




# BMJ Open Examination of gaze behaviour in social anxiety disorder using a virtual reality eye-tracking paradigm: protocol for a case-control study

Fatime Zeka <sup>1,2</sup>, Lars Clemmensen <sup>1</sup>, Benjamin Thorup Arnfred,<sup>1</sup> Merete Nordentoft,<sup>3</sup> Louise Birkedal Glenthøj <sup>1,2</sup>

**To cite:** Zeka F, Clemmensen L, Arnfred BT, *et al.* Examination of gaze behaviour in social anxiety disorder using a virtual reality eye-tracking paradigm: protocol for a case-control study. *BMJ Open* 2023;**13**:e071927. doi:10.1136/bmjopen-2023-071927

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2023-071927>).

Received 18 January 2023  
Accepted 08 August 2023



© Author(s) (or their employer(s)) 2023. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

<sup>1</sup>VIRTU Research Group, Copenhagen Research Centre on Mental Health (CORE), Hellerup, Denmark

<sup>2</sup>Department of Psychology, University of Copenhagen, Copenhagen, Denmark

<sup>3</sup>Copenhagen Research Centre on Mental Health (CORE), Mental Health Center Copenhagen, Copenhagen University Hospital, Copenhagen, Denmark

## Correspondence to

Fatime Zeka;  
[fatime.zeka@regionh.dk](mailto:fatime.zeka@regionh.dk)

## ABSTRACT

**Introduction** Social anxiety disorder (SAD) has an early onset, a high lifetime prevalence, and may be a risk factor for developing other mental disorders. Gaze behaviour is considered an aberrant feature of SAD. Eye-tracking, a novel technology device, enables recording eye movements in real time, making it a direct and objective measure of gaze behaviour. Virtual reality (VR) is a promising tool for assessment and diagnostic purposes. Developing an objective screening tool based on examination of gaze behaviour in SAD may potentially aid early detection. The objective of this current study is, therefore to examine gaze behaviour in SAD utilising VR.

**Methods and analysis** A case-control study design is employed in which a clinical sample of 29 individuals with SAD will be compared with a matched healthy control group of 29 individuals. In the VR-based eye-tracking paradigm, participants will be presented to stimuli consisting of high-res 360° 3D stereoscopic videos of three social-evaluative tasks designed to elicit social anxiety. The study will investigate between-group gaze behaviour differences during stimuli presentation.

**Ethics and dissemination** The study has been approved by the National Committee on Health Research Ethics for the Capital Region of Denmark (H-22041443). The study has been preregistered on OSF registries: <https://doi.org/10.17605/OSF.IO/XCTAK>

All participants will be provided with written and oral information. Informed consent is required for all the participants. Participation is voluntarily, and the participants can at any time terminate their participation without any consequences. Study results; positive, negative or inconclusive will be published in relevant scientific journals.

## INTRODUCTION

Social anxiety disorder (SAD) is characterised by a persistent and excessive fear or anxiety of being subject to scrutiny, criticism, rejection or humiliation in social and/or performance situations.<sup>1</sup> Lifetime prevalence is estimated at 12.1%<sup>2</sup> with higher prevalence among girls and women.<sup>3 4</sup> SAD has an early age of onset (mean 14.5 years) compared with other

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ The present study aims to examine gaze behaviour in three novel social evaluative environments using 360° videos in virtual reality (VR) on a clinical sample of social anxiety disorder (SAD).
- ⇒ Using 360° videos as stimuli may enhance the sense of presence because of the enhanced realism of the videos making it a paradigm with high ecological validity in VR compared with VR-constructed environments.
- ⇒ The chosen experimental tasks are novel and not previously used in research studies limiting the comparability with other studies.
- ⇒ The current study only comprises a clinical population of SAD participants which precludes investigating whether the gaze patterns are specific to SAD.

psychiatric disorders<sup>5</sup> as well as a high degree of comorbidity with other psychiatric disorders that are typically preceded by an SAD,<sup>6-8</sup> suggesting that SAD may be a predisposition and a risk factor for development of other psychiatric disorders.<sup>9</sup> In Denmark, anxiety disorders have an estimated lifetime prevalence between 13% and 29% and an incidence rate of approximately 17 000 new cases yearly.<sup>10</sup> In addition, anxiety disorders are associated with an increased mortality,<sup>11</sup> and economic burden of approximately 10 billion Danish Krone (DKK)<sup>10</sup> signifying the importance of early detection and early treatment of the disorder.

