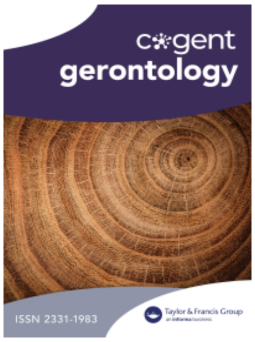
Increased attention to the eye region when playing background music in Alzheimer's disease: a remotely delivered webcam eye-tracking feasibility study



Cogent Gerontology

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/oagt20

Increased attention to the eye region when playing background music in Alzheimer's disease: a remotely-delivered webcam eye-tracking feasibility study

Anne-Marie Greenaway, Faustina Hwang, Slawomir Nasuto & Aileen K. Ho

To cite this article: Anne-Marie Greenaway, Faustina Hwang, Slawomir Nasuto & Aileen K. Ho (2025) Increased attention to the eye region when playing background music in Alzheimer's disease: a remotely-delivered webcam eye-tracking feasibility study, Cogent Gerontology, 4:1, 2484211, DOI: 10.1080/28324897.2025.2484211

To link to this article: https://doi.org/10.1080/28324897.2025.2484211

COGENT GERONTOLOGY
2025, VOL. 4, NO. 1, 2484211
https://doi.org/10.1080/28324897.2025.2484211

Taylor & Francis
Taylor & Francis Group

RESEARCH ARTICLE

OPEN ACCESS Check for updates

Increased attention to the eye region when playing background music in Alzheimer's disease: a remotely-delivered webcam eye-tracking feasibility study

Anne-Marie Greenaway [a], Faustina Hwang [a], Slawomir Nasuto [a] and Aileen K. Ho [b]

[a]Biomedical Engineering, School of Biological Sciences, University of Reading, Berkshire, UK; [b]School of Psychology and Clinical Language Sciences, University of Reading, Berkshire, UK

ABSTRACT
Music modulates dwell-times on discriminating facial features (e.g. eyes) and rumination levels modulate visual attention/responses to music. As these factors are understudied in dementia, particularly in non-care settings, home-based music research with webcam-based eye tracking (WBET) was explored. Participants completed online self-report mood/rumination measures and a cognitive status interview. In silence and then with background music, participants fixated on a cross, naturally viewed emotional-neutral facial pairings, and then fixated on a dot. Percentage dwell-time on emotional faces, and the top-half versus bottom-half of these images was examined and changes were registered by the eye tracker during the music condition. WBET use was feasible (i.e. full datasets were collected for both conditions) for 39% of the participants. Data could not be collected from 33% of the participants due to initial calibration failures attributed to head movement and/or blinking, and face detection and internet connection issues. All other issues could be resolved remotely with assistance. In conclusion, WBET use in music-based research is feasible and provides access to eye-tracking studies for some individuals. The large amount of data/participant loss should be considered in sample size calculations. Practical recommendations, preliminary data, and hypotheses based on these data are provided for future research.

ARTICLE HISTORY Received 23 December 2024; Accepted 24 February 2025; Revised 21 February 2025

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

JEL CLASSIFICATION Y4

CONTACT Anne-Marie Greenaway anne-marie.greenaway@pgr.reading.ac.uk Biomedical Engineering, School of Biological Sciences, University of Reading, Polly Vacher, Whiteknights, Reading, Berkshire RG6 6DH, UK

Supplemental data for this article can be accessed online at https://doi.org/10.1080/28324897.2025.2484211

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). More music studies involving older persons are conducted in care settings (e.g. hospitals, nursing homes, and psychiatric wards) than in the community (e.g. daycare centres, singing clubs, and participant homes) (Allfree et al., 2024; Dhippayom et al., 2022; Moreno-Morales et al., 2020; Sousa et al., 2020; Zhang et al., 2017). As a larger proportion (up to 80%) of persons with dementia are community-dwelling (Livingston et al., 2014), 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 (the types of visual stimuli that individuals attend to or avoid) has been understudied in dementia. Although studies report that music can affect attention 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).

The attentional biases of older persons

Attentional biases are thought to play a key role in the aetiology, maintenance, and recurrence of anxiety and depression, yet attentional biases 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 attentional biases (Arditte & Joormann, 2014; Bantin et al., 2016), studies have shown that cognitively healthy older persons can demonstrate attentional biases 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), and those experiencing apathy can display reduced attentional biases towards social stimuli (Chau et al., 2016). Investigating the attentional biases of persons with dementia using eye-tracking could prove beneficial to clinicians (Greenaway et al., 2024a) as anxiety and depression treatment response can be difficult to assess (Dudas et al., 2018). Anti-depressant treatment (the front-line intervention in dementia) and psychological therapy (a recommended intervention for persons with dementia experiencing mild to moderate symptoms) can be associated with attentional bias change in cognitively healthy older persons and other populations, with early changes in attentional biases being associated with successful anti-depressant treatment (Banerjee et al., 2011; Godlewska & Harmer, 2021; Harmer et al., 2009; Mohlman et al., 2013; NICE, 2018; L. Zhang et al., 2020). To our knowledge, it is yet to be established if the attentional biases 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 by, for example, modulating the stress response, regulating emotion, and modulating the production of neurotransmitters (e.g. dopamine and serotonin) which can be depleted in anxiety and depression (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), play important roles in attention allocation/visual processing (e.g. perception, social cue and stimuli processing) (Lockhofen & Mulert, 2021). Music modulates attention allocation (e.g. fixations) and attentional biases for emotional stimuli for younger adults (Arriaga et al., 2014; Bravo, 2014; Invitto et al., 2017; Mera & Stumpf, 2014; Millet et al., 2021), and increases 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). For example, the eye region is thought to facilitate the identification of anger and sadness (Ebner et al., 2011; Eisenbarth & Alpers, 2011; Low et al., 2022), and increased viewing of this region improved emotional recognition for persons with Alzheimer's disease (Hot et al., 2013). Reduced eye-contact or dwelling on the eyes is also thought to be a risk factor of anxiety, and a feature and maintenance factor of both anxiety and depression (Schneier et al., 2011; Spence & Rapee, 2016; Suslow et al., 2024), with clinical or significant improvements in mood being associated with increased eye contact (Fiquer et al., 2013; Matsumoto et al., 2023).

While eye contact has been assessed within music-based dementia research (Clare et al., 2020), to our knowledge, the relative attention to facial regions for different emotional expressions required exploration via eye tracking. Remote webcam-based eye tracking was explored in the current study as it is feasible for some persons with and without dementia to perform from their homes via their personal devices (A.-M. Greenaway et al., 2021) and has the potential to reach individuals who are unable to take part in lab-based eye-tracking studies (e.g. travel issues), who may avoid exposure to unfamiliar devices, and/or those who may feel uncomfortable having a researcher in their homes.

