Biological Psychology 109 (2015) 151–158

Contents lists available at ScienceDirect

Biological Psychology

journal homepage: www.elsevier.com/locate/biopsycho

Psychophysiological responses to eye contact in adolescents with social anxiety disorder

Aki Myllyneva[a,*], Klaus Ranta[b], Jari K. Hietanen[a]

[a] Human Information Processing Laboratory, School of Social Sciences and Humanities/Psychology, University of Tampere, Tampere, Finland
[b] Department of Adolescent Psychiatry, Helsinki University Hospital, and University of Helsinki, Finland

ARTICLE INFO

Article history:
Received 19 November 2014
Received in revised form 26 May 2015
Accepted 27 May 2015
Available online 29 May 2015

Keywords:
Social phobia
Skin conductance
Electroencephalography
Face perception
Social cognition

ABSTRACT

We investigated whether eye contact is aversive and negatively arousing for adolescents with social anxiety disorder (SAD). Participants were 17 adolescents with clinically diagnosed SAD and 17 age- and sex-matched controls. While participants viewed the stimuli, a real person with either direct gaze (eye contact), averted gaze, or closed eyes, we measured autonomic arousal (skin conductance responses) and electroencephalographic indices of approach–avoidance–motivation. Additionally, preferred viewing times, self-assessed arousal, valence, and situational self-awareness were measured. We found indications of enhanced autonomic and self-evaluated arousal, attenuated relative left-sided frontal cortical activity (associated with approach–motivation), and more negatively valenced self-evaluated feelings in adolescents with SAD compared to controls when viewing a face making eye contact. The behavioral measures and self-assessments were consistent with the physiological results. The results provide multifaceted evidence that eye contact with another person is an aversive and highly arousing situation for adolescents with SAD.

1. Introduction

Social anxiety is commonly defined as feelings of uneasiness arising when an individual interacts with others and anticipates the possibility of being negatively evaluated. The criteria for a clinical form of social anxiety, social anxiety disorder (SAD), are met when anxiety related to social situations interferes significantly with the person's normal life (American Psychiatric Association, 2013). The lifetime prevalence of SAD is estimated to be 7–13% (Furmark, 2002) and it typically emerges between early and late adolescence, the mean age of onset being between 10 and 16 years (Wittchen & Fehm, 2001). Cognitive-behavioral models of social anxiety suggest that negative self-appraisals in social situations are essential in the development and maintenance of social anxiety (Clark & Wells, 1995; Rapee & Heimberg, 1997). It has been proposed that social anxiety is associated with approach–avoidance conflicts resulting, on one hand, from increased investment in peer relationships in adolescence and, on the other hand, from a fear of humiliation and embarrassment aroused by peer evaluation (Caouette & Guyer, 2014).

Eyes are considered to be the strongest fear-producing cue in situations containing social appraisal (Öhman, 1986). An eye contact is a prominent way to signal preparedness for social interaction. A direct gaze signals that one's attention is directed towards the other person and an averted gaze suggests that one's attention is directed to someplace else. Thus, a direct gaze may be a potential threat for people with social anxiety. A prominent clinical symptom of SAD is avoidance of eye contact as well as other safety behaviors in social situations (Greist, 1994).

Previous research has shown shortened viewing times of the eye region or reduced eye contact in participants with social anxiety in comparison to non-anxious participants (Daly, 1978; Farabee, Holcom, Ramsey, & Cole, 1993; Garner, Mogg, & Bradley, 2006; Moukheiber et al., 2010). However, some studies have not found differences in gazing behavior between participants with and without social anxiety (Hofmann, Gerlach, Wender, & Roth, 1997), and even longer fixation times to the eye region by socially anxious females compared to non-anxious counterparts have been reported (Wieser, Pauli, Alpers, & Mühlberger, 2009). These discrepancies have been partly explained with a hypervigilance-avoidance hypothesis proposing that anxious individuals initially attend to but subsequently avoid threatening stimuli (Wieser, Pauli, Weyers, Alpers, & Mühlberger, 2009). It is also noteworthy, that only two of the studies cited above investigated clinically diagnosed socially anxious participants (Moukheiber et al., 2010; Hofmann et al.,

* Corresponding author. Tel.: +35 850 318 6083.
E-mail address: aki.myllyneva@uta.fi (A. Myllyneva).

http://dx.doi.org/10.1016/j.biopsycho.2015.05.005

1997). Studies reporting physiological responses to eye contact in adults or adolescents with social anxiety are scarce. Wieser, Pauli, Alpers, et al. (2009) found more pronounced cardiac acceleration, an index of autonomic reactivity, in participants scoring high in social anxiety to direct vs. averted gaze, whereas this difference was reversed in the group with medium scores and it was non-existing in low socially anxious group. However, measurements of skin conductance responses, another measure of autonomic arousal shown to be sensitive to gaze direction in several studies (Helminen et al., 2011Helminen, Kaasinen, & Hietanen, 2011; Hietanen, Leppänen, Peltola, Linna-aho, & Ruuhiala, 2008; Nichols & Champness, 1971; Pönkänen et al., 2011b; Myllyneva & Hietanen, 2015), did not indicate differences in responses to direct versus averted gaze in any of the groups.