Early detection may prevent a chronic course of the disorder, the development of other psychiatric disorders, further burdens to the individual, impaired functioning and ultimately decrease the significant societal burden associated with the disorder.<sup>6 7 12</sup> Early detection of the disorder may be aided by developing an objective screening tool for SAD that comprises behavioural markers for the disorder specifically by examining gaze



behaviour, which is considered to be aberrant in SAD.<sup>1 13</sup> Advances within virtual reality (VR) and eye-tracking technology are considered promising to improve early identification of SAD. This notion is corroborated by a growing body of research employing eye-tracking technologies to study attentional bias and gaze behaviour.<sup>14 15</sup> Eye-tracking is argued to enable a direct measure of visual attention as it allows recording overt eye movements directly and continuously in real time.<sup>16</sup>

### Gaze behaviour in SAD

Whereas in many species, direct gaze is perceived as threatening, evoking an aversive response, the opposite is thought to happen in humans, where eye contact is believed to modulate communication and social interaction processes.<sup>13 17 18</sup> Direct gaze perception is believed to play a pivotal role both in the development of the social cognition and in the social functioning of the individual.<sup>18</sup>

Direct gaze perception is associated with enhanced self-awareness, increased memory for face identity in adults, increased positive appraisals of others and with activate prosocial behaviours.<sup>18</sup> Moreover, it is suggested that direct gaze causes affective reactions to the perceiver of the direct gaze,<sup>19</sup> indicating it has a high social significance. In SAD, gaze behaviour is thought to be aberrant with SAD individuals showing inadequate eye contact in social situations characterised by fear and avoidance of direct eye contact.<sup>1 13</sup> Theoretical models of SAD suggest that in social or performance-based situations, individuals with SAD tend to engage in avoidant behaviour by avoiding any potential real or perceived confrontation or negative evaluation from others. In situations where a total withdrawal from the situation is impossible, the avoidance may be subtle such as avoiding salient social stimuli (eg, avoidance of looking at faces, avoidance of gaze exchange, avoidance of eye contact). This avoidant behaviour is considered a safety behaviour; a maladaptive strategy that perpetuates the anxiety and, thus, serves as a maintenance factor of the disorder.<sup>20 21</sup> The visual avoidance of faces has indeed been confirmed in many studies<sup>22</sup>; however, most studies have used paradigms (typically free viewing paradigms consisting of viewing photographs) that are considered to lack ecological validity.<sup>23</sup> Additionally, many studies have used samples from the community as opposed to clinical samples of SAD. However, gaze behaviour findings from community may not generalise to the clinical populations of SAD.<sup>22 23</sup>

Moreover, SAD individuals may have a selective attention to threat.<sup>21</sup> In the so-called vigilance-avoidance hypothesis, it is theorised that SAD individuals may tend to have a selective attention to threat by initially paying attention to any external indicators of negative social evaluation followed by avoidance of such external indicators, which in turn perpetuates anxiety symptoms.<sup>24 25</sup> The empirical evidence in this area is mixed with some studies demonstrating a maintenance of attention to threatening stimuli, while others show avoidance.<sup>14</sup> The mixed results are argued to be due to methodological diversity in the

experimental tasks used to study the selective attention to threat.<sup>23</sup> Some authors have, therefore, studied hyper-scanning, another aspect that is considered to indicate hypervigilance. A hyperscanning strategy defined as a vigilant strategy characterised by an excessive scanning of the environment typically for threat detection<sup>26 27</sup> has indeed been confirmed in some studies making it a promising aspect of SAD to be further investigated.<sup>26-29</sup>

Thus, a considerable amount of research on gaze behaviour has used paradigms that may lack ecological validity.<sup>23 30</sup> This has led to the necessity of designing experiments as social interaction and/or performance-based tasks that resemble real-life situations. In these so-called 'social evaluative tasks', the participant is required to perform a real-life task with a risk of negative social evaluation (eg, performing a speech in front of a prerecorded audience)<sup>23</sup> thus enhancing the ecological validity of the paradigm.

### Assessing gaze behaviour in SAD using VR

Virtual reality (VR) has shown good potential in psychotherapeutic intervention but has been used to a lesser degree for assessment or diagnostic purposes.<sup>31 32</sup> Empirical findings using VR in SAD have demonstrated that social fear can be successfully induced in VR environments,<sup>33-35</sup> indicating its usefulness for conducting ecologically valid experiments. A sense of presence, that is, the experience of being present in a mediated environment and not in a physical environment,<sup>36</sup> has been argued to be paramount for experiments conducted in VR. However, some studies have demonstrated that gaze behaviour in VR and in prerecorded videos may be experienced differently than in real life by having lesser physiological reactions in the VR and prerecorded videos compared to face-to-face interactions, suggesting that findings from studies conducted in VR may not necessarily apply to the real life.<sup>37 38</sup> To date, a small number of studies have used VR to examine gaze behaviour in SAD.<sup>39-44</sup> These studies report that compared with healthy control groups, individuals with SAD or individuals with social anxiety symptoms show an avoidant gaze behaviour in social and performance situations. Studies utilising immersive 360° video environments in VR are still scarce. 360° video environments in VR may enhance the sense of presence due to their immersive and realistic presentation<sup>45</sup> and it can be hypothesised that it may be superior to animated environments in VR in terms of ecological validity although a study comparing the two has not yet been conducted. Holmberg *et al* have demonstrated that anxiety in SAD can be successfully triggered by 360° videos of real-life situations in VR.<sup>46</sup> In addition, Rubin *et al* conducted the first study to assess gaze behaviour in participants with social anxiety symptoms using 360° stimuli (a public speaking task) in VR. The study showed that compared with a healthy control group, individuals with social anxiety symptoms showed a pattern of avoidance of social threat,<sup>47</sup> thus demonstrating good potential of utilising 360° stimuli as a highly ecological environment