Webcam-based eye tracking in music research

While similar patterns of results and reliability levels comparable to lab-grade and remote eye-trackers have been found using webcam-based eye tracking (Bott et al., 2020; Greenaway et al., 2024a; Semmelmann & Weigelt, 2018; Wisiecka et al., 2022), to our knowledge, one music-related study has been conducted exploring the feasibility of tracking infants' gaze during a preferential looking task assessing audio-visual synchrony perception (Bánki et al., 2022). Although being deemed feasible, high attrition (~50%) was reported and attributed to issues surrounding calibration and potentially the fact that the study was unmoderated (i.e. no immediate technical support was available). To our knowledge, the current study is the first to explore the feasibility of conducting music-based dementia research with webcam-based eye tracking. Further, to explore music, attentional biases, and rumination, 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 attentional biases 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, attentional biases are linked to anxiety, depression, and rumination, and attentional biases can be modified by music. Yet, how older persons' attentional biases may be modified by music and how rumination may be implicated have received little focus. In hopes of engaging community-based older persons to address the aforementioned literature gaps in a larger study, the aim of the current study was to explore the feasibility of incorporating webcam-based eye tracking within remotely-delivered music-based research. Although attentional bias changes should be observed (Arriaga et al., 2014; Lazarov et al., 2017; Shamai-Leshem et al., 2021), the preliminary attentional bias data were collected for sample size calculations and to develop working hypotheses for exploration 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/) (see supplementary material for detailed recruitment information). Persons with Alzheimer's disease and mild cognitive impairment were combined to form a participants with cognitive impairment group. Full eye-tracking datasets were obtained from seven participants (female = 4, male = 3; Alzheimer's disease = 4, mild cognitive impairment = 1, cognitively healthy = 2). The participants with cognitive impairment 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 (Alzheimer's disease = 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 cognitively healthy 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, cognitively healthy = 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., 2024a) and is summarised here. Prior to the eye-tracking session, participants received preparation notes, a personalised link to 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

Table 1. Descriptive age, cognitive, and mood data.

	PwCI (n = 5)		HC (n = 2)	
Measures	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

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.

their laptop screens with the researcher. They received an emailed link to Gorilla (Anwyl-Irvine et al., 2020) to complete the attentional bias tasks during the session. Participants completed two attentional bias measure 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 University of Reading's Research Ethics Committee and received a favourable ethical opinion for conduct (UREC 19/71). All participants provided written or verbal consent before the start of the study. All participants with cognitive impairment 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 the 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 points for mild, moderate, and severe anxiety, respectively. The scale has high internal consistency ($\alpha = .89$) (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 ($\alpha = .92$) and adequate test-retest reliability ($r = .77$) for persons with dementia (Greenaway et al., 2024b).

Eye tracking

Detailed positioning, calibration, and validation information have been previously described (see Greenaway et al. (2021) and Semmelmann and 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 attentional bias measure block and their sub-blocks (described next).

Attentional biases

A modified dot-probe task (MacLeod et al., 2002) was used to measure attentional biases (see Figure 1). The dot-probe was used as a foil task in the current study and the critical display was the facial stimuli slide that precedes the dot-probe. 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

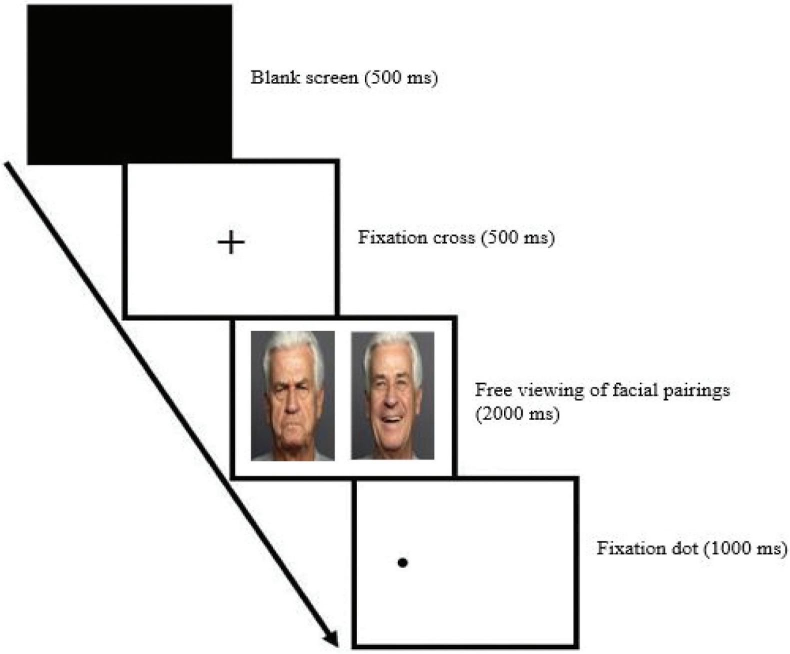


Figure 1. Trial presentation details.

had disappeared, a black dot appeared in the centre of one of the face's previous locations 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 attentional bias measure 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.

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 (anxious and depressed).

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 participants with cognitive impairment were younger, more cognitively impaired, anxious, and depressed than the cognitively healthy participants (see Table 1 for descriptive data). They also used a ruminative response to depression to a greater extent than the cognitively healthy participants.

Eye tracking

None of the participants had previously taken part in an eye-tracking study. Four participants with cognitive impairment had assistance from their spouse/friend (full assistance = 2, partial = 2). Usable eye-tracking data from both conditions were obtained from 39% of participants. Partial eye-tracking data were obtained from 28% of participants

(participants with cognitive impairment = 2, cognitively healthy = 3). Reasons included internet connection instability/within block calibration failure (participants with cognitive impairment = 1, cognitively healthy = 1), study time (i.e. study overran/conflict with other commitment) (participants with cognitive impairment = 1, cognitively healthy = 1), and a sampling issue (i.e. a lag before the first eye-gaze prediction was generated across all slides within the music condition) (cognitively healthy = 1). Calibration was unsuccessful for 33% of participants (participants with cognitive impairment = 5, cognitively healthy = 1) and attributed to face-meshing difficulties (participants with cognitive impairment = 3), head movement and/or blinking (participants with cognitive impairment = 2), and internet connection (participants with cognitive impairment = 2, cognitively healthy = 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 webcam-based eye tracking 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 & Weigelt, 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 webcam-based eye-tracking program, at times, could try to face-mesh a background object (see Figure 2). Having participants think about their backgrounds in advance, e.g. having a plain wall behind them (if possible), could facilitate the face-meshing process.

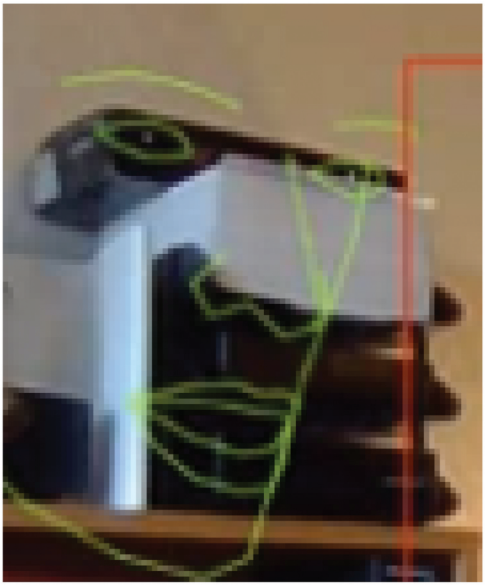


Figure 2. Webcam-based eye-tracking program attempting to face-mesh a background object.

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 participants with cognitive impairment who had face-meshing/internet difficulties/unsuccessful calibration enquired if a downloadable eye-tracking package was an option.

Preliminary data

The preliminary data used for developing hypotheses are presented in Table 2 and Figure 3 (see supplementary material for group and individual data). Significant differences were found between silent and music conditions for those displaying silent-condition AB towards angry faces, $t(4) = 3.850$, $p = .02$, 95% CI [2.6, 16], and for the HC group's dwell-time on the top-half, $T = 111.00$, $z = -2.86$, $p = .004$, 95% CI [−25, −6.5], and the bottom-half, $t(31) = -2.054$, $p = .048$, 95% CI [−23, −.08], of angry-faces. The relationship between sad-face AB and rumination scores approached significance, $r(5) = -.73$, $p = .06$, 95% CI [−.96, .05] for the music condition.

