significance (2-tailed)	0.585	0.936	0.000	0.000	0.000	0.000		0.000
		df	61	61	61	61	61	61	0	61
	GAD7	Correlation	-0.190	0.181	0.457	0.723	0.410	0.356	0.466	1.000
		Significance (2-tailed)	0.135	0.155	0.000	0.000	0.001	0.004	0.000	
		df	61	61	61	61	61	61	61	0

Correlations

Control Variables			Age	TICS	CERQ	RTSQ	Brooding	Reflection	RRS-combined	PHQ9
GAD7	Age	Correlation	1.000	-0.126	-0.156	-0.034	0.065	-0.140	0.002	-0.070
		Significance (2-tailed)		0.326	0.222	0.793	0.614	0.274	0.990	0.585
		df	0	61	61	61	61	61	61	61
	TICS	Correlation	-0.126	1.000	0.191	0.081	-0.174	0.221	-0.079	0.093
		Significance (2-tailed)	0.326		0.134	0.530	0.174	0.082	0.537	0.468
		df	61	0	61	61	61	61	61	61
	CERQ	Correlation	-0.156	0.191	1.000	0.140	0.363	0.510	0.417	0.293
		Significance (2-tailed)	0.222	0.134		0.275	0.003	0.000	0.001	0.020
		df	61	61	0	61	61	61	61	61
	RTSQ	Correlation	-0.034	0.081	0.140	1.000	0.225	0.210	0.245	-0.021
		Significance (2-tailed)	0.793	0.530	0.275		0.076	0.098	0.053	0.872
		df	61	61	61	0	61	61	61	61
	Brooding	Correlation	0.065	-0.174	0.363	0.225	1.000	0.399	0.829	0.141
		Significance (2-tailed)	0.614	0.174	0.003	0.076		0.001	0.000	0.269
		df	61	61	61	61	0	61	61	61
	Reflection	Correlation	-0.140	0.221	0.510	0.210	0.399	1.000	0.630	0.204
		Significance (2-tailed)	0.274	0.082	0.000	0.098	0.001		0.000	0.109
		df	61	61	61	61	61	0	61	61
	RRS-combined	Correlation	0.002	-0.079	0.417	0.245	0.829	0.630	1.000	0.270
		Significance (2-tailed)	0.990	0.537	0.001	0.053	0.000	0.000		0.032
		df	61	61	61	61	61	61	0	61
	PHQ9	Correlation	-0.070	0.093	0.293	-0.021	0.141	0.204	0.270	1.000
		Significance (2-tailed)	0.585	0.468	0.020	0.872	0.269	0.109	0.032	
		df	61	61	61	61	61	61	61	0

HC

Correlations

Control Variables			Age	CERQ	RTSQ	Brooding	Reflection	RRS-combined	PHQ9	GAD7
TICS	Age	Correlation	1.000	-0.292	-0.152	-0.093	-0.172	-0.197	-0.261	-0.230
		Significance (2-tailed)		0.012	0.197	0.432	0.142	0.093	0.025	0.049
		df	0	72	72	72	72	72	72	72
	CERQ	Correlation	-0.292	1.000	0.260	0.252	0.533	0.428	0.324	0.315
		Significance (2-tailed)	0.012		0.025	0.030	0.000	0.000	0.005	0.006
		df	72	0	72	72	72	72	72	72
	RTSQ	Correlation	-0.152	0.260	1.000	0.381	0.251	0.499	0.475	0.479
		Significance (2-tailed)	0.197	0.025		0.001	0.031	0.000	0.000	0.000
		df	72	72	0	72	72	72	72	72
	Brooding	Correlation	-0.093	0.252	0.381	1.000	0.397	0.716	0.450	0.502
		Significance (2-tailed)	0.432	0.030	0.001		0.000	0.000	0.000	0.000
		df	72	72	72	0	72	72	72	72
	Reflection	Correlation	-0.172	0.533	0.251	0.397	1.000	0.714	0.508	0.519
		Significance (2-tailed)	0.142	0.000	0.031	0.000		0.000	0.000	0.000
		df	72	72	72	72	0	72	72	72
	RRS-combined	Correlation	-0.197	0.428	0.499	0.716	0.714	1.000	0.690	0.737
		Significance (2-tailed)	0.093	0.000	0.000	0.000	0.000		0.000	0.000
		df	72	72	72	72	72	0	72	72
	PHQ9	Correlation	-0.261	0.324	0.475	0.450	0.508	0.690	1.000	0.699
		Significance (2-tailed)	0.025	0.005	0.000	0.000	0.000	0.000		0.000
		df	72	72	72	72	72	72	0	72
	GAD7	Correlation	-0.230	0.315	0.479	0.502	0.519	0.737	0.699	1.000
		Significance (2-tailed)	0.049	0.006	0.000	0.000	0.000	0.000	0.000	
		df	72	72	72	72	72	72	72	0