for conducting research on gaze behaviour in SAD as well as using it for attention guidance training in SAD.<sup>48</sup> We aim to extend these preliminary findings by including three novel naturalistic social evaluative tasks using 360° stimuli in VR in a clinical sample of SAD. The three tasks capture both the social and performance aspect of SAD and we believe that the tasks are relatable and recognisable to the participants since the tasks resemble everyday situations in VR.

## Objectives

The current study aims to identify eye gaze patterns in SAD using VR across three different social and performance real-life situations and, thus, extend the existing literature on the utility of VR for assessment purposes in SAD.

In line with previous findings on gaze avoidance,<sup>44 49 50</sup> we hypothesise that (1) compared with a healthy control group (HCG), SAD participants will exhibit fewer number of fixations and less fixation duration (dwell time) on social areas (faces and body regions) of the participants presented in the three VR tasks.

In line with previous findings,<sup>26–28</sup> we hypothesise that (2) SAD participants will show a hyperscanning strategy indicated by increased total length of scan path compared with the HCG across the three VR tasks.

In line with the vigilance-avoidance model,<sup>24</sup> we also hypothesise that (3) SAD individuals will exhibit shorter time to first fixations on social stimuli compared with HCG across the three VR tasks.

Additionally, we will examine the interaction of the tasks on gaze behaviour, (4) hypothesising that both SAD participants and HCG participants will show greater avoidance and hyperscanning in task C compared with tasks A and B, given that task C contains an objective threat for negative evaluation.

## METHODS

### Study design

The proposed study is a case-control study including a clinical sample of 29 individuals with SAD and a matched healthy control group of 29 individuals. A VR-based eye-tracking paradigm will be employed in which gaze behaviour as indicated by eye movements will be examined using the integrated eye tracker in the VR headset. Stimuli will be presented as 360° 3D videos in VR.

### Setting

The experimental study will be carried out by VIRTU research group at the Copenhagen Research Centre for Mental Health CORE, at Mental Health Center Copenhagen, Copenhagen University Hospital, Denmark. The inclusion period will start in January 2023 and is expected to last approximately 9 months.

**Table 1** Overview of inclusion and exclusion criteria for the SAD participants and healthy control group (HCG) participants

<i>Inclusion criteria for the SAD group</i>	<i>Inclusion criteria for the HCG group</i>
<ul style="list-style-type: none"> <li>▶ Fulfilling diagnostic criteria for social anxiety disorder (ICD: F40.1)</li> <li>▶ Age 18–75</li> <li>▶ Sufficient knowledge of the Danish language</li> <li>▶ Informed consent</li> </ul>	<ul style="list-style-type: none"> <li>▶ Age 18–75</li> <li>▶ Sufficient knowledge of the Danish language</li> <li>▶ Informed consent</li> </ul>
<i>Exclusion criteria for the SAD group</i>	<i>Exclusion criteria for the HCG group</i>
<ul style="list-style-type: none"> <li>▶ Psychotic disorders, autism spectrum disorders and personality disorders</li> <li>▶ A diagnosis of alcohol or drug dependence (ICD: F10-19, 20–26)</li> <li>▶ Significantly impaired vision hindering engagement in VR experiences</li> <li>▶ Epilepsy</li> </ul>	<ul style="list-style-type: none"> <li>▶ Any psychiatric diagnoses including alcohol and drug dependence</li> <li>▶ Significantly impaired vision hindering engagement in VR experiences</li> <li>▶ Epilepsy</li> </ul>
HCG, healthy control group; SAD, social anxiety disorder; VR, virtual reality.	

## Participants

The study will include a total of 58 participants comprising 29 individuals with an SAD diagnosis (ICD: F 40.1) referred to psychiatric clinics in the Capital Region of Denmark and 29 HCG individuals that will be recruited from the community, using ads at relevant institutions or via the research recruitment service [www.forsoegsperson.dk](http://www.forsoegsperson.dk).