Table 2. Preliminary eye tracking data.

				% dwell time							
				PwCI (n = 5)				HC (n = 2)			
		Bias score		Top-half of faces		Bottom-half of faces		Top-half of faces		Bottom-half of faces	
Expression type/condition	*N*	*M (Mdn)*	*SD (IQR)*	*M (Mdn)*	*SD (IQR)*	*M (Mdn)*	*SD (IQR)*	*M (Mdn)*	*SD (IQR)*	*M (Mdn)*	*SD (IQR)*
Sad faces											
Silence	7	49	4	(10)	(22)	(32)	(40)	(12)	(17)	35	14
Music		51	6	(14)	(30)	(25)	(27)	(8)	(19)	(40)	(52)
Angry faces											
Silence	7	54	6	(14)	(30)	(31)	(41)	**26**	16	**27**	18
Music		48	5	(18)	(31)	(24)	(29)	**(2)**	(18)	**39**	25
Happy faces											
Silence	7	51	6	(16)	(27)	(27)	(38)	(15)	(32)	28	19
Music		51	9	(17)	(28)	(26)	(36)	(5)	(22)	(24)	(45)
Angry face[a]											
Silence	5	**57**	3	–	–	–	–	–	–	–	–
Music		**47**	6	–	–	–	–	–	–	–	–

PwCI: participants with cognitive impairment; HC: cognitively healthy control.
Bias score: proportion of the average dwell-time on the 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 emotional faces, <50% less dwelling. % dwell time: the percentage of time spent looking at the top-half (containing the eye region) relative to the bottom-half (containing the mouth region) of the emotional face and its corresponding neutral face. [a]Sub-group containing participants with a bias scores of >50% only. Bold text: significant difference p = <.05.

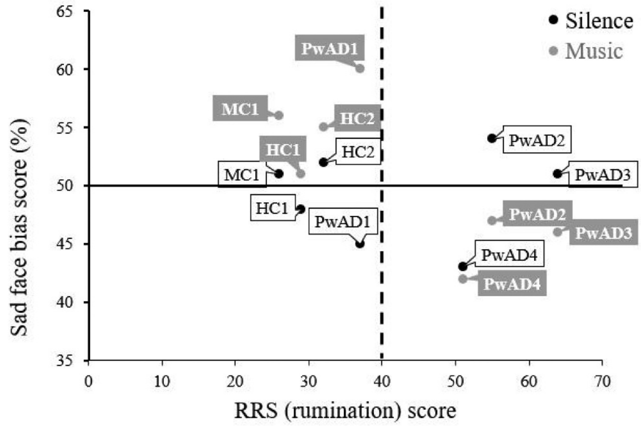


Figure 3. Individual participants' sad bias scores against ruminative response scale (RRS) scores for silence and music conditions. Bias score: proportion of the average dwell-time on the sad face relative to the average dwell-time on both the sad face plus its corresponding neutral face. Bias scores 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 music condition whereas high ruminators displayed reduced dwelling.

Discussion

The aim of the current study was to explore the feasibility of incorporating webcam-based eye tracking within remotely delivered music-based research. As little focus had been given to how older persons' attentional biases may be modified by music and how rumination levels may be implicated, older persons' rumination levels were assessed and their attentional biases to emotional facial images and the relative attention to the top-half and bottom-half of these images (i.e. discriminating feature regions containing the eyes and the mouth) when viewing in silence and with background music were measured using webcam-based eye tracking. 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., 2023), participant age may have impacted data collection. Still, factors associated with aging (e.g. glasses wearing, irregular pupil/eye shape, and cataract) can result in a loss of participants within remote and traditional eye-trackers studies (Davis, 2021; Nyström et al., 2013). Additionally, 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 participant's 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 webcam-based eye tracking 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 (Kaduk et al., 2023).

Other considerations

The feasibility of using webcam-based eye tracking in (music-based) research also depends on the study’s experimental design and the phenomenon being measured (Van der Cruyssen et al., 2023). Using up to six areas of interest should not result in a degradation of data quality and the lower sampling rate associated with webcam-based eye tracking should be sufficient for collecting data from large areas of interest as described in the current study (Prystauka et al., 2023; Yang & Krajbich, 2021). Further, our music track was uninterrupted and began playing before the first facial stimuli was presented in the music condition. For other experimental aims (e.g. examining the effect of specific segments of the music on attention), the timing of the music(/audio) sample should be considered as there may be a lag between the audio and visual stimuli presentation (Prystauka et al., 2023).

Limitations

While the current study is a first step towards exploring music, attentional biases, and rumination in combination for older persons with and without cognitive impairment, individuals without access to a device with webcam-based eye-tracking capability were unable to take part in our study. Time (i.e. long set-up times and calibration issues associated with webcam-based eye tracking) 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 webcam-based eye-tracking data collection (Hutt & D'Mello, 2022). As such, future webcam-based eye-tracking study times could potentially be reduced as the time taken for calibration would be removed.

Clinical and research implications, and recommendations

The attentional biases measured via webcam-based eye tracking in the current study related to (1) emotional facial expressions, and (2) the eye and mouth region areas of these images. These attentional biases are of theoretical and clinical relevance in anxiety and depression (De Raedt & Koster, 2010; Fiquer et al., 2013; MacLeod & Clarke, 2015; Matsumoto et al., 2023; Schneier et al., 2011; Spence & Rapee, 2016), and there is evidence that they can be modified during music exposure (Arriaga et al., 2014; Clare et al., 2020; Lazarov et al., 2017; Shamai-Leshem et al., 2021), with clinically-relevant reductions in mood symptoms being reported (Lazarov et al., 2017; Shamai-Leshem et al., 2021). However, older persons' response to music may be different to younger adults (i.e. more positively focussed) (Isaacowitz et al., 2006; Vieillard & Gilet, 2013). Our finding that webcam-based eye tracking can be used to collect data from persons with and without dementia exploring the effect of music on these biases may provide an opportunity to expand the limited literature to older and hard to reach populations in community-based settings. Moreover, our findings may prompt researchers to explore the process by which music is associated with older persons' symptom reductions as the existing literature is insufficient (Jang & Kunde, 2021). Process explanations should include (1), (2) *and* rumination given their roles in anxiety and depression. Our preliminary data (a) provide a starting point for individuals conducting music-based research such as this, (b) are a positive indicator that webcam-based eye tracking may be a potential tool to provide objective outcome measures for music-based studies, and (c) are supportive of the notion that rumination should be considered within older-person music intervention/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 webcam-based eye-tracking 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 webcam-based eye tracking 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., 2023). From our observations, explicit information about the appearance of their face in their video stream may be warranted. 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 avoid eye tracking at times when large changes in light levels occur (e.g. around sunset) or have an additional light source to hand.

Although we kept to schedule in most instances, participants should be advised to leave a gap between the suggested study end and subsequent engagements in case of unexpected issues.

