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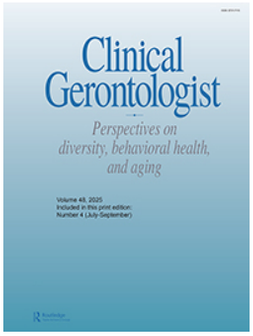

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Home-Based Attentional Bias Modification with Webcam-Based Eye Tracking with Persons with Cognitive Impairment: A Feasibility Study

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ABSTRACT

Objectives: Remotely delivered attentional bias modification (ABM) studies involving persons with cognitive impairment are lacking. Thus, the feasibility of an adapted ABM paradigm with webcam-based eye tracking was explored.

Methods: Four of the eight participants recruited (males, M_{age} = 69 years, Alzheimer's disease = 3, mild cognitive impairment = 1) completed up to four daily ABM sessions. Tasks comprised pre- and post-intervention depression (PHQ-9), anxiety (GAD-7), and rumination (RRS) measures, a cognitive screen (TICS) (A), affect (PANAS) (B) and dot-probe AB measures (C), and dot-probe ABM (D) (Session 1–A, B, C, D, C, and B; Sessions 2 to 4–B, D, C, and B).

Results: The intervention was feasible (as defined by completion rates) and appeared beneficial in this small sample (as defined by post-intervention improvements in mood). Sessions were long, and task completion/adherence was impacted by task access/participants' ability to complete tasks independently. Mind wandering, stimuli familiarity, and eye/fatigue were reported.

Conclusions: The intervention requires further adaptation (e.g. fewer eye-tracking tasks per session). Limitations include participant self-selection/loss, a lack of control group, and that the determinants of mood change are unclear.

Clinical Implications: ABM, a novel intervention, may be an effective mood-disorder treatment for individuals with cognitive impairment.

KEYWORDS

Alzheimer's disease; anxiety; attentional bias modification; depression; rumination; webcam eye-tracking

Introduction

Depression in later life is associated with increased disability and healthcare use, and persons with cognitive impairment (PwCI) or dementia (PwD) are at risk of poorer outcomes (e.g., further cognitive decline at a faster rate, reduced functional capability, and a higher risk of hospitalization, re-admission, and residential care-home admission) compared to PwCI/PwD without depression and persons without dementia (Breitve et al., 2016; Gonzalez-Salvador et al., 1999; Lyketsos et al., 1997; Meeks et al., 2011; Okura et al., 2010; Pickens et al., 2017; Spalletta et al., 2012; Starkstein & Mizrahi, 2006). Anxiety in dementia is associated with poorer cognitive performance and quality of life, as well as disturbed sleep and more problem behaviors (Seignourel et al., 2008; Tales & Basoudan, 2016).

Co-occurring anxiety and depression in dementia has prevalence rates of 26% to 75%, is difficult to treat, and is associated with more severe cognitive impairment compared to anxiety or depression alone, and no anxiety or depression (Bennett & Thomas, 2014; Costello et al., 2023; Goyal et al., 2019; Ryu et al., 2005; Seignourel et al., 2008; Sibley et al., 2021; Starkstein et al., 2007). Comorbid anxiety and depression (referred to as comorbid hereafter), particularly at disorder level, is associated with higher disability levels (e.g., frailty), is more persistent, and fewer comorbid (older) persons recover compared to those with anxiety or depression alone (Almeida et al., 2012; Braam et al., 2014; Van Balkom et al., 2008; Zhao et al., 2020). Moreover, remission may take longer for PwD, and there is an increased risk of early relapse and reoccurrence (Neville & Teri, 2011). As most PwD (≥90%) will experience at least one neuropsychiatric symptom during disease progression, the impact of anxiety, depression, and associated

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poorer outcomes contribute to the burgeoning socioeconomic impact of an aging global population and dementia care (Pless et al., 2023; Staedtler & Nunez, 2015; Wimo et al., 2017). Although guidelines to address comorbidity for PwD are lacking, treatment may be more urgent, require targeted interventions, and symptoms should be treated simultaneously (Davydow et al., 2014; Neville & Teri, 2011; Sibley et al., 2021).

Anti-depressant treatment is the front-line intervention, with little efficacy for some individuals (Banerjee et al., 2011; Costello et al., 2023). While reviews (Bell et al., 2022; Orgeta et al., 2022) suggest that psychological therapy may be more effective than anti-depressant treatment and treatment as usual, fewer PwD access psychological therapy and reliable (clinically relevant) improvement and recovery is less likely (Bell et al., 2022). A variety of interventions that are (1) low-cost, given the numbers that could be affected and relapse/reoccurrence risks, (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). In the most commonly used ABM paradigm, i.e. the dot-probe task (MacLeod et al., 2002), pairs of stimuli (e.g., one more positive and one more negative image) are viewed naturally, followed by a probe which appears in the previous location of one of the stimuli. Participants then indicate the location of the probe by key press (e.g., using the "L" and "R" keys to indicate the left and the right side of the screen, respectively). The probe appears 80% to 100% in the previous location of the to-be-trained stimuli (e.g., the more positive image). Using this type of paradigm, computerized ABM interventions can be delivered remotely, may increase accessibility, and potentially 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).