Participants from the HCG will be matched to the SAD sample (1:1) on age ( $\pm 2$  years) and gender (see [table 1](#)). For the social anxiety levels among the HCG, participants with a score above 30 on Liebowitz Social Anxiety Scale (LSAS) will be excluded from the study as this cut-off will exclude participants with subclinical levels of SAD.<sup>51</sup>

## Patient and public involvement

A panel of patients have been involved in developing the stimuli material. The stimuli material was originally developed to be used for exposure purposes in the So-REAL study: a randomised control trial, evaluating a VR-based intervention for SAD. The videos have been developed by a team consisting of clinicians, a panel of patients with SAD in collaboration with the VR production company KHORA-VR. The videos consist of various real-life social and performance environments, typically feared by patients with SAD. Actors were paid to deliver the content in the different videos. The process of the development of the videos consisted of regular meetings between clinicians, patients and the VR production company. The





**Figure 1** Demonstration of the VR job interview situation. VR, virtual reality.

experience of the patients (level of anxiety provoked by the videos, the validity of the videos) seeing the videos were considered for further development of the videos. In the final stage, the videos were tested by two clinicians in a group therapy format. This led to further feedback from the clinicians and patients on the videos and their use for exposure purposes in group therapy. The process of development lasted approximately 16 months producing 12 real-life situations for SAD.<sup>52</sup>

### The experimental tasks

All participants will be presented to high-resolution 360° stereoscopic videos in high-end VR head mounted display (HMD).

The three experimental tasks are:

Task A is a job interview situation that we conceptualise as a performance task. In the video, a male and a female interviewer ask a variety of job-related questions. After each question, a 'listening loop' of 30s follows allowing the participant to answer while the two interviewers appear to listen. The participant will be instructed to act as if this was a real job interview and to respond to the questions. The job interview includes questions such as: 'Can you tell us something about yourself', 'what is your motivation for applying for this job?', 'how can you contribute to this job?'. The attitude of both interviewers is welcoming and warm (see [figure 1](#)).

Task B is a social interaction situation comprising small talk/discussion in a canteen while eating lunch in a work setting. The participant is joined by four colleagues: two male and two female colleagues. The participant is instructed to act as if this was a real interaction. No direct questions are made to the participant and as such the participant is not required to verbally engage in the conversation but will be free to do so. The atmosphere is welcoming and warm. The colleagues look sporadically at the participant and smile at times (see [figure 2](#)).

Task C is conceptualised as a performance task, where there is an objective threat for being negatively

evaluated. The participant is instructed to verbally engage in the video. The participant is asked to do a presentation together with a colleague in front of a group of people. The task starts with the colleague introducing himself to the audience and asks the participant to present him/herself to the audience. The colleague must, however, leave the room after a phone call he receives, leaving the participant alone in the room. In addition, the computer in which the participant is to use for a power point presentation stops working and as such the participant must carry out the presentation without the support of power point. The atmosphere gets a bit tense, and the group of people appear to be impatient. However, the task ends before the participant must do a presentation (see [figure 3](#)).

### Apparatus

To collect gaze data, eye movements will be tracked using eye-tracking integrated in the HTC VIVE Pro Eye HMD. Eye movements are tracked at 120 Hz (binocular). The integrated eye tracker has a trackable field of 110°, an accuracy of 0.5°–1.1° and a calibration of 5-point. A powerful gaming computer will serve as an interface between the eye-tracking software and the HMD.

### Data preparation

The Imotions software will be used to collect, calculate and analyse gaze-based data.<sup>53 54</sup> Analysis will be carried out on predefined areas of interest (AOI) as well as on raw gaze-based data. In the current study, AOI will be predefined and categorised as social stimuli and non-social stimuli. The social stimuli comprising of face regions and body regions will be predefined and categorised separately while the non-social stimuli (the background) will be predefined and categorised as the rest of stimuli expect faces and body regions (see [figure 4](#)). An I-VT (Velocity-Threshold Identification) filter will be used to analyse the raw eye-tracking data and to classify fixations and saccades by comparing the speed of the



**Figure 2** Demonstration of the VR social interaction situation. VR, virtual reality.

eye's movements to a velocity threshold. The velocity threshold will be of  $100^{\circ}/s$  and a minimum fixation of 100 ms. Thus, the I-VT filter classifies a fixation if the eye moves slower than this threshold, whereas if the eye moves faster than this threshold, the I-VT filter classifies it as a saccade. The total fixation time will be calculated as the sum of all fixations within an AOI.

### Procedure

Eligible participants from the SAD and HCG will be invited to the VR lab, where they will undergo a clinical assessment conducted by experienced psychologists followed by completion of psychometric questionnaires (see online supplemental file 1). Prior to beginning the

experiment, participants will be given verbal instructions about the nature of the experimental tasks. Each experimental task lasts approximately 2 to 2.5 min. After each experimental task, a pause of 10 s follows. The order of the tasks presented to the participants is randomised by the Imotion software. As stated earlier, participants will be instructed to answer the questions of the interviewers in task A, whereas in task B, the verbal communication is not mandatory. In task C, the participants are as well instructed to verbally engage with the people in the task. Before beginning the experiment, participants will also be calibrated to the HMD. To minimise distractions from the surroundings, the



**Figure 3** Demonstration of the VR presentation situation. VR, virtual reality.



**Figure 4** Demonstration of a predefined and categorised area of interest (AOI).

researcher will leave the room, when the VR tasks are being performed.