Correlations

Control Variables			Age	TICS	CERQ	RTSQ	Brooding	Reflection	RRS-combined	GAD7
PHQ9	Age	Correlation	1.000	-0.231	-0.249	-0.048	0.040	-0.071	-0.027	-0.019
		Significance (2-tailed)		0.047	0.032	0.685	0.733	0.548	0.817	0.870
		df	0	72	72	72	72	72	72	72
	TICS	Correlation	-0.231	1.000	0.129	0.068	-0.055	0.107	0.016	-0.200
		Significance (2-tailed)	0.047		0.272	0.562	0.644	0.363	0.890	0.088
		df	72	0	72	72	72	72	72	72
	CERQ	Correlation	-0.249	0.129	1.000	0.135	0.118	0.460	0.298	0.102
		Significance (2-tailed)	0.032	0.272		0.251	0.317	0.000	0.010	0.385
		df	72	72	0	72	72	72	72	72
	RTSQ	Correlation	-0.048	0.068	0.135	1.000	0.208	0.020	0.269	0.216
		Significance (2-tailed)	0.685	0.562	0.251		0.075	0.866	0.020	0.065
		df	72	72	72	0	72	72	72	72
	Brooding	Correlation	0.040	-0.055	0.118	0.208	1.000	0.212	0.625	0.298
		Significance (2-tailed)	0.733	0.644	0.317	0.075		0.070	0.000	0.010
		df	72	72	72	72	0	72	72	72
	Reflection	Correlation	-0.071	0.107	0.460	0.020	0.212	1.000	0.581	0.238
		Significance (2-tailed)	0.548	0.363	0.000	0.866	0.070		0.000	0.041
		df	72	72	72	72	72	0	72	72
	RRS-combined	Correlation	-0.027	0.016	0.298	0.269	0.625	0.581	1.000	0.480
		Significance (2-tailed)	0.817	0.890	0.010	0.020	0.000	0.000		0.000
		df	72	72	72	72	72	72	0	72
	GAD7	Correlation	-0.019	-0.200	0.102	0.216	0.298	0.238	0.480	1.000
		Significance (2-tailed)	0.870	0.088	0.385	0.065	0.010	0.041	0.000	
		df	72	72	72	72	72	72	72	0

Correlations										
Control Variables			Age	TICS	CERQ	RTSQ	Brooding	Reflection	RRS-combined	PHQ9
GAD7	Age	Correlation	1.000	-0.264	-0.273	-0.087	0.017	-0.113	-0.089	-0.183
		Significance (2-tailed)		0.023	0.019	0.460	0.887	0.337	0.453	0.119
		df	0	72	72	72	72	72	72	72
	TICS	Correlation	-0.264	1.000	0.180	0.154	0.034	0.201	0.185	0.174
		Significance (2-tailed)	0.023		0.125	0.191	0.775	0.087	0.114	0.138
		df	72	0	72	72	72	72	72	72
	CERQ	Correlation	-0.273	0.180	1.000	0.155	0.119	0.475	0.328	0.179
		Significance (2-tailed)	0.019	0.125		0.188	0.314	0.000	0.004	0.128
		df	72	72	0	72	72	72	72	72
	RTSQ	Correlation	-0.087	0.154	0.155	1.000	0.188	0.033	0.267	0.244
		Significance (2-tailed)	0.460	0.191	0.188		0.109	0.777	0.022	0.037
		df	72	72	72	0	72	72	72	72
	Brooding	Correlation	0.017	0.034	0.119	0.188	1.000	0.188	0.587	0.164
		Significance (2-tailed)	0.887	0.775	0.314	0.109		0.109	0.000	0.162
		df	72	72	72	72	0	72	72	72
	Reflection	Correlation	-0.113	0.201	0.475	0.033	0.188	1.000	0.589	0.265
		Significance (2-tailed)	0.337	0.087	0.000	0.777	0.109		0.000	0.023
		df	72	72	72	72	72	0	72	72
	RRS-combined	Correlation	-0.089	0.185	0.328	0.267	0.587	0.589	1.000	0.383
		Significance (2-tailed)	0.453	0.114	0.004	0.022	0.000	0.000		0.001
		df	72	72	72	72	72	72	0	72
	PHQ9	Correlation	-0.183	0.174	0.179	0.244	0.164	0.265	0.383	1.000
		Significance (2-tailed)	0.119	0.138	0.128	0.037	0.162	0.023	0.001	
		df	72	72	72	72	72	72	72	0