Remotely delivered technology-based solutions are needed as out-of-home therapy is the most abandoned out-of-home activity by community-based older persons with and without dementia (Gaber et al., 2020). Digital mental-health interventions for older persons are affected by ease-of-use, and everyday technologies, rather than dementia-specific ones, are preferred by PwD (Evans et al., 2022; Riadi et al., 2022). However, reaction-time tasks involve perceptual, decision making (e.g., to trigger the appropriate motor response), motor response (e.g., key press), and attentional (i.e., sustained alertness) components (Andriuta et al., 2019). ABM with eye tracking removes some of the cognitive processing (e.g., decision making and motor response/coordination) associated with the typically used internet-based methodology (i.e., the dot-probe reaction-time task) (Bourgin et al., 2018; Gratton et al., 2018). This could prove beneficial for PwCI as decision-making, motor response/coordination, and reaction-time impairments have been found in mild cognitive impairment (MCI) and AD (Andriuta et al., 2019; Martelli et al., 2012; Namkoong & Roh, 2024; Tse et al., 2010). As fewer/easier task instructions are presented and need to be remembered when using eye tracking (e.g., the response buttons and location contingency information is unnecessary), task completion could be facilitated and less demand is placed on working memory which is impaired in MCI and AD (Gagnon & Belleville, 2011). ABM with eye tracking could potentially improve data quality in this population. For example, reaction times can be variable in AD (Tse et al., 2010) which may impact attentional bias (AB) measures (i.e., biases are determined by the differences in reaction time to the probe). More broadly, ABM does not require verbal responses, and as such, could be suitable for individuals with communication difficulties. Aphasia, a communication disorder, can be present in MCI and from the early stage of dementia (Masuda et al., 2024). Importantly, (some) community-based older persons with and without dementia will engage with home-based eye tracking via their webcams with assistance (Greenaway et al., 2021, 2023).

ABM paradigms are based on the premise that negative biases play a core role in the etiology, maintenance, and recurrence of anxiety and depression. Encouraging attentional disengagement from negative stimuli should be associated with a reduction in negative biases and symptom levels (De Raedt & Koster, 2010; MacLeod &

Clarke, 2015; Sanchez & Vazquez, 2014). Rumination (e.g., repetitive thoughts and feelings surrounding depressed or dysphoric mood), which increases the risk of anxiety and depression and the probability of experiencing future anxious and depressive episodes, can be reduced by ABM alongside anxiety and depression (Brinker & Dozois, 2009; McLaughlin & Nolen-Hoeksema, 2011; Nolen-Hoeksema et al., 2008; Roberts et al., 1998; Xia et al., 2023; W. Yang et al., 2015) but not always (Bø et al., 2023). The majority of ABM literature reflects findings involving younger populations and there is conflicting evidence with regard to the moderating effects of age. For example, age may moderate ABM effects in favor of younger persons (≤37 years old) (Price et al., 2016) or older persons (up to 50 years old) (Abend et al., 2019), or show no moderating effect (Heeren et al., 2015). And while ABM study samples may include older persons (Price et al., 2016), there is a lack of studies specifically focussed on older persons, and to our knowledge, none involving PwCI/PwD. Rumination in dementia has also received little focus but has recently been explored as a potential intervention target and outcome measure in this population (Greenaway et al., 2024; Keune et al., 2023).

Recent findings (Bø et al., 2024) indirectly support the concept of ABM for PwCI given that ABM was found to be more effective for individuals with weak inhibitory control. Inhibitory and interference resolution, as well as attention switching, 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). These processes are also affected in MCI (Chehrehnegar et al., 2020; Rabi et al., 2020). The aims of the current study were to explore with persons with MCI and AD, the feasibility of a remotely delivered adapted ABM intervention (i.e., could it be done, should we continue, and if so, how (Eldridge et al., 2016)). The study objectives were to identify logistical challenges (e.g., delivering multi-session webcam-based eye tracking [WBET], as the literature pertains to single sessions), potential study design issues, and to assess the impact of task completion on participant mood to inform the potential for and design of a subsequent randomized pilot study.

