Original Article



# Image reprocessing via wearable cameras: effects on memory recall and rumination after a social-stress task

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**Background:** Video feedback has been used in the context of social anxiety disorder (SAD) to help modify individuals' perceptions about performance during exposure tasks. A novel way to capture both the observer and field perspective is through the use of wearable cameras. Compared to video feedback, which only provides information from the observer perspective and hence addresses concerns regarding the individual's own performance, field/first-person image capture has the advantage that it can direct attention to external information during social situations. We aimed to develop a paradigm to capture both field and observer perspective images generated during a social stress task, to manipulate the mode of memory re-processing, and to evaluate the impact on state anxiety, memory recall, and negative post-event processing.

**Method:** A total of 46 participants (22 males and 24 females) with a mean age of 24.30 (SD =8.86) performed a 3-minute speech in front of a pre-recorded audience, after which they reviewed images taken during the speech task either from a field or observer perspective, or mentally reviewed the task or were assigned to the control condition. Twenty-four hours after the speech, they completed follow-up measures of memory recall and ruminative post-event processing.

**Results:** Participants in the field perspective condition recalled more factual memories of the speech task compared to those in the mental review and control conditions. Observer perspective re-processing (akin to video feedback review) was associated with higher post-event processing at 24-hour follow-up relative to control, but only for the negative Self subscale.

**Conclusions:** Results indicate that wearable cameras can facilitate recall of corrective information during exposure-based tasks and could be integrated into behavioural experiments for SAD. Ethical consideration and future direction are discussed.

**Keywords:** Social anxiety disorder (SAD); wearable cameras; rumination; memory recall; imagery; technology

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## Introduction

Social anxiety disorder (SAD) is characterized by a persistent fear of social performance situations, in which one is exposed to the scrutiny of others and fears to act in a way that might be negatively evaluated (1). With average lifetime prevalence rates between 2.1% and 2.7%, SAD is a common psychiatric disorder (2). It is associated with increased psychological distress, impaired functioning, as well as high comorbidity rates with other disorders, such as depression or substance abuse (3,4).

According to the cognitive model of SAD (5), a core maintaining factor in social anxiety is self-focused attention, which is characterized by heightened awareness of one's thoughts, physical states, and emotions (6). When a social situation arises that is perceived as threatening, individuals with SAD tend to shift their focus inwards and to engage in detailed self-monitoring (5). The self is consequently perceived from an "observer perspective" and an image as seen through the eyes of another person is created (7). Individuals with social anxiety report more observer memories when remembering social situations than non-social situations (8). Typically, this image reflects an exaggeration of one's anxiety symptoms and an overly negative perception of oneself (5).

Further, this shift in attention focus can result in individuals not attending to, or processing, external social cues, which can make it difficult to accurately evaluate their own performance in social situations. Post-event processing, or rumination, is another associated maintaining factor of SAD. After a social event has occurred, individuals with SAD tend to engage in rumination, mentally going over details of what has happened (9). Post-event processing can result in misinterpretation of ambiguous information as threatening, and result in more negative self-evaluations over time (10).

One evidence-based treatment for SAD that addresses these maintaining factors and has consistently been demonstrated to be effective (11) is cognitive behavioural therapy (CBT), which aims at stimulating behavioural, as well cognitive change. CBT for SAD consists of a behavioural component, including behavioural experiments and exposure, which help patients face their fears either in imagination, during role-play, or by confronting them outside of therapy sessions. The cognitive component, on the other hand, focuses on correcting automatic negative cognitions (12). For example, a patient might be asked to reconstruct a situation, in which he or she felt negatively evaluated and, together with the clinician, work on modifying the unhelpful automatic thoughts or distorted images based on objective processing of evidence. In order to facilitate objective reprocessing and to prevent rumination, camera and video feedback techniques have been developed and used to diminish the gap between distorted, negative self-representations and reality. Rapee and Hayman (13) found that video feedback, wherein individuals are video recorded while completing an anxiety-provoking task and then asked to review the playback, can help correct maladaptive cognitions and distorted self-perception, and therefore reduce anxiety. Subsequent work has generally supported beneficial effects of vide feedback (14-16). Nevertheless, Clark and Wells (5) encountered an issue with this otherwise promising method in 1995. They observed that instead of objectively reviewing the images, some individuals interpreted the footage in a rather subjective way. As a result, the feelings they recalled became confused with the actual content of the video. To circumvent this problem, Harvey *et al.* (14) proposed a form of cognitive preparation, to be delivered prior to the video viewing to maximize the difference between the mental self-images and the video images, and to help correct distorted self-evaluations, as well as underestimation of social skills. The preparation typically involves three steps; participants have to make specific predictions about observable performance indicators, generate a vivid mental image of their performance, and try to objectively review the video playback (as if they were watching a stranger). Warnock-Parkes *et al.* (17) report on additional strategies to prepare individuals for the use of video feedback.