AB Sub-group analyses

Correlations					
			Sad dwell-time	Angry dwell-time	Happy dwell-time
Spearman's rho	CERQ	Correlation Coefficient	0.541	-0.060	0.570
		Sig. (2-tailed)	0.133	0.879	0.109
		N	9	9	9
	RTSQ	Correlation Coefficient	0.231	-.797*	0.370
		Sig. (2-tailed)	0.550	0.010	0.327
		N	9	9	9
	Brooding	Correlation Coefficient	0.414	0.103	0.034
		Sig. (2-tailed)	0.268	0.793	0.931
		N	9	9	9
	Reflection	Correlation Coefficient	0.013	0.245	-0.051
		Sig. (2-tailed)	0.974	0.526	0.896
		N	9	9	9
	RRS combined	Correlation Coefficient	0.376	0.254	0.017
		Sig. (2-tailed)	0.318	0.509	0.966
		N	9	9	9
	GAD-7	Correlation Coefficient	0.275	-0.102	0.312
		Sig. (2-tailed)	0.474	0.794	0.413
		N	9	9	9
	PHQ-9	Correlation Coefficient	0.474	0.137	0.246
		Sig. (2-tailed)	0.197	0.726	0.524
		N	9	9	9
	Sad dwell-time	Correlation Coefficient	1.000	0.304	-0.121
		Sig. (2-tailed)		0.426	0.757
		N	9	9	9
	Angry dwell-time	Correlation Coefficient	0.304	1.000	-0.513
		Sig. (2-tailed)	0.426		0.158
		N	9	9	9
	Happy dwell-time	Correlation Coefficient	-0.121	-0.513	1.000
		Sig. (2-tailed)	0.757	0.158	
		N	9	9	9
*. Correlation is					
**. Correlation is					

Confidence intervals

PWD $n = 64$

Confidence Intervals of Spearman's rho				
	Spearman's rho	Significance (2-tailed)	(2-tailed)a,b Lower	Upper
CERQ - GAD7	0.636	0.000	0.443	0.773
CERQ - PHQ9	0.559	0.000	0.346	0.717
RTSQ - GAD7	0.789	0.000	0.653	0.875
RTSQ - PHQ9	0.457	0.000	0.226	0.639
Brooding - GAD-7	0.549	0.000	0.334	0.709
Brooding - PHQ-9	0.420	0.001	0.184	0.611
Reflection - GAD-7	0.522	0.000	0.302	0.690
Reflection - PHQ-9	0.450	0.000	0.217	0.634
RRS combined - GAD-7	0.638	0.000	0.445	0.774
RRS combined - PHQ-9	0.545	0.000	0.330	0.707
GAD-7 - PHQ-9	0.592	0.000	0.388	0.741

a. Estimation is based on Fisher's r-to-z transformation.

b. Estimation of standard error is based on the formula proposed by Bonett and

HC $n = 75$

Confidence Intervals of Spearman's rho				
	Spearman's rho	Significance (2-tailed)	(2-tailed)a,b Lower	Upper
CERQ - GAD7	0.295	0.010	0.068	0.493
CERQ - PHQ9	0.327	0.004	0.102	0.520
RTSQ - GAD7	0.465	0.000	0.255	0.634
RTSQ - PHQ9	0.477	0.000	0.268	0.642
Brooding - GAD-7	0.502	0.000	0.297	0.662
Brooding - PHQ-9	0.448	0.000	0.236	0.620
Reflection - GAD-7	0.499	0.000	0.295	0.660
Reflection - PHQ-9	0.510	0.000	0.307	0.669
RRS combined - GAD-7	0.727	0.000	0.580	0.828
RRS combined - PHQ-9	0.691	0.000	0.532	0.803
GAD-7 - PHQ-9	0.688	0.000	0.528	0.801

a. Estimation is based on Fisher's r-to-z transformation.

b. Estimation of standard error is based on the formula proposed by Bonett and

Chapter 4 (section 4.1) – Technology ownership and spontaneous use by people living with and without cognitive impairment

Table showing the percentage of participants who played games on each device, per group.