Methods

Participants

Eight participants (AD = 5, MCI = 3) were recruited via the Join Dementia Research platform (https://www.joindementiaresearch.nihr.ac.uk/) (see supplementary material for details). One participant transferred to another study (AD = 1). Two participants (MCI = 2) did not pass the initial calibration so did not participate in the ABM sessions (see supplementary material for further calibration details). One participant (AD = 1) withdrew during ABM session 1. One participant completed one ABM session (as planned) (AD = 1) and three participants (AD = 2, MCI = 1) completed all four ABM sessions. The participants with cognitive impairment (four males, aged 61 to 76 yrs old) were classified as being non-anxious/depressed (NAD) (MCI = 1), depressed (AD = 1), or being comorbid (AD = 2). Two participants (AD = 1, MCI = 1) were taking cognitive medication (Donepezil). None of the participants were taking anti-depressant medication. One participant had full assistance from a friend to complete the technical requirements (i.e., device and task navigation). The remaining participants completed the technical requirements themselves, with some input from the researcher (see supplementary material for support details).

All participants provided written or verbal consent before the study commenced, and their caregiver/spouse/representative provided written or verbal confirmation of the participant's ability to provide informed consent.

Procedure

Each participant completed the study in a quiet room in their own home. The researcher was based elsewhere in the UK. Participants completed self-report anxiety and depression screens, and rumination scales 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 laptop screens with the researcher in each session. During session one, the participant's cognitive status was assessed via an interview, and they received an

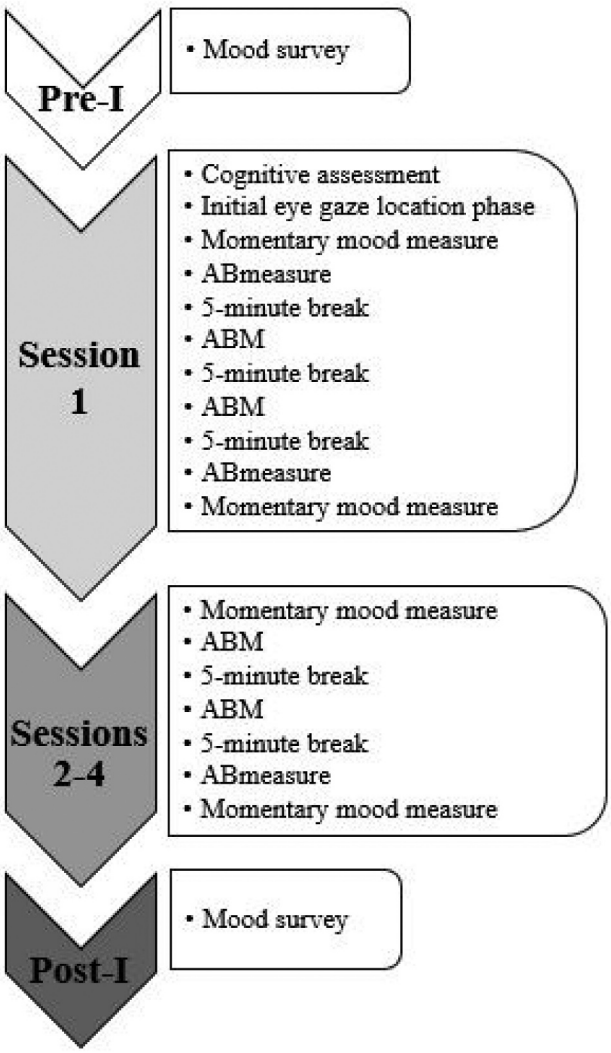

Figure 1. An outline of the online study tasks completed by the participants across the study (pre-I = pre-intervention; post-I = post-intervention).

emailed link to Gorilla (Anwyl-Irvine et al., 2020), the web-based eye-tracking platform used in the study (see Figure 1). 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). 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 AB measure (ABmeasure) block in silence. After a 5-min break in which the participants were free to move around, two ABM blocks were conducted with background music, with a 5-min break following each ABM block. The same ABmeasure block 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 preset time of 10 am each day for the relevant ABM session, and a Microsoft Teams meeting reminder prior to the scheduled meeting time. The researcher would call if the participant had not logged into the session as an additional reminder and/or to provide assistance to enable the participant to join the session. The eye-tracking and mood tasks were conducted in the same manner as session one without the initial eye-gaze location phase nor an ABmeasure block at the start of the session. Participants received support from the researcher (e.g., technical, lighting, and positioning [see supplementary material for the types of assistance provided]). 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. The average session lasted 69 min. 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

Cognitive status, affect, and mood assessments

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 affect. The high number of calibration failures (i.e., eye-gaze location) associated with WBET (Semmelmann & Weigelt, 2018) could lead to irritation or frustration, potentially negating the intended ABM intervention effect. Thus, we

assessed momentary affect before and after each ABM session as well as pre- and post-intervention mood. The Positive Affect Negative Affect Schedule (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. Positive affect (PA) item scores were totaled to provide the PA score, and negative affect (NA) item scores totaled to provide the NA score. The total affect scores ranged from 10 to 50, with higher scores representing higher levels of affect. For each participant, their pre- and post-session PA and NA scores were plotted with their total number of calibration failures for each session, and their post-intervention (i.e., the last PANAS measure) (T2) scores were subtracted from their pre-intervention (i.e., the first PANAS measure) (T1) scores.

