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2 **Social anxiety is associated with alterations in heart rate but not**
3 **gaze in a real social interaction**

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24 variability

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Abstract

Much of our current understanding of social anxiety rests on the use of simplistic stimulation material in laboratory settings. Latest technological developments now allow the investigation of eye movements and physiological measures during real interactions with adequate recording quality. Considering the wealth of conflicting findings on gaze behavior in social anxiety, the current study aimed at unraveling the mechanisms contributing to differential gaze patterns in a naturalistic setting in the general population and in social anxiety. We introduced participants with differing social anxiety symptoms to a waiting room situation while recording heart rate and electrodermal activity using mobile sensors and eye movements using mobile eye-tracking glasses. We observed fewer fixations on the head of the confederate in the initial waiting phase of the experiment. These head fixations increased when the confederate was involved in a phone call and head fixations were most pronounced during the actual conversation. In opposition to gaze-avoidance models of social anxiety, we did not observe any correlations between social anxiety and visual attention. Social anxiety was, however, associated with elevated heart rate throughout the entire experiment suggesting that physiological hyperactivity constitutes a cardinal feature of the disorder.

1. Introduction

Understanding social contexts is essential for human interactions. At the core of interpreting the social dynamics of a scene lies an attentional bias towards the fellow humans taking part in it (Birmingham & Kingstone, 2009). Various laboratory studies have shown increased gaze towards human bodies and, in particular, faces, independent of the task at hand (Flechsenshar & Gamer, 2017) or the surrounding visual information (Birmingham, Bischof, & Kingstone, 2009; Boggia & Ristic, 2015; End & Gamer, 2017; Rösler, End, & Gamer, 2017). However, recent advances in technology have enabled researchers to move the studies on social attention from laboratory settings to the real world. After all, the viewing of stimuli on a PC screen lacks many aspects a genuine social encounter entails. A major concern of the proponents of ecological validity (Kingstone, 2009; Kingstone, Smilek, & Eastwood, 2008; Risko, Laidlaw, Freeth, Foulsham, & Kingstone, 2012; Smilek, Birmingham, Cameron, Bischof, & Kingstone, 2006) is that most of the psychological stimulation material does not adequately approximate the complexity of daily life situations. While participants are known to preferentially fixate eyes of schematic or photographed faces presented in isolation (e.g. Friesen & Kingstone, 1998; Frischen, Bayliss, & Tipper, 2007; Langton, Watt, & Bruce, 2000), more intricate visual elements of real world scenes might draw attention away from the eyes. Indeed, numerous studies have shown substantially reduced overt attention to humans when participants are moved from the lab into environments with higher ecological validity (Foulsham, Walker, & Kingstone, 2011; Hayward, Voorhies, Morris, Capozzi, & Ristic, 2017; Laidlaw, Foulsham, Kuhn, & Kingstone, 2011). Participants look significantly less frequently at an actual person sitting in a waiting room with them than if that same person is not physically present but displayed on a computer screen. These gaze reductions possibly stem from an active avoidance of a social interaction with the confederate (Laidlaw et al., 2011). These results argue for further investigations of gaze behavior in everyday situations to conclusively elucidate the mechanisms that underlie these observed reductions.

While an attentional shift towards humans is vital for various higher socio-cognitive tasks, several psychiatric disorders display altered processing of human features. Social anxiety, which is characterized by a penetrating fear of social encounters and social-evaluative situations (Clark & Wells, 1995) and typically has a life-long impact on the relationships of the affected individuals (Wittchen, Stein, & Kessler, 1999), is assumed to feature differential processing of social information as a core symptom (Wells et al., 1995). There is, however, vast disagreement regarding the characteristics of these gaze behavior alterations (Chen & Clarke, 2017). Studies using emotional faces as probes to investigate attentional biases have shown that socially anxious patients predominantly avoid these threatening stimuli (Chen, Ehlers, Clark, & Mansell, 2002; Mansell, Clark, Ehlers, & Chen, 1999). As heightened processing of emotional faces has also been reported in the social anxiety literature (Asmundson & Stein, 1994; Gilboa-Schechtman, Foa, & Amir, 1999), Mogg and colleagues have proposed to focus on the temporal dynamics of gaze in social

anxiety and suggested an initial hypervigilance to social or emotional stimuli followed by a subsequent avoidance (Mogg, Bradley, De Bono, & Painter, 1997).