In addition to video technology, a novel manner in which behavioural experimental recording could capture both the observer and field perspective is through the use of wearable cameras. Similar to video feedback, images captured during anxiety-inducing situations can be used to help individuals reprocess and re-evaluate the experiences and associated cognitions in therapy sessions. It has previously been shown that reviewing photographs stimulates the functioning of memory and recall of factual information (18,19). Recent studies employing passive image capture using the wearable camera SenseCam found that reviewing such images can help improve memory recall and correct negative self-perception (20) and improve mood when paired with a cognitive bias training task (21).

These small unobtrusive cameras can be attached to clothes or objects and passively capture images at pre-set intervals, which allows for first person images without agency on the part of the wearer. Sellen *et al.* (22) found that these pictures were still recognized as taken from the wearer's perspective and therefore can be seen as autobiographical information, despite not actively being taken by the individual. The cameras further provide images rich in detail and with an abundance of cues to trigger memory and emotion (23). Using visual data capture to facilitate objective reflection could therefore be a way to confront the storage of biased information and to provide a step in the correction of distorted memories and negative imagery. Finally, compared to video feedback, which provides only information from the observer perspective and hence addresses concerns regarding the individual's own performance, passive image capture has the advantage that it can help direct attention to much needed external information during social stress situations.

To our knowledge, no study has investigated the use of wearable camera technology in the context of social anxiety. Rennert and Karapanos (24) report on an interesting concept for a technology platform to incorporate GPS tracking and wearable cameras in exposure tasks for SAD, but do not report project outcome data. Based on previous research however, wearable cameras could have the potential to complement exposure and behavioural experiments by aiding objective recollection of anxiety-inducing events. Therefore, the aim of the current study was to develop a paradigm to induce anxiety while capturing both field and observer perspective images generated during a social stress task and to manipulate the mode of memory re-processing following the social stress task. In order to test effects from both perspectives, images were simultaneously captured of the participant (observer perspective), as well as the environment from the participants' view (field/first-person perspective). Given the role of post-event processing (i.e., rumination) in SAD, we also wanted to assess whether re-exposure to images would prompt maladaptive post-event processing. Therefore, we also evaluated whether image reprocessing was differentially associated with negative post-event processing at 24-hour follow-up. We made three primary predictions: (I) that the speech task would result in increased anxiety from baseline as measured by both subjective [Subjective Units of Distress (SUDS)] anxiety ratings and heart rate (Fitbit); (II) that participants assigned to reprocess the speech task using standardised field-perspective images extracted from the wearable camera would recall more factually correct information about the social stress task relative to participants assigned to reprocess the speech task using images generated from internal representations of the speech task (i.e., using mental recall); and (III) that image review from the observer perspective would increase participants' level of post-event rumination following the speech task, relative to participants in the field perspective.

## Method

### *Participants*

Participants were recruited via online advertisement on the social media network Facebook, as well as posters and flyers distributed around Utrecht University. Participants who studied psychology were eligible for research participation credit upon completion of the experiment. All participants provided informed consent. The study was approved by the Human Research Ethics Committee of Utrecht University.

### *Materials*

#### Questionnaires

The screening and debriefing stages were completed online using Qualtrics survey software licensed to Utrecht University. In the laboratory, questionnaires were presented via a research computer. As some questionnaires were not available in Dutch, the following measures were translated by the researchers: Focus of Attention Questionnaire (FAQ) and Extended Post-Event Processing Questionnaire (E-PEPQ). First, one researcher translated the questionnaire into Dutch, then the second researcher translated it back to English. Finally, the other two researchers compared the English back- translation with the original version.