Anxiety. The Generalized Anxiety Disorder 7 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 seven 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). It has been validated for PwCI and is widely used in primary-care psychological therapy services (Bell et al., 2022; Wild et al., 2014). A change (plus or minus) of 4 points indicated clinically relevant changes (Toussaint et al., 2020).

Depression. The Patient Health Questionnaire 9 (PHQ-9) scale (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 eight 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). The PHQ-9 has been validated for PwCI and is widely used in primary-care psychological therapy services (Bell et al., 2022; Wong et al., 2022). A change (plus or minus) of 5 points indicated clinically relevant changes (Kroenke, 2012).

Symptom status. Participants were classified as non-anxious/depressed (NAD) (score = <5 PHQ-9, <5 GAD-7), anxious (score = <5 PHQ-9, ≥5 GAD-7), depressed (score = ≥5 PHQ-9, <5 GAD-7), or comorbid (score = ≥5 PHQ-9, ≥5 GAD-7).

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 subtypes 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 ($\alpha = .92$) and adequate test–retest reliability ($r = .77$) for PwD (Greenaway et al., 2024).

Eye tracking components

Detailed information regarding the calibration and validation process is reported elsewhere (Greenaway et al., 2021; Semmelmann & Weigelt, 2018), and the general eye-tracking procedure summarized here, has previously been described (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 reflected detection of 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 green face outline (face-mesh). Glasses were removed,

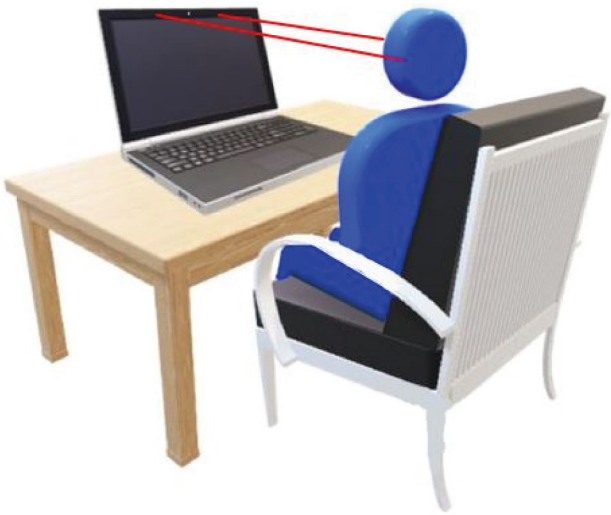

Figure 2. Diagram presented to participants to assist with laptop and body positioning.

where possible, if lens reflection interfered with face-meshing.

Eye-gaze location (calibration and validation). Briefly, in both the calibration (first) and validation (second) phases, 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. The dot was red in the calibration phase, and green 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-blocks) (total across the four intervention sessions = 39).

Eye-gaze accuracy

The Support Vector Machine (SVM) classifier score 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.

Attentional bias measure and modification protocols

Attentional bias measure. AB was 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 center 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 center 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.

Attentional bias modification protocol adaptation. Attentional disengagement from negative stimuli (as encouraged by ABM) requires attention switching and inhibitory control to stop the negative stimuli re/gaining the attentional focus, and to override its attentional interference (Koster et al., 2011; Ng et al., 2022). As mentioned earlier, these processes are less efficient in MCI and AD. Consequently, we combined ABM with background music as music can improve attention switching for PwCI and PwD (Ito et al., 2022; Jordan et al., 2022; Särkämö, 2018), stimulate brain areas that are thought to be associated with successful disengagement and inhibition (Vanderhasselt et al., 2013, 2017) and can reduce cognitive interference in older persons (Cloutier et al., 2020; Fernandez et al., 2020).

Additionally, ABM interventions typically use dysphoric stimuli for persons with depression and threat-related stimuli for persons with anxiety as mood-congruent AB are thought to operate (i.e., persons with depression maintaining their gaze on dysphoric stimuli [e.g., sad faces], and persons with anxiety avoiding and/or maintaining their gaze on threat-related stimuli [e.g., angry]) (Armstrong & Olatunji, 2012; Clauss et al., 2022; Suslow et al.,