Up to date, only a handful of studies investigated gaze behavior in social anxiety during a real interaction and, again, provided conflicting results (Farabee, Holcom, Ramsey, & Cole, 1993; Gilbert, 2001; Howell, Zibulsky, Srivastav, & Weeks, 2016; Langer, Lim, Fernandez, & Rodebaugh, 2017; McManus, Sacadura, & Clark, 2008). Considering that viewing preferences of social features change from lab to real-world environments (Foulsham et al., 2011; Hayward et al., 2017; Laidlaw et al., 2011; Rubo, Huestegge, & Gamer, 2019) and that elevated skin conductance levels in social anxiety are primarily associated with real eye contact rather than the observation of photographed faces (Myllyneva et al., 2015), an investigation of gaze and physiological responses in social anxiety towards different degrees of social interaction in a real-world setting will help to clarify the mechanisms underlying anxious behavior. The aim of the present studies was hence to investigate whether the presence or absence of a potential social interaction influences gaze allocation and whether social anxiety modulates viewing behavior and physiological responses across these different social situations. We measured eye gaze, heart rate and electrodermal activity (EDA) of participants with different degrees of (sub-)clinical social anxiety using a mobile eye-tracking device and mobile physiological sensors while they were sitting in a waiting room with a male confederate who they believed to be another participant. Throughout the entire recording, participants were not aware that the experiment had already started. To modulate the degree to which a social interaction was possible, the confederate received a phone call after the initial two minutes of the experiment rendering him unavailable for a conversation. After two minutes on the phone, he addressed the participant directly and initiated a semi-stereotyped conversation. Based on the results of the waiting room study of Laidlaw and colleagues (2011), we expected that head fixations would be most reduced in the initial waiting phase when an interaction had to be actively avoided. Additionally, we expected that socially anxious participants would display reduced social gaze accompanied by increased physiological arousal throughout all conditions but most prominently during the interaction phase.

2. Methods

2.1 Participants

Prior to recruitment, we asked potential participants to fill in several questionnaires via an online recruiting platform hosted by the university. The pre-screening enabled us to include a wide spectrum of social anxiety manifestations in our sample. Of 409 people who participated in the online screening, we invited 98 people to join the study. A few participants had to be excluded because of various issues with data acquisition or quality, including too large gaze drifts evoked by moving glasses ($n = 4$), hardware recording issues on the day of testing ($n = 5$), too many missing valid fixations ($> 30\%$ of recorded frames, $n = 7$) and insufficient quality of the electrocardiogram (ECG) data ($n = 2$). Additionally, unforeseeable events during the recording

led to further exclusions, to be specific the non-permitted use of mobile phones ($n = 4$), the initiating of a conversation with the confederate during the waiting phase of the experiment ($n = 2$), disbelief in the cover story of the experiment ($n = 2$) and acquaintance with the confederate ($n = 1$). Since we preselected participants according to their social anxiety and higher levels are more prevalent among females than males (McLean, Asnaani, Litz, & Hofmann, 2011), the final analysis included 71 participants of which 61 were female (mean age = 24.50 years, $SD = 6.37$ years). The study was approved by the local ethics committee. Each participant provided written informed consent prior to the start of the experiment for the experiment they believed to take part in. Participants were informed about the purpose of the actual experiment and their rights to withdraw consent after recordings were complete. Participants were awarded monetary compensation for their participation.