#### Social anxiety

The Dutch version of the Social Phobia Scale (SPS-NL) (25) was used to assess social anxiety. It contains 20 items, which are rated on a five-point scale from 0 ("not at all characteristic or true of me"), to 4 ("extremely characteristic or true of me"). Items include for example: "*I fear I may blush when I am with others*" and "*I become self-conscious when using public toilets*". A higher score indicates greater performance anxiety in social interactions. Internal consistency was 0.84 in the current sample.

#### General anxiety

The Dutch version of the General Anxiety Disorder scale (GAD-7-NL) (26) was used to assess anxiety levels. It contains 8 items based on the DSM criteria for GAD, which are rated on a 4-point scale from 0 ("not at all") to 4 ("almost every day"). A higher score indicates greater general anxiety. The GAD-7 showed good reliability in previous research, $\alpha$ =0.89. The GAD-7 also shows sufficient reliability in the current study: GAD-7 $\alpha$ =0.71

#### Depression

A validated Dutch translation of the Patient Health Questionnaire (PHQ-9) (27) was used to measure depression, which contains 9 items based on the DSM-IV criteria for major depressive disorder. The questions are each rated on a three-point scale, from 0 ("not at all") to 3 ("nearly everyday"), with a higher score indicating greater depression. The internal consistency in previous research was $\alpha$ =0.82, and concurrent validity with the BDI is .67. In the current research the PHQ-9 shows sufficient reliability, $\alpha$ =0.77.

**Rumination**

At baseline, rumination was measured using the Dutch version of the Perseverative Thinking Questionnaire (PTQ-NL) (28). The PTQ-NL uses 15 items rated on a four-point Likert scale to assess repetitive negative thinking (e.g., "I feel driven to continue dwelling on the same issue"). The PTQ-NL shows high internal consistency, $\alpha$ =0.94 (28), current study $\alpha$ =0.91. In order to measure post-event rumination, the E-PEPQ (29) was used. The 15-item questionnaire uses an 11-point Likert scale (0= "not at all" to 100= "very much so") to measure prolonged review of a social-evaluative situation (instructions were modified to anchor responses specifically to the social-stress speech task used in the current study). The scale consists of 3 subscales: cognitive interference (e.g., "thoughts about event interfere with concentration"); negative self (e.g., "sense of shame while remembering behavior during event"); thoughts about the past (e.g., "think about anxious feelings during event"). The E-PEPQ was translated from English to Dutch by one researcher. Then two other researchers translated it back to English and compared it to the original version. Reliability in the current study was high, $\alpha$ =0.89.

**Level of imagery**

In order to assess the level of imagery used in everyday life the Subjective Use of Imagery Scale (SUIS) (30) was administered. The SUIS contains 12 items, each item (e.g., "When I think about a series of errands I must do, I visualize the stores I will visit") is rated on a 5-point scale from 0 ("does not apply to me at all") to 5 ("does perfectly apply to me"). A higher score indicates a greater level of imagery. The SUIS has a good internal consistency and reliability in previous research, $\alpha$ =0.83. In the current research the SUIS also shows a sufficient level of reliability, $\alpha$ =0.69.

**Attentional focus**

The FAQ (31), a 10-item measure consisting of 2 subscales: a self-focus subscale that measures the extent to which individuals focused on themselves during a social situation [e.g., "I was focusing on my internal bodily reactions (for example, heart rate)"], and an external-focus subscale that measures the extent to which individuals focused on the environment (e.g., "I was focusing on what the other person was saying or doing"). The FAQ was administered as a manipulation check to assess attention during the speech task. Internal consistency was $\alpha$ =*0*.78 in the current sample.

**Distress**

The Subjective Units of Distress (SUDS) (32) was used to measure state anxiety. The single item asks the following: "How much anxiety are you experiencing right now?" on a scale from 0= "totally relaxed" to 10= "most anxiety ever experienced".