Previous research has thus provided some evidence suggesting that seeing another person's direct gaze may be an aversive and arousing stimulus for individuals suffering from social anxiety. In the present study, we aimed at providing further evidence for the aversive and arousing nature of direct gaze for socially anxious individuals and, more specifically, we aimed to investigate whether this is reflected in the psychophysiological measurements of cortical and autonomic nervous system activity. Electroencephalographic (EEG) studies have associated approach–avoidance–motivation to asymmetries in the frontal alpha activity (8–13 Hz). Stronger left-sided vs. right-sided frontal activity has been associated with activations of the approach–motivation system, whereas stronger right-sided vs. left sided activity has been associated with the activation of the avoidance–motivation system (Davidson, 2004; Harmon-Jones, 2003; Van Honk & Schutter, 2006). Now there is experimental evidence showing that, in healthy adults, seeing a face with a direct vs. averted gaze results in more pronounced left-sided, approach-related frontal EEG activity in the perceiver's brain (Hietanen et al., 2008; Pönkänen et al., 2011b). Interestingly, stronger relative left-sided activity to direct vs. closed eyes has been observed also in typically developing children, but not in children with autism spectrum disorder (Kylliäinen et al., 2012). Although there are no previous studies measuring asymmetries in the frontal alpha activity of people suffering from social anxiety in response to perceiving a face with different gaze directions, individuals with social anxiety have been shown to exhibit elevations in right-sided, avoidance-related frontal EEG activity during resting state measurements under social stress (Davidson, Marshall, Tomarken, & Henriques, 2000). However, the findings concerning frontal alpha asymmetry in anxiety disorders are not totally consistent (for a review, see Thibodeau, Jorgensen, & Kim, 2006). One possible reason for these inconsistencies may be that passive resting state measurements are not optimal to capture state or trait relevant EEG-asymmetries and that emotionally and motivationally relevant situations should be employed instead (e.g., Coan, Allen, & McKnight, 2006; Wacker, Chavanon, & Stemmler, 2010).

In earlier studies from our laboratory, we have shown that viewing a face of a real live person, physically present in the experimental situation, elicits differential physiological and self-assessed responses compared to viewing a picture of a face (Hietanen et al., 2008; Pönkänen, Peltola et al., 2011; Pönkänen, Alhoniemi, Leppänen, & Hietanen, 2011). For example, pronounced left-sided, approach-related frontal EEG activity and enhanced skin conductance responses to direct versus averted gaze were observed in response to live faces, but not when the faces of the same persons were shown in a pictorial format. The differences were suggested to be due to mentalizing processes, following from being looked at by another person (Hietanen et al., 2008; Myllyneva & Hietanen, 2015; Pönkänen, Peltola et al., 2011). Being looked at by another individual is likely to elicit feelings of being evaluated. These feelings are, in turn, associated to public self-awareness (Buss, 1980). Our previous studies have shown, indeed, that self-assessed public self-awareness is higher when being looked at by a real person versus not being looked at (Hietanen et al., 2008; Pönkänen et al., 2011b; Myllyneva & Hietanen, 2015). Cognitive theories of SAD postulate that heightened public self-awareness plays a central role in social anxiety (Clark & Wells, 1995; Rapee & Heimberg, 1997) and this is supported by empirical evidence (Hope & Heimberg, 1988; George & Stopa, 2008). Against these previous findings, we reasoned that the use of live social stimuli with a potential for interaction is especially important when investigating participants with social anxiety suffering from fear of negative evaluation and criticism from other people. Several other researchers working in the field of social cognition and social neuroscience have also raised similar concerns regarding the ecological validity of facial stimuli presented in pictorial or video format (Risko, Laidlaw, Freeth, Foulsham, & Kingstone, 2012; Schilbach et al., 2013; Teufel et al., 2012). In the above mentioned studies investigating socially anxious individuals' gazing of the eye region, only three had participants viewing real persons instead of pictures or videos (Daly, 1978; Farabee et al., 1993; Hofmann et al., 1997), and yet the difference between using real persons vs. pictures or videos as stimuli can be considerable on gazing behavior (Laidlaw, Foulsham, Kuhn, & Kingstone, 2011).

In the present study, we investigated autonomic arousal and approach–avoidance related brain activity in response to a face with different gaze directions in adolescents with clinically diagnosed SAD vs. age and sex matched controls. We showed the participants a live face with either direct gaze, averted gaze, or closed eyes through a liquid crystal window, and simultaneously recorded skin conductance responses (SCR) and electroencephalographic (EEG) cortical activity. We hypothesized that all participants would show heightened sympathetic activity and, thus, larger SCRs to direct gaze compared to averted gaze or closed eyes. Because anxiety and fear are related to heightened autonomic activation (Kreibig, 2010), we expected that this pronounced sympathetic activation to direct gaze would be more salient in the SAD group than in the control group. Secondly, we hypothesized that participants in the SAD group would show less relative left-sided frontal cortical activity specifically when observing a face with a direct gaze compared to participants in the control group. In the second part of the experiment, the participants controlled the presentation of the stimuli (a face with a direct or averted gaze) themselves, and in addition to the psychophysiological responses, we measured the viewing time of the facial stimuli. We expected shorter self-controlled viewing times for direct gaze in the SAD group than in the control group. Finally, the participants were also asked to assess their subjective arousal, valence, and situational self-awareness when viewing a face with a direct or averted gaze. We expected that participants in the SAD group would show higher ratings of self-assessed arousal, lower ratings of affective valence (pleasantness), and higher levels of self-assessed public self-awareness for direct gaze compared to participants in the control group.

