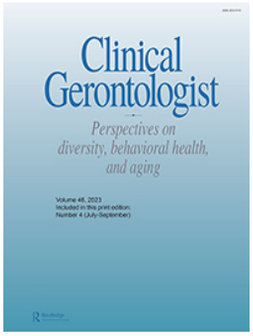
Webcam-based eye-tracking of attentional biases in Alzheimer's disease: a proof-of-concept study



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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).

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Attentional biases in AD: A webcam eye-tracking study.

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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 toward 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 ($\alpha = 0.89$) (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 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 the

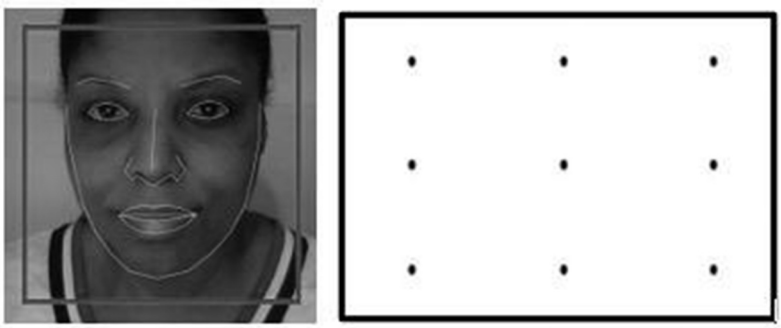

Figure 1. a). (left) showing successful face-meshing, and 1b). (right) illustrating the dot locations.

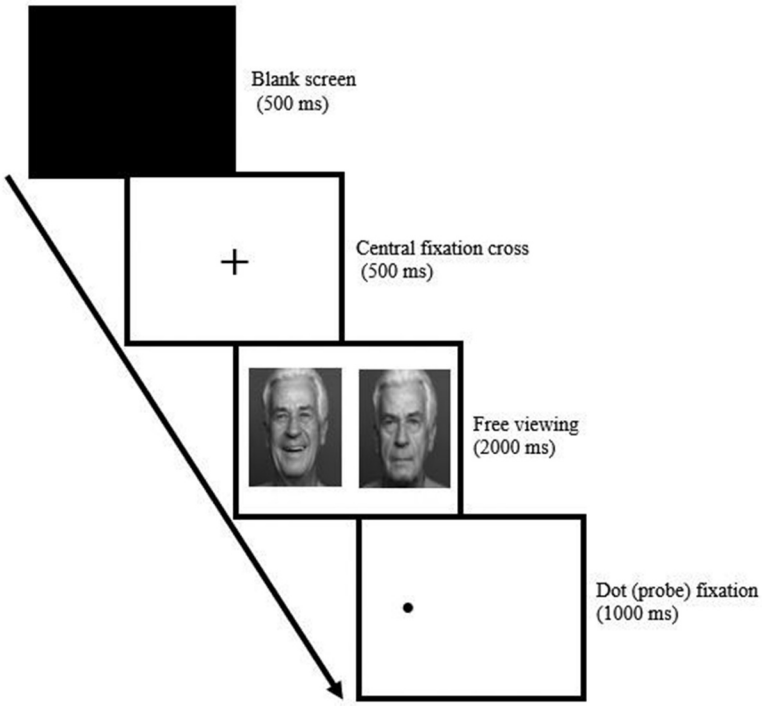

Figure 2. Showing the trial presentation.

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 reliabililty analyses were performed with the Statistical Package for the Social Sciences, version 25 (IBM Corp, 2017). Significance testing and correlational analyses of attentional bias 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. The findings relating to emotional-emotional pairings will be presented elsewhere.

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 ambigously 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 the emotional expressions. GAD-7 and PHQ-9 scores of ≥ 10 points are indicative of generalized anxiety disorder and major depressive disorder respectively.