Forward thinking

The impact of the music on participant mood requires consideration in future music-based attentional bias webcam-based eye-tracking studies. For example, an attentional bias away from threat (e.g. angry faces) and eye contact avoidance reduces immediate distress and regulates fear (Mogg & Bradley, 2018; Schulze et al., 2013). It is possible that music may reduce the negative emotion (e.g. anxiety/stress (Thoma et al., 2013)) associated with looking towards threat stimuli and the eyes, modulating mood and dwell-time. Encouragingly, researchers are developing tools to assess musically-induced emotional responses (e.g. heart rate/variability and respiration rate) from facial video recordings, allowing for remote data collection without additional/specialised recording equipment (e.g. sensors) (Juslin & Laukka, 2004; Yue et al., 2023) and reduced participant burden (i.e. a momentary mood scale/measure of musically-induced emotions would be unnecessary). Developers/researchers should ensure that older-persons' faces are included in training sets and that these tools are able to process the low-quality videos obtained from device-embedded webcams.

The impact of dual processing (i.e. the visual stimuli and the musical stimuli) should also be considered. Knight et al. (2007) found that older persons can display a reversal of emotional biases when their attention was divided (i.e. a dot-probe task with a tone sequence discrimination task). However, rumination was not assessed (and persons with [possible] cognitive impairment were excluded) so cannot be ruled out as a contributing factor. Including an eye-tracking metric (e.g. pupil size [dilation]), which has been associated with the 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 method for remote assessment. Unfortunately, current webcam-based eye-tracking 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 within a remote webcam-based eye-tracking versus mobile infrared-tracker comparison study.

Futures studies should examine the impact of music exposure/musically-induced viewing shifts on other factors as eye contact is important for 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 participants with Alzheimer's disease (Hietanen, 2018; Kleinke, 1968; Lopis & Conty, 2019). Further, insufficient viewing of facial regions (e.g. the eyes) could contribute to the emotional recognition difficulties seen in older persons with and without Alzheimer's disease, and impact self-reported quality of life (Noiret et al., 2015; Phillips et al., 2010). Increased attending to the eyes (e.g. revealing the eye region first) can improve emotional recognition for participants with Alzheimer's disease (Hot et al., 2013) but not cognitively healthy participants (Low et al., 2022).

The preliminary eye-tracking data from the current study were used to create working hypotheses as a starting point for a future larger study.

H_1: A relationship between dwell time and rumination scores will be seen when background music is played

H_2: A difference between silent and background music dwell-times will be seen for participants displaying (silent-condition/baseline) negative attentional biases

H_3: A difference between silent and background music dwell-times on discriminating features will be seen

Caution should be applied as these hypotheses are based on small samples and data which approached significance (H_1) or had wide confidence intervals (H_2 and H_3) (see supplementary material for further details).

Conclusion

Remotely-delivered music-based research with webcam-based eye tracking involving older persons with and without cognitive impairment is feasible and provides access to eye-tracking studies for some individuals. Future studies should factor in the large level of participant loss.

Acknowledgements

We would like to thank the Join Dementia Research volunteers and those providing aid to enable them to participate in our study.

Data availability statement

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

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This project has been supported by a University of Reading Strategic PhD Studentship and by the School of Biological Sciences.

ORCID

Anne-Marie Greenaway http://orcid.org/0000-0002-0394-8791
Faustina Hwang http://orcid.org/0000-0002-3243-3869
Slawomir Nasuto http://orcid.org/0000-0001-9414-9049
Aileen K. Ho http://orcid.org/0000-0002-2581-126X

Preprint information

A preprint of this article has been published via Advance (DOI: 10.31124/advance.171111621.18505452/v2).

References

Allard, E. S., Wadlinger, H. A., & Isaacowitz, D. M. (2010). Positive gaze preferences in older adults: Assessing the role of cognitive effort with pupil dilation. *Aging, Neuropsychology & Cognition*, *17*(3), 296–311. https://doi.org/10.1080/13825580903265681

Allfree, R., Greenaway, A.-M., Chatterjee, A., & McColl, A. (2024). 2035 the feasibility to staff of patient specific music choice on elderly care wards - a post intervention survey. *Age & Ageing*, *53*(Supplement_1), afad246.040. https://doi.org/10.1093/ageing/afad246.040

Anwyl-Irvine, A., Massonnié, J., Flitton, A., Kirkham, N., & Evershed, J. (2020). Gorilla in our midst: An online behavioral experiment builder. *Behavior Research Methods*, *52*(1), 388–407. https://doi.org/10.3758/s13428-019-01237-x

Arditte, K. A., & Joormann, J. (2014). Rumination moderates the effects of cognitive bias modification of attention. *Cognitive Therapy and Research*, *38*(2), 189–199. https://doi.org/10.1007/s10608-013-9581-9

Arriaga, P., Esteves, F., & Feddes, A. R. (2014). Looking at the (mis) fortunes of others while listening to music. *Psychology of Music*, *42*(2), 251–268. https://doi.org/10.1177/0305735612466166

Banerjee, S., Romeo, M., Dewey, R., Dewey, M., Bentham, N., Murray, J. M., Poppe, M., Thomas, A., Banerjee, S., Hellier, J., Knapp, M., Romeo, R., Ballard, C., Baldwin, R., McCrae, P., Fox, C., Holmes, C., Katona, C., Knapp, M., . . . Burns, A. (2011). Sertraline or mirtazapine for depression in dementia (HTA-SADD): A randomised, multicentre, double-blind, placebo-controlled trial. *Lancet*, *378*(9789), 403–414. https://doi.org/10.1016/S0140-6736(11)60830-1

Bánki, A., de Eccher, M., Falschlehner, L., Hoehl, S., & Markova, G. (2022). Comparing online webcam- and laboratory-based eye-tracking for the assessment of infants' audio-visual synchrony perception. *Frontiers in Psychology*, *12*, 733933. https://doi.org/10.3389/fpsyg.2021.733933

Bantin, T., Stevens, S., Gerlach, A. L., & Hermann, C. (2016). Journal of behavior therapy and what does the facial dot-probe task tell us about attentional processes in social anxiety? A systematic review. *Journal of Behavior Therapy and Experimental Psychiatry*, *50*, 40–51. https://doi.org/10.1016/j.jbtep.2015.04.009

Bertrand, J. K., & Chapman, C. S. (2023). Dynamics of eye-hand coordination are flexibly preserved in eye-cursor coordination during an online, digital, object interaction task. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (pp. 1–13). https://doi.org/10.1145/3544548.3580866

Blood, A. J., Zatorre, R. J., Bermudez, P., & Evans, A. C. (1999). Emotional responses to pleasant and unpleasant music correlate with activity in paralimbic brain regions. *Nature Neuroscience*, *2*(4), 382–387. https://doi.org/10.1038/7299

Bott, N. T., Madero, E. N., Glenn, J. M., Lange, A. R., Anderson, J. J., Newton, D. O., Brennan, A. H., Buffalo, E. A., Rentz, D. M., & Zola, S. M. (2020). Device-embedded cameras for eye tracking-based cognitive assessment: Implications for teleneuropsychology. *Telemedicine Journal and E-Health*, *26*(4), 477–481. https://doi.org/10.1089/tmj.2019.0039

Botto, R., Callai, N., Cermelli, A., Causarano, L., & Rainero, I. (2022). Anxiety and depression in Alzheimer's disease: A systematic review of pathogenetic mechanisms and relation to cognitive decline. *Neurological Sciences*, *43*(7), 4107–4124. https://doi.org/10.1007/s10072-022-06068-x

Bourgin, J., Silvert, L., Borg, C., Morand, A., Sauvée, M., Moreaud, O., & Hot, P. (2020). Impact of emotionally negative information on attentional processes in normal aging and Alzheimer's disease. *Brain & Cognition*, *145*(April), 105624. https://doi.org/10.1016/j.bandc.2020.105624