2. Methods

2.1. Participants

The participants were seventeen adolescents with SAD (mean age 15.2 years, std 1.52, range 13–17) and seventeen age- and gender-matched controls (mean age 15.3 years, std 1.53, range 13–17). Both groups consisted of 4 males and 13 females. The control group was composed in such a way that each socially anxious participant had a gender-matched counterpart differing less than six months in age. Adolescents with SAD were recruited from the Department of Adolescent Psychiatry, Tampere University Hospital. Participants were included in the clinical group if their primary reason for referral was social anxiety and they fulfilled DSM-IV criteria for SAD. The diagnosis was based on a clinical interview K-SADS-PL (Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime version; Kaufman et al., 1997), which has shown validity for identifying anxiety disorders in adolescents. Comorbidity with K-SADS-PL affective and anxiety disorders was allowed. The participants did not have neurological or medical diseases and did not have regular medication.

The control participants were recruited from local upper comprehensive and high schools. The controls were first screened with the Social Phobia Inventory (SPIN) (Connor et al., 2000), an instrument possessing good screening properties for SAD in the Finnish adolescent population (Ranta, Kaltiala-Heino, Rantanen, Tuomisto, & Marttunen, 2007), and invited to an interview if the total score was 0–9 representing low levels of social anxiety. All the clinical participants had SPIN scores higher than 20. Finally, the controls were also interviewed clinically with the K-SADS-PL by adolescent psychiatrist. Only those without SAD, and without any other anxiety/affective or other K-SADS-PL based Axis I disorders were included in the control group. All participants gained 2 movie tickets for participation. Laboratory measurements of one socially anxious participant were aborted after the first part due to headache. Consequently, the data of the first part of the experiment consist of 17 clinical and 17 control participants, and the data of consecutive parts consist of 16 clinical and 17 control participants. Informed, written consent was obtained from all participants and their parents. Ethical statement for the study was obtained from the Ethical Committee of Pirkanmaa Hospital District.

2.2. Stimuli and the experimental procedure

The stimulus was a face of a person (model) gazing either directly at the participant, gazing 30° to the left or right, or having eyes closed. Three females, naïve to the purpose of the experiment and trained to act similarly towards the participants served as models. Each participant saw only one model. During the experiment, the models bore a neutral expression on their faces. The ages of the models' were 23, 24 and 24 years. Faces were presented through a 30 × 40 cm liquid crystal (LC) window (NSG UMU Products Co., Ltd.), attached to a black frame. The LC-window switched between the opaque and transparent state within milliseconds. The participants were seated at a distance of 60 cm from the LC-window and the overall distance to the model sitting on the other side was 120 cm.

The experiment consisted of three separate blocks. In the first block, the presentation of the stimuli was computer-controlled. The face of the model had a direct gaze, averted gaze or closed eyes. The first block consisted of 27 trials (nine trials in each gaze condition). The presentation order of the stimuli in the trial sequence was randomized. The stimulus duration was 5 s and the inter-stimulus interval (ISI) varied between 20 and 40 s. A new trial was initiated after recovery from previous skin conductance response. The participants were allowed two short breaks during the first block (after nine and eighteen trials). Stimulus presentation was controlled by Neuroscan Stim-software running on a desktop computer.

In the second block, participants controlled the presentation time themselves with a computer mouse and the face of the model had either a direct or averted gaze. The second block consisted of 20 trials (10 with direct gaze and 10 with averted gaze). The participants were instructed to use a computer mouse for opening and closing the LC-window. They heard a soft audio signal, after which they were able to open the window with one button and close it with another. For the controlling of the viewing time, the participant was instructed as follows: the time that different people find it natural to look at another person's face in different situation varies. You can choose your own looking time based on how you feel. There are no right or wrong answers. This is not a contest of who can stare the longest at the other person, the looking time can also be quite short. In the instruction, it was not mentioned that it would have been possible for the participants not to open the window at all. No participant asked about this possibility nor left the window unopened. The presentation order of the stimuli in the trial sequence was randomized. A new trial was allowed 20 seconds after the ending of the previous one. In both blocks, during the ISI, the LC-window remained opaque. Along with the physiological measures, viewing times were recorded.