After the completion of the experimental tasks, the participants are asked to fill in a presence scale questionnaire, using the Multimodal Presence Scale (MPS), which measures the level of the experience of presence in VR.<sup>36</sup> Subjective distress will be measured before the experimental tasks and after completion of the experimental tasks using Subjective Units of Distress Scale (SUDS).<sup>55</sup> At the end of the experiment, participants will be thoroughly debriefed and thanked for the participation.

### Assessment battery

Participants from both groups will undergo an assessment consisting of the listed measurements.

- ▶ Mini International Neuropsychiatric Interview (MINI), V.7.0 for Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5). Psychometric analyses of the MINI have demonstrated acceptable test-retest and inter-rater reliability.<sup>56 57</sup> MINI will be used to screen for diagnosis and rule out psychiatric diagnoses in the HCG.
- ▶ Personal and Social Performance Scale (PSP) will be used to measure the social functioning of the participant.<sup>58</sup>
- ▶ LSAS will be used to measure symptom severity of SAD. LSAS assesses 24 situations typically feared by individuals with SAD, rated on anxiety and avoidance, divided into subscales of performance anxiety and

social situations. It has acceptable psychometric properties.<sup>59</sup> The LSAS will be used as a diagnosis supplement to MINI.

- ▶ The experience of presence in VR is measured using MPS developed and validated by Makransky *et al.*<sup>36</sup> This scale consists of 15 items measuring aspects of the physical presence, social presence and self-presence using a 5-point Likert Scale (1=completely disagree, 2=disagree, 3=neither disagree nor agree, 4=agree, 5=strongly disagree).<sup>36</sup>
- ▶ Fear of Negative Evaluation using the Brief Version of the Fear of Negative Evaluation Scale (FNES).<sup>60</sup>
- ▶ SUDS<sup>55</sup> will be used to rate the state anxiety pre and post the experimental tasks.

### Outcome measures

The outcome measures are eye movement data derived from the eye-tracking and consist of the following: fixation-based parameters: total fixation duration (dwell time) in milliseconds, total number of fixations and mean fixation time measured on AOI. These parameters indicate high and low levels of gaze avoidance. Raw data parameters: scan path length, mean distance between fixations, time to first fixation and length of first fixation on social stimuli are indices that indicate hypervigilance and hyperscanning. Exploratory outcomes are association between eye movement data and LSAS, PSP, Presence in VR, and FNES.



### Sample size calculation

Our primary hypothesis concerns differences in the number of fixations in SAD subjects compared with HCG. In a previous study of<sup>49 49</sup> the HCG had a mean score of 56.7 (SD=5.1) on the number of fixations. We set the minimal clinically important difference to a true difference in the experimental and control means to 0.75 SD (=3.8). Corresponding to an expected mean score of 52.9 in patients with SAD. We calculated effect sizes revealing that 29 subjects are required in each group to detect the expected difference in a t-test with 80% power at the 0.05 significance level using a two-sided hypothesis.

### Statistical methods

Data will be analysed using Stastical Package for the Social Sciences (SPSS). The analysis of data will be conducted using a mixed design Analysis of Variance(ANOVA) combining between-subject's and within-subject's analysis. Initially, a one-way ANOVA will be conducted to assess group (SAD vs HCG) differences on psychometric measures (LSAS, FNES, PSP, MPS and SUDS). Means, SD and F-scores will be reported.

To examine gaze behaviour, three ANOVAs will be conducted with group (SAD vs HCG) as the between-subject factor and AOI (face vs body) as the within-subjects factor for each task (tasks A, B and C).

To examine whether there is a difference in gaze behaviour between task A, B and C, a two-way Multivariate analysis of variance (MANOVA) will be conducted with task as a within-subject factor and group (SAD group vs HC group) as a between-subject factor. Order of task presentation will be included as a between-subject control variable. Eye-tracking metrics (the number of fixations and the total fixation duration and the mean duration of fixations on social areas, total scan path length and mean distance between fixations) are the dependent variables.

Furthermore, exploratory analyses using a repeated measure ANOVA will be conducted on SUDS score with group (SAD vs HCG) as a between-subject factor and time (pre vs postexperimental task) as a within-subject factor.

Exploratory analyses using Pearson correlational analyses will also be carried out on the SAD group assessing eye movement data and psychometric measures (LSAS, FNES, PSP, MPS).

All statistical tests of significance will be two-tailed, with significance level set at  $p < 0.05$ . Missing data will be handled by multiple imputations.

### Ethics and dissemination

The study will be conducted in accordance with the Helsinki Declaration. The study has been approved by the National Committee on Health Research Ethics for the Capital Region of Denmark (*H-22041443*). All participants will receive participant information 48 hours prior to the conduct of the study. Any adverse events will be monitored and recorded throughout the study period and reported to the Committee on Health Research Ethics of the Capital Region Denmark. VR may cause

cyber sickness to some people, which corresponds to motion sickness. Given that VR is in general well tolerated, we do not expect any adverse events to happen.<sup>61</sup> Participation is voluntary, and the participants can at any time terminate their participation without any consequences. Study results; positive, negative or inconclusive will be published in relevant scientific journals.