Device	With cognitive impairment	Without cognitive impairment
Smartphone	1/28 = 4%	11/49 = 22%
Tablet	6/34 = 18%	8/38 = 21%
Laptop	2/24 = 8%	3/41 = 7%
Desktop-PC	2/31 = 6%	2/41 = 5%
Games console	1/55 = 2%	2/66 = 3%

Games mentioned:

- Sudoku
- Scrabble
- Solitaire
- Toon Blast
- Word Cookies
- Fruit game
- Wordfeud
- Flight simulator
- Word
- Chess
- Spider
- Global Domination
- Spelling games (no name)
- GameChanger

Technology survey

Q1. Do you own a mobile phone?

□ No

□ Yes

If yes,

a) it is a:
□ Non-smartphone

□ Smartphone

b) How often do you use this device?
□ Most days

□ Some days

□ Rarely

□ Never

c) Do you use this device for:
□ Emailing

□ Talking (non-smartphone)

□ Texting/messaging (non-smartphone)

□ Reading (i.e., newspapers or articles)

□ Shopping

□ Banking

□ Social media

□ Playing games

□ Skype

□ Other

Q2. Do you own a tablet?

□ No

□ Yes

If yes,

a) How often do you use this device?
□ Most days

□ Some days

□ Rarely

□ Never

b) Do you use this device for:
□ Emailing

□ Talking

□ Texting/messaging

□ Reading (i.e., newspapers or articles)

□ Shopping

□ Banking

□ Social media

□ Playing games

□ Skype

□ Other

Q3. Do you own a laptop?

□ No

□ Yes

If yes,

a) How often do you use this device?
□ Most days

□ Some days

□ Rarely

□ Never

b) Do you use this device for:
□ Emailing

□ Talking

□ Texting/messaging

□ Reading (i.e., newspapers or articles)

□ Shopping

□ Banking

□ Social media

□ Playing games

□ Skype

□ Other

Q4. Do you own a desktop-PC?

□ No

□ Yes

If yes,

a) How often do you use this device?
□ Most days

□ Some days

□ Rarely

□ Never

b) Do you use this device for:
□ Emailing

□ Talking

□ Texting/messaging

□ Reading (i.e., newspapers or articles)

□ Shopping

□ Banking

□ Social media

□ Playing games

□ Skype

□ Other

Q5. Do you own an eBook?

□ No

□ Yes

If yes,

a) How often do you use this device?
□ Most days

□ Some days

□ Rarely

□ Never

Q6. Do you own a games console?

□ No

□ Yes

If yes,

a) How often do you use this device?
□ Most days

□ Some days

□ Rarely

□ Never

Q7. Do you own a television?

□ No

□ Yes

If yes,

a) it is a:
□ Non-smart-TV

□ Smart-TV

b) How often do you use this device?
□ Most days

□ Some days

□ Rarely

□ Never

If a smart-TV is owned,

c) Do you use any apps on this device?

Q8. Do you own a music device or listen to music on any devices?

□ No

□ Yes

If yes,

a) How often do you use this device to listen to music?
□ Most days

□ Some days

□ Rarely

□ Never

Q9. Do you own any other technology-based devices?

If yes,

a) How often do you use this/these devices?
□ Most days

□ Some days

□ Rarely

□ Never

Chapter 4 (section 4.4) – Multi-session attentional bias modification using webcam-based eye-tracking. Feasibility and impact on mood for persons with and without cognitive impairment.

MCI SVM scores

	ABmeasure session 1	**ABmeasure session 2**	**ABmeasure session 3**	ABmeasure session 4
Start of block	0.72	**0.67**	**0.72**	0.75
Sub-block 1	0.74	**0.76**	**0.74**	0.74
Sub-block 2	0.65	**0.77**	**0.65**	0.75
Average	0.70	**0.74**	**0.70**	0.74

PwAD 2 SVM scores

	ABmeasure session 5
Start of block	**0.74**
Sub-block 1	0.77
Sub-block 2	NA

Bold text = scores when the researcher was absent.