In the third block, the participants were asked to fill self-assessment forms. First they were asked to assess their arousal and affective valence to seeing a face with direct gaze, averted gaze, and closed eyes with 9-point scales of the Self-Assessment Manikin (SAM) (Bradley & Lang, 1994; 1 = unpleasant/calm, 9 = pleasant/arousing). The same face as previously with direct gaze, averted gaze or closed eyes was presented through the LC-window for 5 s in a random order. Lastly, the participants were introduced a nine-item Situational Self-Awareness Scale (SASS) form (Govern & Marsch, 2001) measuring public self-awareness (e.g., Right now, I am concerned about the way I present myself), private self-awareness (e.g., Right now, I am conscious of my inner feelings) and awareness of immediate surroundings (e.g., Right now, I am keenly aware of everything in my environment). Again, the same face as previously with a direct gaze and averted gaze was shown for the participant for 5 s in a random order. The participants were asked to fill the SSAS ratings after seeing each face. The form used 7-point scale (1 = strongly disagree, 7 = strongly agree). No task was required during the experiment, except to watch the face of the model when the LC-window is open.

2.3. Acquisition of the physiological data

For the skin conductance measurements, two electrodes (Ag/AgCl) were coated with isotonic electrode paste and attached to the palmar surface of the distal phalanxes of the index and middle fingers on the participant's left hand. Power Lab 400 equipment running on a desktop computer was used to measure the skin conductance. The sampling rate was 100 Hz.

Continuous EEG was recorded from eight electrode sites (F3, F4, F7, F8, C3, C4, P3, P4) positioned according to 10–20 system. The signal was referenced to mathematically linked ears as recommended by Hagemann, Naumann, and Thayer (2001). Horizontal and vertical eye movements were recorded from the sites beside the outer canthi of each eye and above and below the left eye. Skin abrasion and electrode paste were used to reduce the electrode impedances below 5 kΩ. The EEG signal was amplified with SynAmps amplifiers with a gain of 5000. The signal was filtered using a 1–200 band-pass filter (50 Hz notch filter enabled). The sampling rate for the digitized signal was 1000 Hz.

2.4. Data analysis

The skin conductance response was defined as a maximal amplitude change from the baseline level during a 4-s time period starting after 1 s from the stimulus onset. If the maximum amplitude was negative, it was set to zero. If there was more than 0.1 μS amplitude change before 1 s after stimulus onset, the trial was rejected for being too early to be elicited by the gaze stimulus (Dawson, Schell, & Filion, 2000). Of all trials, 13.1% were rejected in the computer-controlled condition and 18.9% in the self-controlled condition because of these criteria or because of technical error. The data were averaged in each condition for each participant, including those trials with zero response. This method of calculation results in the magnitude of the galvanic skin conductance response (Dawson et al., 2000).

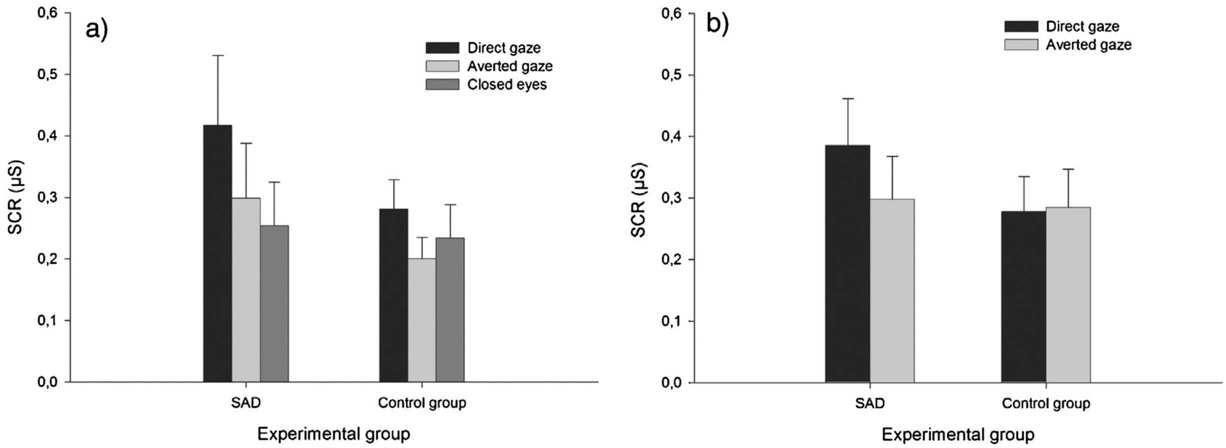

Fig. 1. Mean skin conductance responses to direct gaze, averted gaze and closed eyes (a) in computer-controlled viewing time condition and (b) in self-controlled viewing time condition

The EEG-signal was filtered with a 0.5–30 band-pass filter with 24 dB/oct slope on both end, and ocular-corrected using Gratton/Coles–algorithm. The signal was segmented into nine 1024 ms long epochs with 50% overlap between adjacent epochs starting from the stimulus onset. The epochs were manually checked for artifacts. Spectral power was calculated for each artifact-free epoch using fast Fourier transform (FFT) with a 25% Hanning window. The obtained power spectra were averaged over all artifact-free epochs within each trial and over separate trials within each experimental condition (direct gaze, averted gaze and eyes closed). Periods with less than 50% artifact-free epochs were excluded from the analysis. Power density values (μV^2/Hz) within the alpha-band (8–13) were calculated. Lastly, alpha-asymmetry [Ln (PowerDensity F4) – Ln (PowerDensity F3)] scores were calculated.