As part of the experiment, participants completed the following questionnaires to allow for a comprehensive characterization of the sample regarding anxiety, autism and general personality traits (see Table 1): The German versions of the Social Interaction Anxiety Scale (SIAS; English original version: Mattick & Clarke, 1998; German version: Stangier, Heidenreich, Berardi, Golbs, & Hoyer, 1999), the Brief Fear of Negative Evaluation Scale – Revised (BFNE; English original version: Nicholas Carleton, McCreary, Norton, & Asmundson, 2006; German version: Reichenberger et al., 2016), the short version of the Autism Spectrum Quotient (AQ; English original version: Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001; German version: Freitag et al., 2007), State-Trait Anxiety Inventory (STAI; English original version: Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983; German version: Laux, Glanzmann, Schaffner, & Spielberger, 1981) and the short version of the Big Five Inventory (BFI; English original version: John, Donahue, & Kentle, 1991; German version: Rammstedt & John, 2005). The range of SIAS scores that were observed in the current sample indicates that we were successful in recruiting participants ranging from very low social anxiety to levels that are also observed in clinical samples which is usually determined by a cut-off score of 30 (Stangier et al., 1999).

Table 1.

	Mean	SD	Minimum	Maximum
SIAS	25.96	15.66	6	71
BFNE	37.49	11.89	13	60
STAI	42.04	12.04	24	73
AQ	8.63	5.04	1	20
BFI Extraversion	13.59	4.13	5	20
BFI Agreeableness	11.24	2.93	4	18
BFI Conscientiousness	15.06	2.63	9	20
BFI Neuroticism	13.85	3.54	4	20
BFI Openness	20.42	3.23	9	25

2.2 Measurement devices

We used mobile SMI ETG 2W eye-tracking glasses to record eye movements of both eyes with a frame rate of 60 Hz (SensoMotoric Instruments GmbH, 2014). The front camera of the glasses had a resolution of 1280 x 980 pixels and recorded the field of view with a frame rate of 24 Hz. A Samsung Galaxy Note 4, which the participant was carrying in a waist bag, stored all recorded data.

To measure heart rate and heart rate variability, we attached a mobile EcgMove 3 Sensor (Movisens GmbH, 2017) to the sternum of participants by means of a chest belt. The ECG raw signal was sampled with a frequency of 1024 Hz. We additionally used a mobile EdaMove 3 Sensor (Movisens GmbH, 2017) attached to the thenar and hypothenar eminences of the participant's non-dominant hand to record electrodermal activity with a sampling rate of 32 Hz by a constant voltage system (0.5 V).

Apart from the paper-pencil sociodemographic form, questionnaires were filled in on a Dell Latitude 11" Pro 5170 Tablet using the software Presentation (Neurobehavioral Systems, 2016).

2.3 Procedure

Participants expected to take part in an experiment which investigated pupil size and physiological responses in response to differing visual stimuli. Upon their arrival at the institute, the experimenter informed participants that the prior participant (confederate) experienced a slight delay and was therefore still filling in some questionnaires. To allegedly save time, ECG- and EDA-electrodes as well as mobile eye-tracking glasses were attached to the participant in the meantime. The eye-tracker was subsequently calibrated by using three points of reference on a poster (see Figure 1). Upon successful calibration, eye-tracking recording started. Simultaneously, successful calibration cued the confederate to remark that one of the

questionnaires had not been copied properly. To minimize movements as all devices were already attached and calibrated, the participant was asked to take a seat facing the confederate (see Figure 2). Under the pretense of fetching a new questionnaire, the experimenter left the room, which marked the onset of the actual experiment. During the first two minutes, which will be referred to as the waiting phase throughout the article, confederate and participant did not interact but the confederate was occupied filling in the remaining questionnaires. After two minutes, he received a phone call, allegedly by a friend but in truth by the experimenter, which lasted approximately another two minutes (phone phase). Upon hanging up the phone, the confederate initiated a two-minute interaction phase discussing a catalogue of statements and questions regarding previous experiences with psychological experiments which was standardized as much as a natural conversation allows. Although we attempted to generate experimental phases with a length of exactly 2 minutes, these durations varied slightly due to several reasons (e.g., time to establish and finish the phone call, responses of the participant in the interaction phase). On average, the waiting phase lasted 114.72 s ($SD = 8.62$ s), the phone phase 119.58 s ($SD = 4.64$ s) and the interaction phase 115.27 s ($SD = 7.88$ s) respectively.