Chapter 5 – Increased attention to the eye region when playing background music in Alzheimer's disease: A webcam eye-tracking proof-of-concept study

Individual participant data

Silence									
pwAD1									
Image	**No. of slides**	**min**	**max**	**median**	**iqr**	**mean**	**sd**	**se**	**ci**
Sad_n	16	54	1905	912	1257	898	662	166	353
Angry_n	16	34	1878	800	1156	878	643	161	343
Happy_n	16	113	1837	1127	1017	1055	599	150	319
Neutral_s	16	67	1940	1074	1265	1084	666	167	355
Neutral_a	16	103	1945	1183	1159	1103	644	161	343
Neutral_h	16	138	1873	857	1016	927	599	150	319
pwAD2									
Image	**No. of slides**	**min**	**max**	**median**	**iqr**	**mean**	**sd**	**se**	**ci**
Sad_n	16	0	1916	1020	376	1039	564	141	301
Angry_n	16	0	1835	1291	912	1137	627	157	334
Happy_n	15	0	1717	751	839	876	517	133	286
Neutral_s	16	24	1952	922	415	887	569	142	303
Neutral_a	16	57	1955	694	929	813	641	160	341
Neutral_h	15	203	1865	1164	839	1049	502	130	278
pwAD3									
Image	**No. of slides**	**min**	**max**	**median**	**iqr**	**mean**	**sd**	**se**	**ci**
Sad_n	16	0	1629	1030	241	982	384	96	205
Angry_n	16	297	1902	1059	463	1064	410	103	219
Happy_n	16	587	1739	1056	552	1124	342	85	182
Neutral_s	16	329	1930	887	218	958	380	95	202
Neutral_a	16	37	1635	897	462	881	408	102	217
Neutral_h	16	169	1372	873	533	811	347	87	185
pwAD4									
Image	**No. of slides**	**min**	**max**	**median**	**iqr**	**mean**	**sd**	**se**	**ci**
Sad_n	16	0	1971	883	684	847	604	151	322
Angry_n	16	0	1973	1020	740	1020	594	149	317
Happy_n	16	27	1979	878	1032	885	698	175	372
Neutral_s	16	0	1967	1084	711	1123	604	151	322
Neutral_a	16	0	1975	953	752	951	595	149	317
Neutral_h	16	0	1943	1090	1031	1085	695	174	370
MCI1									
Image	**No. of slides**	**min**	**max**	**median**	**iqr**	**mean**	**sd**	**se**	**ci**
Sad_n	16	0	1978	1048	440	1001	588	147	313
Angry_n	16	140	1955	1251	1111	1200	624	156	332
Happy_n	16	0	1942	1161	1435	1091	760	190	405
Neutral_s	16	0	1976	932	436	974	585	146	312
Neutral_a	16	13	1832	731	1106	776	625	156	333
Neutral_h	16	28	1979	823	1421	887	760	190	405
HC1									
Image	**No. of slides**	**min**	**max**	**median**	**iqr**	**mean**	**sd**	**se**	**ci**
Sad_n	16	221	1633	935	745	929	432	108	230
Angry_n	16	289	1707	1155	391	1123	392	98	209
Happy_n	16	386	1675	1029	381	1026	381	95	203
Neutral_s	16	339	1601	1026	740	1009	412	103	220
Neutral_a	16	215	1608	782	459	809	395	99	211
Neutral_h	16	196	1554	922	344	912	387	97	206
HC2									
Image	**No. of slides**	**min**	**max**	**median**	**iqr**	**mean**	**sd**	**se**	**ci**
Sad_n	16	416	1683	1017	493	1026	360	90	192
Angry_n	16	487	1447	978	431	944	292	73	155
Happy_n	16	143	1474	1079	674	960	433	108	231
Neutral_s	16	292	1590	961	494	952	364	91	194
Neutral_a	16	508	1496	1009	418	1035	299	75	159
Neutral_h	16	510	1842	892	649	1021	434	108	231

Background music									
pwAD1									
Image	**No. of slides**	**min**	**max**	**median**	**iqr**	**mean**	**sd**	**se**	**ci**
Sad_n	16	402	1736	1251	618	1188	428	107	228
Angry_n	16	189	1558	1052	511	973	359	90	192
Happy_n	16	442	1886	999	568	1010	407	102	217
Neutral_s	16	243	1571	736	608	791	423	106	225
Neutral_a	16	428	1784	929	512	1010	358	89	191
Neutral_h	16	110	1549	978	550	971	406	101	216
pwAD2									
Image	**No. of slides**	**min**	**max**	**median**	**iqr**	**mean**	**sd**	**se**	**ci**
Sad_n	16	394	1742	895	417	912	388	97	207
Angry_n	16	74	1575	960	569	921	409	102	218
Happy_n	16	217	1768	951	596	975	445	111	237
Neutral_s	16	168	1520	1051	329	1013	389	97	207
Neutral_a	16	389	1864	966	539	1017	409	102	218
Neutral_h	16	157	1745	986	563	953	447	112	238
pwAD3									
Image	**No. of slides**	**min**	**max**	**median**	**iqr**	**mean**	**sd**	**se**	**ci**
Sad_n	16	188	1726	858	377	895	367	92	196
Angry_n	16	19	1913	1103	905	1073	526	131	280
Happy_n	16	330	1927	1040	652	1043	410	103	219
Neutral_s	16	239	1775	1081	406	1044	368	92	196
Neutral_a	16	18	1913	844	929	862	536	134	286
Neutral_h	16	0	1612	911	624	899	405	101	216