### DISCUSSION

The proposed study aims to examine gaze behaviour differences in a clinical sample of SAD compared with an HCG using a VR eye-tracking paradigm. Determining behavioural markers may have important clinical implications, not only for enhancing the understanding of the aetiology of SAD but also by attempting to develop an objective screening tool that may aid the assessment of SAD. Thus, the results from this study may provide the foundation for conducting subsequent studies evaluating VR-based eye-tracking as an objective, automated screening tool for SAD. However, aberrant gaze behaviour has also been found in other mental disorders such as autism.<sup>62</sup> As the current study only comprises a clinical population of SAD participants, it precludes investigating whether the gaze patterns are specific to SAD. This may be explored further in future studies.

Whereas studies using VR as a tool in psychotherapeutic intervention is growing,<sup>31</sup> the use of VR for assessment or diagnostic purposes is still scarce. Conducting experimental research with VR-based paradigms may add further evidence on the usefulness of VR as an assessment tool capturing aspects of psychopathology. The potential of establishing a specific gaze pattern in SAD using VR may also have treatment-related implications by informing targets for interventions that may involve exposure of gaze avoidance and/or selective attention to threat.

**Acknowledgements** The authors express a deep felt gratitude to the psychiatric clinics and the anxiety association (angstforeningen) that will help with the recruitment of patients. We would also like to thank the IT company KhoraVR who has helped with the creation of the stimuli material.

**Contributors** FZ is the first author of the manuscript. FZ has contributed with the conceptualisation, writing the research protocol, statistical analysis and writing this first draft of the manuscript under supervision of LBG and LC. LC has contributed with the conceptualisation, sample size calculation and statistical analysis. MN is the initiator of the project. LBG is a major contributor in supervising and revising the manuscript. BTA has contributed with the conceptualisation and the practical setup of the study. All authors have read, revised and approved the final manuscript.

**Funding** This project is part of the So-REAL trial and is funded by the Novo Nordisk Foundation with 5.000.000 DKK [NNF170C0027780] and Trygfonden with 3.517.500 DKK [ID: 146169]. The funding bodies have no influence in the planning, execution or dissemination of the project.

**Competing interests** None declared.

**Patient and public involvement** Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

**Patient consent for publication** Not applicable.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Supplemental material** This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

**Open access** This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

**Author note** The individuals depicted in Figure 1-4 are not patients, but actors and were taken with the participants' knowledge.