**Memory intrusions**

At follow-up participants were asked about the occurrence of memory intrusions of the speech task: "in the past 24 hours did you have any memories of the speech task come into your mind?", emotional valence: "in general, how did this/these memories make you feel (0 = very negative to 4 = very positive), and memory vantage perspective: "please indicate the perspective from which you generally experienced this/these memories" (0 = completely first-person perspective to 4 = completely third person perspective).

**Memory recall**

This questionnaire was constructed specifically for the study in order to measure focus of attention and memory recall. It consists of nine true and nine false statements about the audience's behaviour and the environment in the video (e.g., "someone in the audience was smiling during the speech"). These items A higher score indicates greater memory recall.

**Additional measures**

The Cognitions of Bodily Sensations (CBS) (33) and the Ambiguous Scenarios Test for Depression (AST-D) (34), were administered but these measures are not reported in the current study.

**Researcher script**

A standardized script was written by the researchers with instructions on how to guide participants through the social experiment in the laboratory. It included information about the materials, the timing for the "fake interaction scene" in the recorded video, the speech, and the audience.

**Narrative clips**

The Narrative Clip is a small wearable camera that automatically captures photos at set intervals. Two Narrative Clips were used; one was clipped onto the participant's clothing, the other one was attached to the computer screen with an elastic band. The Clips were programmed to take photos at 30 second intervals. A total of 10 pictures taken from the first-person perspective were standardised and presented to the participants following the speech. These pictures showed 10 cues of the audience, which were either positive, ambiguous or negative. Pictures taken from the field perspective showed 10 images of the participant, selected based on quality of the captured image.

**Fitbit**

Participants' heart rate was measured with a wrist-worn Fitbit Charge HR smartwatch, which tracks activity with a built-in heart rate sensor.

**Webcam**

The Logitech C920 HD pro webcam was used by attaching it on top of the computer screen, where the video was displayed. The webcam was turned off during the experiment, but was used to create the impression of a live video feed.

**Video audience**

A standardized video of an audience based on (35) was developed and pre-recorded to last the duration of the speech task. The audience consisted of four confederate students who played their roles according to the script, which had been pilot-tested for credibility. The video contained a short scene of fake interaction between the "audience" and researcher, followed by the display of 2 positive cues, 7 ambiguous cues and 3 negative cues (e.g., a positive cue was smiling, a negative cue was yawning, and an ambiguous cue was looking away) at pre-determined time intervals throughout the recording.

### *Procedure*

**Screening**

After responding to the advertisement, participants received a link to the screening questionnaire. Upon completion, they were informed whether they were eligible for participation or not. Participants were excluded from the study if they had a score of 20 or higher on depression (PHQ-9), 15 or higher on general anxiety (GAD-7), higher than 0 on the suicidality question and if they were not in the age range of 18–74 years. Data was collected during the Spring semester in 2016.

**Lab procedure**

The study took place in a laboratory at Utrecht University. Participants were informed that they would have to perform a speech task, the subject of which was the ideal relationship between an employer and an employee. To help the participants, some keywords were provided: "commitment, trust, equality, severance pay, holiday, sick leave and payment". They were told that the focus of this study was information processing in social situations and that the researchers would mainly focus on the interaction between the participant and the audience. The audience would ostensibly appear on the computer screen via live stream, using a webcam. Participants were then asked to pin the Narrative Clip onto their shirt and to put on the FitBit watch on their non-dominant wrist. At this point, participants' heart rate and SUDS were measured. Then they were given three minutes to prepare their speech. They were told that the audience members were instructed not to interrupt the participants at any moment of the speech. The computer screen was turned on and a contrived interaction occurred, wherein one of the researchers asked the audience members to move their chairs closer to the camera, in order to increase realism. After the speech, participants were asked to complete the SUDS, FAQ, and the Memory questionnaire and had their heart-rate recorded. The following step depended on which condition participants were randomly assigned to.

**Conditions**

Three conditions contained a re-processing task. In order to ensure participants would review images objectively, a brief cognitive preparation based on Harvey *et al.* (14) was provided to the participants. Reprocessing was either done by verbally describing the presented images (conditions 1, 2) or mental imagery (condition 3). Participants were asked to describe the images out loud in order to ensure task adherence. Participants were randomly assigned to one of four conditions using the website random.org.