pwAD4									
Image	**No. of slides**	**min**	**max**	**median**	**iqr**	**mean**	**sd**	**se**	**ci**
Sad_n	16	0	1759	766	770	823	502	126	268
Angry_n	16	48	1418	640	887	742	482	121	257
Happy_n	16	0	1976	810	934	889	647	162	345
Neutral_s	16	219	1964	1199	768	1145	500	125	266
Neutral_a	16	554	1909	1332	883	1225	477	119	254
Neutral_h	16	0	1964	1166	948	1080	648	162	345
MCI1									
Image	**No. of slides**	**min**	**max**	**median**	**iqr**	**mean**	**sd**	**se**	**ci**
Sad_n	16	161	1932	1226	1057	1095	625	156	333
Angry_n	16	14	1824	1053	557	965	570	142	304
Happy_n	16	43	1962	1379	1230	1145	638	160	340
Neutral_s	16	54	1809	751	1069	877	626	157	334
Neutral_a	16	145	1967	916	559	1011	572	143	305
Neutral_h	16	0	1919	588	1241	828	640	160	341
HC1									
Image	**No. of slides**	**min**	**max**	**median**	**iqr**	**mean**	**sd**	**se**	**ci**
Sad_n	16	185	1772	909	800	997	535	134	285
Angry_n	16	168	1998	846	672	912	555	139	296
Happy_n	16	144	1722	981	786	931	511	128	272
Neutral_s	16	188	1718	1031	793	953	528	132	282
Neutral_a	16	0	1759	1092	722	1041	544	136	290
Neutral_h	16	177	1784	963	809	1018	521	130	278

HC2									
Image	**No. of slides**	**min**	**max**	**median**	**iqr**	**mean**	**sd**	**se**	**ci**
Sad_n	16	372	1766	1047	568	1090	445	111	237
Angry_n	16	394	1714	1070	598	1052	447	112	238
Happy_n	16	345	1453	881	578	882	346	86	184
Neutral_s	16	205	1602	933	564	883	448	112	239
Neutral_a	16	259	1570	903	600	920	448	112	239
Neutral_h	16	513	1647	1082	583	1091	346	87	185

Key:	_n = neutral
	_s = sad
	_a = angry
	_h = happy
	distribution

Chapter 6 – Clinically-relevant reductions in depression, anxiety, and rumination levels following gaze-contingent musical attentional bias modification: A pilot study

Monitor

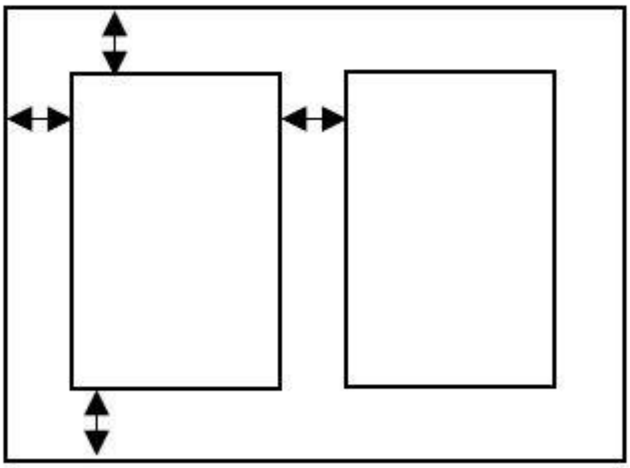
The ViewSonic (VA2413wm) monitor had a resolution of 1920 × 1080 pixels and refresh rate of 60Hz.

Tobii TX300 eye tracker

Focusing binocularly, at a sampling rate of 300Hz.

Facial stimuli

The screen display area was 20.5 × 11.5 inches.