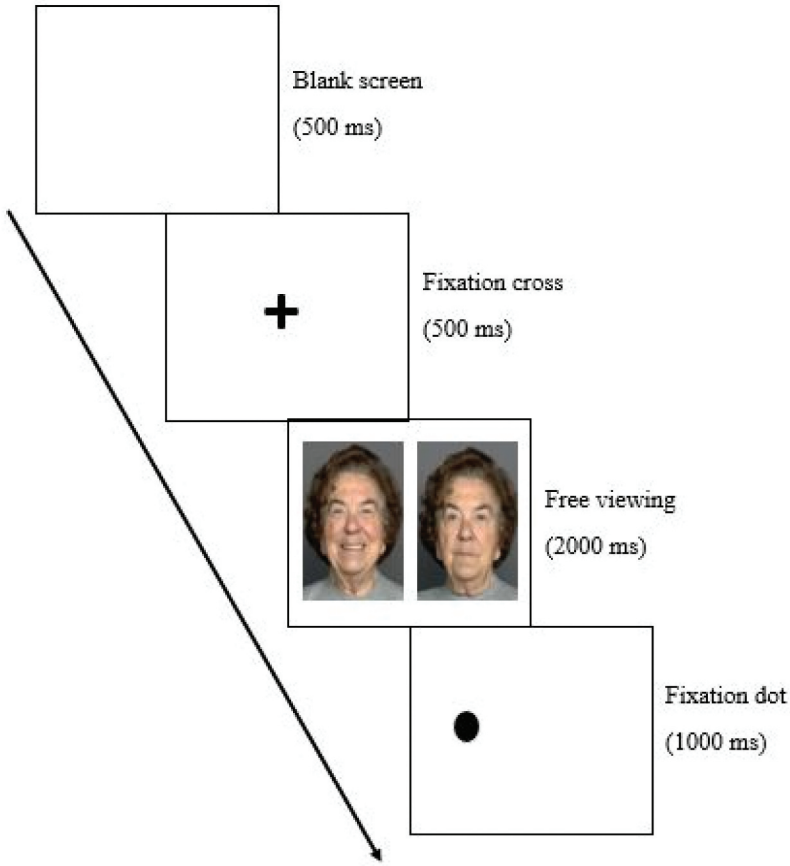

Figure 3. Diagram of stimuli position, order, and presentation duration in an example trial.

2020). In the few studies examining comorbidity, findings are mixed showing that clinically comorbid younger persons may demonstrate anxiety-related biases (e.g., AB toward and away from angry faces), may or may not demonstrate depression-related biases (i.e., AB to sad faces) (Hankin et al., 2010; Kishimoto et al., 2021; LeMoult & Joormann, 2012), 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). Given the higher rate of comorbidity in dementia, the increased negative outcomes related to comorbidity, and the call for symptoms to be treated simultaneously by targeted interventions (Davydow et al., 2014; Neville & Teri, 2011; Sibley et al., 2021), we used both angry and sad faces within the current intervention to address anxiety-related and depression-related biases contemporaneously.

Attentional bias modification delivery. 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 slide 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.

Feasibility and continuation

Can it be done. The intervention would be deemed feasible if (some) participants were able to complete the study components/intervention.

Should we continue. We would continue to the next stage of testing the intervention (i.e., a randomized pilot study) if beneficial effects were identified (i.e., lower NA, anxiety, depression, and rumination scores were reported post-intervention).

How to proceed. The protocol for a subsequent randomized pilot study would be informed by the outcomes of a study evaluation.

Participant spontaneous comments

We report the spontaneous comments made by the participants during the study (see supplementary material).

Results

Participant characteristics

The NAD and depressed participants had lower levels of anxiety, depression, and rumination than the comorbid participants. The comorbid participants reported depressive symptoms indicative of MDD, one of whom also reported anxiety symptoms indicative of GAD. Overall, anxiety scores were lower than depression scores, with more scores falling within the minimal/mild ranges (minimal/mild = 3, moderate = 1) compared to depression scores (minimal/mild = 2, moderate = 2) (see Table 1 for descriptive data).

Momentary affect

Pre-session and post-session affect comparisons

Post-session, PA scores reduced more often than they increased or showed no change across sessions, whereas NA scores reduced or showed no change more often than they increased (see Figure 4a–d). With the exception of PwAD 1 (i.e.,

Table 1. Participant demographic and mood data.

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

Notes: PA = positive affect; NA = negative affect; GAD-7 = Generalized Anxiety Disorder 7 scale; PHQ-9 = Patient Health Questionnaire 9; RRS = Ruminative Response Scale; TICS = Telephone Interview for Cognitive Status; NAD = non-anxious/depressed; D = depressed; C = comorbid (anxious and depressed); T1 = timepoint one; T1 = timepoint two; MCI = mild cognitive impairment; PwAD = participant with Alzheimer's disease.