**Condition 1**

Speech task followed by review of 10 standardized images of the audience taken from the first-person perspective. Images were selected which coincided with the pre-defined behavioural cues enacted by the (pre-recorded) "audience" during the speech task.

**Condition 2**

Speech task followed by review of 10 standardized images of the participant taken from the observer perspective. Images were selected to match the time-points in condition 1 (i.e., images were of the participant in response to the pre-defined behavioural cues enacted by the "audience").

**Condition 3**

Speech task followed by mental review of the task from the first-person perspective. Participants were asked to verbally recall what they have seen of the audience during their speech.

**Condition 4**

Speech task followed by a control period in which no type of review occurred. After 24-hour delay participants were

**Table 1** Demographic characteristics and baseline scores across conditions

| Characteristics | Field perspective (n=13) | Observer perspective (n=10) | Mental review (n=12) | Control (n=11) |
|---|---|---|---|---|
| Age | 26.38±12.99 | 26.00±11.37 | 22.25±2.45 | 22.30±1.57 |
| SPS | 31.92±7.25 | 29.20±4.75 | 33.25±6.55 | 30.45±10.1 |
| PHQ-9 | 5.00±4.02 | 4.70±4.52 | 4.75±2.70 | 4.91±3.30 |
| SUIS | 39.53±5.86 | 39.40±6.07 | 36.66±7.60 | 37.54±8.68 |
| PTQ | 26.92±6.82 | 23.20±9.51 | 27.16±7.49 | 22.81±8.89 |

The data are described as mean ± SD. SPS, Social Phobia Scale; PHQ-9, Patient Health Questionnaire-Depression; SUIS, Spontaneous Use of Imagery Scale; PTQ, Perseverative Thinking Questionnaire.

emailed a link to complete the Memory questionnaire, the post-event processing measure (modified E-PEPQ) and debriefing.

## Results

### *Sample characteristics*

The sample included 22 females and 24 males with a mean age of 24.30 (SD =8.86; range 18–58 years; *Table 1*). Scores on the baseline measures are also reported in *Table 1*. Mean social anxiety scores (SPS, M =31.32, SD =7.34) were within one SD from the mean reported in clinical populations (36,37) and above the recommended clinical cut-off for the Dutch version (of >15 for men and >18 for women) (25). One-way ANOVA's indicated no significant differences in baseline scores across the 4 conditions, all F's <1, all P's>0.05. Chi-square analysis indicated no significant differences in gender distribution, $\chi^2_{[2]}$ =3.68, P>0.05.

### *Speech task anxiety*

Two separate repeated measures ANOVAs were conducted to check for the anxiety-inducing impact of the speech on self-reported anxiety (SUDS) and objective anxiety (heart rate). For SUDS there was a significant main effect of time, $F_{[2, 41]}$ =41.48, P<0.001, and crucially no time × condition interaction. Collapsed across condition, results indicated a significant increase in anxiety from baseline (M =3.84, SE =0.25) to post-speech (M =5.07, SE =0.32), followed by a reduction (M =2.79, SE =0.28).

For heart-rate measured with the Fitbit, the ANOVA did not meet Mauchly's assumption of sphericity, $\chi^2_{[2]}$ =18.26, P<0.001, therefore the degrees of freedom were corrected using the Huynh-Feldt estimates (ε =0.81). The results indicated that there was a significant main effect of time on heart rate, $F_{[1.62, 68.06]}$ =5.01, P<0.01, and crucially no time × condition interaction. Collapsed across condition, results indicated a significant increase in heart-rate (M =76.19, SE =3.17) to post-speech (M =81.86, SE =0.3.45), followed by a non-significant reduction (M =80.93, SE =3.56).

### *Memory intrusions and recall*

At follow-up (due to a programming error, data for the memory questionnaire was missing for 10 participants), the mean frequency of reported intrusive memories of the speech task was 2.11 (SD =2.30, range 0–10) with average valence ratings in the positive range (M =3.00, SD =0.63). The vantage perspective in which these memories were experienced was primarily from the first-person perspective (M =1.81, SD =0.93). These ratings did not differ across the conditions, F's < 1, Ps>0.05.