The self-controlled viewing times were recorded in the second experimental condition. The viewing time–data were averaged in both gaze-conditions for each participant.

In statistical analyses, Greenhouse–Geisser correction procedure was applied when appropriate. Planned comparisons (two-tailed) were performed for the analysis of simple main effects when interactions were observed. When needed, data were normalized using ln-transformation. Due to artifacts, there was a substantial (9.3%) number of missing values in the EEG power density dataset for the facial stimuli scattered randomly to the data. For maximal utilization of the available data, we used mean imputation to replace the missing values. As means, we used the arithmetic means of variables over both experimental groups. In SCR and viewing time data, there were no values differing more than 1.5 interquartile lengths from the first and third quartiles. For frontal asymmetry data, we included values differing less than 3 interquartile lengths from Q1 or Q3. This lead to exclusion of one control participant from the analysis

3. Results

3.1. Skin conductance response

For the computer-controlled presentations, a 3 × 2 ANOVA was conducted with gaze direction (direct, averted, eyes closed) as a within-subjects factor and group (clinical, control) as a between-subjects factor. A main effect of gaze direction was revealed($F_{(2,60)} = 4.4$, $p = 0.026$, $\eta_p^2 = 0.129$) indicating larger responses to direct gaze compared to averted gaze or closed eyes regardless of experimental group. Other effects remained non-significant. Mean SCRs for each gaze direction are presented in Fig. 1a.

For the self-controlled presentations, a 2 × 2 ANOVA was conducted with gaze direction (direct, averted) as a within-groups factor and group as a between-subjects factor. A main effect of gaze direction was marginally significant ($F_{(1,31)} = 3.5$, $p = 0.07$, $\eta_p^2 = 0.102$). More importantly, however, there was an interaction between gaze direction and group ($F_{(1,31)} = 4.4$, $p = 0.043$, $\eta_p^2 = 0.125$). When comparing the responses to direct and averted gaze between groups, *t*-tests did not find any significant effects (all ps < 0.1). Further analysis revealed that interaction was due to differences in responses to direct and averted gaze within groups: *t*-tests indicated greater response to direct gaze than to averted gaze in the clinical group ($t = 2.5$, $p = 0.023$, df = 15, $d = 0.63$) but not in the control group ($t = 0.18$, $p = 0.86$, df = 16, $d = 0.04$). Mean SCRs for each gaze direction and for both groups are presented in Fig. 1b.

3.2. Frontal EEG asymmetry to facial stimuli

Fig. 2 presents mean frontal alpha-asymmetry scores for both experimental groups in the computer-controlled stimulus presentation condition. A 3 × 2 ANOVA revealed no main effects, but there was a marginally significant interaction between gaze direction and

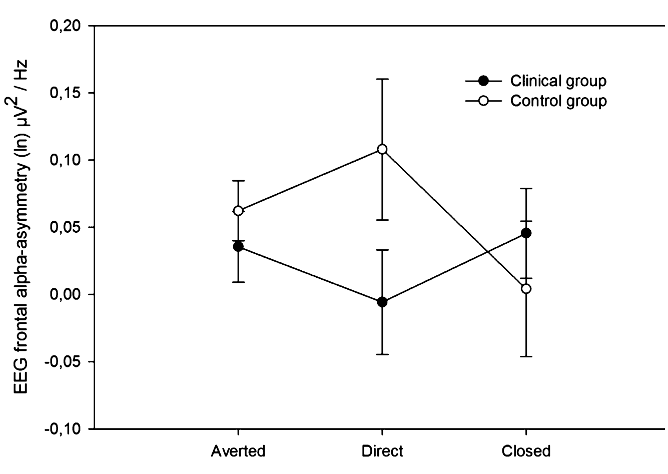

Fig. 2. Mean frontal alpha-asymmetry scores to direct gaze, averted gaze and closed eyes. A positive value indexes stronger relative left-sided frontal brain activity associated with approach–motivation and a negative value indexes stronger relative right-sided frontal brain activity associated with avoidance–motivation.

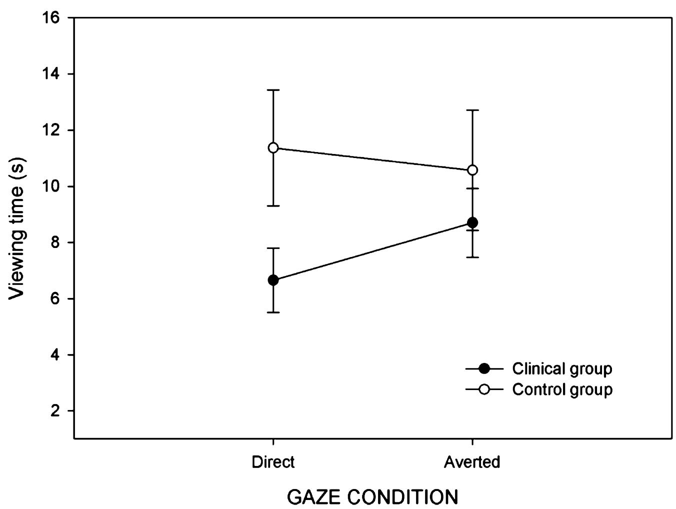

Fig. 3. Mean preferred viewing times to direct gaze and averted gaze facial stimuli in self-controlled viewing time condition.

group ($F_{(1,30)}=2.66$, $p=0.078$, $\eta_p^2=0.08$). A *t*-test for independent samples suggested that alpha-asymmetry scores for seeing a face with direct gaze was marginally more positive in the control group compared to the clinical group ($t=1.73$, $p=0.094$, df = 30, $d=0.53$).