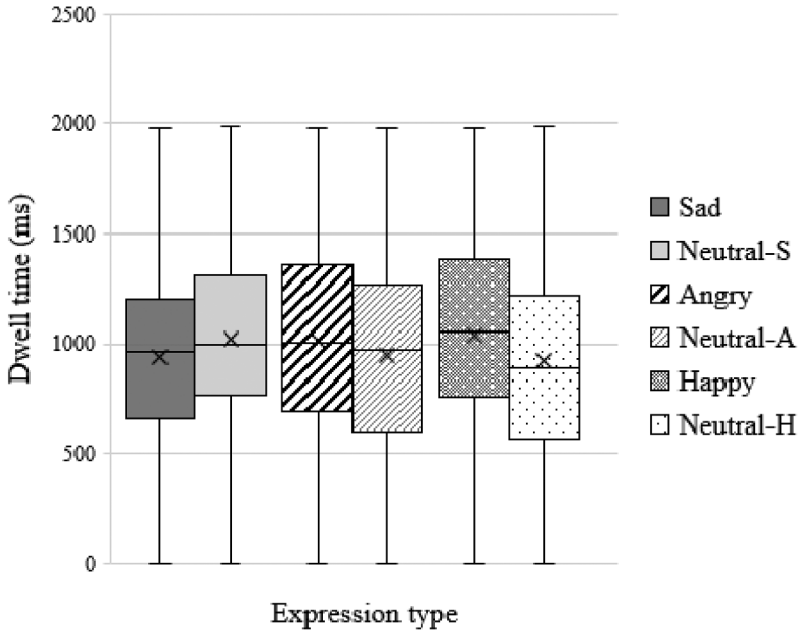

Figure 3. Showing the full cohort's ($N = 12$) average dwell-time data for emotional-neutral pairings. A hyphen followed by S, A, or H denotes the corresponding neutral face data for sad, angry, and happy pairings respectively. Dwell-time data were non-normally distributed.

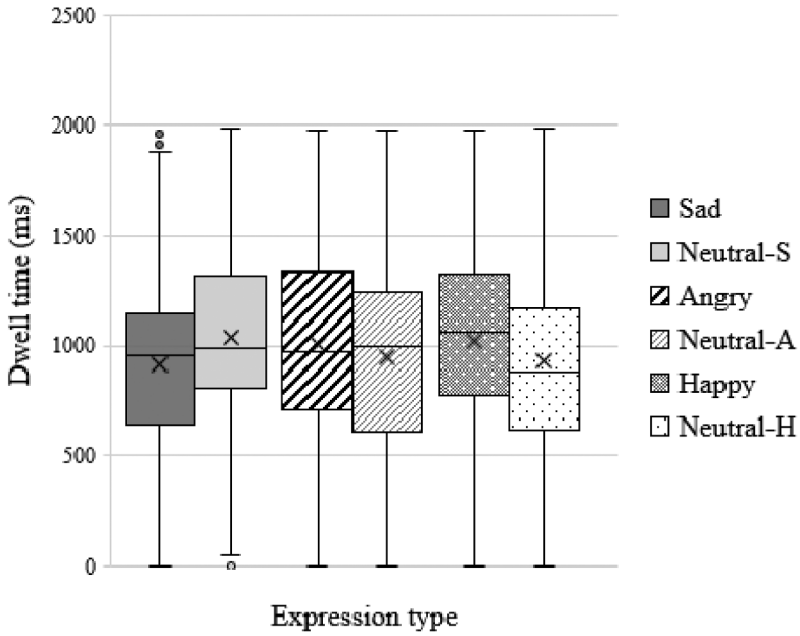

Figure 4. Showing the comorbid (anxious and depressed) groups's ($n = 6$) average dwell-time data for emotional-neutral pairings. A hyphen followed by S, A, or H denotes the corresponding neutral face data for sad, angry, and happy pairings respectively. Dwell-time data were non-normally distributed 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 web-cam-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 (Lazarov et al., 2016; Sears et al., 2019) (see Skinner et al., 2018 for 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 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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Disclosure statement

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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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