= 10% of the screen's display width or height

Each facial expressions area of interest represented 35% (width) × 80% (height) of the screen's display area.

Facial stimuli were selected via a random number generator.
Age of actors 19 to 31 years

ABmeasure

Within the block, each facial expression type was presented 24 times by a total of 8 actors, each actor being presented 12 times.

GCM-ABM

Within the block, each facial expression type was presented 24 times by a total of 24 actors, each actor being presented 4 times. None of the actors in the GCM-ABM trials appeared in the AB-measure trials.

Music

The algorithmically generated track was composed with harp sounds and at a tempo defined as seven notes per second (see Bravo et al., (2017) for detailed composition information). The consonant version of the track comprised consonant interval sets of perfect fourths, perfect fifths, and octaves. The dissonant version comprised highly dissonant interval sets of minor seconds, major seconds, and tritones.

The romantic period style track was a choral piece composed with string sounds (e.g., violin, and viola) at a tempo defined as quarter note = 36 (see Bravo et al., (2020) for detailed composition information). The consonant version of the track comprised interval sets of thirds, fourths and fifths, The dissonant version comprised interval sets of major seconds, minor seconds, and tritones.

Table 1. Study 1 Descriptive and bias score data

	NDNA (*n* = 3)	Anxious (*n* = 2)	Comorbid (*n* = 4)
Measure	Mean/***Median*** (*SD*)/**[*IQR*]**	Mean/***Median*** (*SD*)/**[*IQR*]**	Mean/***Median*** (*SD*)/**[*IQR*]**
Age	19 (1)	19 (0)	***19* [19]**
Depression (PHQ-9)	3 (2)	3 (1)	13 (4)
Anxiety (GAD-7)	3 (2)	7 (2)	***9* [3]**
Positive affect			
Baseline	24 (7)	31 (2)	33 (7)
Post-intervention	26 (5)	21 (2)	24 (9)
Negative affect			
Baseline	***12* [0]**	13 (2)	17 (6)
Post-intervention	***10* [0]**	12 (2)	15 (6)
State rumination			
Baseline	36 (6)	21 (18)	18 (13)
Post-intervention	23 (13)	15 (9)	16 (15)
Trait rumination (RRS)	40 (8)	47 (1)	55 (7)
Bias score (% dwell-time)			
Sad (*versus neutral*)			
Baseline	46 (9)	49 (9)	50 (7)
Post-intervention	57 (11)	46 (2)	51 (5)
Angry (*versus neutral*)			
Baseline	58 (11)	54 (8)	47 (5)
Post-intervention	69 (9)	51 (2)	45 (5)
Happy (*versus neutral*)			
Baseline	47 (11)	55 (0)	51 (5)
Post-intervention	59 (16)	51 (1)	59 (11)
Sad (*versus happy*)			
Baseline	52 (14)	44 (3)	***53* [4]**
Post-intervention	51 (4)	49 (4)	47 (7)
Angry (*versus happy*)	**(*n* = 2)**		
Baseline	43 (15)	52 (6)	48 (7)
Post-intervention	47 (10)	46 (2)	49 (5)

Notes. NDNA = non-depressed/non-anxious; SD = standard deviation; PHQ-9 = Patient Health Questionnaire 9; GAD-7 = Generalized Anxiety Disorder scale; RRS = Ruminative Response Scale.

The average AB score equated to the average AB score of the participants with the same symptom status.

Study 1 Individual affect scores

Affect type	NDNA 1	NDNA 2	NDNA 3	Anxious 1	Anxious 2	Comorbid 1	Comorbid 2	Comorbid 3	Comorbid 4
Positive									
Interested	0	1	-1	-2	-2	0	-1	-3	-1
Excited	0	0	-1	-1	-1	0	-2	-1	-1
Strong	1	0	0	-2	-1	-1	-2	0	-2
Enthusiastic	-1	1	0	-2	-1	1	1	-1	-1
Proud	0	-1	1	0	-1	0	0	0	0
Alert	1	0	0	0	-1	-2	0	-1	-1
Inspired	-1	2	1	0	0	0	-1	0	-1
Determined	0	0	0	-1	-1	0	-2	0	-3
Attentive	0	0	2	-2	-2	0	-1	-2	-1
Active	-1	0	2	0	0	0	0	-1	-3
Total	-1	3	4	-10	-10	-2	-8	-9	-14
Distressed	0	-1	0	0	1	0	-1	0	-4
Upset	0	-1	0	0	0	0	0	-1	0
Guilty	0	0	0	0	0	0	0	0	0
Scared	0	0	0	0	0	-1	0	0	0
Hostile	0	0	0	0	0	0	0	1	0
Irritable	-1	0	0	0	1	0	0	0	0
Ashamed	0	0	0	0	0	0	0	0	0
Nervous	-1	-1	-1	-1	-1	-1	-1	0	0
Jittery	1	-1	-1	-2	1	0	1	0	0
Afraid	0	0	0	-1	0	0	0	0	0
Negative	-1	-4	-2	-4	2	-2	-1	0	-4