3.3. Viewing time

Fig. 3 shows mean viewing times in the self-controlled presentation block for direct and averted gaze in both experimental groups. A 2 × 2 ANOVA revealed a main effect of gaze direction ($F_{(1,31)}=5.5$, $p=0.026$, $\eta_p^2=0.15$) and an interaction between gaze direction and group ($F_{(1,31)}=12.8$, $p=0.001$, $\eta_p^2=0.29$). For direct gaze, an independent-samples *t*-test indicated shorter viewing times in the clinical group compared to the control group ($t=2.27$, $p=0.03$, df = 31, $d=0.77$). For averted gaze, there was no difference between the groups ($t=0.62$, $p=0.54$, df = 31, $d=0.21$).

3.4. Self-assessed arousal and valence

The subjective ratings of arousal and valence are shown in Table 1. A 3 × 2 ANOVA for self-ratings of arousal revealed a main effect of gaze direction ($F_{(2,60)}=32.9$, $p<0.001$, $\eta_p^2=0.523$) and an interaction between gaze direction and group ($F_{(2,60)}=4.7$, $p=0.013$, $\eta_p^2=0.135$). For direct gaze, a *t*-test showed higher arousal ratings in the clinical group compared to the control group ($t=2.52$, $p=0.02$, df = 30, $d=0.80$), whereas the difference was not significant between the groups for averted gaze ($t=0.78$, $p=0.44$, df = 31, $d=0.25$) or for closed eyes ($t=1.51$, $p=0.14$, df = 30, $d=0.52$).

A 3 × 2 ANOVA for valence ratings indicated significant main effects of gaze direction ($F_{(2,60)}=16.9$, $p<0.001$, $\eta_p^2=0.361$) and group ($F_{(1,30)}=7.2$, $p=0.011$, $\eta_p^2=0.196$). Overall, the pleasantness ratings were the lowest for direct gaze and the highest for closed eyes; participants in the control group gave higher pleasantness ratings than participants in the clinical group. Importantly, the interaction between gaze direction and group was significant ($F_{(2,60)}=6.2$, $p=0.004$, $\eta_p^2=0.170$). When analyzing the responses to different gaze directions separately between the clinical and control groups, *t*-tests indicated lower pleasantness ratings in the clinical vs. control group to direct gaze ($t=3.81$, $p=0.001$, df = 31, $d=1.21$), marginally significantly to an averted gaze ($t=1.76$, $p=0.09$, df = 30, $d=0.56$), and no difference in ratings to closed eyes ($t=0.25$, $p=0.80$, df = 31, $d=0.33$). Importantly, participants in the control group evaluated direct gaze as mildly pleasant ($M=5.43$), whereas the participants with SAD evaluated direct gaze as unpleasant ($M=3.19$).

3.5. Self-awareness

Situational self-awareness was analyzed separately for each of three components (public, private and awareness of surroundings). For public self-awareness, a 2 × 2 ANOVA with gaze direction (direct, averted) as a within-subjects factor and group (clinical, control) as a between subjects factor revealed main effects of gaze direction ($F_{(1,31)}=15.9$, $p<0.001$, $\eta_p^2=0.339$) and group ($F_{(1,31)}=10.3$, $p=0.003$, $\eta_p^2=0.248$The self-assessed public self-awareness was higher to direct vs. averted gaze and, overall, it was higher in the clinical than in the control group. No effects were found for private self-awareness or awareness of immediate surroundings (all ps > 0.1). Mean SSAS scores for both groups are shown in Table 1.

4. Discussion

In the present study, we investigated adolescents with clinically diagnosed social anxiety disorder (SAD) and age- and sex-matched controls in their responses to seeing another person live with a direct gaze, averted gaze, and closed eyes. We investigated whether eye contact is aversive and physiologically arousing for adolescents with SAD by measuring autonomic skin conductance responses (SCR), cortical EEG activity measures (i.e., lateral asymmetry in frontal alpha activity) indexing behavioral approach–avoidance tendencies, as well as self-controlled viewing time of the stimulus faces. Additionally, we measured self-assessed arousal, valence, and situational self-awareness during looking at the stimulus face with different gaze directions.