#### ORCID iDs

Fatime Zeka <http://orcid.org/0000-0003-0960-3310>

Lars Clemmensen <http://orcid.org/0000-0002-1750-4649>

Louise Birkedal Glenthøj <http://orcid.org/0000-0003-3621-8450>

#### REFERENCES

- American Psychiatric Association. *Diagnostic and statistical manual of mental disorders*. DSM Library. American Psychiatric Association, 2013: 1.
- Kessler RC, Berglund P, Demler O, et al. Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the national comorbidity survey replication. *Arch Gen Psychiatry* 2005;62(June):593–602.
- Gren-Landell M, Tillfors M, Furmark T, et al. Social phobia in Swedish adolescents: prevalence and gender differences. *Soc Psychiatry Psychiatr Epidemiol* 2009;44:1–7.
- Dalsgaard S, Thorsteinsson E, Trabjerg BB, et al. Incidence rates and cumulative incidences of the full spectrum of diagnosed mental disorders in childhood and adolescence. *JAMA Psychiatry* 2020;77:155–64.
- Solmi M, Radua J, Olivola M, et al. Age at onset of mental disorders worldwide: large-scale meta-analysis of 192 epidemiological studies. *Mol Psychiatry* 2022;27:281–95.
- Wittchen HU, Fehm L. Epidemiology and natural course of social fears and social phobia. *Acta Psychiatr Scand Suppl* 2003;108:4–18.
- Fehm L, Pelissolo A, Furmark T, et al. Size and burden of social phobia in Europe. *Eur Neuropsychopharmacol* 2005;15:453–62.
- Lépine J-P, Péliissolo A. Why take social anxiety disorder seriously? *Depress Anxiety* 2000;11:87–92.
- Krygsman A, Vaillancourt T. Elevated social anxiety symptoms across childhood and adolescence predict adult mental disorders and cannabis use. *Compr Psychiatry* 2022;115:152302.
- Flachs EM, Eriksen LKM, Ryd JT, et al. *Sygdomsbyden i Danmark - sygdomme*. Sundhedsstyrelsen, Statens Institut for Folkesundhed, Syddansk Universitet, København, 2015.
- Meier SM, Mattheisen M, Mors O, et al. Increased mortality among people with anxiety disorders: total population study. *Br J Psychiatry* 2016;209:216–21.
- Ruscio AM, Brown TA, Chiu WT, et al. Social fears and social phobia in the USA: results from the national comorbidity survey replication. *Psychol Med* 2008;38:15–28.
- Schulze L, Renneberg B, Lobmaier JS. Gaze perception in social anxiety and social anxiety disorder. *Front Hum Neurosci* 2013;7:872.
- Clauss K, Gorday JY, Bardeen JR. Eye tracking evidence of threat-related attentional bias in anxiety- and fear-related disorders: a systematic review and meta-analysis. *Clin Psychol Rev* 2022;93:102142.
- Armstrong T, Olatunji BO. Eye tracking of attention in the affective disorders: a meta-analytic review and synthesis. *Clin Psychol Rev* 2012;32:704–23.
- Clay V, König P, König S. Eye tracking in virtual reality. *J Eye Mov Res* 2019;12.
- Senju A, Johnson MH. The eye contact effect: mechanisms and development. *Trends Cogn Sci* 2009;13:127–34.
- Conty L, George N, Hietanen JK. Watching eyes effects: when others meet the self. *Conscious Cogn* 2016;45:184–97.
- Hietanen JK. Affective eye contact: an integrative review. *Front Psychol* 2018;9:1–15.
- Clark DM, Wells A. The cognitive model of social phobia. In: *Social Phobia: diagnosis, assessment, and treatment*. 1st edn. New York: New York: Guilford Press, 1995: 69–93.
- Rapee RM, Heimberg RG. A cognitive-behavioral model of anxiety in social phobia. *Behav Res Ther* 1997;35:741–56.
- Chen J, van den Bos E, Westenberg PM. A systematic review of visual avoidance of faces in socially anxious individuals: influence of severity, type of social situation, and development. *J Anxiety Disord* 2020;70:102193.
- Chen NTM, Clarke PJF. Gaze-based assessments of vigilance and avoidance in social anxiety: a review. *Curr Psychiatry Rep* 2017;19:1–9.
- Bögels SM, Mansell W. Attention processes in the maintenance and treatment of social phobia: hypervigilance, avoidance and self-focused attention. *Clin Psychol Rev* 2004;24:827–56.
- Schultz LT, Heimberg RG. Attentional focus in social anxiety disorder: potential for interactive processes. *Clin Psychol Rev* 2008;28:1206–21.
- Horley K, Williams LM, Gonsalvez C, et al. Face to face: visual scanpath evidence for abnormal processing of facial expressions in social phobia. *Psychiatry Res* 2004;127:43–53.
- Chen NTM, Thomas LM, Clarke PJF, et al. Hyperscanning and avoidance in social anxiety disorder: the visual scanpath during public speaking. *Psychiatry Res* 2015;225:667–72.
- Horley K, Williams LM, Gonsalvez C, et al. Social phobics do not see eye to eye: a visual scanpath study of emotional expression processing. *J Anxiety Disord* 2003;17:33–44.
- Günther V, Kropidlowski A, Schmidt FM, et al. Attentional processes during emotional face perception in social anxiety disorder: a systematic review and meta-analysis of eye-tracking findings. *Prog Neuropsychopharmacol Biol Psychiatry* 2021;111:110353.
- Claudino RG e, de Lima LKS, de Assis EDB, et al. Facial expressions and eye tracking in individuals with social anxiety disorder: a systematic review. *Psicol Refl Crit* 2019;32.
- Geraets CNW, Wallinius M, Sygel K. Use of virtual reality in psychiatric diagnostic assessments: a systematic review. *Front Psychiatry* 2022;13(February):828410.
- Meyerbröcker K, Morina N. The use of virtual reality in assessment and treatment of anxiety and related disorders. *Clin Psychol Psychother* 2021;28:466–76.
- Shiban Y, Reichenberger J, Neumann ID, et al. Social conditioning and extinction paradigm: a translational study in virtual reality. *Front Psychol* 2015;6:1–10.
- Reichenberger J, Porsch S, Wittmann J, et al. Social fear conditioning paradigm in virtual reality: social vs. electrical aversive conditioning. *Front Psychol* 2017;8(NOV):1–15.
- Reichenberger J, Pfaller M, Forster D, et al. Men scare me more: gender differences in social fear conditioning in virtual reality. *Front Psychol* 2019;10:1–20.
- Makransky G, Lilleholt L, Aaby A. Development and validation of the multimodal presence scale for virtual reality environments: a confirmatory factor analysis and item response theory approach. *Comput Hum Behav* 2017;72:276–85.
- Lyrra P, Myllyneva A, Hietanen JK. Mentalizing eye contact with a face on a video: gaze direction does not influence autonomic arousal. *Scand J Psychol* 2018;59:360–7.
- Syrjämäki AH, Isokoski P, Surakka V, et al. Eye contact in virtual reality – A psychophysiological study. *Comput Hum Behav* 2020;112:106454.
- Reichenberger J, Pfaller M, Mühlberger A. Gaze behavior in social fear conditioning: an eye-tracking study in virtual reality. *Front Psychol* 2020;11:1–12.
- Reichenberger J, Wechsler TF, Diemer J, et al. Fear, Psychophysiological arousal, and Cognitions during a virtual social skills training in social anxiety disorder while manipulating gaze duration. *Biol Psychol* 2022;175:108432.
- Mühlberger A, Wieser MJ, Pauli P. Visual attention during virtual social situations depends on social anxiety. *Cyberpsychol Behav* 2008;11:425–30.
- Dechant M, Trimpl S, Wolff C, et al. Potential of virtual reality as a diagnostic tool for social anxiety: a pilot study. *Comput Hum Behav* 2017;76:128–34.
- Wieser MJ, Pauli P, Grosseibl M, et al. Virtual social interactions in social anxiety - the impact of sex, gaze, and Interpersonal distance. *Cyberpsychol Behav Soc Netw* 2010;13:547–54.
- Kim H, Shin JE, Hong Y-J, et al. Aversive eye gaze during a speech in virtual environment in patients with social anxiety disorder. *Aust N Z J Psychiatry* 2018;52:279–85.