Bravo, F. (2014). Changing the interval content of algorithmically generated music changes the emotional interpretation of visual images. In M. Aramaki, O. Derrien, R. Kronland-Martinet, & S. Ystad (Eds.), *Sound, music, and motion. CMMR 2013.*

Lecture notes in computer science (Vol. 8905). Springer. https://doi.org/10.1007/978-3-319-12976-1

Bravo, F., Cross, I., Hopkins, C., Gonzalez, N., Docampo, J., Bruno, C., & Stamatakis, E. A. (2020). Anterior cingulate and medial prefrontal cortex response to systematically controlled tonal dissonance during passive music listening. *Human Brain Mapping*, *41*(1), 46–66. https://doi.org/10.1002/hbm.24786

Bravo, F., Cross, I., Stamatakis, E. A., & Rohrmeier, M. (2017). Sensory cortical response to uncertainty and low salience during recognition of affective cues in musical intervals. *PLOS ONE*, *12*(4), e0175991. https://doi.org/10.1371/journal.pone.0175991

Breitve, M. H., Hynninen, M. J., Brønnick, K., Chwiszczuk, L. J., Auestad, B. H., Aarsland, D., & Rongve, A. (2016). A longitudinal study of anxiety and cognitive decline in dementia with Lewy bodies and Alzheimer's disease. *Alzheimer's Research & Therapy*, *8*(3). https://doi.org/10.1186/s13195-016-0171-4

Buolamwini, J., & Gebru, T. (2018). Gender shades: Intersectional accuracy disparities in commercial gender classification. In *Proceedings of the 1st Conference on Fairness, Accountability and Transparency*, New York, NY, USA (pp. 77–91).

Chanda, M. L., & Levitin, D. J. (2013). The neurochemistry of music. *Trends in Cognitive Sciences*, *17*(4), 179–191. https://doi.org/10.1016/j.tics.2013.02.007

Chau, S. A., Chung, J., Herrmann, N., Eizenman, M., & Lanctôt, K. L. (2016). Apathy and attentional biases in Alzheimer's disease. *Journal of Alzheimer's Disease*, *51*(3), 837–846. https://doi.org/10.3233/JAD-151026

Clare, A., Camic, P. M., Crutch, S. J., West, J., Harding, E., & Brotherhood, E. (2020). Using music to develop a multisensory communicative environment for people with late-stage dementia. *Gerontologist*, *60*(6), 1115–1125. https://doi.org/10.1093/geront/gnz169

Davis, R. (2021). The feasibility of using virtual reality and eye tracking in research with older adults with and without Alzheimer's disease. *Frontiers in Aging Neuroscience*, *13*, 607219. https://doi.org/10.3389/fnagi.2021.607219

Demeyer, I., Sanchez, A., & De Raedt, R. (2017). Older adults' attentional deployment: Differential gaze patterns for different negative mood states. *Journal of Behavior Therapy and Experimental Psychiatry*, *55*, 49–56. https://doi.org/10.1016/j.jbtep.2016.11.012

De Raedt, R., & Koster, E. H. W. (2010). Understanding vulnerability for depression from a cognitive neuroscience perspective: A reappraisal of attentional factors and a new conceptual framework. *Cognitive, Affective & Behavioral Neuroscience*, *10*(1), 50–70. https://doi.org/10.3758/CABN.10.1.50

Dhippayom, T., Saensook, T., Promkhatja, N., Teaktong, T., Chaiyakunapruk, N., & Devine, B. (2022). Comparative effects of music interventions on depression in older adults: A systematic review and network meta-analysis. *EClinicalMedicine*, *50*, 101509. https://doi.org/10.1016/j.eclinm.2022.101509

Dudas, R., Malouf, R., Mccleery, J., & Dening, T. (2018). Antidepressants for treating depression in dementia. *Cochrane Database of Systematic Reviews*, *2018*(8), CD003944–CD003944. https://doi.org/10.1002/14651858.CD003944.pub2

Ebner, N. C., He, Y., & Johnson, M. K. (2011). Age and emotion affect how we look at a face: Visual scan patterns differ for own-age versus other-age emotional faces. *Cognition & Emotion*, *25*(6), 983–997. https://doi.org/10.1080/02699931.2010.540817

Ebner, N. C., Riediger, M., & Lindenberger, U. (2010). Faces-a database of facial expressions in young, middle-aged, and older women and men: Development and validation. *Behavior Research Methods*, *42*(1), 351–362. https://doi.org/10.3758/BRM.42.1.351

Eisenbarth, H., & Alpers, G. W. (2011). Happy mouth and sad eyes: Scanning emotional facial expressions. *Emotion*, *11*(4), 860–865. https://doi.org/10.1037/a0022758

El Haj, M., Chapelet, G., Moustafa, A. A., & Boutoleau-Bretonnière, C. (2022). Pupil size as an indicator of cognitive activity in mild Alzheimer's disease. *EXCLI Journal*, *21*, 307–316. https://doi.org/10.17179/excli2021-4568

Evers, S., & Suhr, B. (2000). Changes of the neurotransmitter serotonin but not of hormones during short time music perception. *European Archives of Psychiatry and Clinical Neuroscience*, *250*(3), 144–147. https://doi.org/10.1007/s004060070031

Fiquer, J. T., Boggio, P. S., & Gorenstein, C. (2013). Talking bodies: Nonverbal behavior in the assessment of depression severity. *Journal of Affective Disorders*, *150*(3), 1114–1119. https://doi.org/10.1016/j.jad.2013.05.002

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, *12*(3), 189–198. https://doi.org/10.1016/0022-3956(75)90026-6

Gallagher, D., Coen, R., Kilroy, D., Belinski, K., Bruce, I., Coakley, D., Walsh, B., Cunningham, C., & Lawlor, B. A. (2011). Anxiety and behavioural disturbance as markers of prodromal Alzheimer's disease in patients with mild cognitive impairment. *International Journal of Geriatric Psychiatry*, *26*(2), 166–172. https://doi.org/10.1002/gps.2509

Garrido, S. (2009). Rumination and Sad Music: A review of the literature and a future direction. In *The Second International Conference on Music Communication Science*, Sydney, Australia (pp. 20–23).

Garrido, S., Dunne, L., Chang, E., Perz, J., Stevens, C. J., & Haertsch, M. (2017). The use of music playlists for people with dementia: A critical synthesis. *Journal of Alzheimer's Disease*, *60*(3), 1129–1142. https://doi.org/10.3233/JAD-170612

Garrido, S., Dunne, L., Stevens, C. J., Chang, E., & Clements-Cortes, A. (2020). Music playlists for people with dementia: Trialing a guide for caregivers. *Journal of Alzheimer's Disease*, *77*(1), 219–226. https://doi.org/10.3233/JAD-200457

Garrido, S., Eerola, T., & McFerran, K. (2017). Group rumination: Social interactions around music in people with depression. *Frontiers in Psychology*, *8*(MAR). https://doi.org/10.3389/fpsyg.2017.00490

Gentzel, M. (2021). Biased face recognition technology used by government: A problem for liberal democracy. *Philosophy & Technology*, *34*(4), 1639–1663. https://doi.org/10.1007/s13347-021-00478-z

Godlewska, B. R., & Harmer, C. J. (2021). Cognitive neuropsychological theory of antidepressant action: A modern-day approach to depression and its treatment. *Psychopharmacology*, *238*(5), 1265–1278. https://doi.org/10.1007/s00213-019-05448-0