Consistently with previous results using real persons as stimuli (Helminen et al., 2011; Hietanen et al., 2008; Myllyneva & Hietanen, 2015; Nichols & Champness, 1971; Pönkänen, Peltola et al., 2011), we found larger SCRs when seeing a face with direct gaze compared to seeing a face with averted gaze or closed eyes. Interestingly, however, in the self-controlled viewing block, this difference was observed only in adolescents with SAD. Thus, only the adolescents with SAD had larger SCRs to seeing a face with direct vs. averted gaze when having a control over the presentation onset and viewing time. There is experimental evidence that increases in the situational control can reduce people's stress and arousal (Miller, 1979). Thus, it may be that having the possibility to control the moment of stimulus presentation lowered the arousal response in the control group. However, our self-controlled stimulus presentation not only gave more control to the participants, but also forced them to be more active and initiate the visual interaction with the model. This may have resulted in additional stress and anxiety in the participants with SAD, specifically when perceiving a direct gaze, i.e., being looked at by another person. According to the cognitive-behavioral model of social anxiety, the primary threat in SAD is a possibility of being negatively evaluated by others because of one's own actions (Rapee & Heimberg, 1997). Thus, in a situation where one is active in the initiation of an interaction, one naturally exposes oneself more to others' evaluation compared to a situation where one is passive while being observed by another individual.

In the self-controlled experimental situation, it was possible to choose very short viewing times also. Is it possible that the observed SCR results, in this situation, were affected by differences in the viewing-times? We do not find this likely. First, if anything, shorter viewing times would be expected to result in smaller SCRs, but the results showed that the SCRs do direct gaze were larger in the clinical than in the control group even though the viewing-times were shorter in the clinical group. Secondly, previous studies have shown that a 2-s presentation of a real human face evokes similar

Table 1
The self-assessed situational self-awareness scores (and standard deviations) to direct gaze and averted gaze facial stimuli, and the self-assessed ratings of valence and arousal. The scores of SSAS include three factors of self-awareness: public, private and surroundings. The scale-range in SSAS scores is 1–7 and valence and arousal scores 1–9.

	Clinical group			Control group		
	Direct gaze	Averted gaze	Closed eyes	Direct gaze	Averted gaze	Closed eyes
Arousal	4.63 (2.03)	3.12 (1.69)	2.38 (1.20)	3.00 (1.59)	2.71 (1.45)	1.75 (1.13)
Valence	3.19 (1.94)	4.5 (1.67)	5.94 (1.43)	5.43 (1.59)	5.44 (1.31)	6.06 (1.34)
Public	4.74 (1.71)	3.68 (1.30)	–	2.90 (1.71)	2.35 (1.40)	–
Private	3.75 (1.38)	3.52 (1.23)	–	3.47 (1.18)	3.47 (1.09)	–
Surroundings	3.75 (1.20)	3.85 (0.98)	–	4.65 (1.57)	4.37 (1.70)	–

SCRs compared to a 5-s presentation (Helminen et al., 2011). In the present experiment, there were two participants who had viewing times shorter than 2-s in the self-controlled block for direct gaze stimuli. Both participants were from the clinical group, and the number of trials viewed less than 2s was relatively large (8/10 and 9/10). However, the mean SCR of these two participants to the direct gaze stimuli in the self-controlled block ($M = 0.37$ μS) did not differ from the mean SCR of the rest of the clinical group ($M = 0.38$ μS). Thus, we find it unlikely that the SCRs in the self-controlled block would have been affected by the differences in the stimulus viewing-times.

Our results showed weaker left-sided (approach-related) frontal EEG asymmetry among adolescents with SAD when viewing facial stimuli with direct gaze compared to the control participants. No differences were found in the frontal EEG asymmetry between the groups when seeing a face with averted gaze or closed eyes. The effect was only marginally significant but we think that the effect-size of the pairwise comparison was notable ($d = 0.53$). Considering that the left-sided frontal EEG asymmetry has been associated with the functioning of the approach motivational system (Davidson, 2004; Harmon-Jones, 2003; Van Honk & Schutter, 2006), the present results suggest that seeing another person with a direct gaze elicits less behavioral tendencies of approach in adolescents with SAD than in the control adolescents. These results fit well with the current cognitive theories linking social anxiety with avoidance in social situations (Clark & Wells, 1995; Rapee & Heimberg, 1997). The alpha-asymmetry results are also interesting considering the several behavioral studies showing shortened viewing times of the eye region or reduced eye contact in participants with versus without social anxiety (Daly, 1978; Farabee et al., 1993; Garner et al., 2006; Moukheiber et al., 2010). These results combined with ours suggest that, in SAD, facing another person looking back at the perceiver elicits frontal EEG asymmetry at the level of brain activation, and simultaneously a tendency to avoid eye contact at the behavioral level.

As expected, the participants with SAD viewed a face with direct gaze for shorter time than the controls, whereas this difference was not present when viewing a face with averted gaze. Our results are in line with the majority of previous studies reporting shortened viewing times to an eye area or reduced eye contact by participants with social anxiety (Daly, 1978; Farabee et al., 1993; Garner et al., 2006; Moukheiber et al., 2010). Admittedly, our measure is not directly linked to viewing behavior per se, but to preferred viewing time. Nevertheless, our results show that adolescents with SAD not only display reduced eye contact, but also choose such actions that result in shorter interaction times with a person who is in eye contact with them. This, again, is well in line with cognitive models of social anxiety (Clark & Wells, 1995; Rapee & Heimberg, 1997) and expands the previous behavioral results concerning social interaction in social anxiety.