Throughout all three phases, we measured ECG, EDA and gaze by the previously attached mobile devices. After completion of the interaction phase, the three-point poster was used to re-assess the initial calibration and enable a later drift correction. The participants were then informed about the actual purpose of the study and asked to fill in a sociodemographic and the other trait questionnaires.

2.4 Data processing

Eye-tracking and video data were handled within the BeGaze software (Version 3.6; SensoMotoric Instruments GmbH, 2016) and, as an initial step, field-of-view videos were exported as full-length AVI-files excluding any fixation data. Instead, fixation coordinates for each frame were exported separately as CSV-files. The AVI-files were then converted into single pictures per video frame using Matlab (The MathWorks Inc, 2018). As many participants displayed a slight gaze drift tested by the final three-point validation at the end of the experiment, this drift was corrected per participant. For this purpose, the distance between the three actual fixations and points to be fixated was measured manually using the GIMP compass tool (Version 2.8; The GIMP Documentation Team, 2015). The mean of the deviations was then used for a linear gaze drift correction of the extracted fixation coordinates. If the mean deviation was larger than 200 pixels, equivalent to half of the confederate's head size, the participant was excluded entirely from the analyses. Using Matlab, the drift-corrected coordinates were projected onto the video frames creating a ring shape with an inner radius of 9 pixels and an outer circle diameter of 25 pixels around the fixation (see Figure 2 for an example image). We evaluated fixations manually in an application created specifically for this coding purpose at 6 Hz (i.e., every fifth frame to reduce the time spent on the still lengthy manual procedure). One independent coder who was not involved with the design or implementation of the study

rated which region of interest (ROI; confederate head, body or surroundings) was fixated or if no valid fixation was present in the respective frame. A subset of participants ($n = 6$) was rated by a second rater to establish that sufficient inter-rater reliability was present (Cohen's $\kappa = .93$). Based on these ratings, fixation proportion per ROI for all valid fixations within a phase were calculated for each participant.

EDA and ECG raw data were initially read and exported to CSV-files via the `unisens4matlab` toolbox (Movisens GmbH, 2018). During this step, ECG data were downsampled to 512 Hz. Heart beat detection was then performed using specifically developed scripts within the open-source statistical programming language R (R Core Team, 2018). First, ECG data were filtered using a 2 Hz high-pass filter in order to remove slow signal drifts. Subsequently, R-waves were detected from the ECG recordings using a semi-automatic method and R-R-intervals were converted to HR (in beats per minute, bpm) (for a similar approach see Rubo & Gamer, 2018). Heart rates below 50 or above 130 bpm were visually inspected for plausibility and corrected if necessary (i.e., in cases of undetected or erroneously detected R-waves). Subsequently, the data were transferred to a real time scale (Velden, M., & Wölk, 1987) and the average heart rate (HR) per experimental phase was calculated within each participant.

Additionally, heart rate variability (HRV) in the high frequency (HF) band was calculated per phase using the R package `RHRV` (Rodríguez-Liñares, Vila, Méndez, & Lado, 2011) analogous to the procedure of Pittig and colleagues (Pittig, Arch, Lam, & Craske, 2013). In detail, Fourier analysis (window length = 60 s, window displacement = 5 s) was used to determine the spectral power density of HRV in the high frequency range of 0.15–0.40 Hz. These values were expressed in normative units by dividing them by the total absolute power across all frequencies between 0.003 and 0.40 Hz and multiplying the resulting fraction by 100. Since HRV is affected by the length of the recording period (Berntson et al., 1997), we calculated HF-HRV only for the first 90 s of each experimental phase.

From the EDA recordings, we calculated the skin conductance level (SCL) for each experimental phase as the average of the low-pass filtered (1 Hz cutoff-frequency) skin conductance signal for each participant. These values are expressed in μS .