Gonfrier, S., Andrieu, S., Renaud, D., Vellas, B., & Robert, P. (2012). Course of neuropsychiatric symptoms during a 4-year follow up in the REAL-FR cohort. *The Journal of Nutrition, Health & Aging*, *16*(2), 134–137. https://doi.org/10.1007/s12603-011-0147-9

Greenaway, A.-M., Hwang, F., Nasuto, S., & Ho, A. (2024a). 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

Greenaway, A. M., Hwang, F., Nasuto, S., & Ho, A. K. (2024b). Rumination in dementia and its relationship with depression, anxiety, and attentional biases. *Aging, Neuropsychology & Cognition*, *31*(6), 1–27. https://doi.org/10.1080/13825585.2024.2327679

Greenaway, A.-M., Nasuto, S., Ho, A., & Hwang, F. (2021). Is home-based webcam eye-tracking with older adults living with and without Alzheimer's disease feasible? *The 23rd International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '21*) (pp. 1–3). https://doi.org/10.1145/3441852.3476565

Harmer, C. J., Goodwin, G. M., & Cowen, P. J. (2009). Why do antidepressants take so long to work? A cognitive neuropsychological model of antidepressant drug action. *British Journal of Psychiatry*, *195*(2), 102–108. https://doi.org/10.1192/bjp.bp.108.051193

Hietanen, J. K. (2018). Affective eye contact: An integrative review. *Frontiers in Psychology*, *9*, 1587–1587. https://doi.org/10.3389/fpsyg.2018.01587

Hot, P., Klein-Koerkamp, Y., Borg, C., Richard-Mornas, A., Zsoldos, I., Richard-Mornas, A., Thomas Antérion, C., & Baciu, M. (2013). Fear recognition impairment in early-stage Alzheimer's disease: When focusing on the eyes region improves performance. *Brain & Cognition*, *82*(1), 25–34. https://doi.org/10.1016/j.bandc.2013.02.001

Hutt, S., & D'Mello, S. K. (2022). Evaluating calibration-free webcam-based eye tracking for gaze-based user modeling. In *Proceedings of the 2022 International Conference on Multimodal Interaction* (pp. 224–235). https://doi.org/10.1145/3536221.3556580

IBM Corp. (2017). *IBM SPSS statistics software for windows*. IBM Corp.

Invitto, S., Calcagnì, A., Mignozzi, A., Scardino, R., Piraino, G., Turchi, D., De Feudis, I., Brunetti, A., Bevilacqua, V., & de Tommaso, M. (2017). Face recognition, musical appraisal, and emotional crossmodal bias. *Frontiers in Behavioral Neuroscience*, *11*, 144. https://doi.org/10.3389/fnbeh.2017.00144

Isaacowitz, D. M., Wadlinger, H. A., Goren, D., & Wilson, H. R. (2006). Selective preference in visual fixation away from negative images in old age? An eye-tracking study. *Psychology and Aging*, *21*(1), 40–48. https://doi.org/10.1037/0882-7974.21.1.40

Ito, E., Nouchi, R., Dinet, J., Cheng, C. H., & Husebø, B. S. (2022). The effect of music-based intervention on general cognitive and executive functions, and episodic memory in people with mild cognitive impairment and dementia: A systematic review and meta-analysis of recent randomized controlled trials. *Healthcare (Switzerland)*, *10*(8), 1462. https://doi.org/10.3390/healthcare10081462

Jang, S., & Kunde, L. (2021). A systematic review of music therapy interventions used to address emotional needs of older adults. *The Arts in Psychotherapy*, *76*, 101842. https://doi.org/10.1016/j.aip.2021.101842

Jordan, C., Lawlor, B., & Loughrey, D. (2022). A systematic review of music interventions for the cognitive and behavioural symptoms of mild cognitive impairment (non-dementia). *Journal of Psychiatric Research*, *151*(April), 382–390. https://doi.org/10.1016/j.jpsychires.2022.04.028

Juslin, P. N., & Laukka, P. (2004). Expression, perception, and induction of musical emotions: A review and a questionnaire study of everyday listening. *Journal of New Music Research*, *33*(3), 217–238. https://doi.org/10.1080/0929821042000317813

Kaduk, T., Goeke, C., Finger, H., & König, P. (2023). Webcam eye tracking close to laboratory standards: Comparing a new webcam-based system and the EyeLink 1000. *Behavior Research Methods*, *56*(5), 5002–5022. https://doi.org/10.3758/s13428-023-02237-8

Kallinen K. (2017). Processing of congruent and incongruent facial expressions during listening to music: an eye-tracking study. Journal of Vision, 17(10), 199 10.1167/17.10.199

Kleinke, C. L. (1968). Gaze and eye contact: A research review. *Psychological Bulletin*, *100*(1), 78–100. https://doi.org/10.1037/0033-2909.100.1.78

Knight, M., Seymour, T. L., Gaunt, J. T., Baker, C., Nesmith, K., & Mather, M. (2007). Aging and goal-directed emotional attention: Distraction reverses emotional biases. *Emotion*, *7*(4), 705–714. https://doi.org/10.1037/1528-3542.7.4.705

Kroenke, K., & Spitzer, R. L. (2002). The PHQ-9: A new depression diagnostic and severity measure. *Psychiatric Annals*, *32*(9), 509–515. https://doi.org/10.3928/0048-5713-20020901-06

LaBar, K. S., Mesulam, M. M., Gitelman, D. R., & Weintraub, S. (2000). Emotional curiosity: Modulation of visuospatial attention by arousal is preserved in aging and early-stage Alzheimer's disease. *Neuropsychologia*, *38*(13), 1734–1740. https://doi.org/10.1016/S0028-3932(00)00077-4

Lazarov, A., Pine, D. S., & Bar-Haim, Y. (2017). Gaze-contingent music reward therapy for social anxiety disorder: A randomized controlled trial. *The American Journal of Psychiatry*, *174*(7), 649–656. https://doi.org/10.1176/appi.ajp.2016.16080894

LeMoult, J., & Gotlib, I. H. (2018). Depression: A cognitive perspective. *Clinical Psychology Review*, *69*, 51–66. https://doi.org/10.1016/j.cpr.2018.06.008

Livingston, G., Kelly, L., Lewis-Holmes, E., Baio, G., Morris, S., Patel, N., Omar, R. Z., Katona, C., & Cooper, C. (2014). Non-pharmacological interventions for agitation in dementia: Systematic review of randomised controlled trials. *British Journal of Psychiatry*, *205*(6), 436–442. https://doi.org/10.1192/bjp.bp.113.141119

Lockhofen, D. E. L., & Mulert, C. (2021). Neurochemistry of visual attention. *Frontiers in Neuroscience*, *15*, 643597–643597. https://doi.org/10.3389/fnins.2021.643597

Lopis, D., & Conty, L. (2019). Investigating eye contact effect on people's name retrieval in normal aging and in alzheimer's disease. *Frontiers in Psychology*, *10*, 1218–1218. https://doi.org/10.3389/fpsyg.2019.01218

Low, A. C. Y., Oh, V. Y. S., Tong, E. M. W., Scarf, D., & Ruffman, T. (2022). Older adults have difficulty decoding emotions from the eyes, whereas easterners have difficulty decoding emotion from the mouth. *Scientific Reports*, *12*(1), 7408–7408. https://doi.org/10.1038/s41598-022-11381-8

Löwe, B., Decker, O., Müller, S., Brähler, E., Schellberg, D., Herzog, W., & Herzberg, P. Y. (2008). Validation and standardization of the generalized anxiety disorder screener (GAD-7) in the general population. *Medical Care*, *46*(3), 266–274. https://doi.org/10.1097/MLR.0b013e318160d093