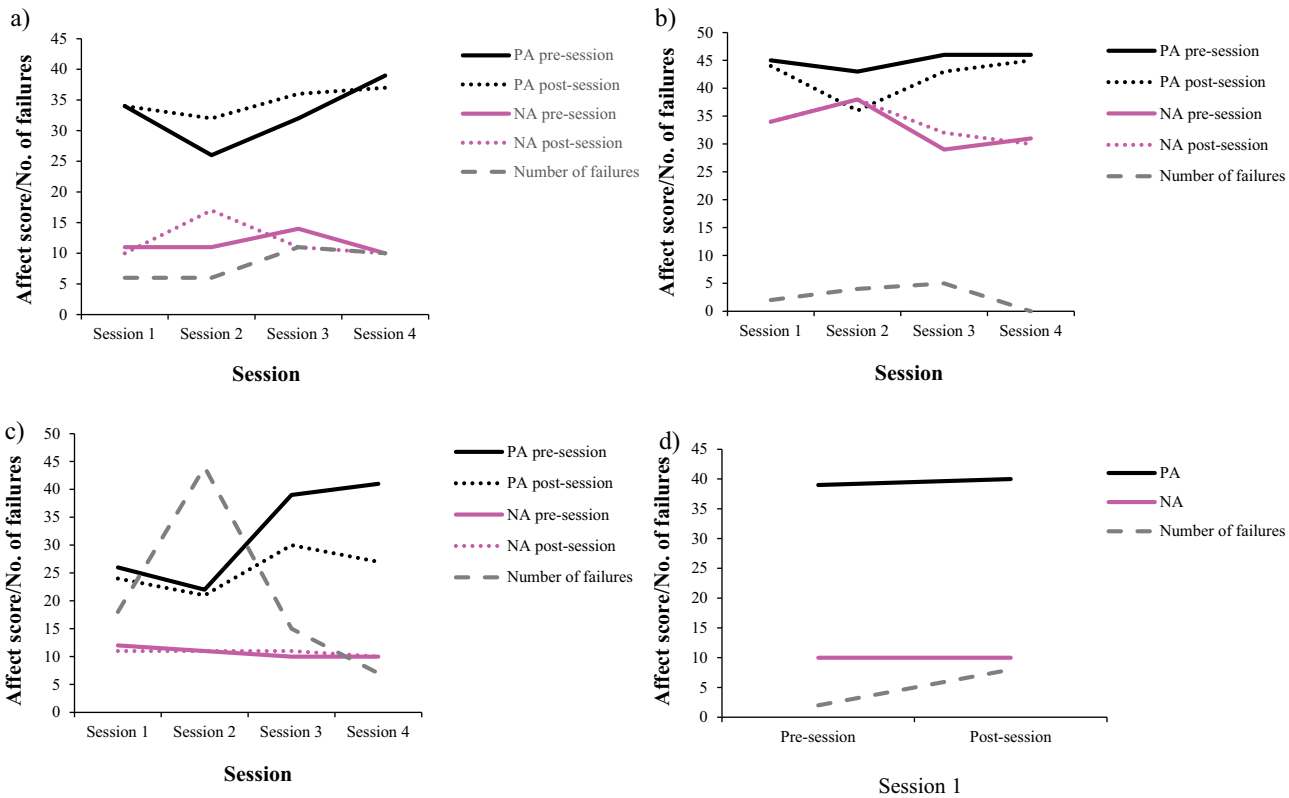

Figure 4. (a–d) Line graph of positive and negative affect scores along with the number of calibration failures per session (participant with mild cognitive impairment (a); participants with Alzheimer's disease 1 (b), 2 (c), and 3 (d)).

session 3 NA score), the largest negative changes (i.e., reduction in PA, increase in NA) did not correspond with the highest number of calibration failures, and positive changes (i.e., increase in PA, reduction in NA) were also seen when the highest number of calibration failures occurred (see Figure 4a–d).

Pre-intervention and post-intervention momentary mood comparisons

Post-intervention, PA scores increased by between 1 and 3 points for three participants, whilst the remaining participant reported the same pre- and post-intervention score (see Table 1 for T1 and T2 affect scores). NA scores decreased by between 1 and 4 points for all four participants. The PA type which most often increased post-intervention was "proud," and "interested" most often decreased (see supplementary material Table 2 for individual item data). The only NA type which increased post-intervention, in one instance, was "scared," and "nervous" most often decreased.

Anxiety, depression, and rumination

The NAD participant reported an increase (1 point) in anxiety, whereas depressed and comorbid participants reported reductions (2 and 5 points) in anxiety post-intervention, with the comorbid participant showing clinically relevant reductions (5 points). All three participants reported a reduction in (1) depression (1 and 10 points), with the comorbid participant showing a clinically relevant reduction (10 points), and (2) rumination levels (1–12 points) post-intervention (see Table 1 for T1 and T2 anxiety, depression, and rumination scores).