2.5 Statistical Analyses

Data were analyzed using R (R Core Team, 2018). An a priori significance level of $\alpha = .05$ was specified for all statistical tests. As our key question was to discern whether social anxiety impacts either gaze or physiological parameters, we computed four separate analyses of covariance (ANCOVAs) using the R package `afex` (Singmann, Bolker, Westfall, & Aust, 2015). For heart rate, heart rate variability and skin conductance levels, we included the mean-centered covariate SIAS score and the three-level factor experimental phase as well as their interaction term in the model. To model fixation proportions, we again included the mean-centered SIAS score and experimental phase as predictors but added the two-level factor

ROI (head versus body), all possible two-way interactions and the triple interaction term to the model (for analyses of eye versus mouth region fixations see Supplemental Material and Supplemental Figures S1 and S2). We additionally included gender as a covariate in all models to correct for potential effects of gender on our dependent variables. Post-hoc tests were performed using the R package emmeans. Generalized η^2 values (Bakeman, 2005) are reported as estimates of the effect size for linear model fixed effects. Correlation coefficients between questionnaire data and the dependent variables are reported in Supplemental Tables S1 to S3, while correlations between our dependent variables per phase are reported in Supplemental Figure S4.

As an additional analysis, we computed split-half consistencies of head fixations per phase across participants since recent studies showed stable fixation patterns within individuals across trials and we were interested to see if we can replicate this finding in our real-life dataset (De Haas, Iakovidis, Schwarzkopf, & Gegenfurtner, 2019; Guy et al., 2019). To this end, we split the three experimental phases per participant into two equally long periods and computed head fixations within each half. We then calculated Pearson's correlation coefficients between halves across all participants for each phase.

3. Results

3.1 Gaze data

To investigate how fixation proportions on the confederate are impacted by social anxiety, experiment phase and ROI we performed an ANCOVA with fixation proportions as the dependent variable and ROI (head versus body) and experimental phase (waiting, phone and interaction phase) as factorial predictors and SIAS score and gender as covariates. We found a significant main effect of ROI ($F_{(1,68)} = 19.01, p < .001, \eta^2 = .07$) as there were overall considerable differences between body and head fixations (see Figure 3 and Supplemental Table S4). A significant main effect of experiment phase ($F_{(2,136)} = 101.54, \varepsilon = 0.95, p < .001, \eta^2 = .21$) is driven by higher fixation densities on the confederate during the interaction phase (see Supplemental Table S4). Importantly, we observed a significant interaction of experiment phase and ROI ($F_{(2,136)} = 101.94, \varepsilon = 0.88, p < .001, \eta^2 = .30$) which mainly describes an increase of head fixations throughout the experiment (see Figure 3 and Supplemental Table S4). Regarding potential influences of social anxiety on fixation proportion, we did not observe a significant main effect ($F_{(1,68)} = 1.03, p = .313, \eta^2 = .004$) and none of the individual interactions with experimental phase and ROI, nor the triple interaction between all three predictors reached statistical significance (all $p > .49$). To test whether no effect of social anxiety on gaze behavior was more likely than social anxiety having an effect on gaze data, we compared the Bayesian ANCOVA models with and without SIAS as a covariate using the BayesFactor package (Morrey & Rouder, 2018). Using the default prior, the resulting Bayes Factor in favor of the model without

the SIAS predictor amounted to $4.26 \pm 0.79\%$ suggesting that a model which does not take social anxiety into account is approximately 4 times more likely to be the true data-generating model.

Examinations of split-half consistencies in our sample revealed strong and highly significant correlations in all phases (waiting phase: $r = 0.56, p < .001$; phone phase: $r = 0.80, p < .001$, interaction phase: $r = 0.71, p < .001$). Thus, viewing patterns were individually stable across participants.