Ma, L. (2020). Depression, anxiety, and apathy in mild cognitive impairment: Current perspectives. *Frontiers in Aging Neuroscience*, *12*, 9–9. https://doi.org/10.3389/fnagi.2020.00009

MacLeod, C., & Clarke, P. J. F. (2015). The attentional bias modification approach to anxiety intervention. *Clinical Psychological Science*, *3*(1), 58–78. https://doi.org/10.1177/2167702614560749

MacLeod, C., Rutherford, E., Campbell, L., Ebsworthy, G., & Holker, L. (2002). Selective attention and emotional vulnerability: Assessing the causal basis of their association through the experimental manipulation of attentional bias. *Journal of Abnormal Psychology*, *111*(1), 107–123. https://doi.org/10.1037/0021-843X.111.1.107

Matsumoto, J., Hirano, Y., Nakaguchi, T., Tamura, M., Nakamura, H., Fukuda, K., Sahara, Y., Ikeda, Y., Takiguchi, N., Miyauchi, M., & Shimizu, E. (2023). Effectiveness of eye communication training device for social anxiety disorder treatment: A single-arm pilot trial. *Journal of Affective Disorders Reports*, *14*, 100626. https://doi.org/10.1016/j.jadr.2023.100626

Menon, V., & Levitin, D. J. (2005). The rewards of music listening: Response and physiological connectivity of the mesolimbic system. *Neuroimage*, *28*(1), 175–184. https://doi.org/10.1016/j.neuroimage.2005.05.053

Mera, M., & Stumpf, S. (2014). Eye-tracking film music. *Music and the Moving Image*, *7*(3), 3–23. https://doi.org/10.5406/musimoviimag.7.3.0003

Millet, B., Chattah, J., & Ahn, S. (2021). Soundtrack design: The impact of music on visual attention and affective responses. *Applied Ergonomics*, *93*(June 2020), 103301. https://doi.org/10.1016/j.apergo.2020.103301

Mogg, K., & Bradley, B. P. (2018). Anxiety and threat-related attention: Cognitive-motivational framework and treatment. *Trends in Cognitive Sciences*, *22*(3), 225–240. https://doi.org/10.1016/j.tics.2018.01.001

Mohlman, J., Price, R. B., & Vietri, J. (2013). Attentional bias in older adults: Effects of generalized anxiety disorder and cognitive behavior therapy. *Journal of Anxiety Disorders*, *27*(6), 585–591. https://doi.org/10.1016/j.janxdis.2013.06.005

Moreno-Morales, C., Calero, R., Moreno-Morales, P., & Pintado, C. (2020). Music therapy in the treatment of dementia: A systematic review and meta-analysis. *Frontiers in Medicine*, *7*. https://doi.org/10.3389/fmed.2020.00160

NICE. (2018). *Dementia: Assessment, management and support for people living with dementia and their carers*. NG97. https://www.nice.org.uk/guidance/ng97/resources/dementia-assessment-management-and-support-for-people-living-with-dementia-and-their-carers-pdf-1837760199109

Noiret, N., Carvalho, N., Laurent, É., Vulliez, L., Bennabi, D., Chopard, G., Haffen, E., Nicolier, M., Monnin, J., & Vandel, P. (2015). Visual scanning behavior during processing of emotional faces in older adults with major depression. *Aging & Mental Health*, *19*(3), 264–273. https://doi.org/10.1080/13607863.2014.926473

Nolen-Hoeksema, S. (1991). Responses to depression and their effects on the duration of depressive episodes. *Journal of Abnormal Psychology*, *100*(4), 569–582. https://doi.org/10.1037/0021-843X.100.4.569

Nolen-Hoeksema, S., Morrow, J., & Fredrickson, B. L. (1993). Response styles and the duration of episodes of depressed mood. *Journal of Abnormal Psychology*, *102*(1), 20–28. https://doi.org/10.1037/0021-843X.102.1.20

Nolen-Hoeksema, S., Parker, L. E., & Larson, J. (1994). Ruminative coping with depressed mood following loss. *Journal of Personality & Social Psychology*, *67*(1), 92–104. https://doi.org/10.1037/0022-3514.67.1.92

Nyström, M., Andersson, R., Holmqvist, K., & van de Weijer, J. (2013). The influence of calibration method and eye physiology on eyetracking data quality. *Behavior Research Methods*, *45*(1), 272–288. https://doi.org/10.3758/s13428-012-0247-4

Ogrocki, P. K., Hills, A. C., & Strauss, M. E. (2000). Visual exploration of facial emotion by healthy older adults and patients with Alzheimer disease. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology*, *13*(4), 271–278.

Opwonya, J., Doan, D. N. T., Kim, S. G., Kim, J. I., Ku, B., Kim, S., Park, S., & Kim, J. U. (2022). Saccadic eye movement in mild cognitive impairment and Alzheimer's disease: A systematic review and meta-analysis. *Neuropsychology Review*, *32*(2), 193–227. https://doi.org/10.1007/s11065-021-09495-3

Phillips, L. H., Scott, C., Henry, J. D., Mowat, D., & Bell, J. S. (2010). Emotion perception in Alzheimer's disease and mood disorder in old age. *Psychology and Aging*, *25*(1), 38–47. https://doi.org/10.1037/a0017369

Prystauka, Y., Altmann, G. T. M., & Rothman, J. (2023). Online eye tracking and real-time sentence processing: On opportunities and efficacy for capturing psycholinguistic effects of different magnitudes and diversity. *Behavior Research Methods*, *56*(4), 3504–3522. https://doi.org/10.3758/s13428-023-02176-4

Puurtinen, M. (2018). Eye on music reading: A methodological review of studies from 1994 to 2017. *Journal of Eye Movement Research*, *11*(2). https://doi.org/10.16910/jemr.11.2.2

Ramirez-Melendez, R., Matamoros, E., Hernandez, D., Mirabel, J., Sanchez, E., & Escude, N. (2022). Music-enhanced emotion identification of facial emotions in autistic spectrum disorder children: A pilot EEG study. *Brain Sciences*, *12*(6), 704. https://doi.org/10.3390/brainsci12060704

Ranchet, M., Morgan, J. C., Akinwuntan, A. E., & Devos, H. (2017). Cognitive workload across the spectrum of cognitive impairments: A systematic review of physiological measures. *Neuroscience & Biobehavioral Reviews*, *80*, 516–537. https://doi.org/10.1016/j.neubiorev.2017.07.001

Sanchez, A., & Vazquez, C. (2014). Looking at the eyes of happiness: Positive emotions mediate the influence of life satisfaction on attention to happy faces. *Journal of Positive Psychology*, *9*(5), 435–448. https://doi.org/10.1080/17439760.2014.910827

Saxena, S., Fink, L. K., & Lange, E. B. (2023). Deep learning models for webcam eye tracking in online experiments. *Behavior Research Methods*, *56*(4), 3487–3503. https://doi.org/10.3758/s13428-023-02190-6

Schäfer, T., Sedlmeier, P., Städtler, C., & Huron, D. (2013). The psychological functions of music listening. *Frontiers in Psychology*, *4*, 511–511. https://doi.org/10.3389/fpsyg.2013.00511

Schneier, F. R., Rodebaugh, T. L., Blanco, C., Lewin, H., & Liebowitz, M. R. (2011). Fear and avoidance of eye contact in social anxiety disorder. *Comprehensive Psychiatry*, *52*(1), 81–87. https://doi.org/10.1016/j.comppsych.2010.04.006