Study adherence

Adherence

All of the scheduled Microsoft Teams meetings were attended by the participants. Two participants deviated from the study protocol by performing eye-tracking tasks outside of their scheduled meeting (MCI on two occasions [sessions 2 and 3], PwAD 2 on one occasion). After the first occasion (session 2), MCI advised that they had received the eye-tracking task invite e-mail in the morning so had, "got it [the task] out of the way." After the second occasion (session 3), MCI stated that the eye-tracking tasks had been completed earlier due to an impromptu event. However, two ABmeasure sub-blocks were in fact outstanding and MCI was prompted to complete these tasks. 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 were able to explore eye-gaze accuracy (SVM score) for the tasks completed in the absence of the researcher. Independent sessions/task SVM scores were above the ideal score of 0.5 (see supplementary material Tables 3 and 4 for SVM data).

Negative impact

Calibration failure resulted in one participant's withdrawal from the study during session 1, before the post-session momentary measure. The researcher noted signs of negative impact such as the participant sighing upon failure, furrowed eyebrows, and showing increased slumping of the body over time (Kohler et al., 2004, Nair et al., 2015). One participant (PwAD 2) stated, "[calibration failure] starts to make you feel like you're doing something wrong" although they completed the study and their calibration failures did not correspond with their momentary mood scores. This participant also commented on their physiological state stating, "I'm a bit tired" toward the end of session 3, and, "my eyes are a bit tired" at the end of session 4 (see supplementary material for other spontaneous participant comments).

Discussion

The recommended treatments for depression and anxiety can be underutilized by PwD (i.e., psychological therapy), overutilized by professionals (i.e., pharmacological treatment) although they can have serious side effects, and treatment efficacy is reduced in dementia (Bell et al., 2022; Costello et al., 2023; NICE, 2018; Van Der Spek et al., 2018). As such, alternative interventions are required. The aims of the current study were to explore the feasibility of ABM with webcam-based eye tracking (WBET) for persons with cognitive impairment (i.e., MCI and AD). With the exception

of the participants who were unable to engage in ABM sessions due to calibration failure issues (43%, which is in-line with WBET study attrition rates of 20% to > 50% [Bánki et al., 2022; Prystauka et al., 2023; X. Yang & Krajbich, 2021]), participants were able to join each study session, all other issues (e.g., speaker settings) could be resolved remotely, and the intervention was completed by three out of the four participants.

Although it is premature to attribute symptom reductions to the intervention, and the protocol factors that could be associated with these reductions require investigation (e.g., the effect of background music versus no background music (Greenaway et al., 2025)), the post-intervention data showed that mood and rumination levels were positively affected (i.e., generally, lower negative affect, anxiety, depression, and rumination scores and increased positive affect scores) in spite of in-session negative effects (i.e., reduced positive affect). Comorbid anxiety and depression at disorder level and comorbidity in dementia is harder to treat, fewer older persons recover, and remission may take longer for PwD (Almeida et al., 2012; Braam et al., 2014; Neville & Teri, 2011; Van Balkom et al., 2008; Zhao et al., 2020). As such, it is encouraging that post-intervention clinically relevant reductions in anxiety and depression symptoms were reported by a participant with dementia with baseline symptoms indicative of major depressive disorder and generalized anxiety disorder. Symptom severity can moderate ABM outcomes, with ABM being less effective for those with fewer anxiety symptoms (MCI = 1, PwAD = 1 in the current study) (Bø et al., 2021). It is therefore possible that with the recruitment and completion of the intervention by more individuals with higher levels of anxiety, more participants could report clinically relevant reductions in symptoms.

Overall, the intervention was deemed feasible and should be explored further with the caveat that feasibility findings may differ in samples with greater cognitive impairment (e.g., TICS score of < 26) and for individuals not represented within the study sample (e.g., participants with MCI experiencing anxiety and/or depression and female participants, who can have more technology anxiety [Reid et al., 2024]). The study evaluation showed that the intervention could be refined in the following areas.

Calibration failure procedure

An initial calibration stage was incorporated to ascertain whether the basic study components could be met (e.g., the participant's equipment/internet connection, lighting levels, and behavior [e.g., moving the eyes not the body]). However, rejection at this stage may have been premature as calibration success was variable across sessions. Moving forward, participants would be given the opportunity to attempt the initial calibration stage again, on another day/alternative session, when repeated calibration failures occur. This would also be available to those already engaging in the ABM tasks as the interval between ABM sessions may not influence the intervention effect size (Cristea et al., 2015; Mogoaşe et al., 2014).

Study adherence and task access

Study adherence was affected by the participant's (1) access to the tasks, (2) ability to complete the tasks independently, and (3) (re)scheduling needs. Non-adherence to the eye-tracking task protocol could affect task completion (i.e., a delay between the start of a task and its completion and an error in the completion status of the task). However, non-adherence allowed us to present novel and important findings that after some exposure to the experimental paradigm (one session), some participants 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.