Table 2. Study 2 Descriptive, mood, and bias score data

	NDNA (n = 2)	Depressed (n = 1)	Comorbid (n = 5)
Measure	Mean (*SD*)/ ***Median* [*IQR*]**	Score	Mean (*SD*)/ ***Median* [*IQR*]**
Age	34 (3)	18	***19* [*16*]**
Depression (PHQ-9)			
Baseline	2 (3)	14	10 (4)
Post-intervention	2 (3)	14	8 (3)
Anxiety (GAD-7)			
Baseline	1 (1)	3	9 (4)
Post-intervention	1 (1)	4	***9* [*6*]**
Positive affect			
Baseline	30 (12)	29	34 (5)
Post-intervention	24 (12)	21	30 (9)
Negative affect			
Baseline	10 (0)	16	***11* [*3*]**
Post-intervention	10 (0)	10	***10* [*8*]**
Trait rumination (RRS)			
Baseline	29 (8)	59	58 (10)
Post-intervention	29 (8)	72	49 (7)
Bias score (% dwell-time)			
Sad (*versus neutral*)			
Baseline	45 (6)	50	***48* [22]**
Post-intervention	52 (0)	50	48 (10)
Angry (*versus neutral*)			
Baseline	45 (0)	57	45 (15)
Post-intervention	47 (7)	52	51 (4)
Happy (*versus neutral*)			
Baseline	58 (11)	51	58 (13)
Post-intervention	54 (1)	46	63 (15)
Sad (*versus happy*)			
Baseline	42 (13)	45	39 (14)
Post-intervention	48 (2)	54	41 (17)
Angry (*versus happy*)			
Baseline	55 (23)	38	36 (10)
Post-intervention	45 (4)	46	35 (13)

Notes. NDNA = non-depressed/non-anxious; SD = standard deviation; PHQ-9 = Patient Health Questionnaire 9; GAD-7 = Generalized Anxiety Disorder scale; RRS = Ruminative Response Scale.

The average AB score equated to the average AB score of the participants with the same symptom status.

Study 2 Individual affect scores

Affect type	NDNA 1	NDNA 2	Depressed	Comorbid 1	Comorbid 2	Comorbid 3	Comorbid 4	Comorbid 5
Positive								
Interested	0	-2	-1	-2	-1	0	0	0
Excited	-1	1	0	-1	-1	0	0	-1
Strong	-1	-2	-1	-1	-1	1	-1	0
Enthusiastic	-1	-1	-1	-3	-1	-1	-1	0
Proud	-1	0	-1	1	-1	2	0	0
Alert	0	0	-1	0	-1	0	-1	0
Inspired	0	0	0	0	-1	1	-1	-1
Determined	-1	0	-2	1	0	0	-1	0
Attentive	0	-2	1	1	0	1	-1	-1
Active	-1	0	-2	-2	-1	0	0	-1
Total	-6	-6	-8	-6	-8	4	-6	-4
Negative								
Distressed	0	0	0	0	0	2	0	0
Upset	0	0	0	0	0	0	0	0
Guilty	0	0	0	0	0	2	0	0
Scared	0	0	-1	0	0	0	0	0
Hostile	0	0	-1	0	0	1	0	0
Irritable	0	0	0	0	0	0	0	0
Ashamed	0	0	0	0	0	1	0	0
Nervous	0	0	-1	-1	0	-1	0	-1
Jittery	0	0	-3	0	0	1	2	0
Afraid	0	0	0	0	0	0	0	0
Total	0	0	-6	-1	0	6	2	-1

Participant RRS reliable change index (RC) scores

Participant	RC score
NDNA 1	0.00
NDNA 2	0.20
Depressed	2.57
Comorbid 1	-4.15
Comorbid 2	-0.59
Comorbid 3	-2.77
Comorbid 4	0.00
Comorbid 5	-1.58

S-Diff =5.06