3.2 Physiological data

To investigate whether mean HR differed across phases and was impacted by social anxiety, we calculated an ANCOVA with the three-level factor experimental phase (waiting, phone and interaction phase) and the continuous SIAS score and the factorial variable gender as covariates. A main effect of phase confirmed that heart rate differed between experimental phases ($F_{(2,136)} = 22.12, \epsilon = 0.78, p < .001, \eta^2 = .02$, see Figure 4 and Supplemental Table S5) and a main effect of SIAS revealed that social anxiety was also associated with heart rate levels ($F_{(1,68)} = 6.54, p = .01, \eta^2 = .08$). The interaction term did not reach statistical significance ($F_{(2,136)} = 0.08, \epsilon = 0.78, p = .87, \eta^2 < .001$), indicating that there was a stable influence of social anxiety on heart rate independent of the phase. The main effect of gender ($F_{(1,68)} = 0.45, p = .51, \eta^2 = .006$) and the interaction term with experimental phase ($F_{(2,136)} = 1.22, \epsilon = 0.78, p = .29, \eta^2 = .001$) did not reach statistical significance. To further assess the relationship between heart rate and social anxiety, we calculated Pearson's correlation coefficients comparing the association between SIAS scores and mean heart rate for each phase individually. Indeed, SIAS scores were significantly correlated with mean heart rate across all phases (waiting phase: $r = 0.30, p = .012$; phone phase: $r = 0.27, p = .024$; interaction phase: $r = 0.30, p = .012$, see Figure 5).

An analogous ANCOVA model investigating influences of social anxiety and experimental phase on HF-HRV revealed that only the main effect of experimental phase was statistically significant ($F_{(2,134)} = 7.38, \epsilon = 0.96, p = .001, \eta^2 = .04$), while the main effect of SIAS ($F_{(1,67)} = 0.03, p = .86, \eta^2 < .001$) and the interaction term ($F_{(2,134)} = 0.19, \epsilon = 0.96, p = .82, \eta^2 = .001$) did not reach statistical significance (for post-hoc comparisons see Supplemental Table S6). Moreover, there was a significant main effect of gender on HF-HRV ($F_{(1,67)} = 4.80, p = .03, \eta^2 = .04$) but not of its interaction with experimental phase ($F_{(2,134)} = 0.38, \epsilon = 0.96, p = .67, \eta^2 = .002$).

Similar results were obtained regarding the influences of social anxiety and experimental phase on mean SCL. Skin conductance levels varied across phase as revealed by a main effect of experimental phase ($F_{(2,136)} = 37.76, \epsilon = 0.72, p < .001, \eta^2 = .060$) but we did neither observe a significant effect of SIAS ($F_{(1,68)} = 0.10, p = .75, \eta^2 = .001$), nor for the interaction term ($F_{(2,136)} = 0.96, \epsilon = 0.72, p = .36, \eta^2 = .001$). There was no statistically significant effect of gender ($F_{(1,68)} = 0.45, p = .51, \eta^2 = .006$), nor of its interaction with

experimental phase ($F_{(2,136)} = 3.41$, $\varepsilon = 0.72$, $p = .05$, $\eta^2 = .005$) on SCL (for post-hoc comparisons see Supplemental Table S7). For this reason, we did not conduct any follow-up correlational analyses between social anxiety and HF-HRV or SCL, respectively.

4. Discussion

Most of our current knowledge on the behavioral and physiological manifestation of social anxiety is based on the processing of simple social stimuli in a laboratory setting. The aim of the present study was to investigate autonomic responses and gaze behavior in (sub-)clinically socially anxious individuals in a naturalistic scenario while manipulating the degree to which a social interaction is likely to develop. Participants were not informed about the start of the recordings but waited to start a different experiment while another participant, the confederate, filled in questionnaires. We generally found that, independent of social anxiety, head fixations are most prominently reduced when a social interaction is possible but likely undesired as in this initial waiting phase. By subsequently rendering the confederate unavailable to talk through responding to a phone call, fixations on his head were seen to significantly increase. The likelihood of the confederate looking back or initiating a conversation hence seems to strongly affect gaze behavior. Overall, the final interaction, in which the confederate openly sought a conversation with the participant, was most demanding as indicated by elevated heart rate and skin conductance levels and a reduced heart rate variability. Surprisingly, social anxiety levels did not impact gaze behavior in any of the phases of the experiment. With regard to physiological measurements, however, heart rate consistently correlated with social anxiety scores independent of the phase. These findings suggest that individuals with (sub-)clinical social anxiety might be able to behaviorally compensate their fear of direct eye contact at the expense of increased physiological arousal in the presence of or the interaction with other individuals. These findings represent an important addition to observations made in simplistic laboratory scenarios.