- 45 Ionescu A, Van Daele T, Rizzo A, et al. 360° videos for Immersive mental health interventions: a systematic review. *J Technol Behav Sci* 2021;6:631–51.
- 46 Holmberg TT, Eriksen TL, Petersen R, et al. Social anxiety can be triggered by 360-degree videos in virtual reality: a pilot study exploring fear of shopping. *Cyberpsychol Behav Soc Netw* 2020;23:495–9.
- 47 Rubin M, Minns S, Muller K, et al. Avoidance of social threat: evidence from eye movements during a public speaking challenge using 360°- Video. *Behav Res Ther* 2020;134:103706.
- 48 Rubin M, Muller K, Hayhoe MM. Attention guidance augmentation of virtual reality exposure therapy for social anxiety disorder: a pilot randomized controlled trial. *Cogn Behav Ther* 2022;51:371–87.
- 49 Moukheiber A, Rautureau G, Perez-Diaz F, et al. Gaze avoidance in social phobia: objective measure and correlates. *Behav Res Ther* 2010;48:147–51.
- 50 Chen NTM, Clarke PJF, MacLeod C, et al. Aberrant gaze patterns in social anxiety disorder: an eye movement assessment during public speaking. *J Exp Psychopathol* 2016;7:1–17.
- 51 Mennin DS, Fresco DM, Heimberg RG, et al. Screening for social anxiety disorder in the clinical setting: using the liebowitz social anxiety scale. *J Anxiety Disord* 2002;16:661–73.
- 52 Arnfred B, Bang P, Hjorthøj C, et al. Group cognitive behavioural therapy with virtual reality exposure versus group cognitive behavioural therapy with in vivo exposure for social anxiety disorder and Agoraphobia: a protocol for a randomised clinical trial. *BMJ Open* 2022;12:e051147.
- 53 iMotions (9.3), iMotions A/S, Copenhagen, Denmark, (2022), Available: [www.imotions.com](http://www.imotions.com)
- 54 iMotions. Eye tracking the complete pocket guide. *Lang Cogn Process* 2017;11:583–8. Available: <http://www.ncbi.nlm.nih.gov/pubmed/21527449>
- 55 Tanner BA. Validity of global physical and emotional SUDS. *Appl Psychophysiol Biofeedback* 2012;37:31–4.
- 56 Sheehan DV, Lecrubier Y, Harnett Sheehan K, et al. The validity of the mini International neuropsychiatric interview (MINI) according to the SCID-P and its reliability. *Eur Psychiatry* 1997;12:232–41.
- 57 Lecrubier Y, Sheehan D, Weiller E, et al. The mini International neuropsychiatric interview (MINI). A short diagnostic structured interview: reliability and validity according to the CIDI. *Eur Psychiatr* 1997;12:224–31.
- 58 Nasrallah H, Morosini PL, Gagnon DD. Reliability, validity and ability to detect change of the personal and social performance scale in patients with stable schizophrenia. *Psychiatry Res* 2008;161:213–24.
- 59 Heimberg RG, Horner KJ, Juster HR, et al. Psychometric properties of the Liebowitz social anxiety scale. *Psychol Med* 1999;29:199–212.
- 60 Leary MR. A brief version of the fear of negative evaluation scale. *Pers Soc Psychol Bull* 1983;9:371–5.
- 61 Rus-Calafell M, Garety P, Sason E, et al. Virtual reality in the assessment and treatment of psychosis: a systematic review of its utility, acceptability and effectiveness. *Psychol Med* 2018;48:362–91.
- 62 Stuart N, Whitehouse A, Palermo R, et al. Eye gaze in autism spectrum disorder: a review of neural evidence for the eye avoidance hypothesis. *J Autism Dev Disord* 2023;53:1884–905.