To test whether objective reprocessing using standardised field perspective images of the speech task taken with the Narrative Clip led to greater identification of factual events compared to mentally reprocessing the speech task, a repeated-measure ANOVA was conducted. To ensure attentional focus did not vary across the four conditions during the speech, one-way ANOVAs were first conducted on the FAQ self and other subscales. Mean scores did not differ across the conditions on either subscale, F's <3, P's >0.05. The total number of correctly identified factual events were calculated during the test phase following the speech task (T1) and following the 24-hour delay (T2). The main effects of time and condition were not significant, F's <2, P's>0.05, but the interaction was significant, $F_{[3, 23]}$ =4.96, P=0.008. Planned contrasts indicated a significant increase in the number of correctly identified factual events in the Field perspective condition from T1 (M =7.00, SD =3.02) to T2 (M =10.12, SD =4.25),

$t_{[7]}$ =2.63, P=0.03. The small increase in the number of factual events correctly identified in the observer perspective (T1: M =8.80, SD =2.28; T2: M =9.20, SD =3.76), and the decrease in the number in both the mental review (T1: M =7.37, SD =1.59; T2: M =6.25, SD =2.43), and control (T1: M =6.66, SD =2.42; T2: M =4.83, SD =1.53), conditions were not significant, t's<2.2, P's>0.05. Recall at T2 in the field perspective condition was significantly greater than in the mental review and control conditions, P's<0.05. The interaction remained significant when the average time delay (recorded in hours) from the speech task to completion of the follow-up questions at T2 (M =42.16, SD =24.31) was entered as a covariate in the model, $F_{[3, 16]}$ =3.40, P=0.04.

### *Post-event processing*

Lastly, we wanted to evaluate potential adverse effects of re-processing the speech task in the form of negative post-event processing. Separate ANCOVAs using the 3 E-PEPQ subscale scores were conducted with baseline rumination scores (PTQ) entered as a covariate. Only the model for the Negative Self Subscale scores was significant, $F_{[1, 32]}$ =3.82, P=0.02, with post-hoc comparisons indicating a significant difference between the Observer Perspective (M =46.82, SD= 6.62) and Control condition (M =17.41, SD =6.24).

## Discussion

The current pilot study aimed to develop a social stress task that would permit image capture from a small wearable camera simultaneously from the field/first-person perspective and the observer perspective. We then explored whether participants assigned to reprocess standardised field perspective images obtained during the anxiety-provoking speech task would recall more factual information about the task, relative to participants assigned to reprocess the speech task using field perspective images generated from internal representations of the speech task (i.e., mental imagery akin to mental review following a behavioural experiment in CBT). Additionally, we investigated differential effects of the image re-processing task on negative post-event processing of the speech task after a 24-hour delay. Results indicated that it was possible to set-up a paradigm using wearable cameras embedded in a speech task and to induce anxiety in high socially-anxious participants, despite employing an ostensive audience in the form of a pre-recorded video.

Objective image reprocessing of field perspective images was associated with greater recall of factual events of the speech task (e.g., scripted "audience" reactions) compared to mental review of the event (and relative to a control condition wherein participants did not re-process the speech task). This is in line with previous findings, where it was found that when a socially anxious individual engages in mental imagery, their emotions are intensified and can therefore have disruptive effects on memory recall of the event (38). These effects did not diminish over a relatively short amount of time (24 hours after the speech task).

Given the role of post-event processing (i.e., rumination) in SAD, we also wanted to assess whether re-exposure to images might prompt maladaptive post-event processing. Therefore, we evaluated whether image reprocessing was differentially associated with negative post-event processing at 24-hour follow-up. Results indicated higher levels of negative-post event processing specifically for the Negative Self subscale of the modified E-PEPQ (anchored to the speech task), in the Observer condition relative to the Control conditions. No other differences emerged.