By immersing the participants into a naturalistic setting without their awareness of experiment and recording commencement, we were able to gain essential insights into the development of gaze throughout a real social interaction. The presence of another person had previously been shown to induce norm-following and facilitate differential task processing (Guerin, 1986; Zajonc, 1965). As hypothesized by Laidlaw and colleagues (Laidlaw et al., 2011) who also investigated eye movements during a waiting room situation, our results confirm that the chance of interacting with another unknown person clearly influences gaze behavior. We observed increased fixations on the head of the confederate when the possibility of an interaction decreased as the confederate was occupied with a phone call. We thereby provide further support for the notion of *civil inattention* initially formulated by Goffman which suggests that gaze avoidance is a characteristic feature of public anonymous settings (Goffman, 1965). While cardiovascular responses did not differ between the waiting and the phone phase, heart rate was significantly more elevated and heart rate

variability significantly decreased during the conversation with the confederate. Skin conductance levels already increased slightly when the confederate started talking on the phone, possibly because of heightened attention to the sudden auditory stimulation. Again, electrodermal activity was highest during the interaction emphasizing that conversations with strangers seem to come at cost of certain physiological arousal. It is arguably easiest to avoid conversations in a waiting room scenario with strangers by reducing eye contact (Cary, 1978).

Considering the large body of conflicting literature on gaze behavior in social anxiety, the current results aid the interpretation of findings from simulated social exchanges and their potential translation to live social interactions. In line with an abundance of studies drawing on gaze recordings during photographed or video-animated faces (Beidel, Turner, & Dancu, 1985; Boll, Bartholomaeus, Peter, Lupke, & Gamer, 2016; Glasgow & Arkowitz, 1975; Hofmann, Gerlach, Wender, & Roth, 1997; Walters & Hope, 1998; Weeks, Heimberg, & Heuer, 2011), we did not observe any evidence for gaze avoidance in social anxiety. To be more specific, we did not find reduced fixations on the head or body of the confederate in any of the experimental phases. How can this finding be reconciled with the reported observations (Farabee et al., 1993; Howell et al., 2016; Langer et al., 2017; Moukheiber et al., 2010) of gaze avoidance in social anxiety? Social settings are diverse and different social encounters might facilitate distinct behavioral reactions. Possibly, the presence of a real person induces norm-activating behavior (Guerin, 1986; Zajonc, 1965) which, specifically during conversations, requires a certain amount of attention towards the interaction partner. The use of images or videos as a simulation of an interaction might therefore fail to enforce this heightened attention on the interaction partner in socially anxious individuals. Furthermore, the degree to which the social situation is perceived as threatening varies widely across reported experiments. We deliberately chose to investigate a neutral everyday situation to be able to draw inferences about non-threatening daily encounters while observed reductions in gaze in live interactions were yet often in response to conflicts or a disagreeing confederate (Farabee et al., 1993; Langer et al., 2017).

The elevated heart rate observed in socially anxious participants in our study also suggests that overcoming fear of eye contact might ensue at the cost of higher physiological arousal. As this association has also been observed in another study with regard to electrodermal activity (Myllyneva, Ranta, & Hietanen, 2015), it is plausible that social anxiety is primarily associated with either compensatory or concomitant physiological mechanisms in real interactions. One might wonder why we exclusively observed correlations between heart rate and social anxiety and not any of the other physiological measures. However, the literature on physiological responses in social anxiety has been inconsistent and it is plausible that this inconsistency and our failure to observe altered electrodermal activity and heart rate variability in social anxiety stems from too low statistical power and the investigation of subclinical samples.