Although 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. However, researcher observation/tele-presence worked well here, was needed (e.g., for eye-tracking task set-up and assured task completion), provided reassurance (e.g., PwAD 2 stated, "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]"), and is recommended even if the eye-tracking tasks can be conducted independently. Future ABM with WBET studies could explore a protocol whereby one clinician/researcher oversees multiple participants in an

ABM session (via the use of multiple laptops, each hosting one meeting session), with participants who are able to complete tasks independently following one individually conducted ABM session.

Task incompletion occurred due to the same pre-set eye-tracking task invitation e-mail time (10 am for sessions 2–4) being used for all participants (i.e., some participants could access the task before their scheduled meeting with the researcher). Moving forward, personalized timings are recommended.

Intervention sessions

The average session in the current study lasted 69 min. This is fairly long given that sustained attention impairment increases across the stages of dementia and is present in MCI and early dementia (Huntley et al., 2017; Saunders & Summers, 2011) but not always (Perry & Hodges, 1999). Although the presence of background music can facilitate sustained attention (Kiss & Linnell, 2021; Thompson et al., 2005), session lengths could be reduced as the assessments used for exploratory purposes (i.e., the end-of-session AB measures and pre-session affect measures) could be removed. The ABmeasure and ABM blocks took 16 and 22 min on average to complete, respectively (see supplementary material Table 5 for completion times). Future ABM with WBET daily sessions (i.e., two ABM blocks separated by a 5-min break, with an end-of-session mood measure [5 min]) would be 54 min on average, which is comparable to psychological therapy session lengths of up to 60 min. Shorter sessions would also reduce the number of planned calibration phases (and therefore reduce negative impact) and potentially reduce participant fatigue.

While it was encouraging that lowered anxiety, depression, and rumination scores were reported following four sessions, clinically relevant changes were only reported by one participant. However, the number of sessions can moderate the effect of ABM (Jones & Sharpe, 2017; Mogoaşe et al., 2014). Moreover, ABM may be associated with reduced symptoms after post-intervention measures (Browning et al., 2012; Jonassen et al., 2019). Moving forward, eight sessions and follow-up assessments should be trialed.

Trials

One participant (PwAD 1) stated, "I'm starting to see some of my friends faces [in the facial stimuli]". Repeated exposure of the same actor with different facial expressions may become familiar/recognized by participants (Kramer et al., 2018). As ABM could be affected by the repeated use of the same trials (Heeren et al., 2015), the use of distinct trials (i.e., fewer trial repetitions and as many different actors as possible) could potentially avoid familiarity effects whilst increasing efficacy.

One participant (MCI) attempted to figure out the contingency between the facial expressions and the dot location during an unsupervised eye-tracking session, and another (PwAD 1) initially found it hard not to preempt the dot location. We considered asking the participants if they were preempting the dot location/contingency deciphering after each sub-block for data processing and analyses purposes. However, this may cause *all* participants to preempt/decipher/focus on the contingency. As the information regarding preempting/contingency deciphering was elicited during participant checks (i.e., how are you doing/would you like to continue?) without a focus on the contingency, we would continue with this strategy and remove any corrupted data as required.

Mind-wandering

Although only one participant (PwAD 1) reported mind wandering (i.e., the switching of attention from an external current task to self-generated thoughts), other participants may have experienced it but were unaware or did not report it (Smallwood & Schooler, 2015). Mind wandering can be related to task monotony, depression, and rumination (Smallwood & Schooler, 2015; Thomson et al., 2015; van Vugt & van der Velde, 2018). Persons with AD may 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 is what 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). As background music can reduce mind wandering (Kiss & Linnell, 2021), mind-wandering tendency and mind wandering occurrences should be assessed and factored into analyses.

Limitations and future studies

The limitations of this study are that individuals without the appropriate equipment, internet access/a stable connection, the ability to remain still, or who blink a lot could not take part nor complete the study. Moreover, those with more advanced dementia or who are unable to follow/remember instructions would not be able to engage in a study/intervention such as this. The participant sample was self-selecting in that possibly those with less technology anxiety, whether they navigated the process themselves or not, enrolled in the study so our findings may not be generalizable.

Future larger ABM with WBET studies should include older persons without cognitive impairment as a comparator group and assess feasibility in terms of acceptability and accessibility (participant and those providing assistance perspectives), and tolerability. Adverse events should be systematically recorded, and follow-up assessments should be conducted. Although the focus here related to delivering remote ABM with WBET and participant mood, future studies should follow AB measure reliability recommendations (e.g., using longer presentation times) (see Greenaway et al., 2023; McNamara et al., 2023).

Clinical Implications

- Remotely delivered ABM with WBET is feasible for some persons with MCI/AD, and WBET tasks can be completed independently following a single session
- Reductions in rumination, a key process in anxiety and depression development, maintenance, and relapse, were previously unexplored in dementia and reductions were found here
- A randomized pilot study can be developed from these findings

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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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