Adolescents with SAD assessed their subjective level of arousal to be higher when seeing a face with a direct gaze compared to the controls. No differences between the groups were observed when viewing a face with averted gaze or closed eyes. Thus, self-reported arousal for a direct gaze stimulus differentiated between the SAD and control groups even without having control over viewing time. This result differs from those obtained from SCR-measurements, where the difference was observed only when the participants had control over the viewing time. However, it is likely that the SCRs and self-assessments of arousal measured slightly different things in the present study. As SCRs were measured during the viewing task, they were stimulus driven and arguably not much affected by conscious control processes. Self-assessed arousal ratings, on the other hand, were made after both viewing tasks (i.e., the computer- and self-controlled) and, moreover, they were likely to reflect, not only stimulus-driven responses, but also experience-based cognitive appraisal of situations when being looked at by another person. The self-assessed valence ratings provided an important addition to the arousal rating results. They showed that whereas in adolescents with SAD, increased arousal to a face with direct gaze was accompanied by a negatively valenced affect, among the non-anxious adolescents, instead, the increased arousal was accompanied by a positive affect. This result is highly consistent with frontal EEG asymmetry findings of the present experiment. It is also a very obvious factor explaining the self-controlled viewing time results. In several previous studies, eye contact with another live person has not only increased arousal but also public self-awareness (Hietanen et al., 2008; Myllyneva & Hietanen, 2015; Pönkänen, Peltola et al., 2011). Heightened public self-awareness is described in cognitive theories of SAD (Clark & Wells, 1995; Rapee & Heimberg, 1997) and reported in the previous studies (Hope & Heimberg, 1988; George & Stopa, 2008). In the present study, we found both of these effects: public self-awareness was higher to direct versus averted gaze and, overall, it was higher in the SAD than the control group.

Our sample size was rather small which might explain why some of the anticipated effects were not observed. For example, we did not observe differences in frontal asymmetry scores between direct and averted gaze for neither experimental group. Such an effect has been observed in our earlier studies with healthy adults (Hietanen et al., 2008; Pönkänen, Peltola et al., 2011). Additionally, our models were young adults and, therefore, did not belong to the same age group as our participants. It is well known that, in adolescence, the importance of peer relations and peer group acceptance are emphasized (e.g., La Greca & Lopez, 1998). The possibility of being negatively evaluated by an adult may be a smaller threat to a socially anxious adolescent than being negatively evaluated by a peer. This also potentially weakened the effect of the eye contact.

Due to a moderate sample size and unbalanced sex-distribution among our participants, we were not able to consider same-sex versus opposite-sex effects. There is a possibility that the responses to seeing another person are modulated by the sex of the observer and/or the sex of the observed person. For example, Pönkänen, Peltola et al. (2011) observed differential frontal EEG asymmetry responses between seeing a real person with direct versus averted gaze, but only when the stimulus person was a female. We re-analyzed our psychophysiological and viewing time data leaving out all male participants and observed virtually unchanged effect-sizes for SCR and viewing-time, but notably higher effect-sizes for frontal EEG asymmetry results (effect-sizes for all participants, $\eta_p^2 = 0.08$, $d = 0.53$; effect-sizes for females only, $\eta_p^2 = 0.13$, $d = 0.89$). In future studies, it would be worthwhile to systematically explore the sex-effects in responses to seeing another person, both in clinical and in normal populations.

In our experimental situation, participants were not informed about a possibility not to open the window at all and no participant did so. It is probable that some participants (particularly clinical participants) felt uneasiness and, at the same time, social pressure from experimenters towards opening the window. One could argue that this resulted in an unnatural situation and decreased the validity of our results. It is noteworthy, however, that, in many occasions in real life, interaction can be actively initiated but in some sense forced, at the same time. At the grocery store, for example, one may initiate an interaction (by going to a cashier) and yet may feel forced to be an active initiator regardless of whether he/she wants to interact or not (taken that the person wants to buy something). The anxiety stemming from the expectation of interaction in these sorts of situations is one of the core symptoms of SAD.

Recently it was shown that a key factor modulating physiological and self-assessed responses to eye contact is not the visual perception of direct gaze per se but the belief of being seen by another person (Myllyneva & Hietanen, 2015). Thus, the present study can be seen as providing more evidence to propositions that a core feature of SAD is negative cognitions and affect elicited by exposing oneself to other individuals' attention. Our results also demonstrate that by investigating responses to eye contact in a genuine, social situation, it is possible to reveal a highly consistent, multi-level pattern of results characterizing the core symptoms in SAD.

Conflict of interest

The authors declare no conflicts of interest

Aknowledgements

We thank Stefanie Scheid, Sari Oldèn and Leena-Kaisa Saarimaa for their help in collecting the data. This work was supported by the Academy of Finland (projects #131786 and #266187 to J.K.H.)

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