While the use of an everyday interaction allows us to investigate which alleged features of social anxiety survive outside of a standard laboratory setting, several limitations need to be considered. We aimed at maximizing the naturalness of our experimental design, which is why we decided against very standardized conversations between confederate and participant, a specific sequence of direct gaze or gaze avoidance of the confederate or a forced conflict situation. Consequently, we are unable to draw inferences about specific reactions to evaluative gaze or interactions with different emotional valence. Additionally, a potential argument against our interpretation of the observed increase in gaze towards the confederate's head is that it was also the sole source of auditory information in this moment. The auditory stimulation rather than the change in interaction possibility could have impacted the participant's increased attention. Future studies should therefore consider including a non-social auditory source to allow comparisons in attentional capture. While physiological reactions were most prominently increased in the conversation phase suggesting that this part of the experiment was also the most arousing to participants, an increase of movement during speech could also contribute to these observations. As social anxiety was yet correlated with increases in heart rate throughout the entire experiment, the association between physiological responses and anxiety symptoms cannot be fully explained by movement artefacts.

This finding nevertheless needs to be taken with a grain of salt since we are unable to conclude whether the increased heart rate is caused by the impending or current social interaction or by a higher baseline heart rate in socially anxious participants. The participation in an experiment inevitably induces brief social contact with the experimenter, even if no fellow participant is in the room, and it is therefore very difficult to isolate the causes of the observed heart rate increase. Future research should nevertheless aim to elucidate the circumstances under which elevated heart rates can be observed in socially anxious participants. Such examination might include methods of ambulatory assessment to examine heart rate changes across a variety of everyday situations in socially anxious participants (Sperry, Kwapil, Eddington, & Silvia, 2018). Additionally, socially anxious participants in our sample were not clinically diagnosed and altered gaze patterns might only become apparent in a clinical sample. However, 26 out of the 71 participants demonstrated high SIAS scores (30 or higher) that also occur in clinical samples (Stangier et al., 1999). Since we observed virtually no correlations between social anxiety symptoms and measures of gaze (see Supplementary Table S1 and Supplementary Figure S3), the current study does not provide evidence for the assumption that results would look different in a clinical sample. Whether our failure to observe gaze differences in social anxiety is due to homogenous viewing behavior in anxious and non-anxious populations or related to differential responses to social threat remains to be elucidated by future studies. Interestingly, non-clinical socially anxious participants responded with increased gaze to social cues when social evaluation was enhanced (Müller-Pinzler et al., 2015), suggesting that differences in gaze between socially anxious and non-anxious groups might only become apparent when the perceived social evaluation

is sufficiently high. Controlling for state anxiety and the level of perceived social threat might help to interpret gaze patterns in the future.

The current results present evidence for increased heart rate but not for differences in gaze behavior in social anxiety during a real social interaction. Considering the inconsistent literature on social attention in socially anxious individuals, the current null findings regarding this measure suggest that gaze reduction might be either primarily a laboratory phenomenon or restricted to specific situations (e.g., including evaluative threat) or very high (clinically relevant) levels of social anxiety. The reported fear of eye contact might therefore be a more cognitive rather than a behavioral feature of the disorder. By contrast, increases in cardiovascular responses in social situations seem to represent a cardinal feature of social anxiety and current and future therapeutic interventions could thus consider targeting the awareness and regulation of cardiovascular activity.

Declarations of interest: none

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Figures

Figure 1. Experimental setup. A = Participant position, B = Confederate position, 1 = Posters used for three-point eye-tracker calibration and validation, 2 = Measurement devices, 3 = Confederate questionnaires, 4 = Experimental PC with putative experiment message.

Figure 2. Experimental procedure. Exemplary images of each of the three experiment phases as viewed by the participant.

Figure 3. Body and head fixation proportions during waiting, phone and interaction phase. Outliers are denoted by black dots and defined as points further than $1.5 \times$ interquartile range of the lower or upper hinge.

Figure 4. Mean heart rate, skin conductance levels and heart rate variability across the waiting, phone and interaction phase. Heart rate variability is represented in normalized units. Outliers are denoted by black dots and defined as points further than 1.5 * interquartile range of the lower or upper hinge.

Figure 5. Mean heart rate in beats per minute as a function of social interaction anxiety scale (SIAS) scores per phase. Asterisks denote $p < .05$.