The results might be informative to further improve the effectiveness of interventions for social anxiety. In CBT for SAD, individuals are asked to reconstruct distressing events as objectively as possible in order to be able to combat negative biases and cognitions. However, mental recall can be influenced by anxiety and distress (39), which can in turn distort memory and lead to biased information being used to restructure cognitions within therapy. The current findings suggest that passive image capture and reprocessing using first person perspective images could have beneficial effects if integrated into standard CBT techniques, allowing for more detailed and factual recollections which then can be used to aid *in vivo* exposure tasks, behavioural experiments, and cognitive restructuring activities. Nevertheless, image review in therapy should not be seen as a complete substitute for video feedback, as re-processing of stationary images does not confer all the benefits of video footage. However, the use of relatively small and unobtrusive wearable cameras is more practical and could have added value in the process of gathering corrective information, and do so in a covert manner in naturalistic settings (i.e., during between-session homework tasks that can be later reviewed with a clinician). The use of such cameras could also complement the advice of Warnock-Parkes *et al.* (17) to use still images of the most emotional moments during a behavioural experiment (when being video-recorded), or when it is not feasible to have a therapist accompany the client and discretely take photographs of social interactions as they occur naturally. Attention to appropriate cognitive preparation prior to viewing images in either modality should be given (see Warnock-Parkes *et al.*, 2017), particularly as we can envision these strategies incorporated into other evidence-based forms of CBT with limited therapist involvement (e.g., 40). Given we did not find strong support for differential effects of image reprocessing on post-event processing, future studies should investigate the potential for both beneficial and adverse effects, and at longer-term follow-up.

The results must be interpreted in the context of the study limitations. Screening variables (and exclusion criteria) were focused on anxiety and depression scores. There was no screening for variables known to have influence on factors like anxiety and heart rate, such as caffeine intake (41) and physical fitness (42). Additionally, the accuracy of wrist-worn heart rate monitors has been shown to be variable when compared to standard electrocardiography devices (43). However, in the current study heart rate was used to complement the SUDS ratings as the primary index of state anxiety. Although suspicions regarding the contrived nature of the speech task were indirectly assessed, we did not administer a measure to check for awareness of this manipulation. However, even though some participants might have figured out that the audience was pre-recorded, a significant increase in state anxiety and heart rate was still present as a result of the speech task and the implications of being observed. The significant increases in heart rate and state anxiety are in concordance with the Leiden Speech Task, in which participants were informed that the audience was pre-recorded, and still evidenced a significant increase in heart rate and stress levels (44). Additionally, not at all participants completed the follow-up measures resulting in a smaller sample size for these outcome measures. In order to create a more generalizable and more clinically relevant study, future studies should further be conducted with larger samples and in participants with clinical diagnosis of social anxiety.

Wearable cameras can provide a novel platform from which to collect information in naturalistic environments. Research using visual data capture and recording of participants' behaviour entails ethical issues pertaining to privacy and participant autonomy. Wearable cameras collect considerably more information than regular photography and they may capture unwanted images in private situations or of uninformed third parties. Therefore, in order to allow scientists to conduct ethical experiments and research using these devices, Kelly *et al.* (45) provided an ethical framework. The suggested guidelines emphasize the importance of secure data collection, informed consent, confidentiality, as well as protection of participants' (and third parties') autonomy and privacy. Signal *et al.* (46) recently conducted an innovative study in New Zealand to capture children's exposure to products and marketing (e.g., alcohol and fast food). They obtained over 1.5 million images from 168 children wearing a (Autographer), providing unprecedented insights into product exposure across different environmental context (home, school, neighbourhood). The willingness of parents and schools to support the conceivably "invasive" technique suggests that concerns regarding this form of technology may not be insurmountable with appropriate ethical protocols in place. Strict protocols for data storage and access, along with automated digital processing using facial recognition software to obscure identifying facial details (similar to that used by Google's Maps Street View) could reduce the concerns associated with data collection and protect the privacy of individuals. In a world where we are increasingly being monitored by our own digital devices (e.g., mobile phone GPS locators) and unknowingly captured on video or film (e.g., live web-cameras installed in city centres, surveillance cameras, in the background of images other people's social media posts), researchers will need to develop protocols that balance ethics and the potential power of image-based wearable technology to advance our understanding of complex social interactions and behaviours that could inform treatment strategies to best serve those in need.

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## Footnote

*Conflicts of Interest:* The authors have no conflicts of interest to declare.

*Ethical Statement:* The study was approved by the Human Research Ethics Committee of Utrecht University (FETC16-018) and written informed consent was obtained from all participants.

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