Schulze, L., Renneberg, B., & Lobmaier, J. S. (2013). Gaze perception in social anxiety and social anxiety disorder. In *Frontiers in human neuroscience* (Vol. 7, pp. 872–872). Frontiers Media S. A. https://doi.org/10.3389/fnhum.2013.00872

Semmelmann, K., & Weigelt, S. (2018). Online webcam-based eye tracking in cognitive science: A first look. *Behavior Research Methods*, *50*(2), 451–465. https://doi.org/10.3758/s13428-017-0913-7

Seo, E. H., Lee, D. Y., Kim, S. G., Kim, K. W., Kim, D. H., Kim, B. J., Kim, M. D., Kim, S. Y., Kim, Y. H., Kim, J. L., Kim, J. W., Moon, S. W., Park, J. H., Ryu, S. H., Yoon, J. C., Lee, N. J., Lee, C. U., Jhoo, J. H., Choo, L. H., & Woo, J. I. (2011). Validity of the telephone interview for cognitive status (TICS) and modified TICS (TICSm) for mild cognitive imparment (MCI) and dementia screening. *Archives of Gerontology & Geriatrics*, *52*(1), e26–e30. https://doi.org/10.1016/j.archger.2010.04.008

Shamai-Leshem, D., Lazarov, A., Pine, D. S., & Bar-Haim, Y. (2021). A randomized controlled trial of gaze-contingent music reward therapy for major depressive disorder. *Depression and Anxiety*, *38*(2), 134–145. https://doi.org/10.1002/da.23089

Sousa, L., Dowson, B., McDermott, O., Schneider, J., & Fernandes, L. (2020). Music-based interventions in the acute setting for patients with dementia: A systematic review. *European Geriatric Medicine*, *11*(6), 929–943. https://doi.org/10.1007/s41999-020-00381-4

Spalletta, G., Caltagirone, C., Girardi, P., Gianni, W., Casini, A. R., & Palmer, K. (2012). The role of persistent and incident major depression on rate of cognitive deterioration in newly diagnosed Alzheimer's disease patients. *Psychiatry Research*, *198*(2), 263–268. https://doi.org/10.1016/j.psychres.2011.11.018

Spence, S. H., & Rapee, R. M. (2016). The etiology of social anxiety disorder: An evidence-based model. *Behaviour Research and Therapy*, *86*, 50–67. https://doi.org/10.1016/j.brat.2016.06.007

Spitzer, R. L., Kroenke, K., Williams, J. B. W., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder. *Archives of Internal Medicine*, *166*(10), 1092. https://doi.org/10.1001/archinte.166.10.1092

Stypinska, J. (2023). AI ageism: A critical roadmap for studying age discrimination and exclusion in digitalized societies. *AI & Society*, *38*(2), 665–677. https://doi.org/10.1007/s00146-022-01553-5

Suslow, T., Hoepfel, D., Kersting, A., & Bodenschatz, C. M. (2024). Depressive symptoms and visual attention to others' eyes in healthy individuals. *BMC Psychiatry*, *24*(1), 184–113. https://doi.org/10.1186/s12888-024-05633-2

Tanaka, J. W., Sung, A., Columbia, B., & Studies, L. (2017). The "Eye avoidance" hypothesis of autism face processing. *Journal of Autism & Developmental Disorders*, *46*(5), 1538–1552. https://doi.org/10.1007/s10803-013-1976-7

Thoma, M. V., La Marca, R., Brönnimann, R., Finkel, L., Ehlert, U., & Nater, U. M. (2013). The effect of music on the human stress response. *PLOS ONE*, *8*(8), e70156. https://doi.org/10.1371/journal.pone.0070156

Thompson, G. A., & Abel, L. A. (2018). Fostering spontaneous visual attention in children on the autism spectrum: A proof-of-concept study comparing singing and speech. *Autism Research*, *11*(5), 732–737. https://doi.org/10.1002/aur.1930

Van der Cruyssen, I., Ben-Shakhar, G., Pertzov, Y., Guy, N., Cabooter, Q., Gunschera, L. J., & Verschuere, B. (2023). The validation of online webcam-based eye-tracking: The replication of the cascade effect, the novelty preference, and the visual world paradigm. *Behavior Research Methods*, *56*(5), 4836–4849. https://doi.org/10.3758/s13428-023-02221-2

van der Wel, P., & van Steenbergen, H. (2018). Pupil dilation as an index of effort in cognitive control tasks: A review. *Psychonomic Bulletin & Review*, *25*(6), 2005–2015. https://doi.org/10.3758/s13423-018-1432-y

Vieillard, S., & Gilet, A.-L. (2013). Age-related differences in affective responses to and memory for emotions conveyed by music: A cross-sectional study. *Frontiers in Psychology*, *4*. https://doi.org/10.3389/fpsyg.2013.00711

Weiss, E. M., Kohler, C. G., Vonbank, J., Stadelmann, E., Kemmler, G., Hinterhuber, H., & Marksteiner, J. (2008). Impairment in emotion recognition abilities in patients with mild cognitive impairment, early and moderate Alzheimer disease compared with healthy comparison subjects. *The American Journal of Geriatric Psychiatry*, *16*(12), 974–980. https://doi.org/10.1097/JGP.0b013e318186bd53

Wisiecka, K., Krejtz, K., Krejtz, I., Sromek, D., Cellary, A., Lewandowska, B., & Duchowski, A. (2022). Comparison of webcam and remote eye tracking. *2022 Symposium on Eye Tracking Research and Applications* (pp. 1–7). https://doi.org/10.1145/3517031.3529615

Xing, Y., Chen, W., Wang, Y., Jing, W., Gao, S., Guo, D., Xia, Y., & Yao, D. (2016). Music exposure improves spatial cognition by enhancing the BDNF level of dorsal hippocampal subregions in the developing rats. *Brain Research Bulletin*, *121*, 131–137. https://doi.org/10.1016/j.brainresbull.2016.01.009

Yang, X., & Krajbich, I. (2021). Webcam-based online eye-tracking for behavioral research. *Judgment & Decision Making*, *16*(6), 1485–1505. https://doi.org/10.1017/S1930297500008512

Yue, Z., Shi, M., & Ding, S. (2023). Facial video-based remote physiological measurement via self-supervised learning. *IEEE Transactions on Pattern Analysis & Machine Intelligence*, *45*(11), 13844–13859. https://doi.org/10.1109/TPAMI.2023.3298650

Zarrindast, M. R., & Khakpai, F. (2015). The modulatory role of dopamine in anxiety-like behavior. *Archives of Iranian Medicine*, *18*(9), 591–603. https ://doi.org/0151809/AIM.009

Zhang, L., Yu, F., Hu, Q., Qiao, Y., Xuan, R., Ji, G., Zhu, C., Cai, C., & Wang, K. (2020). Effects of SSRI antidepressants on attentional bias toward emotional scenes in first-episode depressive patients: Evidence from an eye-tracking study. *Psychiatry Investigation*, *17*(9), 871–879. https://doi.org/10.30773/pi.2019.0345

Zhang, Y., Cai, J., An, L., Hui, F., Ren, T., Ma, H., & Zhao, Q. (2017). Does music therapy enhance behavioral and cognitive function in elderly dementia patients? A systematic review and meta-analysis. *Ageing Research Reviews*, *35*, 1–11. https://doi.org/10.1016/j.arr.2016.12.003